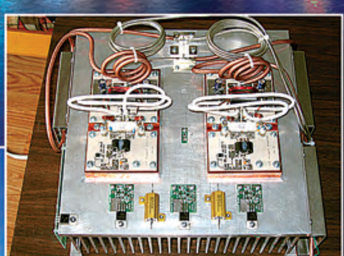
PROCEEDINGS

of the 48th Conference of the

CENTRAL STATES
VHF SOCIETY



July 24-27
Austin, Texas
2014

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CENTRAL STATES VHF SOCIETY
48th Annual Conference, July 24 - 27, 2014
Austin, Texas
http://www.csvhfs.org

President:
Steve Hicks, N5AC

Vice President:
Dick Hanson, K5AND

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Family Program:
Lori Hicks

Technical Program:
Tom Apel, K5TRA

Prizes:
Tom Haddon, K5VH

Vendor Liaison:
Greg Jurrens, K5GJ

Proceedings:
Tom Apel, K5TRA
Dick Hanson, K5AND

Historian:
Bill Tynan, W3XO

AV:
George Fremin, K5TR

Noise Figure Measurement:
Ben Bibb, NO5K

Solar Noise Measurement:
Al Ward, W5LUA

Women's prizes:
Kathie Hanson

Fellow members and guests of the Central States VHF Society,

In 2004, a friend invited me to attend an amateur radio conference much like this one, and that conference forever changed the way I looked at amateur radio. I was really amazed at the number of people and the amount of technology that had come together in one place! Before the end of the conference, I had approached one of the vendors and boldly said that I wanted to get on 222-2304.

As others have pointed out in the past, one of the real values of attendance is getting to know other died-in-the-wool VHF'ers. Yes, the Proceedings is a great resource tool, but it is hard to overstate the value of the one on one time with the real pros at one of these conferences. It is really special to be able to talk with these folks about contesting, expeditions, receivers, preamps, oscillators, antennas, amplifiers, sequencing, phasing lines, noise problems and new modes of operation.

We hope you have a chance to sample some of Austin's music scene, where on any given night, you can visit 50 live performances going on around town. The dinner cruise will let you try some excellent Texas BBQ, see some of the city skyline, and with a little luck, see several million bats on their way to dinner.

73,

Steve Hicks, N5AC	Dick Hanson, K5AND
President	Vice President

City of Austin

Mayor Lee Leffingwell · 301 Willie Nelson Boulevard, Austin, Texas 78701 · www.mayorleffingwell.com
Office (512) 974-2250 · Fax (512) 974-2337 · Lee.Leffingwell@austintexas.gov

Greetings!

It is my privilege to welcome you to the City of Austin for the 2014 Central States VHF Society Conference. It is an honor that you have selected Austin as the host city for your conference; I feel certain that being here in our unique city will enhance your experience.

Austin is a hot spot of creativity and our community embraces progressive thinkers, entrepreneurs, musicians and artists alike. Speaking of musicians, know that they contribute greatly to our city being known as the "Live Music Capital of the World." Hopefully during your visit you will not only get to eat some of our great barbecue and Tex-Mex, you will also get to hear some music at one of our nearly 200 live music venues.

Also know that music is not all that forms our landscape. If time allows, I encourage you to take a walk around or paddleboard on downtown's Lady Bird Lake, visit the Lady Bird Johnson Wildflower Center, or take a dip in our iconic spring-fed Barton Springs pool (where Robert Redford learned how to swim when he was 5 years old). Of course, you will not want to miss the Lyndon Baines Johnson Presidential Library & Museum at the University of Texas, or a tour of the Texas State Capitol.

I hope you see why we're home to a singer named Willie, an Oscar winner named Matthew, a tennis star named Andy, and a longhorn steer named Bevo. And why some of the country's leading magazines sing Austin's praises. Forbes has named us the "Fastest Growing City," the "Best Big City for Jobs" and the "Best City for Young Adults." Kiplinger Finance magazine has named us the "Best City for the Next Decade." Entrepreneur said we are the "#1 Most Creative Center" in the country and Portfolio.com named us to its list of "Least Stressed U.S. Cities."

That last designation alone is reason to visit. Welcome and enjoy your stay.

Sincerely,

Lee Leffingwell
Mayor

The City of Austin is committed to compliance with the American with Disabilities Act. Reasonable modifications and equal access to communications will be provided upon request.

48th Annual CSVHFS Conference Banquet Speaker
Jimmy Treybig, W6JKV

Jimmy has been a ham radio operator for 60 years. His main interest is 6 meters and DX expeditions, including 6 and 2 meter EME and annual Bar-B-Qs focused on these activities. He was awarded the Mel Wilson award in 1987 for his contributions to VHF and UHF. Jimmy has done over seventy 6/2 meter expeditions to over fifty countries. The expeditions provided sixteen of K5FF's one hundred countries (first DXCC 6 meters). His annual Bar-B-Q's (W6JKV and K5AND) attract 100 to 150 VHF operators from around the world since 1980.

Jimmy was featured in the documentary film 'Something Ventured" which premiered in 2011 and focuses on the contributions to the early success and history of Silicon Valley. He founded and was the CEO of Tandem Computers, a Silicon Valley manufacturer of fault tolerant computers. Tandem delivered its first product in 1975, went public in 1977, was ranked by Inc Magazine as the fastest growing public company in 1980, and was on the Fortune 500 list of largest companies in 1984. Jimmy retired in 1996 when Tandem was a $2.3 Billion company with 8000 people worldwide. Today Tandem is part of HP.

Upside Magazine recognized Jimmy as one of the 100 people who changed the world, and the Silicon Valley Forum awarded him the Visionary Award of Silicon Valley Pioneers in 2002. Both Harvard (1981) and Stanford (1980) recognized him with their Entrepreneur of the Year award.

The Anti-Defamation League of B'Nai B'Rith awarded him the "Torch of Liberty Award" for outstanding service to the community (1983).

Since 1996, Jimmy has been a venture capitalist in Austin where he serves as a director on numerous boards including the Seton Healthcare Family, and multiple high tech start-ups. He is associated with the venture capital firm New Enterprise Associates.

Jimmy has a BA and BSEE in Electrical Engineering from Rice University and a MBA from Stanford University.

2014 CONFERENCE FACILITATORS

President	Steve Hicks N5AC
Vice President	Dick Hanson K5AND
Antenna Range	Kent Britain WA5VJB
	Marc Thorson WB0TEM
Pre-Amp Noise Figure Testing	Ben Bibb NO5K
Solar Noise Measurement	Al Ward W5LUA
Rover Row and Dish Bowl	Jim Froemke K0MHC
Audio-Visual	George Fremin K5TR
Technical Program	Tom Apel K5TRA
Prizes	Tom Haddon K5VH
Vendor Liaison	Greg Jurrens K5GJ
Proceedings	Tom Apel K5TRA
	Dick Hanson K5AND
Registration	Ray Mack W5IFS
WEB Support	Bob Hillard WA6UFQ
Facilities Liaison	Lori Hicks
Women's Prizes	Kathie Hanson

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States Above 50 MHz Award
Jim Hermanek, K0KFC

The Central States VHF Society
A Short History

by

Bill Tynan, W3XO

Central States VHF Society Historian

The Central States VHF Society (CSVHFS) began informally among a small group of Midwest VHF hams, who regularly got together on 75 meters to commiserate on their separation from the rest of the VHF fraternity on the East and West Coasts and gripe about the greater distances they had to span to make QSOs and collect states.

In the summer of 1965, Bill Smith, K0CER, later to take the helm of the QST VHF column, “The World above 50 Mcs,” invited a group of these Midwest VHFers to Sioux Falls, SD. Those who attended this first get-togethere didn’t call it a conference and didn’t form an organization. It was merely a bunch of hams with similar interests and problems meeting to swap ideas and stories about operation on what was then considered the upper reaches of the radio spectrum, 144 and 432 Megacycles. They hadn’t yet started calling them Megahertz.

The following year, 1966, another similar informal gathering was held, this time in Sand Springs, OK. Once again, no thought was given to forming a permanent formal organization.

By 1967, it was perceived that regular annual gatherings should be held and an organization, to be called the “Central States VHF Society,“ formed. A General Chairman and several Committee Chairmen were selected and a conference was called for for August 19 and 20 at the Western Hills Lodge, Sequoyah State Park near Wagoner, OK. Those dates were selected to follow the Persieds meteor shower, so attendees could swap stories about what they worked, and didn’t work, during this major shower. Some 125 hams from 19 states and seven call areas descended on that beautiful location. Technical talks were supplemented by antenna tests.

Since then, both antenna gain tests and noise figure measurements have become key activities drawing VHFers to CSVHFS conferences. In those early days, a 2 dB noise figure could well win that competition. It is said that a prominent Iowa 2 meter EMEer, who had just worked Australia via the Moon, surprised everyone, including himself, when the preamp used for the record breaking contact, turned in an 8 dB noise figure. Nowadays, preamps must measure considerably less than a 1 dB to even be in the running. And, that’s not just on 2 meters. Phenomenally low noise figures are regularly turned in by preamps up to 10 GHz and beyond. For many years, Al Ward, W5LUA, was the prime provider of the latest exotic noise figure measuring gear. Through the years, the antenna range has been presided over by Marc Thorson, WB0TEM, and Kent Britain, WA5VJB. They, and those who have assisted them over the years, to measure antennas for various bands from 144 MHz and up, deserve the thanks of all: as do those who conducted the noise figure measurements.

The presence of many wives and children at that first 1967 conference, made it apparent that future meetings must include programs and activities geared to families, as well as presenting high quality technical programs. The family program has since become an important adjunct to all CSVHFS conferences. The toddlers present at those early gatherings are now grown and many are well know VHFers. Among them are such active Society members as Charlie Calhoun, Jr, K5TTT, Bryan Ward, N5QGH, and Ron Marosko Jr. NN5DX.

The 1968 conference, held at the Lake of the Ozarks, marked a milestone in the history of the Central States VHF Society in that it was decided to incorporate. This gathering saw some one-hundred hams from 35 states plus Canada and England, the CSVHFS gatherings already having become internationally known as prime venues for learning about equipment and operating techniques for the VHF, UHF and microwave bands. Participating on the program that year was Ed Tilton, W1HDQ, originator and long-time conductor of the QST VHF column and for many years, that publication's VHF Editor.

The 1970 conference, was held again at the Western Hills Lodge near Tulsa, OK. On the suggestion of K0CER, it was decided to institute an award honoring the memory of John Chambers, W6NLZ, for his many technical contributions to VHF and UHF, including the first terrestrial bridging of the Pacific from California to Hawaii on any VHF band other than 50 MHz. W6NLZ's contacts with Tommy Thomas, KH6UK (K2UK), on 144, 220 and 432 proved the existence of the pacific tropo duct. From then on, the Chambers Award has been presented to those who have made notable technical contributions applicable to the bands above 50 MHz, the award becoming a mainstay of the CSVHF Society conferences. The next year's Conference held in Sioux Falls, SD saw presentation of the Chambers Award, to Mel Wilson, W2BOC, for his studies of Sporadic E propagation.

At the 1974 conference in Boulder, CO, the members decided to affiliate with ARRL and make the CSVHFS a Society Life Member of AMSAT. Mrs John Chambers, W6NTC, was present at the Saturday evening banquet to present the Chambers Award to Dick Knadle, K2RIW, for his 70 cm amplifier design and development of stressed dishes.

The 1982 Conference held in Baton Rouge, LA was dedicated to the memory of Mel Wilson, W2BOC. With the passing of this distinguished Society member, a new award commemorating Mel was instituted. Lists of the recipients of the Chambers and Wilson Awards, are presented below.

In 1984, the Society began printing collections of the various papers presented at its conferences, but this worthwhile endeavor took on a new direction and importance at the 21st conference held in Arlington, TX in 1987. Beginning then, ARRL became the publisher of the official Proceedings, making the technical information presented each year more widely available.

At the 1995 Conference held in Colorado Springs, those members planning the Conference proposed that a second track of presentations be established to bring younger people, both those not yet licensed as well as new hams, into VHF and above operation. This approach has been implimented at several succeeding Conferences, including the one held in San Antonio in 2007, and has become known as "VHF-101."

Also at the 1995 Colorado Springs Conference, Rod Blocksome,K0DAS, prposed that the Society launch the "States Above 50 MHz Award" for VHFers who work the most band/states (later modified to states and provinces) during the year. For initiating the idea, Rod became the first Administrator of the Award. The current Administrator is Jim Hermanek, K0KFC. The States Above 50 MHz Award has become a very popular Central States VHF Society activity as it involves many who never have the opportunity to attend our annual conferences.

The Year 2000 Conference marked a departure in the history of the Central States VHF Society. Not only was it was the first CSVHFS gatering for the new millennium, it was the first Society gathering held outside of the United States. The site was Winnigeg, Manatoba in Canada. Four years later, having broken the ice, the annual affair again moved north of the border, this time to Mississauga, Ontario.

The 2013 Conference held in Oak Grove Village, IL marked a first, but one no one hopes to have repeated. Both the antenna range and rover row, were rained out.

A complete list of the Conference locations and the Society officers who hosted them is shown below.

For those of you have never before attended a Central States VHF Society Conference - **WELCOME**. Those putting on this year's Conference hope that you will get as much out of it as many of us have for many years.

Acknowledgments

The writer wishes to acknowledge the great help a document outlining the early history of the Society retiring Society Historian, Ray Nichols, W5HFV, furnished me. I also want to thank Jay Liebmann, K5JL, for information he provided regarding the early days. Details on some of the later occurrences came from Kent Britain, WA5VJB, Jon Platt, W0ZQ, and Brian Derx, N5BA.

Thanks to all.

Author Bio

Bill Tynan, W3XO, was first licensed in 1945 and received the call, W3KMV, in early 1946. Always intrigued by the bands above 50 MHz, he became active on six meters in 1947 while still attending Rensselaer Polytechnic Institute in Troy, NY. He was one of the founders of AMSAT and, in 1974 became the conductor of the QST column, "The World above 50 MHz." In 1992 he gave up that column's stewardship to devote full time as President of AMSAT. Bill presently serves as an AMSAT Senior Advisor and as Historian for the Central States VHF Society. He is a member of the Radio Club of America, was elevated to Fellow in that organization in 1997 and received the organization's Goldwater Award in 2012.

W3XO is active on all bands from 50 MHz through 3.4 GHz and has hope of getting on 10 GHz. He currently holds one end of the North American records for both 2304 and 3456 MHz.

2014 CSVHFS CONFERENCE SCHEDULE
Austin, TX

THURSDAY 24 JULY 2014

TIME	EVENT	LOCATION
0900 - 1700	Vendor Setup	SALON C & D
1600 - 1800	REGISTRATION	LIMESTONE II
1700 - 1800	CSVHFS Board Meeting	REPUBLIC
1800 - xxxx	Evening Boat Trip / Dinner	Bus leaves Hotel

FRIDAY 25 JULY 2014

TIME	EVENT	LOCATION
0730 - 1500	REGISTRATION	Near SALON A
0800 - 1130	Antenna Range	North Parking Lot
0800 - 1130	NF & Gain Measurements	LONGHORN
0900 - 1100	Rover Row / Dish Bowl	East Parking Lot
0900 - 1600	Bus Trip to Fredericksburg	Bus leaves Hotel
0900 - 1100	VHF-101 program	LONGHORN
0800 - 1700	Vendor Room Open	SALON C & D
1130 - 1250	Lunch	LIMESTONE I & II
1300 - 1700	Technical Program	SALON A & B
1700 - 1730	Auction benefiting CSVHFS	SALON A & B
1730 - 1900	Dinner (on your own)	
1900 - 2100	FLEA MARKET	PECAN A & B
2100 - 2230	CSVHFS Board Meeting	REPUBLIC
2030 - 2300	Hospitality Suite Open	LIMESTONE I & II

2014 CSVHFS CONFERENCE SCHEDULE
Austin, TX

SATURDAY 26 JULY 2014

TIME	EVENT	LOCATION
0830 - 1300	REGISTRATION	Near SALON A
0830 - 1130	Vendor Area Open	SALON C & D
0830 - 1130	Technical Program	SALON A & B
0900 - 1600	Natural Bridge Caverns and San Marcos Premium Outlets	Bus leaves Hotel
1130 - 1250	Lunch	LIMESTONE I & II
1300 - 1530	Technical Program	SALON A & B
1530 - 1630	CSVHFS Business Meeting	SALON A & B
1630 - 1700	CSVHFS Board Meeting	REPUBLIC
1700 - 1800	Social Hour	LIMESTONE I & II
1800 - 2200	Banquet	SALON A & B
2200	Hospitality Suite Open	LIMESTONE I & II

SUNDAY 27 JULY 2014

TIME	EVENT	LOCATION
0600 - 1200	Departure	SALON C & D

TECHNICAL PRESENTATION SCHEDULE
SALON A & B

DAY	TIME	Topic / Title	Call	Name
Friday AM	1300-1305	Welcome	N5AC	Steve Hicks
	1305-1335	Adding Another Dimension to Your Roving Experience	K0MHC	Jim Froemke
	1335-1405	A Reduced Size 6m Moxon For Roving	W0ZQ	Jon Platt
	1405-1445	High vs. Low Antennas Revisited	N6NB	Wayne Overbeck
	1445-1500	*15 minute BREAK*		
	1500-1540	A Comparison of Driven Elements	WA5VJB	Kent Britain
	1540-1615	Using the Si530 XO in Your Projects	WA6UFQ	Bob Hillard
	1615-1700	A Common Design for 6M Through 23CM Beacons	K5TRA	Tom Apel
Saturday AM	0830-0835	Welcome	N5AC	Steve Hicks
	0835-0905	SimpleVHF Contesting	K4SME	Sandra Estevez
	0905-0940	Contest Computer Logging and Interfacing Experiences	W4ZST	Bob Lear
	0940-0955	*15 minute BREAK*		
	0955-1040	SMT Solder Reflow in Toaster Oven	N5YC	Brian Straup
	1040-1130	F-Region Propagation and the Equatorial Ionospheric Anomaly	K6MIO	Jim Kennedy
Saturday PM	1300-1340	Equipment, K3 digital Interface, Amps & Antennas	K5AND	Dick Hanson
	1340-1425	1296 MHz Remote 100W PA and LNA	K5TRA	Tom Apel
	1425-1440	*15 minute BREAK*		
	1440-1530	Solid State Kilowatt Amplifiers	W6PQL	Jim Klitzing

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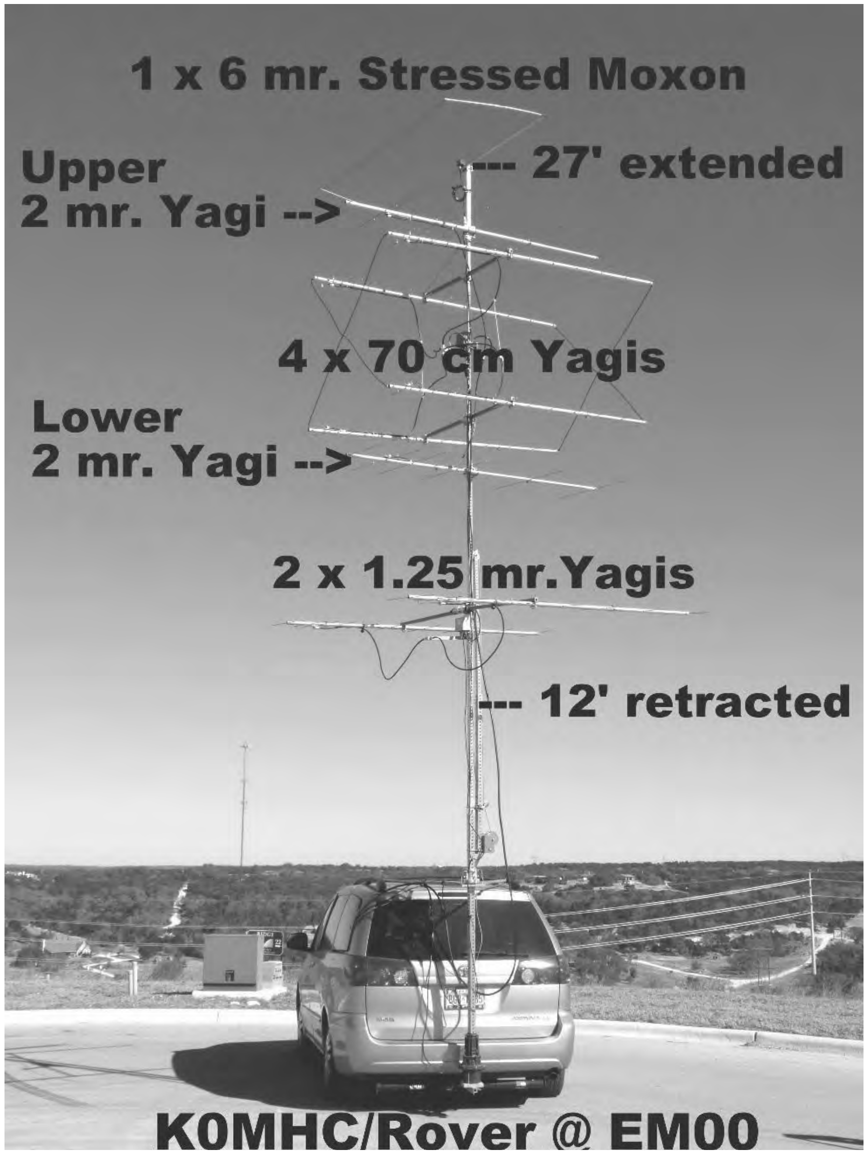
AWARDS and CONTESTS

BEACONS

Adding another Dimension to your Roving Experience



2014 CSVHFS Conference

Jim Froemke

KØMHC/rover

Introduction

- **Within this CSVHFS paper, I've discussed various dimensions that you may choose to explore as you pursue your rover experiences. The implementation details are included in the conference presentation and on my rover blog: http://k0mhc.blogspot.com/**

- **In 1963 my first rover tower/mast was welded to the floor board of my 1956 Chevy convertible. Over time, my rover configurations have continued to push-the-envelope. Many of the mistakes I've made have led to more practical results although my roving partner still insists on bringing his own fire extinguisher along when we rove.**

- **I've learned much from other rovers so this is my chance to give back a few lessons learned. Hopefully, others will benefit from my trial and errors.**

- **Certainly one-size-doesn't-fit-all and everyone has limited resources. So, think about what most meets your needs and go-for-it!**

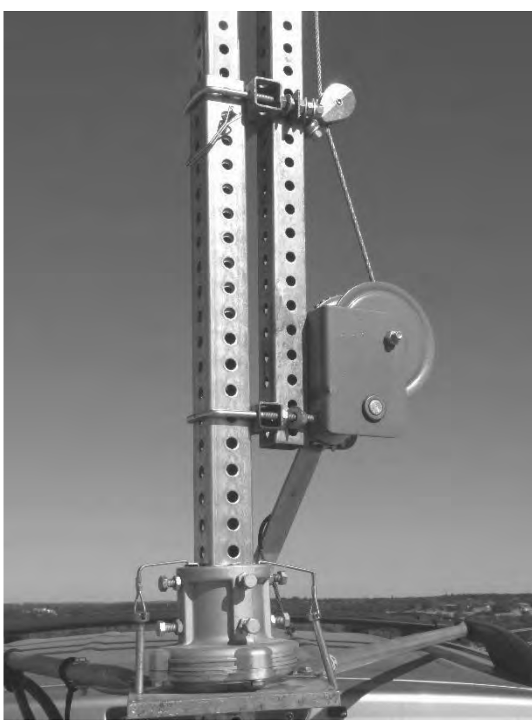
Vertical Elevation of Mast(s)

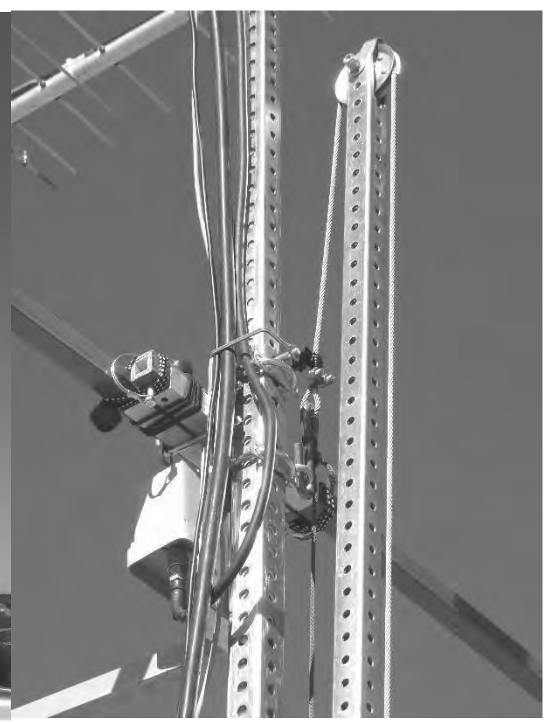
- **Many rover configurations have a short, fixed height mast(s). This works great when you're located at "scenic outlook" sites with distant views of the horizon and minimal blockage from nearby terrain features, foliage or structures. However, these "optimum" rover sites can be**

few and far between. Often it's necessary to elevate antennas to achieve better results when operating from "average" locations.

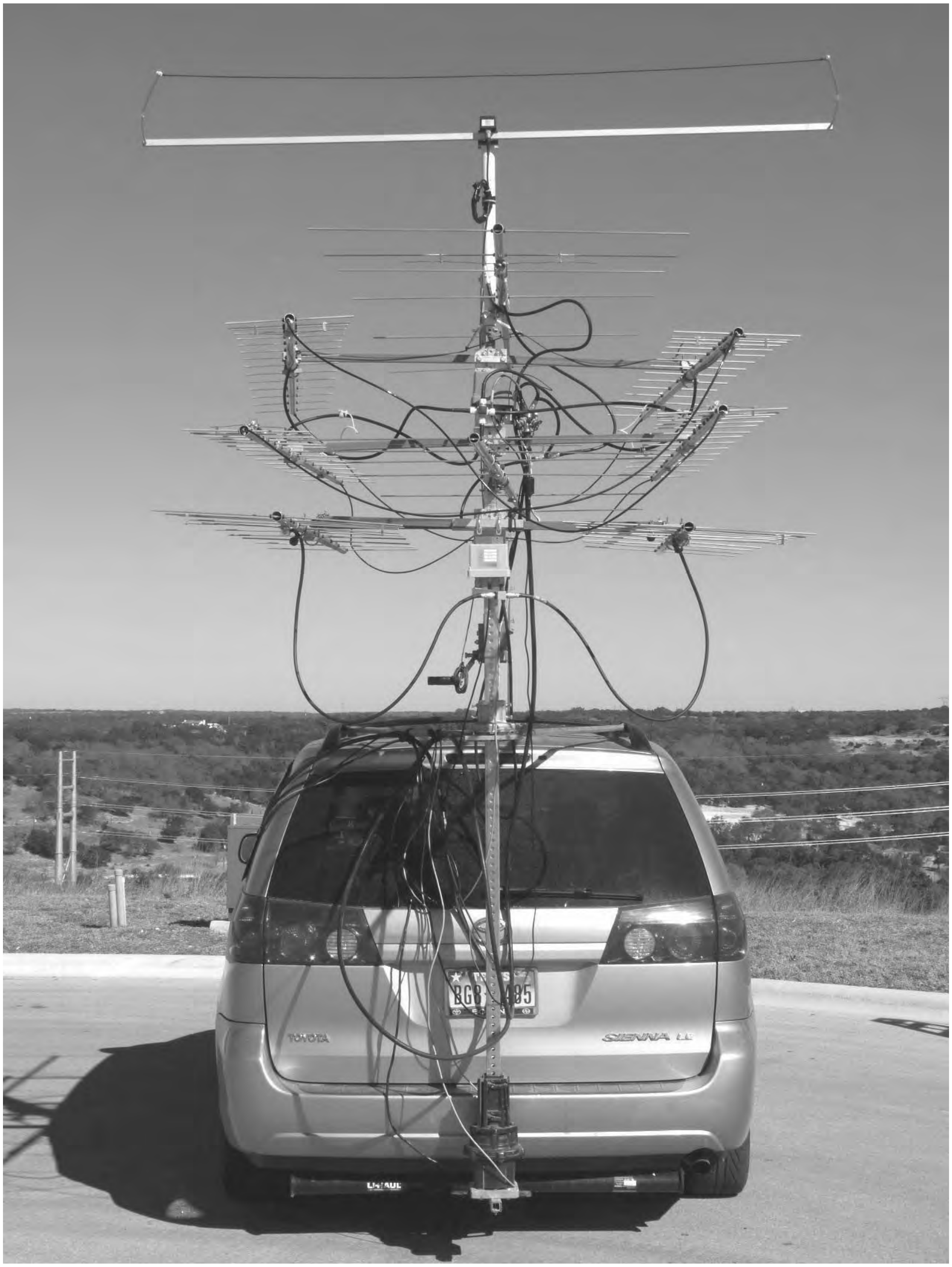
- **Results also vary by band. For example, on 6 meters you benefit more from "ground bounce" when you're antenna is above one wavelength. On the microwave bands, you benefit when your antennas can see over local obstructions (think of Texas cedar trees and Iowa corn stocks).**
- **A fixed height mast(s) has the shortest installation and set-up times and is recommended for the first-time rover.**
- **The obvious advantages are:**
  - ✓ **Better performance when located at "average" locations**
  - ✓ **Lower angle-of-radiation for the "low" bands (6 – 0.7 meters)**
  - ✓ **Less vehicle noise pick-up**
- **The disadvantages include (but are not limited to):**
  - ✓ **Higher complexity , cost and weight**
  - ✓ **Longer assembly & disassembly time before and after roving**
  - ✓ **Longer set-up and break-down times while roving**
  - ✓ **Opportunities for making more mistakes**

- **I didn’t fully anticipate the consequence of traveling height until I tried my first push-up mast. There are a lot of obstructions (man-made and natural) just waiting to raise havoc with your antennas. The “traveling height” and rover routes you select will determine your exposure to unanticipated damage.**
- **Aluminum is a great material for antenna elements and booms. However, it can lead to problems when used as a push-up mast that’s loaded with antennas and coax in a windy situation. Often winds will increase after you’re erected your mast and can make it difficult to retract and/or permanently bend the round, aluminum tubing. Square, steel push-up masts are much more reliable.**





Multi-Dimensional, Collapsible Antenna Array



- **Over the last several years I've increased the amount of aluminum mounted on my single, rover mast more than a**

factor of 4. This includes adding bands, longer booms (within a limited turning radius) and more antennas. Each roving event has resulted in several steps forward and some steps backward as I've learned what works (and doesn't work) in the sometimes harsh, roving environments.

- **One of the major unanticipated consequence was the overall weight "creep". That is, even additional aluminum antennas can add significant weight to the single, push-up mast configuration when you factor in additional coax, relays, power-dividers, pre-amps and non-conductive mast materials. This led to a redesign that includes a manual, crank-up "helper" and a strengthened thrust bearing to luggage rack brace assembly.**
- **Another unanticipated consequence was the "nesting" difficulty when the entire push-up mast configuration is first elevated and then lowered from its "operating" height of 27' to its "traveling" height of < 12'. This must be accomplished manually within 7 minute set-up and 7 minute break-down times so as to minimize the "down" time while roving.**

- **Multi-Dimensional Antenna Arrays can result in a significant overall improvement in addition to whatever else you may have already tried as you pursue the conquest of distant, weak signal stations.**

- **Base stations often employ vertically and/or horizontally stacked antennas to improve both transmission and reception results. Using fixed tower(s)/mast(s) these are not too difficult to implement. However, adding 3-dimensional and/or 2-dimensional stacks to an already crowed, multi-band, rover-vehicle tower/mast can be a bit of a challenge.**

Azimuth Rotors

- **While rotors may seem like an obvious choice, many rovers use fixed, forward aimed antennas that are dependent on the vehicle steering wheel for azimuth aiming. This is a very acceptable alternative and has been used very successfully by many well-known rovers.**

- **Over time, some rovers chose to add an antenna rotor as an operating convince and/or necessity for cramped operating locations. It allows them to have more accurate and faster changes in azimuth bearings.**

- **The obvious advantages are:**
  - ✓ **Faster antenna rotation**
  - ✓ **Better azimuth aiming accuracy**
  - ✓ **Access to smaller operating locations**

- **The disadvantages include (but are not limited to):**
  - ✓ **Higher complexity , cost and weight**
  - ✓ **Need for 115 VAC power**
  - ✓ **Longer assembly & disassembly time**

- **A major unanticipated consequence is the need for an azimuth bearing "off-set" when using a rotor. Often an operating location will not allow your vehicle to park facing north. Therefore, all of your azimuth bearings will be off-set by a fixed amount making your bearing calculations more difficult.**

- **Other rotor related issues include:**
  - ✓ **Local RF interference generated by a DC to AC power inverter**
  - ✓ **Additional coaxial cable distance for an around-the-rotor loop**
  - ✓ **Rotor control cable**
  - ✓ **Rotor base mounting**
  - ✓ **Rotor/mast "stain-relief" bearing**
  - ✓ **Consideration of radius-of-rotation if operating in-motion and/or on road shoulders**

Additional Dimensions included in the conference presentation (depending on the time allocated):

- **Visualization**
- **Digital Modes**
- **Enhanced Propagation**
- **Polarization Diversity**
- **Expanded Computer Assistance**
- **QRO Amplifiers**
- **Time - Rapid Deployment Alternatives**
- **Packaging for Challenging Environments**
- **Social - Family Participation**

A Reduced Size Six Meter Moxon for Roving

Jon Platt W0ZQ

Bloomington, Minnesota

***Abstract* — This paper discusses the antenna and antenna mounting considerations that are important to the 6m rover. Modifications to reduce the physical size of a commercially available 6m Moxon antenna are presented. This reduction in physical size provides for a low cost, small, high performance 6m antenna for portable and rover use.**

***Index Terms* — Moxon, reduced antenna size, rover**

I. Introduction

Generating a strong signal on 6 meters is a challenge for a rover. Federal law limits the height of (moving) antennas to no more than 13 feet 6 inches above ground. In comparison, a wavelength on 6m is approximately 20 feet. For horizontal antennas their performance is directly linked to their height above ground. In addition, a simple half wavelength dipole is nearly 10 feet long representing a significant mechanical design challenge for the rover. Because these challenges are similar to what HF mobile station face some 6m rovers use HF tactics and employ a simple car or truck mounted vertical, but how well does that vertical work and would a dipole be better?

This paper reviews the performance of simple 6 meter antennas that are mounted at heights above ground typically used by rovers. The paper goes on to describes how a commercially made 6 meter Moxon antenna has been modified by the author to reduce its physical size while maintaining most of its performance.

II. Discussion

Before discussing rover antennas let’s take a step back to review how 6m sporadic E propagation works from a geometry perspective. Knowing this is important because we need to understand how the height of the antenna above ground impacts its performance. Critical characteristics of sporadic E propagation include the height above ground of the E layer, the intensity of the E layer ionization, and the angle at which our 50 MHz transmit energy touches the E layer at. The angle that our 50 MHz transmit energy touches the E layer at is directly related to the antennas take-off angle and the antenna performance at these low angles. All of these critical characteristics can lead us to the conclusion that all of our 6m sporadic E contacts take place using take-off angles of not more than 15 degrees and more commonly at take-off angles of 10 degrees or less [1]. Unless you are operating EME, what this means for us is that all the interesting propagation (and hence our interest) occurs with antenna take-off angles of 10 degrees and less. This is where we need to look when looking at antenna performance.

Knowing this we can now take a look at how commonly used 6m rover antennas perform for take-off angles below 10 degrees. For this type of investigation its best to look at the comparison of antenna performance rather than to look at their absolute performance. Fig. 1 plots gain versus take-off angle for a 6m quarter wave vertical along with the gain of a 6m dipole mounted at heights above ground that range from 10 to 20 feet. The dipole data is from its most favored broadside direction. Fig. 1 data was generated with EZNEC using its High Accuracy ground model with a Medium ground description. The vertical antenna was modeled as a simple ground plane antenna using six elevated radials and with the base of the antenna and its radials at five feet above ground (i.e., a typical height for a car roof). Also, I added 10 ohms of resistance at the verticals feed point to simulate ground loss. 10 ohms represents an estimate of what the vertical true ground losses may be.

When viewing Fig. 1 what is important is to look at is how the antennas compare to each other and not what any one antenna absolute gain numbers are. Fig. 1 shows that a 6m quarter wave vertical antenna performs *about the same* as a 6m dipole mounted at 10 feet (in its most favored broadside direction). For a rover it may really be a tossup as to what is better to use, a vertical or a dipole at just 10 feet. Using a vertical will severely limit local contacts due to cross polarization, but for sporadic E contacts the ease of use of a simple quarter wave vertical is attractive.

As the dipole is mounted higher above ground the dipole starts to outperform the quarter wave vertical antenna. Mounted at 13' 6" above ground, the maximum allowable height for a moving vehicle, a 6m dipole is about 5 dB better (in its most favored broadside direction) than the quarter wave vertical antenna. Further, once a rover stops if they can deploy a mast to 20 feet above ground then this higher dipole would provide about an 8 dB improvement when compared to a quarter wave vertical antenna and a 5 dB improvement compared to the same dipole mounted at just 10 feet above ground. For rovers using horizontal antennas the primary 6m antenna performance driver is height above ground.

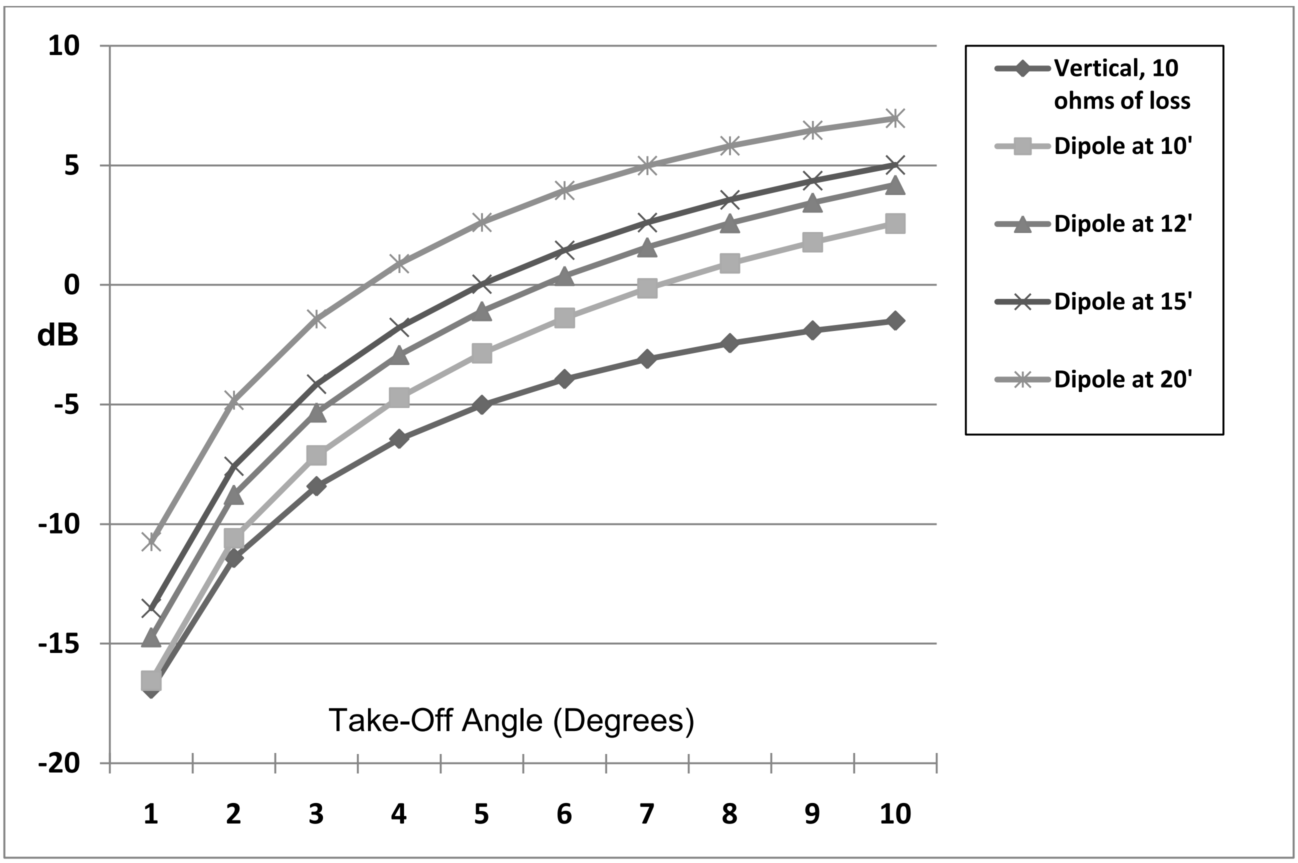


Fig 1. Take-Off Angle versus comparative gain for five different 6m rover antennas.

As a rover, a 6m quarter wave vertical antenna will be as effective as a 6m dipole mounted at 10 feet above ground. If we can move the dipole up to at least 12 or 13 feet, close to the maximum allowed height for a moving vehicle, then we should see a slight performance improvement in favor of the dipole. Beyond this, other than extending a vertical mast once stopped, how do we make any more improvements in our 6m signal? One answer would be to add a parasitic element in the form of a yagi antenna. However, adding a second 10 foot long element along with perhaps a three foot boom to connect them can suddenly make this simple 6m antenna a mechanical challenge for a rover.

In recent years the Moxon yagi antenna designs have become very popular with rovers. A Moxon antenna design has a smaller footprint because the ends of the driven and parasitic elements are folded in towards each other thus reducing the total wing span of the antenna from approximately 10 feet down to approximately seven feet. In addition the folded in portion of the Moxon antenna can add to the physical strength of the antenna and they can be fabricated using simple materials, perhaps even just wire.

How would the performance of a 6m Moxon antenna compare with what has been shown here so far? Fig. 2 is similar to Fig. 1 in format but it compares the performance of a 6m Moxon antenna mounted at 12 feet above ground, 20 feet above ground, and as it compares to a 6m dipole mounted 20 feet above ground. It's no surprise that Fig. 2 shows that the Moxon can provide about 4 or 5 dB of gain above a simple dipole. In doing so the performance of a Moxon antenna mounted at 12 feet above ground is similar to that of a 6m dipole mounted 20 feet above ground. For any rover using a fixed mast height, perhaps using a Moxon at 13 feet represents the best that can be done. Of course the Moxon mounted at 20 feet above ground is the preferred antenna, but driving with such an antenna would be a problem.

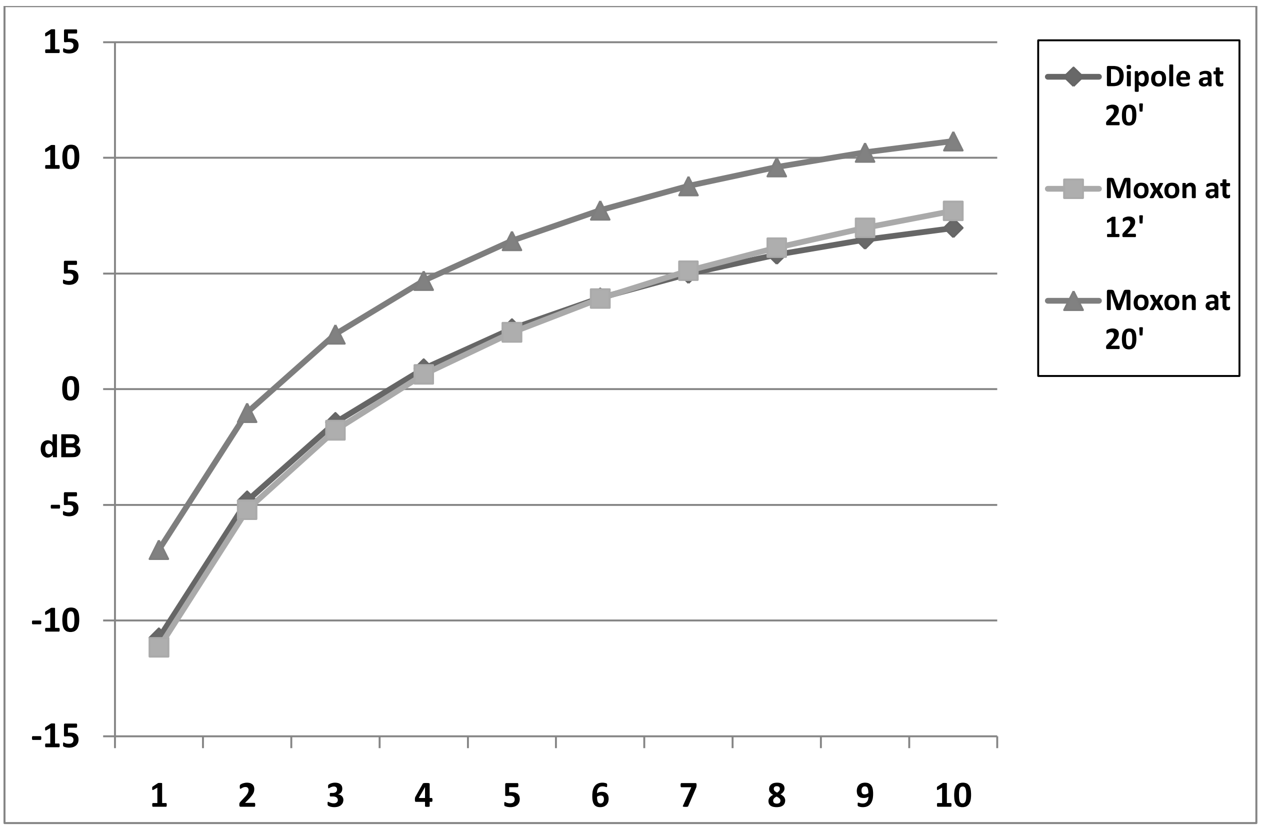


Fig 2. Take-Off Angle versus comparative gain for a 6m dipole and a 6m Moxon.

A downsized 6m Moxon. So we can conclude that a 6m Moxon mounted at 12 to 13 feet above ground should provide for an optimized rover antenna. However, even a seven foot wingspan can present itself as a mechanical challenge for a constantly on the move rover. To determine if the physical size of a 6m Moxon can be reduced even further the author purchased a MFJ-1896 6m Moxon to experiment with. The following information should be considered experimental and other rovers are encouraged to expand upon this work. As designed the MFJ-1896 6m Moxon is approximately seven feet wide with a three foot boom. Such an antenna has a turning radius of nearly four feet. My experience with reducing the physical size of HF antennas is that you can reduce their size by about 30% with no significant impact in their perform other than a reduction in SWR bandwidth and a change in feed point impedance. For 6m rover operations SWR bandwidth is not a significant concern so we can sacrifice SWR bandwidth for size reduction. To address feed point changes I decided to stay with the same boom length and to only modify the element lengths in hopes of having minimum impact to the feed point impedance. The MFJ-1896 is designed with a simple direct coax feed that I wanted to maintain. As it came from the manufacturer I found the coax based pig tail leads that are intended to connect to the feed point were much too long and that they needed to be cut down to just a few inches in order to just reach the mounting screws. A 30% reduction in element length means that the 6m Moxon elements are reduced from their original seven feet in length down to five feet as measured end to end. This now yields a turning radius of just two and three quarter feet which compares to almost four feet in the original design. In order to electrically make up for the reduction in element length loading coils were added in each of the four locations where the ends of each element fold inwards towards each other. The loading coils were added by cutting the existing aluminum tubing in these locations, inserting several inches of 0.25" PVC tubing into the cut ends, and then hand winding 18 gauge (16x#30) PVC wire around the PVC tubing to form the coils. See Fig. 3 and Fig. 4. As an experimental design there was no effort made to optimize coils or coil design. The 0.25 inch PVC tubing easily slips into the ends of the 0.25 inch aluminum tubing that the MFJ-1896 is designed with. The wire ends from each coil were tinned and then mechanically and electrically connected to the aluminum elements using compression clamps. The compression clamps also hold the PVC tubing within the aluminum tubing. Figure Four provides a close up view of one of the loading coil.

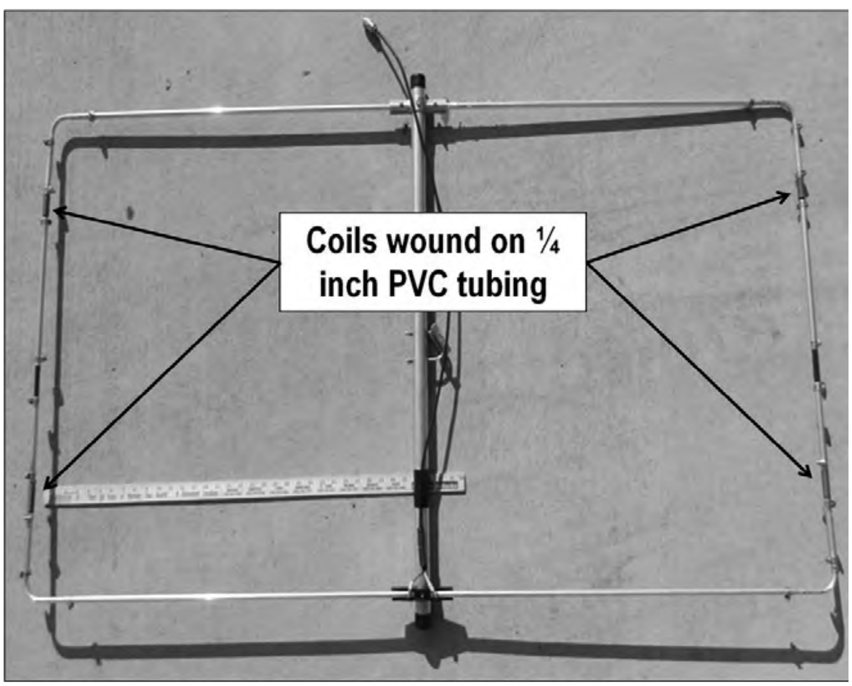


Fig 3. Modified MFJ-1896 showing reduced element length from seven feet down to five feet along with placement of wire wound loading coils

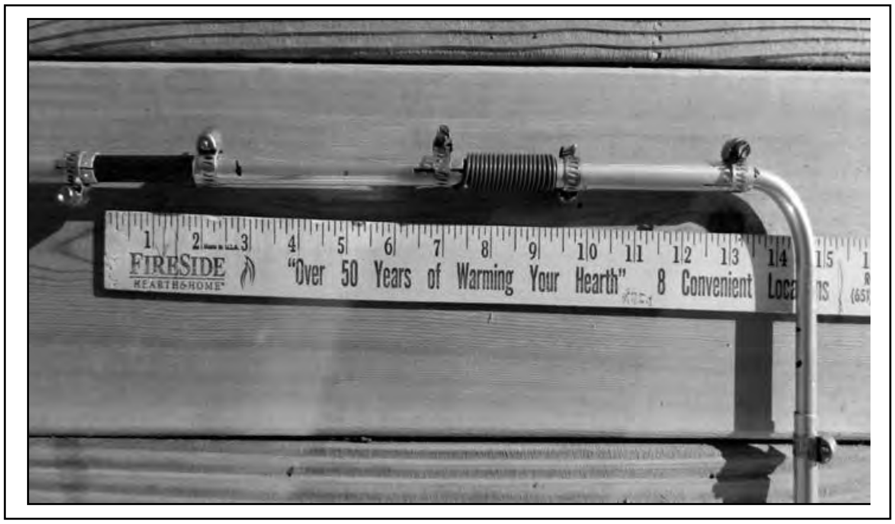


Fig 4. Close up of one of the wire wound loading coils. The darker rod on the far left side of the picture is the insulating rod that electrically separates the two elements from each other

III. Conclusion

When operating as a 6m rover, and in regards to 6m propagation via sporadic E, this paper has shown that the performance of a simple car mounted quarter wave antenna is approximately equivalent to that of a 6m dipole mounted at about 10 feet above ground. If a rover can mount a dipole higher than 10 feet then the dipole should provide improved performance over the simple car mounted quarter wave vertical antenna. A dipole mounted at 20 feet above ground should perform about 8 dB better than the car mounted quarter wave vertical and about 5 dB better than the same dipole mounted at just 10 feet.

For a given mast height, 6m performance can be improved by using a gain antenna such as the Moxon design. This paper has shown that a 6m Moxon can be physically reduced in size by using conventional loading coils and that this reduction in size has minimum impact to 6m performance while improving survivability and providing for easier rover mounting.

References

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The Modular Rover—A Van for All Reasons

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Why a Rover?
Some might say that I made the mistake of moving in 1997 to live in an antenna restricted community that would permanently impair my ability to actively participate in VHF radio activities. On a September 10GHz activity weekend, I operated from the peak of Wachusett mountain. After that great experience, using a few hundred milliwatts to make QSOs over hundreds of miles, I vowed I'd never again try to limit myself by VHF operation from low or obstructed areas, but seek out better portable locations. Thus started my rover fever, coincident with the development of the rover class for the VHF contests. My first roves were to a few local grids FN41, 31 and 42, packing the XYL's station wagon with gear, operating off the tail gate and erecting masts and antennas at each site. I struggled with this type of a set-up until I moved to the Philadelphia, PA area, and decided to invest in a rover van, knowing that I could never really have much VHF enjoyment from the home QTH with the antenna restrictions and covenants of the homeowner's association.

Preparing and Planning
After carefully measuring the garage height of our new home in Pennsylvania, I started to seek a full sized van that was in useable shape and reasonably economical. A 1994 Ford E-150 6 cylinder engine came my way with 105K miles, and the price was right. After studying other's rover set-ups, I went about designing something that would be useful for all types of radio communication, as I also enjoy HF contesting, rag-chewing, and the potential for public service. I would have a 1-1/2" diameter mast that fit through a hole in the roof of the van, extending up 1/2" through the hole, and that the antennas would be mounted on a 1-3/4" mast that was the next size bigger than the base mast, and slide over it so that antennas could be placed on for use easily. The base mast was mounted onto a Ham-M rotor, mounted to a plywood base, which was then bolted to the van floor. A PVC plumbing fitting was used as a protective bearing between the mast and the hole in the roof. A second hole was cut nearby for the passage of all the coaxial cables, again using a PVC fitting as protection for the cut edge of the metal roof. I use a plunger rubber for rain protection, and although the arrangement is not 100% drip-proof, it keeps the cabin relatively dry in a downpour.

I can fit 10 pieces of coaxial cable (RG8, 9913 or LMR400) through the 2" hole, and that allows me to have enough cables for HF, VHF and microwave bands through 3456. My cables for 5GHz, 10GHz and 24GHz feed through the back doors to another mast and rotor that is bolted to the rear corner of the van. I used a similar arrangement of concentric masts for easy erection and removal of the dishes for those bands. I use a 3-4" long ¼" bolt as a pin through the masts to allow them to be stable and low for travel, and then raised and rotatable when on site for communication. The arrangement allows me to push up the antennas an additional 3' above the van roof from inside, if needed when on site, giving extra height to the antennas, and reducing the interaction with the van's metal roof.

Construction
I built an operating table from scrap plywood and 2 X 4 lumber. It was designed with space for the two transceivers and a lap-top computer on the 30" high main working surface. There are two shelves extending the full length of the desk built-in underneath it. The upper shelf has the microwave transverters and their amps for 903, 2304, 3456 and 5760. The lower shelf has the brick amps for 50, 144, 222 and 432, along with a 300W sine-wave inverter. The batteries are on the van floor underneath the desk. The entire desk is fastened securely to the driver's side of the van wall with several screws and bolts. I also built a superstructure that fits around the FT736 and is bracketed to the desk-top that keeps it from moving. Onto this superstructure I also included compartments for the rotor controllers. A rubber pad and double-faced foam tape also keeps things in place, as any rover can attest, everything likes to move around. An electronic key paddle and a few J-38's are also securely screwed onto the desktop. I was lucky to find a swivel captain's chair and the matching rear seat, together with all their seatbelt and mounting base accessories at a local U-pull-it yard for vans and trucks.

Through various hamfests and other sources of used ham equipment sales, I bought a Spyder multiband vertical antenna, with resonators for 75m thru 10m including the WARC bands. Seven resonators can be attached simultaneously to the vertical base, and each of the resonators has a ferrite ring for adjusting frequency use and SWR within the band. I also purchased a 3 element 10-15-20 mini-beam with an 8' boom that is mounted on a 12' mast when in use, and placed in the telescoping position over the mast in the center of the van.

Power is provided with a set of 75AH and 100AH Gel cells that were removed from UPS service. I use 2 in parallel for powering the 100W and up amps for the lower 4 bands, and 2 in parallel for the microwaves. Another is used for the tranverters. For greatest power output, I usually have the engine running, with the vehicle power in parallel with the batteries. I use analog metering and a 50 amp fuse in that line, together with a 100 amp contact solenoid for switching the power and charging on-line.

Operating on the Road

For VHF and up operations, I have a dedicated antenna for each band. At times I have used a simple dipole for 6m, a halo, a 3 element beam, and more recently a stressed Moxon. One time when I was alerted to an Es opening on 6m, I put up the three element beam on the rover van in the driveway and worked European stations. The 6m antenna usually travels in a mount on the van end corner opposite the dish mount, and then if needed, placed on top of the central stack of antennas for better height and rotation. I also stuck a 222 loaded whip on that same mount as the 6m antenna, as having 223.5FM open all the time is a great help during VHF contests. For 144MHz, 222MHz and 432MHz, I use beams with about 10' booms that I have acquired all through the used market of ham gear. They are reasonably sturdy, but periodically require replacement of broken elements, or attention to the matching system. The loop yagis for 903MHz, 1296MHz, 2304MHz and 3456MHz are all from Directive Systems, and they are mounted together on a crossboom in the same horizontal plane, which in turn is bolted to a short mast that fits into the 1-3/4" mast that supports the 144-222-432 beams. It is fixed into place with a pin through both masts, so that all of the antennas are controlled by the same rotor.

Before I had 24GHz capabilities, I used a separate dish and feed mounted on the same mast each for 5GHz and 10GHz. I saw the advantage of using a dual feed for 5/10 and changed to that setup a few years ago. When I added 24GHz, I carefully aligned the dishes, and used another telescoping mast piece to mount the 24GHz dish atop the 5/10 mast.

The basic layout of the van allows me the flexibility of antenna configuration and power-supply, rig, transverter and amplifier. With the central mast and rotor poking through the center of the roof, I can mount all of my rover yagis, keeping the height down to 12' 3" to allow easy passage on most roadways. The microwave dishes for 5-10-24GHz are kept in the rear compartment and easy erected by placing them into a mast stem on a Yaesu 450 rotor mounted on the rear of the van. The 6m Moxon is usually carried on another mast mounted on the rear of the van, and that is placed atop the VHF stack for operation. The set-up allows me to spend more time operating than setting up and breaking down. It also keeps me inside the warm vehicle in January, with only brief time needed to mount the dishes if they are needed.

I have enjoyed taking the van out as a rover in the January VHFSS, spring and fall sprints, the VHF QSO parties in June and September, the August UHF contest and the 10GHz and Up weekends. When there was an opening on 6m, I was able to catch several Europeans with the van in the driveway using the 6m 3 element beam. I have enjoyed operating both HF and VHF for Field Day and various QSO parties. I operated for a few hours for HF SS in November, and intend to put more effort into getting another clean-sweep mug in future outings.

Rover Moonbounce
My interest in EME has been piqued several times, and more recently with sharing operations at both the K1JT 2m EME station and the K2UYH EME station. My latest project has been EME (moonbounce) on 144MHz, 432MHz and 1296MHz. I was alerted to a junk pile of four long 2m yagis that were free for the taking, that were once used as an EME array, and also a 10' TVRO mesh dish that was free for the taking. It's important to remember that a free item can be very costly. How costly? A few thousand dollars later, I have a 400W 2m amp and cavity preamps, a power splitter and new coax, and an elevation rotor. I have a new 180W and another 500W 432MHz SSPA, along with 4 long yagis and a power divider. I bought a 120W amp for 23cm, another 300W SSPA for 23cm, low-noise silver plated 1296 MHz cavity preamp, multiple N relays and sequencer, a TS2000X, a septum feed and superscalar ring, a tower section, new rotor and thrust bearing, along with their mounting plates and a base plate for the tower section. This year I also managed to buy a 180W 13cm SSPA, along with the 28 and 50VDC power supplies that run them. I also decided to add a Honda 2KW generator to run the units when I can't have suitable AC power available. All this is based out of the van. A single long (5wl) yagi was used for the first three 144MHz CW QSOs, but the plan is to use a pair of them with full elevation capability. They will be mounted on the center mast of the van.

My first attempt at a 2m EME CW QSO was a sched with Dave W5UN. We had a one hour sched with 2 minute sequences. I aligned the antenna to the moon as it lowered to about 15 degrees above the horizon and started transmitting. I listened after my transmission, but did not hear him until almost 45 minutes into the hour—then I heard his OOO report for me, but I never did copy his call. Later he told me he copied all of my transmissions. I reviewed the situation, changed the rig, coax and preamp, and then went on to make several other successful contacts on 2m EME CW. I continued to use the single 32' yagi and operated at moonrise. The additional ground gain for the first hour allows for reasonable signals.

I decided that it was time to take the next steps in my EME quest, so I had a trailer hitch installed on my rover van. I bought a 4' x 8' Worthington aluminum trailer hat fit into my garage.I put a new sheet of ¾' plywood on the trailer and then mounted a shortened piece of Rohn hinged tower base. I installed a Yaesu 800 series rotator in the tower and a thrust bearing on a top-plate. The mast is 2" OD thick-walled aluminum. Next I turned my attention to having a fixture made to enable me to use a winch to move the tower section from lying on the trailer bed to the vertical position. Initially I used a hand-cranked worm-drive winch, but after cranking and cranking, I jettisoned that winch and replaced it with a 3000 lb electric winch.

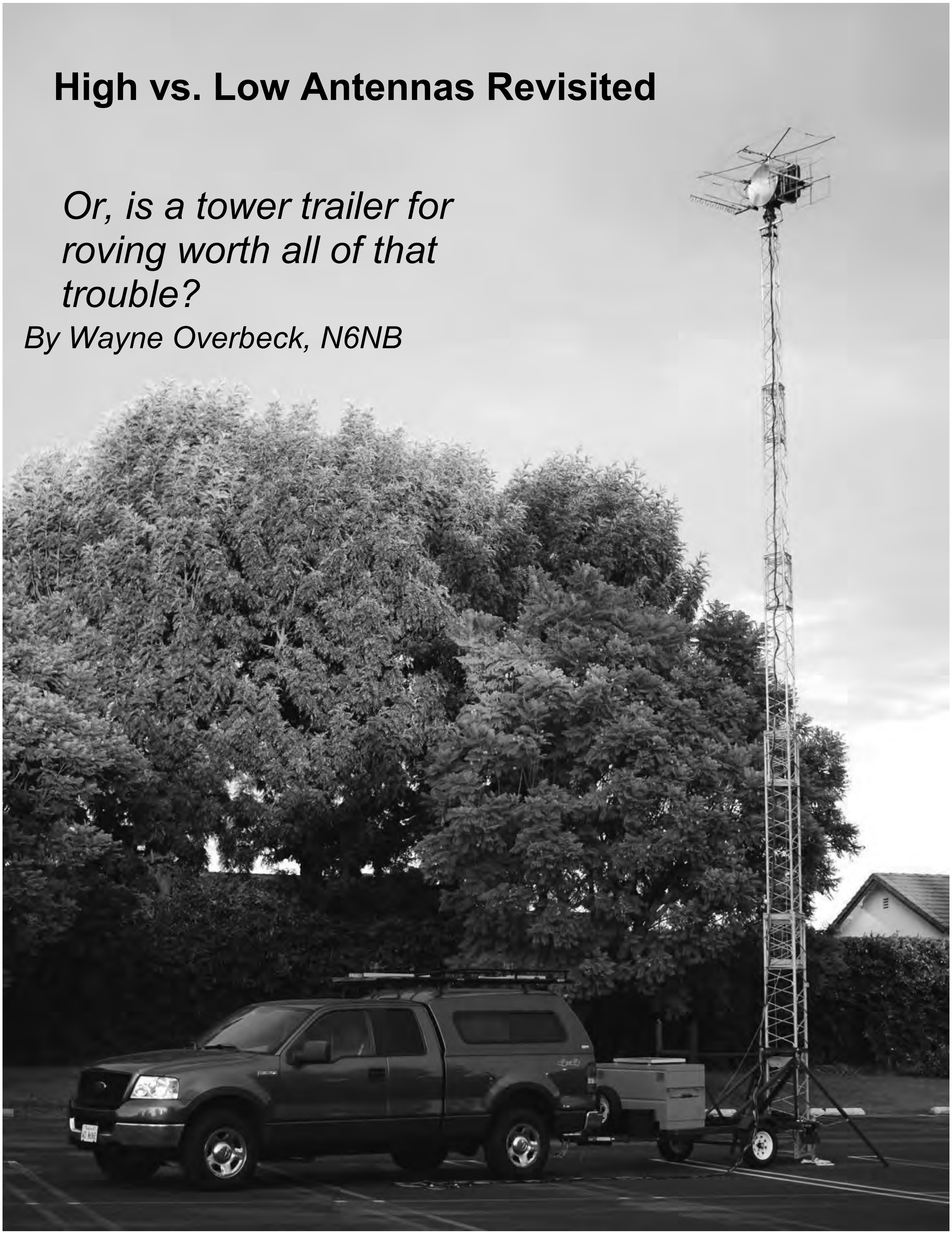
The 10' TVRO dish had a polar mount, that was easily changed to an AZ-EL mount with a bit of sawing and welding. I bought all new hardware for mounting the dish to its central ring. As the dish always has to be erected temporarily, I figured out the next year that it was a lot easier to use pins with retainer clips that more easily slip in and out of the pieces that they stabilize. The more difficult part was making a stable mount for the feed, as it is big and bulky, especially with the scalar ring. I used some ideas from others, assembling a frame of aluminum angle that would encase the feed, yet allow it to be moved in and out from the dish to optimize the focal point. With the use of a down converter and an SDR-IQ, we were able to measure sun noise, and fine-tune the prime focus of the feed to the center of the dish. For my 10' f/D .36 dish, the sun noise of 13dB (for the measured solar flux for that time) seemed to be ideal.

I used this set-up with my 120W 1296 amplifier, but only made 3 contacts over a weekend. I heard plenty of stations, but they barely heard me. Time for more power. I bought a PE1RKI SSPA and spent a few weeks mounting it on a chassis and adding the metering and controls. I obtained a 28V, 22 amp power supply for it and easily measured 275 watts output for 4 watts input. This past summer I was able to make an additional 30 QSOs on 1296MHz CW. I turned my efforts now to 432MHz EME, cleaned up the 4 long yagis, got a 4-way power divider, made cables, an H-frame, and added a W6PQL 500W SSPA with a 50V 20A power supply. Obviously, for EME operations, this is mostly a good-weather activity, and the setup is in one configuration for the weekend. The trailer cannot be driven with the dish or long yagis fully deployed. The antennas or dish petals are easy to stow on the trailer when the tower is lowered. The neighbors have gotten used to seeing me rig the rover for various activities and often inquire about my results. They are especially curious about the moonbounce activity and the countries that I contact. I proudly show off my QSL cards. I am happy that they have no complaints about my activities and that I don't interfere with any of theirs. There are many local and more remote spots that I have operated from. Many of the best mountaintop locations are now off-limits due to commercial enterprises, but there are still enough places available to have rover fun.

High vs. Low Antennas Revisited

Or, is a tower trailer for roving worth all of that trouble?

By Wayne Overbeck, N6NB



44 years ago I published an article in *QST* called "High Versus Low Antennas."[1] It concluded that high antennas are usually far more effective than low ones, with one notable exception. It wasn't the first time that topic had been addressed in amateur or professional literature--and it certainly wasn't the last time. Now the subject is being addressed in a new way in connection with rover stations in VHF contests. As rovers start to use tower trailers, the question is whether the added antenna height is worth all of the extra hassle that it entails.

Rovers like to cover a lot of ground during a VHF contest, sometimes visiting 20 different grid squares during a single contest weekend. I once visited 22. But towing a trailer slows you down. In many states there's a lower highway speed limit for trailers than for passenger cars and light trucks. The trailer speed limit in California, for instance, is 55 even on interstate highways. In states where it may be legal to drive 75 miles per hour towing a trailer, there's another issue. Some trailer tire manufacturers rate their tires as safe only at speeds up to 55. If you drive faster than that and a trailer tire fails, the manufacturer doesn't want to hear from you.

Rovers also need *maneuverability*. They need to be able to navigate narrow dirt roads and turn around in tight quarters when there's a dead end or a locked gate ahead. It's not easy to get out of tight spots if you're towing a trailer.

On top of that, setting up even the best-designed tower trailer takes *time*—time that could be spent on the air. After setting up and then dismantling a tower trailer in 10 grid squares, most rovers would be too tired to do much operating.

If towing a tower trailer has so many drawbacks, why would anybody even consider using a tower trailer for roving?

The answer probably involves psychology as much as it involves the physics of radio propagation, but tower trailers do have some undeniable advantages. Let's just talk about physics. Antennas high above foliage and buildings in the near field and high above the surrounding terrain simply work better than vehicle-mounted antennas that are typically no more than 10 or 12 feet above the road.

About the only time typical rover antennas mounted on a car or truck are really competitive is when the rover is on a hilltop with a clear view in all important directions. Unfortunately, there aren't all that many clear hilltops available. Even Mount Greylock in Western Massachusetts, probably the best VHF location in North America if contest scores over the decades are any indication, isn't a great place for a rover with car-top antennas. The Mount Greylock Expeditionary Force hauls towers up the mountain and spends two or three days setting them up before each contest, only to take them down after the contest is over. If you try to operate on Mount Greylock with typical rover antennas, you quickly discover that the trees and buildings on the mountain gobble up a lot of r.f.

CLEARING LOCAL OBSTRUCTIONS

Anyone who has ever used a crankup tower for long knows how much better it works when it's fully extended than when it's nested. When it's down, the antennas are often obstructed by nearby buildings and trees. Listening to a steady signal while a tower is raised or lowered can be a revelation.

Even disregarding for the moment the advantages of a low radiation angle, an antenna high enough not to be obstructed by trees and buildings far outperforms an antenna in the trees. Tree attenuation has been measured at anywhere from 1 to 2.5 dB. *per meter*, depending on the frequency and the type of tree.[2] Generally, attenuation increases with the frequency. A dipole hidden in the woods may work reasonably well at 3.8 MHz, but a 10 GHz dish in the same woods wouldn't likely set any DX records, even in the winter when there's less foliage. Both the lumber itself and the foliage contribute significantly to tree attenuation.

Every seasoned rover knows ways to minimize the signal-devouring effects of trees and buildings. You do whatever it takes to get on top of a hill with a clear view to the horizon. If you can't do that, you try to aim down a road or across a cleared field (or, better yet, across a body of water) to escape near-field obstructions. But in many, many places there is no escape--except if you can find a way to elevate your antennas above the obstructions. Some rovers love parking structures for that reason (provided there's adequate vertical clearance for vehicle-mounted antennas). Others turn to tower trailers.

I've been building tower trailers since the 1970s. I built a new one, my tenth, in 2012, and described it in the June, 2013, issue of *QST*.[3] It is shown above in the town of Center, TX, during the January, 2013 VHF Contest. Soon after I built it, I outfitted it for 10 VHF+ bands. The black box (behind the dish) on the tower houses transverters and amplifiers for 902 and up. Having the microwave equipment tower-mounted greatly reduces feedline losses.

A good illustration of the advantage of a tower trailer comes from K5QE's multioperator log in the January, 2013 VHF Contest. Marshall's station systematically worked several rovers as they visited up to 10 grid squares in the heavily wooded countryside of East Texas and Louisiana--areas where 90-foot-tall trees are commonplace. W5TV was operating K5QE's white rover (shown at left), a well-equipped station with amplifiers on all bands through 10 GHz. The white rover has its antennas mounted on a classic rover frame over the truck bed. The antennas are up to 12 feet above the ground, about as high as antennas can be mounted safely on a vehicle. I was roving with my tower trailer with antennas extended as high as 45 feet above ground level at various stops.

W5TV and N6NB both worked K5QE consistently on all bands through 1296. On 2304 and above, however, W5TV in the white rover worked K5QE only nine times. With the tower trailer, I was able to work K5QE 24 times. Microwave signals were often S7 or S8 with the tower trailer when they were in the noise in the white rover. Even though the trailer-mounted antennas were not high enough to be clear of all trees, they were high enough to avoid a lot of the tree attenuation that plagued the antennas on the white rover. Being able to raise your antennas above at least some of the trees is a real advantage.[4]

To illustrate why a tower trailer can be useful, I posted a video on YouTube showing what happens to the signal from a 10 GHz beacon 100 miles away as the tower is lowered. With the tower at full height (45 feet), the beacon was a solid S9. The signal got weaker and weaker as the tower was lowered and the antenna became obstructed by nearby trees. When the tower was fully retracted, the beacon signal all but disappeared into the noise level. Here's the link to the video: http://www.youtube.com/watch?v=yomibUV7mwg

HIGH ANTENNAS AND LOW RADIATION ANGLES

Much has been written about the effect of antenna height on the radiation angle, or "takeoff angle," of radio signals, taking into consideration the geometry that produces "ground gain." It has been known since the early days of radio that higher horizontally polarized antennas produce lower takeoff angles, enhancing signals by several decibels at low angles. It's also long been known that a low takeoff angle, and therefore a high antenna, is important for many forms of long-haul skywave communications.

My article in QST 44 years ago reported on side-by-side testing of high and low antennas.[5] Using statistical methods, I summarized the results of hundreds of A-B tests of identical antennas, one 70 feet high and another 34 feet high. Both antenna systems were clear of local obstructions. I found that on HF F-layer propagation, the higher antenna outperformed the lower one by about two S-units on average. On tropospheric paths over flat terrain, the advantage of the higher antenna was even greater. Only on six meter E-layer propagation was the lower antenna superior. It had a mean advantage of 1.3 S-units over the higher antenna on "E skip."

In the years since those tests, very sophisticated software has been released to perform terrain analyses and to ascertain the optimum "takeoff angle" for a given path on a given frequency.[6] We know now that for long-distance HF communications an antenna about 90 feet high is a good compromise for most paths on 20 meters, and that an antenna 45 feet high is quite useful, albeit nowhere near optimum for HF communications.[7] We also know that on six meters there is a bimodal optimum takeoff angle for sporadic E communications, with angles of about 5 degrees and 10 degrees being the two most frequent optimum angles.[8] Given the geometry of ground gain, a horizontally polarized antenna only about 30 feet high (less than two wavelengths at 50 MHz) is often optimum for E-layer communications on six meters. Numerous well-equipped six meter contest stations now have antennas about 30 feet above ground level as well as much higher ones to better work both close-in E skip signals arriving at higher angles and more distant signals arriving at lower angles.

This helps explain the oft-observed reality that even in flat, wide-open terrain, a horizontal antenna 30 or 35 feet high on a tower trailer or a mast is very effective on six meters. An antenna mounted on a vehicle at a height of only 10-12 feet sometimes also works surprisingly well on high-angle E-skip, but even a few A-B tests will usually show that an antenna 30 feet high is far better for most paths. I have seen that phenomenon repeatedly when I had a small Yagi elevated about 30 feet and I was operating alongside rovers with roof-mounted antennas.

Tropospheric propagation, as opposed to skywave ionospheric propagation, presents another example of a case where a higher antenna's lower takeoff angle gives it a significant advantage over a vehicle-mounted antenna. For long-haul tropo, the best takeoff angle is usually the lowest possible one. That was true in the tests I ran 44 years ago--and it has been true in every test I've conducted since then. When I was preparing this paper in April of 2014, I set out to test high and low antennas on a long tropo path in a place with flat, open country not unlike the Great Plains. The closest thing nearby was California's central valley. So I towed my tower trailer to a site near Lost Hills, CA along Interstate 5 (in grid square DM05eo) to compare signals received from the KJ6KO beacons, about 416 km. to the north in CM88ws. The site was chosen because virtually the entire path is over flat terrain, mostly farm land with no obstructions that might favor a high antenna over a lower one. This was a test of radiation angles, not of avoiding near field obstructions. The photo above shows the tower trailer at this site, looking in the direction of the distant beacons (although the antennas are pointed in the opposite direction in this picture to show them better). On every band from 144 MHz to 1296 MHz, KJ6KO/B was far louder with the tower trailer at its full height than with the tower lower.

When roving in other flat areas with few trees or other obstructions, I've seen the same thing often. Even when there are no local obstructions to clear, a higher antenna works far better on long-haul tropo than a lower one. If one can set up on a clear mountaintop, it's all the better, of course, but high is better than low in the flatlands. A low takeoff angle is crucial for good performance with both ionospheric and tropospheric propagation.

MASTS, MINI-MASTS AND TILTING MASTS

There are other ways for rovers to get enough antenna height to clear some local obstructions and achieve a lower takeoff angle for DX work. Solutions range from surplus TV news vans with large pneumatic telescoping masts to lightweight tilting masts, crank-up mini-masts and even towers mounted upright on a vehicle.

There are tales--many of them horror stories--about surplus TV news vans. They're appealing to rovers and other hams because their built-in masts typically achieve a height of 40-50 feet or more. A custom news van can be purchased brand new, but the sticker price (around $200,000 for a well-outfitted one) deters most amateurs. That price may be okay for a corporation with a revenue stream sufficient to recoup the investment, but not for many amateurs who have to pay for their hobby from a family budget. Used vans do show up on the market, but several hams have learned painful lessons about corporate deferred maintenance after buying one. Generally broadcasters and other commercial users only declare a van surplus and sell it at the end of its useful life. Companies tend to repair their vans until it's no longer cost-effective to do so. A surplus van is likely to have an odometer reading approaching 200,000 miles, and the pneumatic mast itself may need costly maintenance. One of the better stories circulating on the Internet involves a ham buying a surplus van and driving it away, only to be stranded by a difficult-to-repair mechanical failure 100 miles out (but 1,000 miles from home). Other stories involve masts that gradually slip down, requiring the user to constantly re-raise the mast while trying to operate. Then there's the reality that the mast itself barely complies with highway height limits. There's not much room for an antenna stack atop the mast. That means the ham must devise a tilt-over mechanism for the antennas or else install everything at each stop.

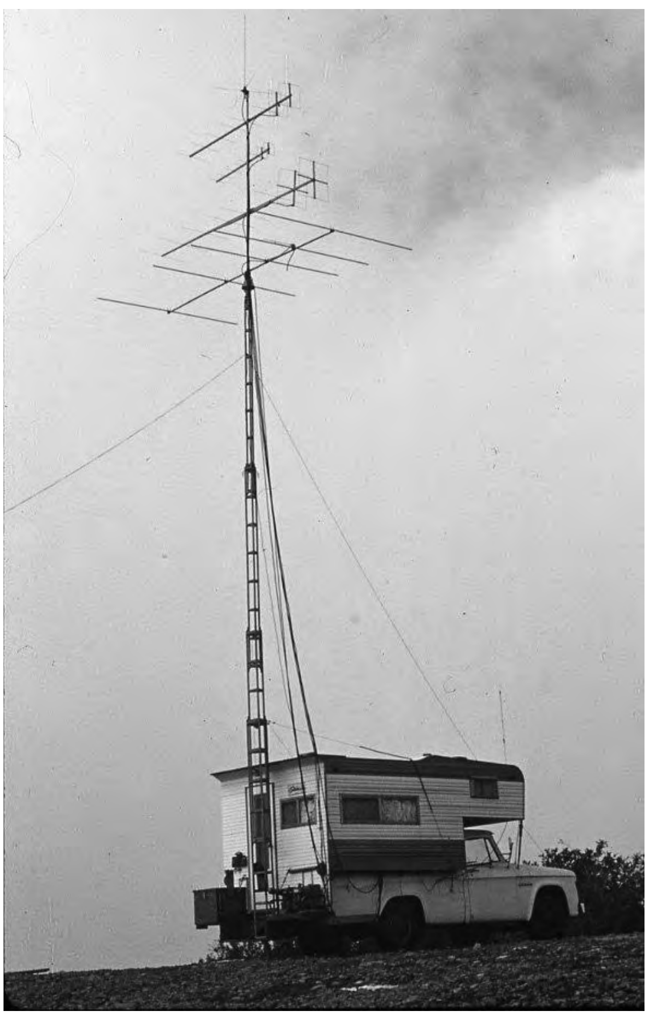
All of that leads many rovers to consider more modest masts that can be installed on a trusted vehicle. I used a tilt-over mast on a van for roving in the early 2000s. It is shown in the photo below. The highest antenna on the mast was 27 feet high--high enough to be reasonably effective.

This photo at left was taken at an overlook on Interstate 80 in western New Jersey during the 2003 January VHF Contest. The mast traveled horizontally on the roof of the van and could be raised in less than a minute, including the time it took to lock the mast in place on a bumper-mounted rotator. The highest antenna, a 3-element six meter Yagi, rested on the mast in front of the van for travel, just clearing the front bumper.

The photos on the next page show the mast being raised on a snowy hilltop near Boonton, New Jersey, beside an observatory operated by local amateur astronomers.

The tilting mast shown in these photos was practical and effective--up to a point. It was a quick way to put up a few small antennas, but it wasn't suitable for a larger array, much less for a top-mounted equipment box for microwave gear.

Some rovers have used crankup masts that can be mounted on the rear deck or even installed upright inside a van (perhaps with a large hole drilled in the roof and then waterproofed). Several eastern rovers have supplemented vehicle-mounted antennas on a fixed mast with



additional antennas on a crankup mast. The setup time at each stop is minimal, and some of the antennas can be raised to a height of 20 or 25 feet. It's an effective arrangement, although it can leave antennas for some bands low enough to be obscured by trees and buildings. Once again, the rover is best off to find a clear hilltop. That's not easy to do in many areas. I remember reading online accounts of a rover who went to the Marconi Site on Cape Cod. That site is one of the highest points on Cape Cod, but the rover found it frustrating even with some antennas on a crankup mast. The bottom line was that he needed still higher antennas or better propagation. I later went there on a trip to the east coast with my tower trailer just to check it out. With antennas up 45 feet, I had all bands well clear of the local foliage. The site seemed promising for roving with a tower trailer. Then I learned about the snarled traffic that plagues Cape Cod on summer weekends. It was great to have a tower trailer at the Marconi Site, but it wasn't so great to try to get in and out of there with a trailer.

The photo at left shows still another way to get antennas above local obstructions: a four-section crankup tower mounted upright on the rear deck of a pickup truck with a cabover camper. I built this thing 44 years ago. It was called "the Cabover Kilowatt," and it ended up on the cover of *QST* in August, 1971. It was a great way to have antennas 40 feet up without the hassle of towing a trailer. But there was a catch: the tower itself stood nearly 13' high. That's below the legal limit for vehicle height, but it left no room for a rotator and a stack of antennas. At each stop, I had to climb the tower, install the rotator, then assemble a stack of antennas. That didn't seem so bad for a ham in his twenties who was only doing the setup once in each contest (roving wasn't permitted by the rules in those days). However, for a rover who is, um, not in his twenties, that's not a very practical arrangement. Maybe the rotator and antenna stack could have been made to fold over for travel so everything could be tilted up quickly at each stop. That was a possibility then, but this is a tower trailer era for me. With a tower trailer, the rotator and all of the antennas can be transported intact, ready to motor up quickly at each stop. But that still takes time that could better be spent on the contest itself.

CONCLUSION

In the kinds of places where rovers often operate, the results with a tower trailer can be spectacular. With buildings and foliage in the near field, normal vehicle-mounted rover antennas have their limitations. Only if it's possible to get into the clear on a foliage-free hilltop does a typical rover setup with vehicle-mounted antennas perform competitively on long paths. But with a tower trailer, it's an entirely different game. When the tower is raised from its nested height to its full height, signals often increase by several S-units. Many locations that would otherwise be mediocre suddenly become outstanding when you can raise your antennas above trees and buildings. Even in an open field where local obstructions are not a problem, raising your antennas from a height of 10' or 12' up to 45' can make an amazing difference on both tropo paths and skywave propagation where a low takeoff angle is important.

None of this makes a tower trailer any less cumbersome on the road. Nor does it make a tower trailer safe to tow at high speeds. And repeatedly setting up a tower trailer in one grid square after another is still exhausting. But if good signals over long paths are a goal, a tower trailer makes sense for a rover.

First licensed in 1957, Wayne Overbeck has been interested in VHF+ operating, and especially portable contesting, for more than 50 years. He holds Ph.D. and J.D. degrees and is a retired university professor who published 20 editions of a communications law textbook to help pay for his hobbies. He won the Radio Amateur of the Year Award at the Dayton Hamvention in 1980 and also the ARRL Technical Excellence Award and the John Chambers Memorial Award of the Central States VHF Society in 1978. The latter awards were in recognition of his work on the original "VHF Quagi" antenna and his early moonbounce expeditions to Alaska and the Utah-Nevada border. See www.n6nb.com for more information.

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[1] Overbeck, Wayne, "High Versus Low Anennas," *QST*, March, 1970, pg. 20.

[2] See, for instance, Vogel, Wolfhard J. and Hagn, George, "Effects of Trees on Slant Propagation Paths," a paper presented at the International Symposium on Advanced Radio Technologies (*ISART*), Boulder, CO, 1999.

[3] Overbeck, Wayne, "A 1200-Pound Gorilla on Wheels," *QST*, June, 2013, p. 20.

[4] Later K5QE decommissioned his fleet of rover vehicles, including the white rover (his premier rover), and sold most of his microwave equipment in order to concentrate on the four-band limited multioperator category in VHF contests. The January, 2013 contest was the last one in which a full complement of microwave-equipped rover stations traversed the East Texas and Louisiana countryside in a systematic effort to work K5QE on as many bands from as many grid squares as possible.

[5] Overbeck, Wayne, "High Versus Low Antennas," *QST*, March, 1970, p. 20.

[6] For example, the U.S. government has published the *Ionospheric Communications Analysis and Prediction* (IONCAP) software package and ARRL published R. Dean Straw's *High Frequency Terrain Assessment* software in The ARRL Antenna Book, 21st edition.

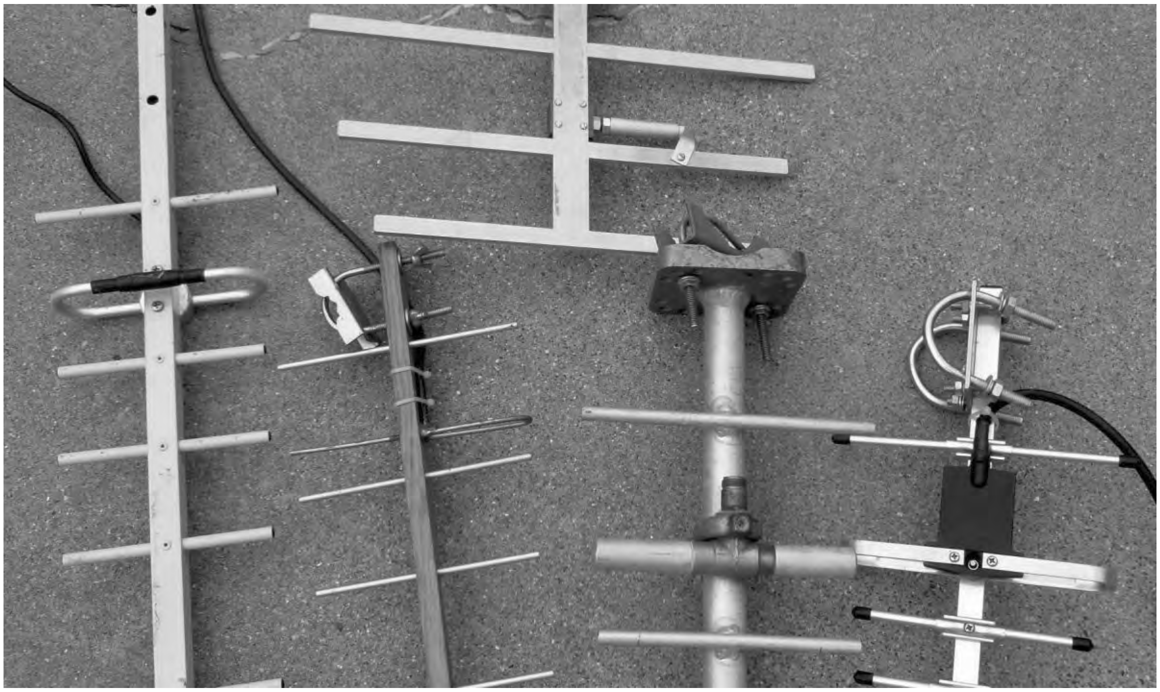
[7] Siwiak, Kai, "An Optimum Height for an Elevated HF Antenna," *QEX*, May;/June, 2011, p. 32.

[8] See Gene Zimmerman's "World Above 50 MHz" columns in *QST* for July and August, 2009, for a discussion of the work of Joe Kraft on six meter takeoff angles for E-layer communications.

Driven Elements for Yagi's

Kent Britain

WA5VJB/G8EMY



This paper and presentation will be a work in progress covering the many Driven Element designs with the advantages and disadvantages of each.   While not ready for the Proceedings, copies can be downloaded at WWW.CSVHFS.ORG or WWW.WA5VJB.COM Reference section.

Again this is to be a work in progress and I welcome additional driven element designs and feedback from others.   Updates should continue for years.

A Common Design for 6M Through 23CM Beacons

Tom Apel K5TRA

AUSTIN, TX

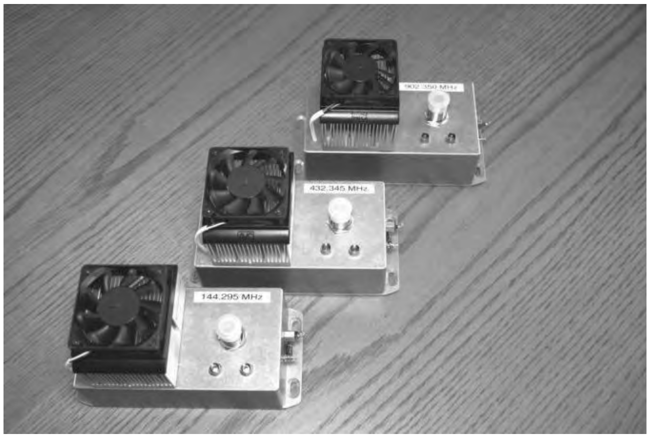


Figure 1 RMG 144, 432, and 902 MHz beacons

I. INTRODUCTION

This paper details the development of a family of beacons for 50, 144, 222, 432, and 902 MHz. A common design and assembly is used for each. The 144 MHz and above beacons are operational at the RMG (Roadrunners Microwave Group) beacon site near Bee Caves Texas. The 50 MHz beacon is associated with the GVARC (Guadalupe Valley ARC) and is operational in the Canyon Lake area north of San Antonio. The RMG beacons are shown in Figure 1 and beacon site is shown in Figure 2. While the each module has a dedicated heat sink, the beacon can operate safely without it. The fan allows the heat sink to remain cool to the touch (in the summer) and thereby an extension to the beacon's life.

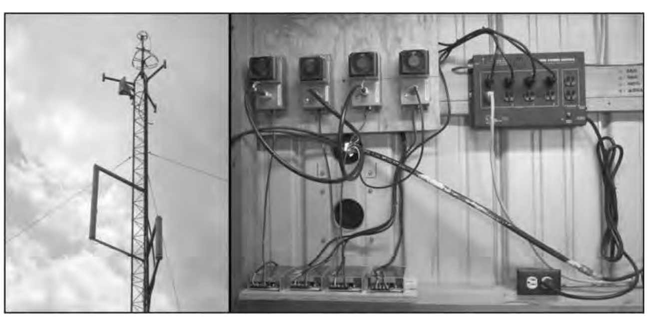


Figure 2 RMG beacon site

II. BACKGROUND

The initial prototype design was on 222.060 MHz. It is fully self-contained in a Hammond 1590P1FL enclosure that houses the RF board, PA module, LPF, and FB-1 (Freakin Beacon) controller. The FB-1 controller is produced by Expanded Spectrum Systems[1]. In addition to transmitting ID and grid square, a 5 second carrier is also transmitted at three power levels. Boards for the original 222 MHz beacon were fabricated using "Press-N-Peel" artwork patterned from a laser printer and homemade bubble etcher. Figure 3 shows that RF board mounted next to the FB-1 controller. The RF board layout was for SMT assembly.

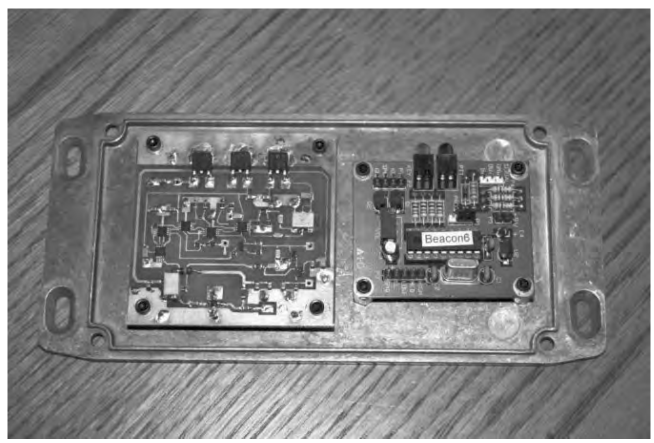


Figure 3 Original 222 MHz Prototype

Motivated by the success of the 1.25M beacon, the RMG club embarked on a group project to build new beacons for 144, 432, and 902 MHz. All PC boards were fabricated through the ExpressPCB process. The design translation from 222 MHz was easily accomplished. In fact, a common layout was used for the RF board and PA/LPF board.

Following the success of the RMG beacons, the GVARC expressed interest in the possibility of translating the design to 6M. This was successfully done early in 2014.

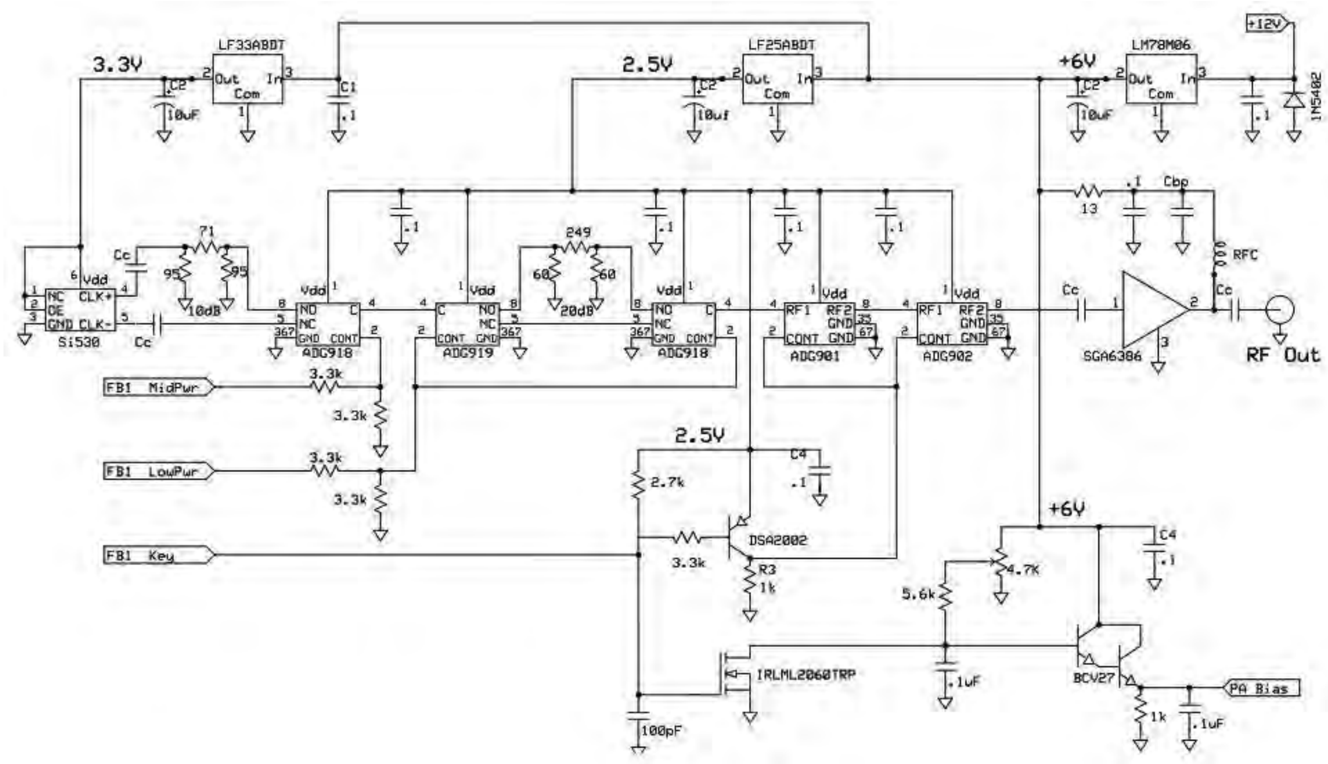


Figure 4 RF board schematic

III. RF BOARD

The core of the beacon design is the RF board. It contains a Si530 phase-locked signal source, level stepping control, Morse gating of RF and PA bias keying, RF driver amplifier, and voltage regulators. The schematic diagram of this board can be seen in Figure 4.

The Si530 chip is a Silicon Laboratories[2] product that is available with 7 PPM frequency stability to temperature. It contains factory programmed PLL circuitry, with integrated crystal oscillator reference. Each beacon has a Si530 that is programmed to the RF output frequency. In order to fully realize the frequency stability performance offered by this chip, two precautions are taken. First, the 3.3V supply regulator is run from the regulated 6V rail. Double regulation also distributes the dissipation on the PC board. The second precaution is to maintain a constant load on the output pins during Morse keying. These beacons operate chirp free.

Differential output pins from Si530 are used as separate single-ended sources. One output provides drive to a 10 dB pad that is routed to the first of several CMOS SPDT switches. The other output provides drive directly to the other leg of the SPDT CMOS switch. The (AD) Analog Devices ADG918 chip provides a switched 50Ω termination on unselected ports. When a 10 dB level reduction step is controlled, the CMOS switch selects the padded input instead of the direct input.

In a similar manner, a pair of ADG919 SPDT CMOS switches select a through path or a 20 dB attenuated path for the lowest power state.

Following the level stepping switch circuitry are a pair of high isolation SPST CMOS switches in cascade. The SPST chips, ADG901 and ADG902, are used to gate the RF drive under Morse control. The ADG901 chip maintains a 50Ω termination while in the off switched state. The isolation of each switch is approximately 55 dB at VHF, but degrades to 40 dB at 900 MHz.

In order to prevent CW leakage during unkeyed intervals, bias to the PA module is also keyed. This also reduces the PA duty cycle for cooler operation. A Darlington emitter-follower is used to buffer the gate bias line applied to the PA module. The bias voltage is set by the pot on the RF board. This is used to control the PA gain and correspondingly, the power output.

RF drive to the PA module is provided by a SiGe driver chip. Fortunately, the required driver gain for all but the 6M beacons was nearly identical. The (RFMD) RF Micro Devices[3] SGA6386 offers 15 to 16 dB of gain over the all of those bands with 21 dBm output capability. The 6M beacon uses a PA module with lower gain; so, a higher gain driver is needed for that band. The RFMD SGA6486 provides 21 dB of gain in the 6M design.

The same RF board layout was used for each beacon above 6M. Only component value changes were needed to build a beacon for a new band.

The necessary band specific design changes are:

- Si530 XO for beacon output frequency
- Coupling and bypass caps selected for band
- RFC in driver circuit selected for band
- SGA6386 (2M – 33CM) or SGA6486 (6M)
- PA module selected for band
- LPF LC values selected for band

Figures 5 and 6 show RMG 144, 432, and 902 MHz RF and FB-1 boards assemblies.

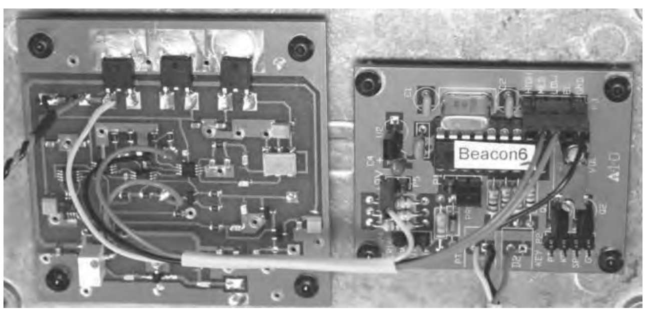


Figure 5 RF and FB-1 board assembly

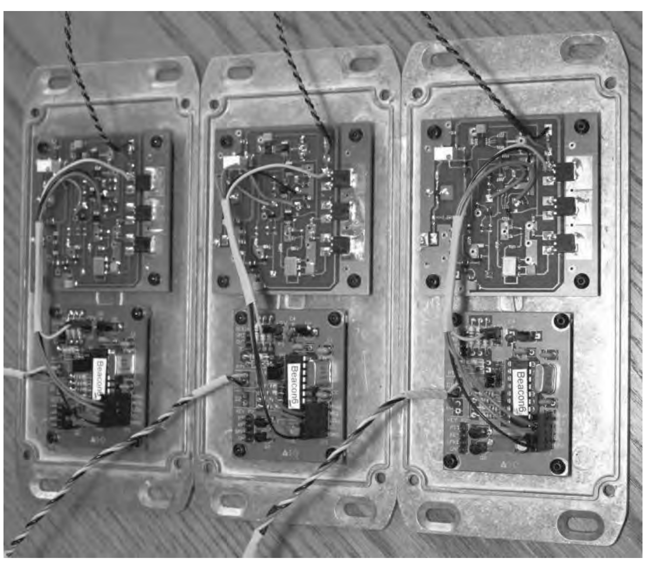


Figure 6 RMG beacons: RF and FB-1 boards

IV. FB-1 CONTROLLER

Level and Morse control is provided by a small FB-1 board. This controller can be programmed from a RS232 serial port. Outputs to control the RF board include Morse keying, mid power level, and low power level. Logic levels are +5V. For more information check Expanded Spectrum Systems[1] web page.

V. POWER AMPLIFIER

Mitsubishi PA modules are used in each of the beacons. The similarities and differences can be seen in Table-1. The footprint for each is nearly identical; so, the housing assembly can be the same. Most have 33 dB of power gain; so, similar drive is required for a given output (15W). Clearly the RF drive for the 6M beacon must be greater than for the other bands. The other significant difference is the nominal bias voltage. The nominal bias required for the 6M PA is higher than the requirement for all the other bands. Due to this, the RF board layout is slightly different for that band. The rail voltage for the bias emitter-follower and bias reference pot must be moved from +6V to +12V. The PA module interface board for the 6M beacon must also differ from the other bands due to the different I/O pin count.

Table-1 PA MODULES

BAND FREQ	MITSUBISHI MODULE	NOM. GAIN	GATE BIAS	RATED POWER	FLANGE FOOTPRINT	NUMBER IO PINS
50 MHz	M57735	28 dB	9 V	20 W	22x66 mm^2	5
144 MHz	RA30H1317M	33 dB	4.5 V	30 W	21x66 mm^2	4
222 MHz	RA30H2127M	33 dB	4.5 V	30 W	21x66 mm^2	4
432 MHz	RA30H4047M	33 dB	4.5 V	30 W	21x66 mm^2	4
902 MHz	RA20H8994M	33 dB	4.5 V	20 W	21x66 mm^2	4

All selected PA modules are operated class AB. The linearity characteristics of a particular module will affect the transmitted power as the level stepping to medium and low levels occurs. In other words a 10 dB step might not be exactly 10 dB.

Table-2 LPF LC VALUES

FREQ	Ls (nH)	Lt (nH)	Ca (pF)	Cb (pF)
50 MHz	147	25.3	68	100
144 MHz	54.3	7.9	27	39
222 MHz	37.9	5.4	16	23
432 MHz	19.5	2.8	8.2	12
902 MHz	7.9	1.1	4.7	7.5

The LPF values for each band are given in Table-2. The common LPF schematic diagram is shown in Figure 7. This is a symmetric 5^{th} order LPF with a shunt trap tuned for enhanced 2^{nd} harmonic rejection.

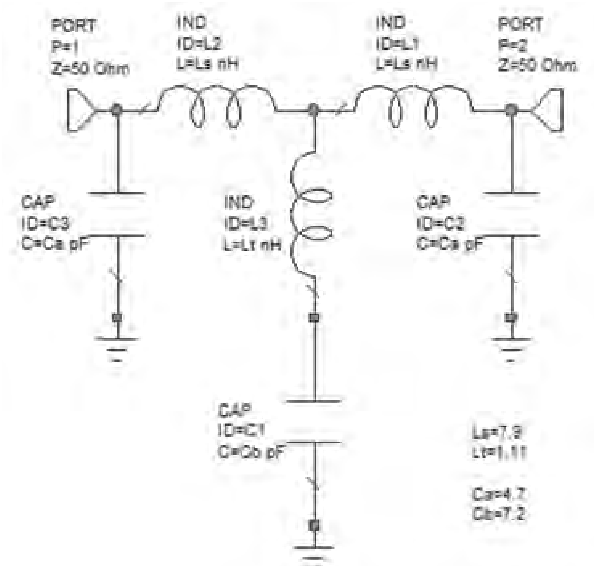


Figure 7 LPF schematic

Photos of the three RMG PA and LPF assemblies are shown in Figure 8. Measured LPF performance from four different band assemblies is displayed in Figure 9.

VI. SUMMARY

The development of fully self-contained beacons for 50, 144, 222, 432, and 902 MHz has been presented. RF output power is adjustable by adjustment of the PA gate bias. Typically, this is set in the 10 W to 15 W level. The initial design was prototyped at 222.060 MHz. The 144, 222, 432, and 902 MHz PC boards share a common layout. Even the PA module interface board LPF pad placement supports good LPF performance from a common layout. Due to physical and electrical differences in the 6M PA module, both the RF and PA/LPF boards are unique for that band. The new RF board layout for the 6M beacon could be used as a standard layout in the future (for all VHF-UHF bands). The many signal reports on all bands of operation has been personally gratifying, for the designer.

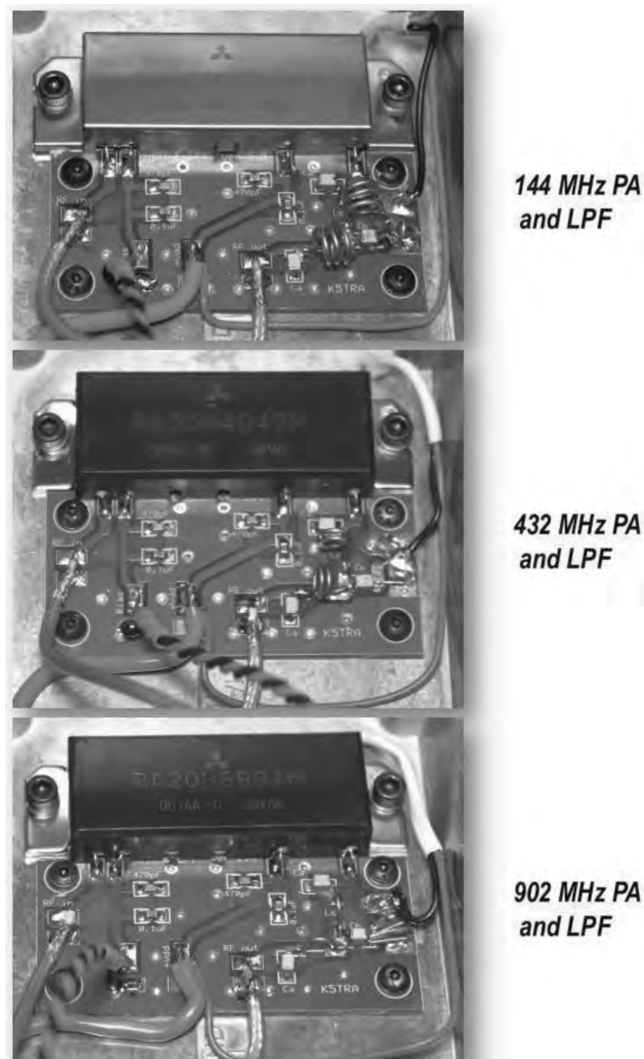


Figure 8 RMG beacons: PA board and LPF

REFERENCES

[1] http://www.expandedspectrumsystems.com

[2] http:// www.silabs.com

[3] http://www.rfmd.com

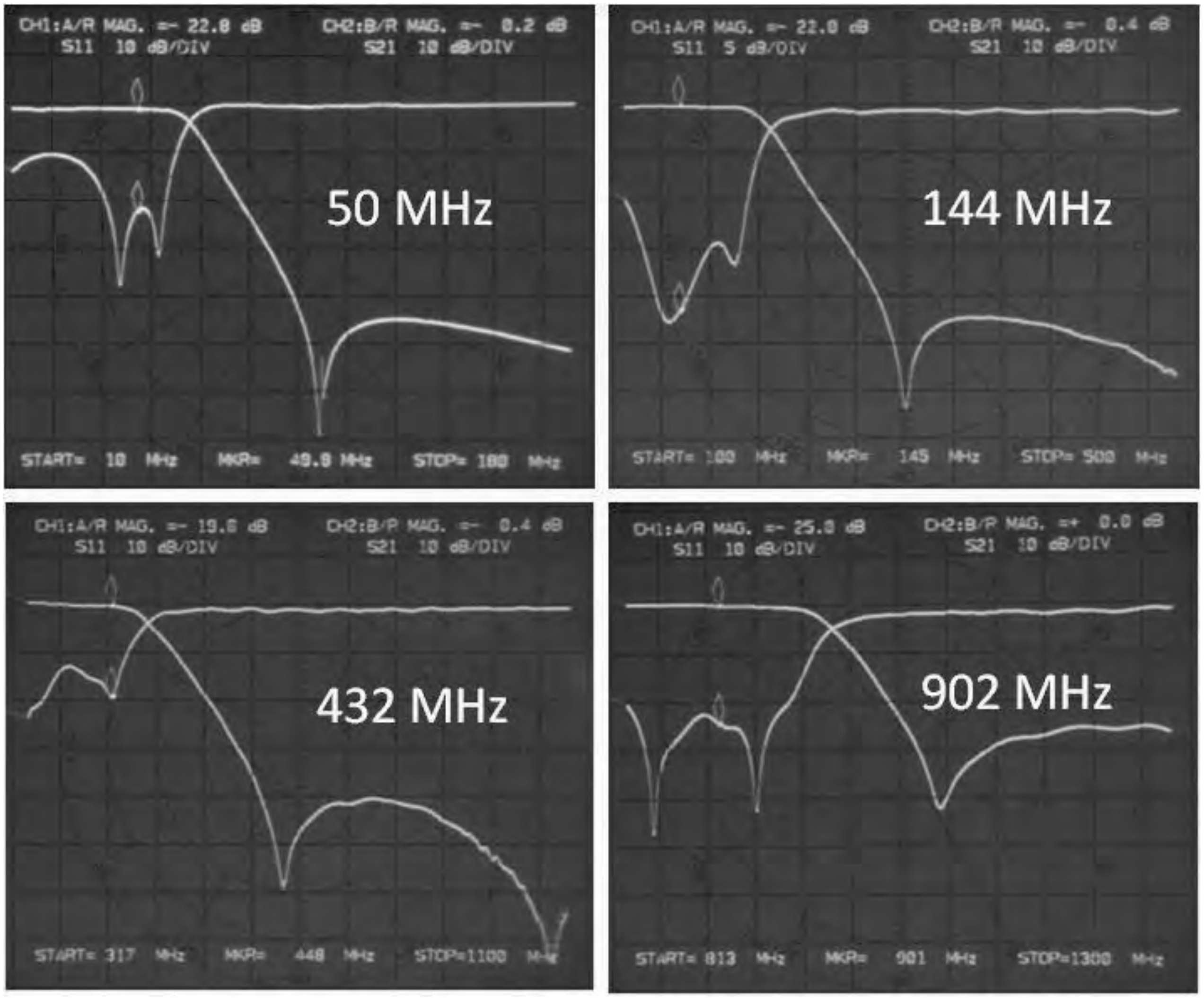


Figure 9 Measured LPF performance from four bands

Simple VHF Contesting

Sandra Estevez, K4SME and Steve Kostro, N2CEI

PREFACE:

The goal of this paper and presentation at the 2014 CSVHF Society's conference is to "possibly motivate" others to try some simple, basic VHF contesting. With the three major ARRL VHF contests, and the CQ VHF contest we just experienced, one can find many classes of operation that do not require excessive amounts of equipment, high power amplifiers, elaborate antenna systems, or even time to be competitive and have fun. You can pick the contest that meets your schedule based on the time of the year and then utilize a station type of choice (construct a mobile, semi-portable, or a home station) that fits a specific set of rules. This paper will identify all of the simple basic classes of operation and explain some of the highlights that differentiate one class from the other. Then since we are talking about contesting, it would be important to discuss some strategies along the way that separate the classes of operation. Also, understand that even though we see contesting as a measurement of station/operator performance, we believe in the hobby in its purest form. If you just enjoy "getting on" for a casual QSO or have thought about operating portable, there is something in this paper and presentation for you. So if you are ready to possibly try something different and have some fun, read on and see our Presentation at this year's conference.

CHOICE OF CONTEST:

Being die-hard VHF and above contesters, we both have been involved in, or associated with, contest stations that covered all classes within the Multi-Op, Single-Op and Rover categories. We have been active in VHF stations during Field Day and other VHF and above contests that cater to the UHF and Microwave operators. Then of course, to complete our spectrum of operation, we have actively participated in various HF contests from portable (Field Day) and home station locations. No matter if it was a Single Band, Multi-band, Single Mode, Multimode, High Power, Low Power or even QRP, we have tried it! Sometimes it was the "Concept" of the contest that attracted us and sometimes it is the competition, but no matter what, it was always for the fun!

Since this paper is about "Simple VHF Contesting", we will only address the four Major VHF contests sponsored by the ARRL and CQ magazine. There are many classes in these four contests but we will concentrate on the classes that require minimal equipment and for the most part, minimal effort. Now by no means to we have any prejudice towards any other type of contesting. It is just where we are at in our hobby adventure now and we desire to try other classes of operation in contests we have enjoyed in the past.

Now it is important to understand before we go any further the term "minimal effort". We will focus on minimal effort compared to a Multi-Op station, a High power Single Op or a Multi-band Rover. As we all know and understand, not much will happen if you do nothing so some work is required in any aspect of the hobby. So contest by contest, we will examine the classes and find a "target" to focus on for our next operation and maybe stimulate you along the way.

To start, let us examine the ARRL contests. We will nix the Multi-Ops, High Power Single Ops, and two out of the three rover classes. These categories go beyond the minimal equipment criteria we established for Simple VHF operation. The Limited rover class could be considered if you only attempt the June contest with the high probability of Sporadic E activity on 6M. The two other contests (Sept and Jan) will require the four allowed bands (6, 2, 1.25M and 70cm) to stay competitive if that is your goal. The June contest allows a fun 2-grid expedition weekend (to qualify as a rover) with a single transceiver and antenna. However, your success in the competition will depend on the sporadic "E" Gods since you will be competing against rovers that could be covering multiple grids on four bands when conditions are down. Therefore—the June contest would be the only time where the probability would be in your favor. Pictured above was a Limited Rover operation that covered eight grids in a June Contest. The extra loop Yagi was for 33cm to give out points in the rare grids we traveled in. In that contest we had multiple 6M openings but the other three bands kept us in the game during the down times. The conclusion is unless you feel extremely lucky, this would not be the best class to operate in with one or two bands if you wanted to be competitive.

The Single- Op low power class sounds like fun since it is from a single fixed position, but again requires as many bands as possible to place in the Top 10 unless extremely great conditions exist for you and only you! Most of us understand that is not likely to happen. The same goes for the Single–Op Portable class. Yes, you can find that remote mountain top and direct your 10 watts in every direction but again, it requires multi band hardware to run up a score! It is something I want to try and it would most likely need to be in the June contest here in Florida to keep it interesting but, for now, it's not a "Us" thing for us to do since it is a Single Operators event.

So let us look at the two newest classes of operation in the ARRL VHF contests, the Single–Op 3 band and the FM only. Both classes could utilize the same Multiband, Multi-mode transceiver and could do rather well with three simple antennas. The FM only class is as it states but with four bands maximum. The 3 Band class could include FM operation also. Therefore, the limitation to being simple would be the requirement of three or four antennas. The up side to this is that it could be accomplished from home or a fixed, portable location. If you were to utilize this setup in two or more grids, it would be a Limited Rover making it a very versatile option. Build a Limited Rover and use it for multiple classes of operation depending on the contest, the time of the year and/or the weather. So then, the "People" become part of the option. If two people wish to contest, it could function as a Limited Rover as we discussed previously.

One of the things I dread in a contest as a rover is after a long day of set up, tear down, travel to the next grid is the inconvenience of the larger 6M and 2M Yagis that we keep on a separate mast. During the UHF or Microwave contest, we leave them home. Alternatively, as shown to the left, we stopped on an overpass on the interstate in IL to make a couple of microwave contacts after the Cedar Rapids Conference in 2012. We simply do not raise the low frequency Yagis if not in use. The 6M Yagi travels with half of its three elements! They are “installed” before operation. Not a complaint, just the best we could do with an “All purpose” VHF/UHF/Microwave station on a trailer.

Now this brings me to the insanity of using it for the CQVHF 2 band contest as a Rover last year. I put the 2M Yagi in place of the top 432 MHz Yagi. Therefore, the tower was “pushed up” and then the 6M Yagi elements were “installed and elevated”. It was a lot of work for two bands but did pay off only because I had some great conditions! Sandra could not make the trip and yes, she was disappointed! Our Rover as shown is committed to a 10-11 band station so if we were to again Rove in the CQVHF contest, we would need do something different to keep it “FUN” for the whole contest! This was the basis of writing this paper and making this weekend’s presentation. How simplified but effective could a two band portable station be? However, before that, let us look at the operating classes in the CQ VHF contest and define what could be simple to do.

The CQ VHF contest is different from all other major contests. It is only two bands, 6M and 2M, so the defining of simple is in the contest. As a multi-op, two bands are required and a lot of hardware should be utilized to be competitive. In the Single-Op categories, it is a bit different. There is Single-Op single band, utilizing 6M or 2M or Single-Op all bands. However, the single transceiver and simple antennas will not compete with stations with the additional “Horse Power” and multiple antennas at a home station. The Single-Op All Band QRP looks to be more what we desire except that it is a Single-Op category. There is the Hilltopper class that has a 6 hr limit and is QRP. Again that fits to what we want to do but again, its Single-OP. The only other category is Rover, which we could repeat, but we will be “Roving” in the June and Sept ARRL contest and I do not want to modify our Trailer just for the CQVHF contest. It looks like the only way the both of us can have a weekend of Radio is to Multi-op or Rove.

However, let us examine the Hilltopper class once again. What if we assembled a simple 10-watt single Yagi station that each of us could operated for 6 Hours? We could travel to two different grids to “help out” the other contesters or just change call signs if in a rare grid. While one of us is taking their turn operating, the other can be taking pictures for the presentation, finding Lunch or Dinner or relaxing in the shade under a Florida palm Tree! It is QRP so we would never run the battery down in our Van and it would offer the cover from Mosquitoes, Hail, Wind and the Sun. The Air conditioning could be on if it was blazing hot. The picture shown below along with the first page picture was a set up that was assembled for the N4SVC 2013 Field Day operation. It netted 500+ QSO's with 100 watts proving if the band is "Right" it's a hoot!

<u>THE PLAN</u>

Our plan is to cobble something up and go out with two bands, 2 or 3 antennas in an air conditioned Van with 10 watts of RF on battery power and take turns operating in 6 hr shifts. Between the time I am writing this paper, and when we will operate the CQVHF contest a week before the CSVHF Conference, (when you will first read this) we may change our strategy, class of operation, or have something pop up that prevents us from completing the task. No matter what, we will make a presentation at the conference to report the results. It will include details of how we traveled, set up, and worked the schedules. It will also include the logs and scores of our results. We may operate from a rare grid such as EL79, or EM71, or a populated grid in South Florida to gather the 2M QSO's. As of this writing, we do not know! Nevertheless, we do know we will have some fun!

<u>CONCLUSION:</u>

You want a conclusion? Well, show up for the presentation and find out what we did, and how we did it, to possible extract some thoughts and ideas for your future adventure in simple VHF Contesting.

Thanks for reading,

Sandra, K4SME
AND
Steve, N2CEI

Contest Computer Logging and Interfacing Experiences

Bob Lear W4ZST

The W4NH contesters, officially The FourLanders VHF/UHF Contest Team, have been together for many years contesting from many locations around the Southeast with a portable operation. Since 1998 though, we have been operating the June and September contests portable from MileHigh Campground, off the Blue Ridge Parkway, between Maggie Valley and Cherokee, NC, EM85jm. We also operate the January VHF and CQWW VHF contests from my home QTH, EM84ao. I have been with the group since 2000 and will relate some of our experiences with logging software and interfaces during that time. I had been asked by a couple of different folks to put a paper together on this.

Before my tenure, the group did use computer logging programs such as CT and NA with some success, but not so well as our more recent experiences with WriteLog software. Some members had tried WL when it first became available and recommended that the group change to it. One of the major advantages was a Windows GUI and very good networking via ethernet. With a full or limited multi-op operation, we felt that the networking aspect was very desirable. It can be done without, but later you will see that we have quite a few advantages with the stations being networked. In years past, full size tower PC's and large CRT monitors were used and you can imagine how much trouble those were to set up portable, especially in a tent and tail-gate situation.

Local networking for the stations was done using one computer as a server, network hubs and the others connected with Cat5 cables running all over the campground. This did work, but all those long cable runs around all that RF sometimes causes problems! No internet connection back then though.

By the time I joined up with the group, laptops were much more affordable and we were slowly changing over as members obtained laptop computers. Then we got very lucky when one of our members, an IT professional, made a donation of a number of identical IBM ThinkPads available to the group for our exclusive use. This helped the situation immensely as having identical computers really does make it easier for setting up, maintaining and for the operators to use. These computers had both serial ports to connect to the radio CAT ports and thru the parallel ports provided PTT keying for the stations (HF rigs + transverters + amplifiers) and CW memory output to the radio. The only other thing we had to do then was provide some isolation between the PC sound card and the radio mic input, which we did by using a small 1:1 audio transformer in-line between them. This worked quite well for some time and eventually, we had another donation of Toshiba Satellite laptops that were more modern and worked well also. Of course, we are still talking Win 95/98 days here.

Along comes Win XP, which wouldn't run on the older laptops. At this time, most band captains went back to supplying their own computer for their station. Most of us used small form factor PC's like HP Vectra models and similar. WriteLog was updated for XP also. Eventually routers and switches came along and we upgraded to those. Around this time we also got spoiled when one of the members started bringing a 16' cargo trailer for us to operate inside. We just set folding tables up inside for the stations. That spoiled us, even though we usually still had to set one station up in tent. Ultimately, we have now graduated to several cargo trailers for the stations to set up in, with built-in folding tables, AC power wiring, networked with a patch panel, router, switch, etc., but that is another complete story. We are glad to not have to worry so much about the weather any more though.

Enough about the networking, let's get to some of the features of WriteLog that we use when contesting.

A screen shot of WL running during a recent contest is shown in Figure 1. All the windows are re-sizable and locatable anywhere you might desire on the screen. In a modern dual monitor set-up, WL windows can be scattered about either screen as desired. The set-up shown is my preference for a contest. Other operators and band captains have their own preferences and WL will accommodate us all. There are common windows that all the networked computers will have on. I will describe what each window shows and how we use it. I have showing here 4 boxes across the top, 3 boxes across the center and then the log listing and at the bottom is the QSO entry box and the networking status box which is usually down like this but can be brought up to read the network status messages generated by WL.

The first box, 'Networked Frequencies', is a display of all the radios connected to WL at the time. This is the CAT port information of the frequency and mode that the radios are on. This is quite handy when passing stations up the bands as one doesn't have to throw a shoe at another operator wearing headphones to find out what frequency he is on for the pass. It even shows TX and RX VFO freqs if one were operating split. This is probably useful for HF contesting, but not a feature that we use.

The next box, 'Band Summary', is the score summary. You really don't need this up during the contest, but like most hams, we want to know how good (or bad) we are doing at the time. It lists the total Q's, grids and points on each band and the total score. This box updates automatically with every Q made. Also useful when the bands are dead and the locals ask you how you're doing, you have that info right there.

The third box is the Schedule box, 'skeds'. If you click the S, WL automatically puts the call sign of the station you are currently working in a message, you then type the frequency, which you get from box 1 or a different freq from the sked station if that's what he wants, and the sked will pop up in that box on the other frequency station and flash to inform the operator there that you have sent him a sked with the call sign to look for and the frequency. Not the best system. Would be nice if we could get the WL guys to include the frequency by clicking on it rather than having to type it in. Of course, we have found other little things we would like to see done our way too! The C in the box clears the sked(s).

The fourth box, 'Check Call' is also quite useful. It shows whether the station has already been worked on a particular band which would save you from having to ask to pass up the bands or to note that we do need that station on other bands. This box and box 1 are pulled down only enough to show the four bands when we are limited. If we are full multi doing microwave, you can enlarge the box to show all the bands you have. It is very useful for passing.

The first box on the middle row is the 'Packet Spots' box. WL takes info from a packet source like the VE7CC page, which will run in the background on the computer, and puts the data here in this box. We sometimes use this on 6m, but haven't ever tried it with any other bands. There is no data shown here as I didn't have it connected when I made the screen shot, but it will show call sign and frequency of spotted stations listed on the packet cluster.

The next window is 'Network Gab'. You just type in a message here and it goes to the Gab box on each networked computer. This is good for asking questions, sending beam headings, asking for Beer or other important uses and also saves on the shoe throwing.

The third window on the middle row is 'Super Check Partial'. This is linked to an internal WL database of all the calls that you have worked with WL on this and/or the connected computers. It follows each letter as you type a call into the QSO entry box and "guesses" all the possible calls. I don't really find it useful as it really has too many calls at first and then by the time you get the station calling typed in, that is the only call left in the box. Some might find it useful if they only get a partial call at first.

The next large box is the log listing itself. Successive entries are added at the bottom of the list. It logs the sequence number which we don't really use in VHF contesting, the date and time (which all the stations are synced with), the frequency of the radio connected, the call, RST (which we don't use) and the grid received. It also logs our grid, the points, multipliers (grids) and the operator of that station. It can be scrolled to look back when someone says they have/haven't worked us, or to make corrections if you've hit enter too soon! Just double click on whatever item; time, call, grid, freq, etc and a box pops up so that the item can be corrected. A nice feature and well implemented by the programmers.
A word here also. If the station is already in the log on that band, it will automatically be marked as a dupe and not counted if you try to log it. It will say duplicate contact in the entry window before you hit 'Enter' and show in a different color too. If you find a mistake it is possible to edit it to correct and the score will update appropriately.

Under the log listing is the small 'QSO Entry' window. Pretty self explanatory here. Just enter the call and space or tab to the grid box, enter the grid and hit 'Enter' to log the call. If you don't get all the info for a valid Q, then the pending entry can be erased (Alt+W) and you are ready to enter the next call.

WL has the capability to automatically repeat sending CQ's or to send your next CQ or QRZ message, either CW or phone on hitting 'Enter', a feature some ops use, mostly CW guys.

Finally the 'Network' box is placed at the bottom by WL. It will always be up when you are connected to the network and one can view error and operation messages about the network here as mentioned.

There are other possible 'boxes' which can be brought to the screen and they are listed under the 'Window' Tab across the top to the WL screen along with all the windows I've mentioned that we use.

I mentioned operators before. There is a column in the log that lists whoever indicates that they are the operator of a station at that time. 'Change Operator' is under the 'Entry' tab. Because WL has built-in voice and cw memory keyers, it also records each operators separate CQ's, exchanges, CW messages, etc. under the operators call sign. You can save several different CW or phone messages for instant playback via keyboard Function keys. You can also go and operate another station and not have to re-record you messages as WL makes them available across the network. You only have to remember to 'Change Operator'. This is a very nice feature as we don't have to have external keyers, voice or cw, on different stations so that the operators only have to learn one method to operate each station. Pretty much every operation is taken care of by WL. One can even change modes and frequencies of the attached radios from the WL screen without touching the radio.

That should give you a good summary of what WL can do and how we use it for our VHF contesting operations. We only have to purchase one copy of the program for the group. We had asked the WL guys about that and they said they were happy that we purchase the one copy for the group. Some of the members do buy their own copies, but not out of necessity. WL updates quite often and they are down-loadable for free during the year of your subscription. VHF contest changes are pretty rare and we might not upgrade for several years. The current price is only $30. Hard to beat.

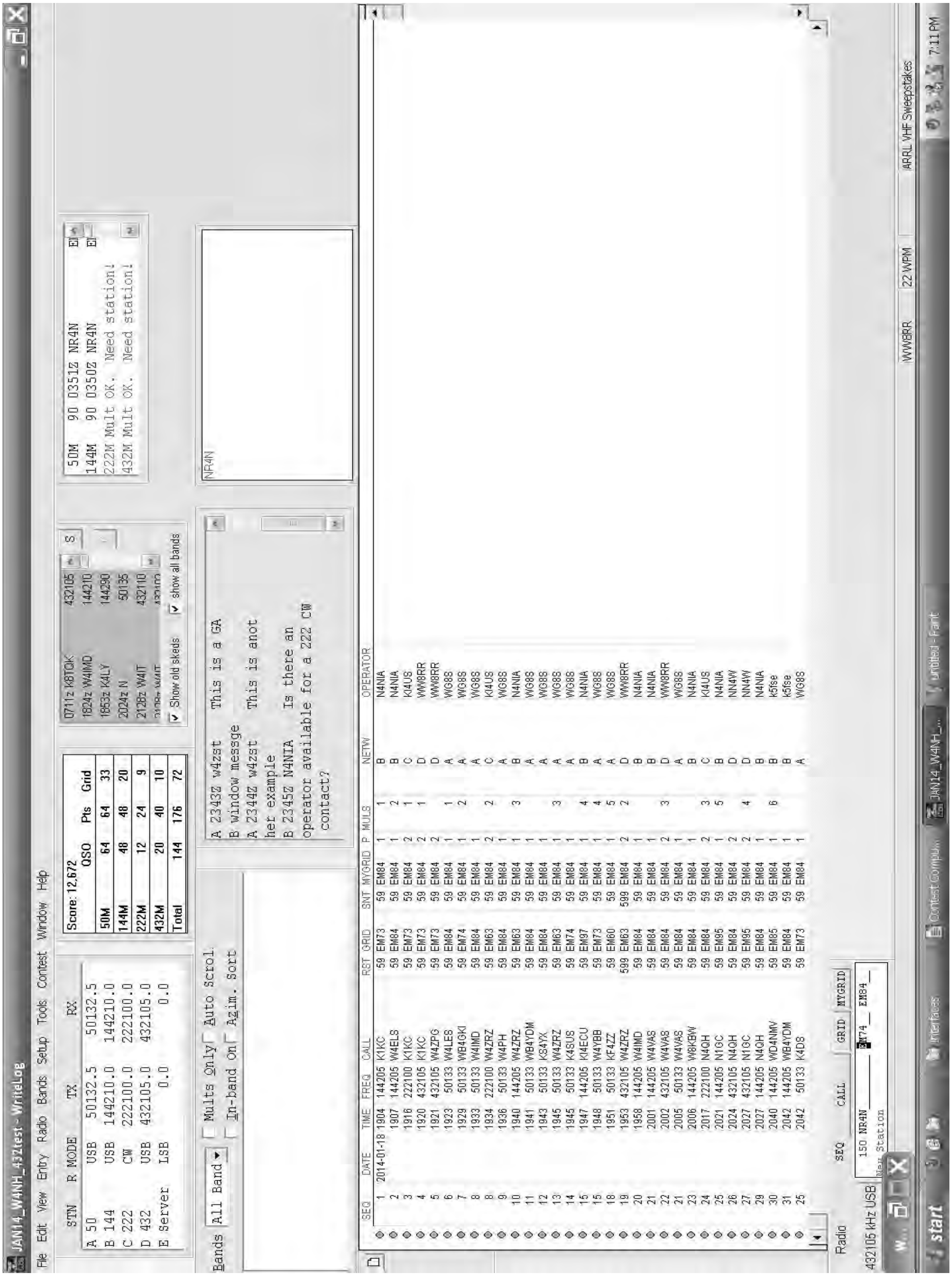


Figure 1: A WriteLog screen image from the W4NH, January 2014 VHF Contest

You might ask, what about the other logging programs and sometimes members of the group have asked that too. Well, if someone will properly test another program, as I tell them when they ask, we would certainly consider it if they could show that it did all the things we wanted (and are used to having) and was as robust on networking. By testing I mean, setting up at least three computers with radios attached, networked and tested by running for many hours, making fictitious QSO entries, having the computers call CQ on both phone and CW etc., pretty much like we would do in a contest. If we had that info, we might consider another alternative like N1MM, N3FJP, RoverLog and others that have been mentioned over the years. I have done that myself with WL a couple of times, but haven't had the time to try other programs with all my other distractions.

Very few complaints about WL. Some years ago we had networking problems that our super computer sleuth Brian NX9O dug deep into Windows to find and correct. He also found some problems with a TSR program that we tried to use with a time server, but did away with that. WL is very robust and has features that redundantly backup automatically so well that I don't think there is a way to lose a Q. Each networked computer backs up all the others automatically. We do use a separate server, but not sure if it's really necessary. We have plenty of computers so we use it. Typical in limited multi, we will have the four stations and the server connected and usually nowadays, another computer which is acting as our internet gateway. With an aircard, we can have 4G service on a remote mountaintop which doesn't have shore power or land-line phone service anywhere near.

A new problem that came in with XP (which we still use) and later versions of Windows was with the computers themselves. We were no longer able to count on having a parallel port and more recently have even not been able to obtain computers with serial ports. This required some changes. This is where the interfaces come in. The WriteLog programmers had added support in the program to now be able to bring PTT and CW out through the serial port, for those without access to a parallel port anymore. WriteLog (and other programs such as WSJT) implements PTT on the serial line RTS (pin 7 on DB9, pin 4 on DB25) and CW memory output from the program on serial line DTR (pin 4 on DB9, pin 20 on DB25). This development then required either two serial ports, one for the radio CAT and another for the PTT/CW and some members did populate their contest PC's with dual serial ports. I searched for information, looked at various commercial interfaces such as rig-blasters, etc. and decided to just build my own so that I would have the configuration I wanted and to save some money.

Since few radios have so far converted over to USB, most still have traditional serial ports for the CAT port. We have had little problem with USB to serial converters for computers without serial ports and so far, no one in the group has a radio that can be connected with only a USB port. I'm sure that USB will be the future, but not until all the radio manufacturers change over. I know, by then the computers will probably have dropped USB as an interface!!!! We'll have to wait and see. The general recommendation about serial to USB converters for amateur use is to find one that uses the FTDI chips and you shouldn't have any problems.

Figure 2 is a schematic of the interface I have been using. It's not original with me other than putting it in the same box and the serial pass-thru. I've never had a problem with it and I've built several different ones, mostly differing with connections for the audio and keying lines. They have been used for many contests with the FourLanders for several years now.

The main thing that I felt like I did different with this interface is to have the RS-232 pass-thru so that only one serial port is needed. So many interfaces available don't do this and I don't understand why. I even added the pass thru to a Rig-Blaster Nomic unit, to make it perform the same a mine. I did make one version without the audio lines and isolation transformers. This one was for use with a K-3 which has audio line isolation built in. Otherwise the same circuit. I am including pictures of the first unit, Photo 1, which has captive serial cables (I just cut a DB9 cable in half), captive audio cables to the computer sound card (Radio Shack 3.5mm phone plug cable in half) and panel connectors out to PTT and CW to the radio. LED's to indicate PTT and CW are also included. The next one was the one for the K-3 that we have been using for the 2m station. It is shown in Photo 2. Same serial pass-thru and PTT and CW brought out to panel connectors and the LED's.

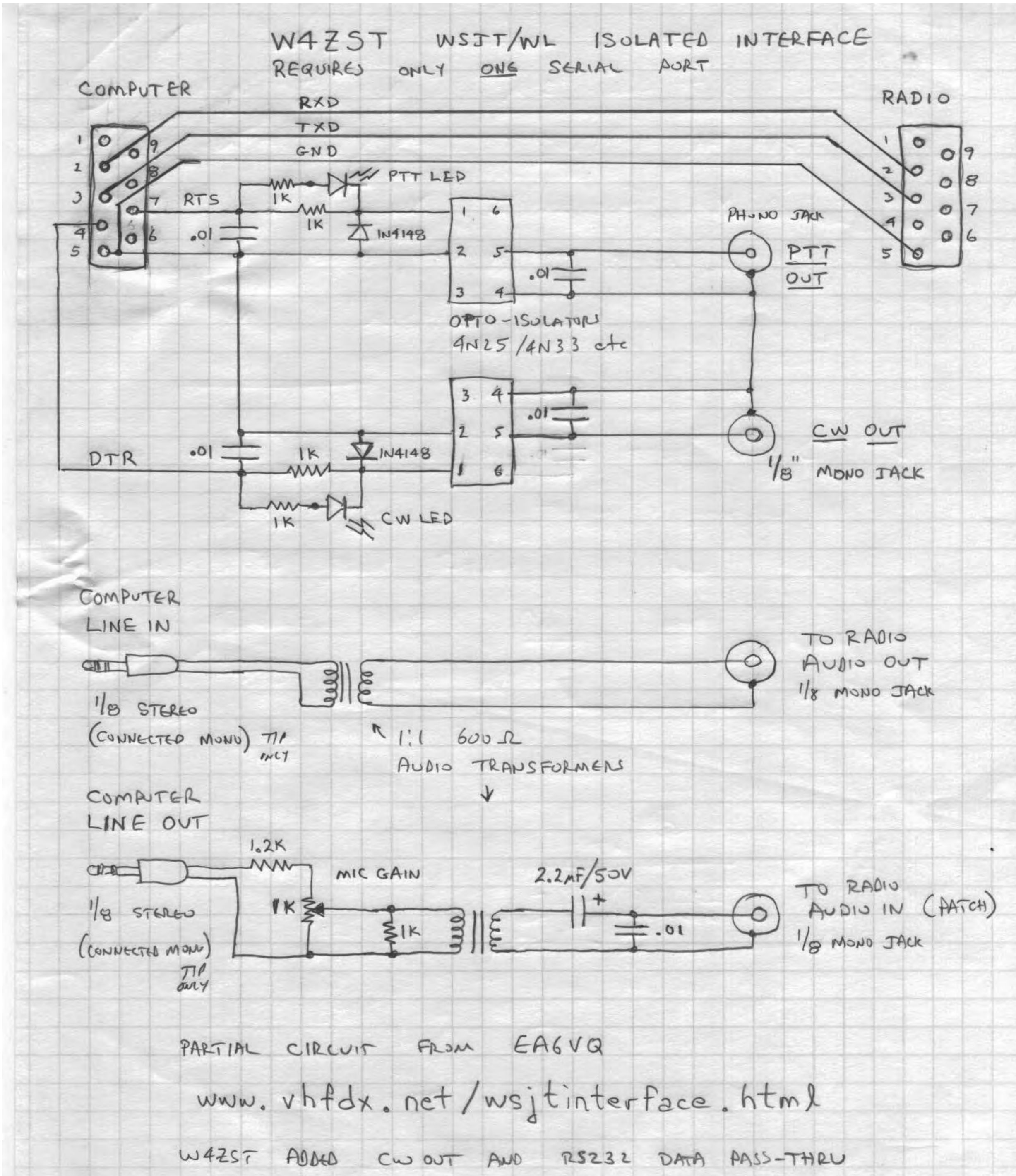


Figure 2: WriteLog/WSJT Isolated Audio and CW/PTT Interface Schematic

The modified RigBlaster Nomic is now essentially the same circuit as mine. I drilled a hole in the case for a DB9 connector cable which was connected to the data pins (2 & 3) and ground pin 5 on the Nomic circuit board as they did bring all nine pins in with the DB9 connector on the box. This carries the serial CAT data on to the radio now. I also carried pin 8 out to the radio cable as I found that the FT-2000 we were using it with required that though I can't say why. This is shown in Photo 3. I mounted another opto upside down on the existing one with double face tape and wired it dead-bug style and drilled 2 more holes for 3.5mm phone jacks to bring the CW out from the DTR line and PTT out from the RTS line. I had to disconnect the DTR and RTS lines from the circuit board as they were originally wired in parallel and also went to the mic connector. I think some radios may have used that line for PTT at some time. I haven't run across that myself, although WSJT did for some time assert both lines for PTT, but it appears that has changed now. The 3.5mm jacks were mounted on top of the audio in and out jacks with double faced tape as shown in Photos 4 and 5. The completed unit is shown in Photo 6 and the schematic as modified is shown in Figure 3.

The latest iteration of the interface is shown in Photo 7, where two of them are under construction, showing the front and back panels. Same circuit, but these will not have captive cables. I'll have to see which way I like them better. One thing about captive cables is that you won't forget the ones you need for a contest, as long as you don't forget the interface itself. Something to said for both ways.

I think you will find one of these interface ideas useful if you run a logging program and want to connect it for PTT and CW and your radio's CAT functions simultaneously.

A copy of this paper in pdf format with color photos will be placed on the SVHFS web page.

Annotated Photos follow.

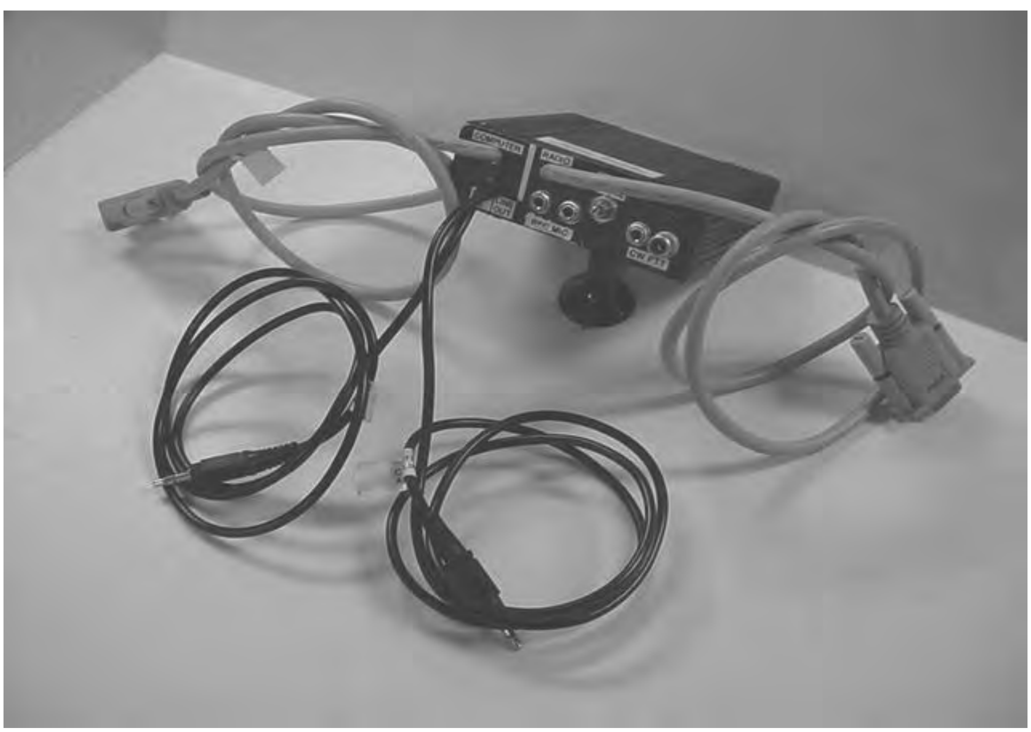


Photo 1: Original design interface box as shown in Schematic Figure 2

Photo 2: K-3 Interface box.
Captive serial cables, LED's, mini phone jacks for PTT and CW. No Audio Isolation

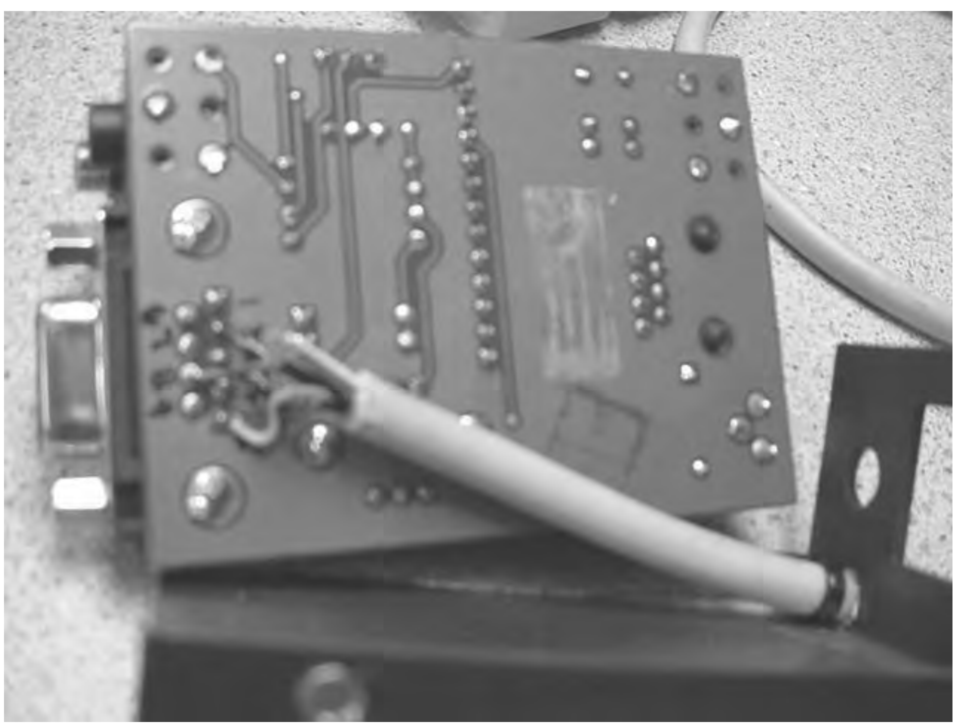


Photo 3: Serial cable out to radio added to RigBlaster Nomic circuit board

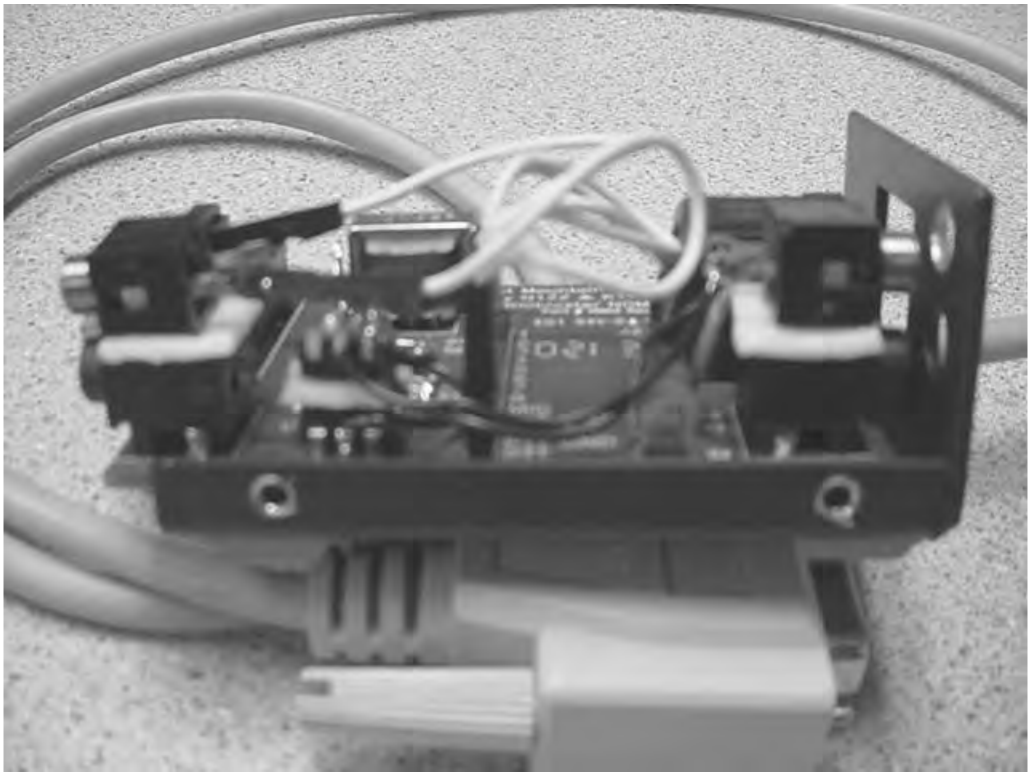


Photo 4: RigBlaster Nomic showing opto and two 3.5mm mini phone jacks added

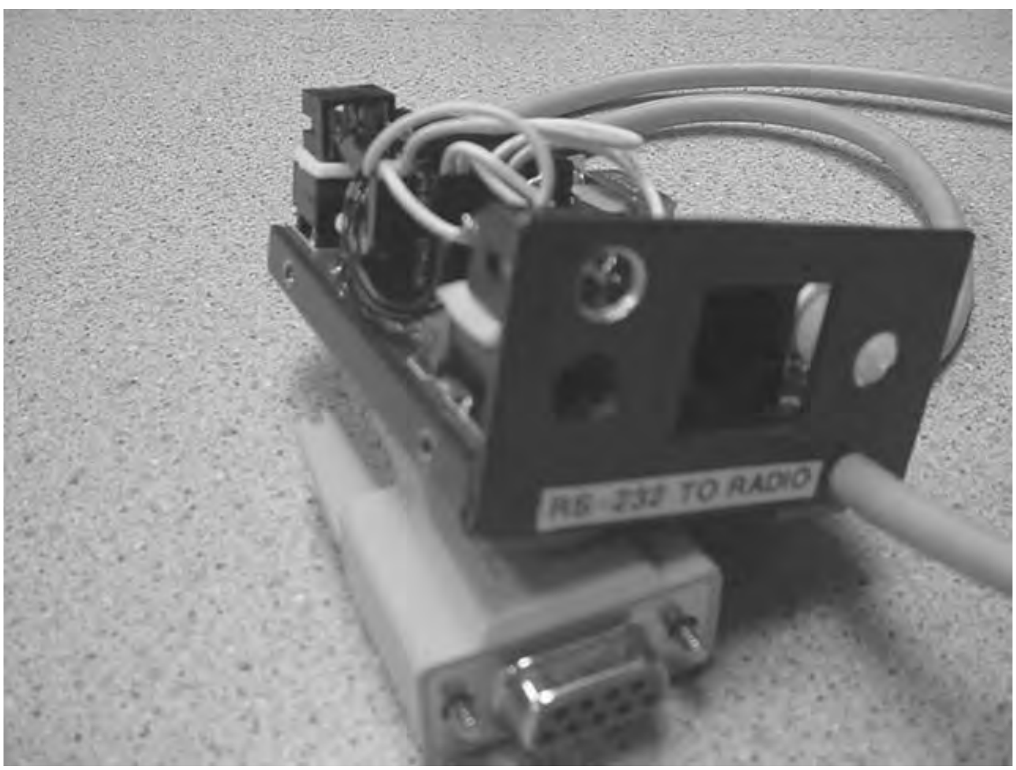


Photo 5: Showing one of the holes drilled in Nomic for added mini jack

Photo 6: Completed modified RigBlaster Nomic with serial, PTT and CW out

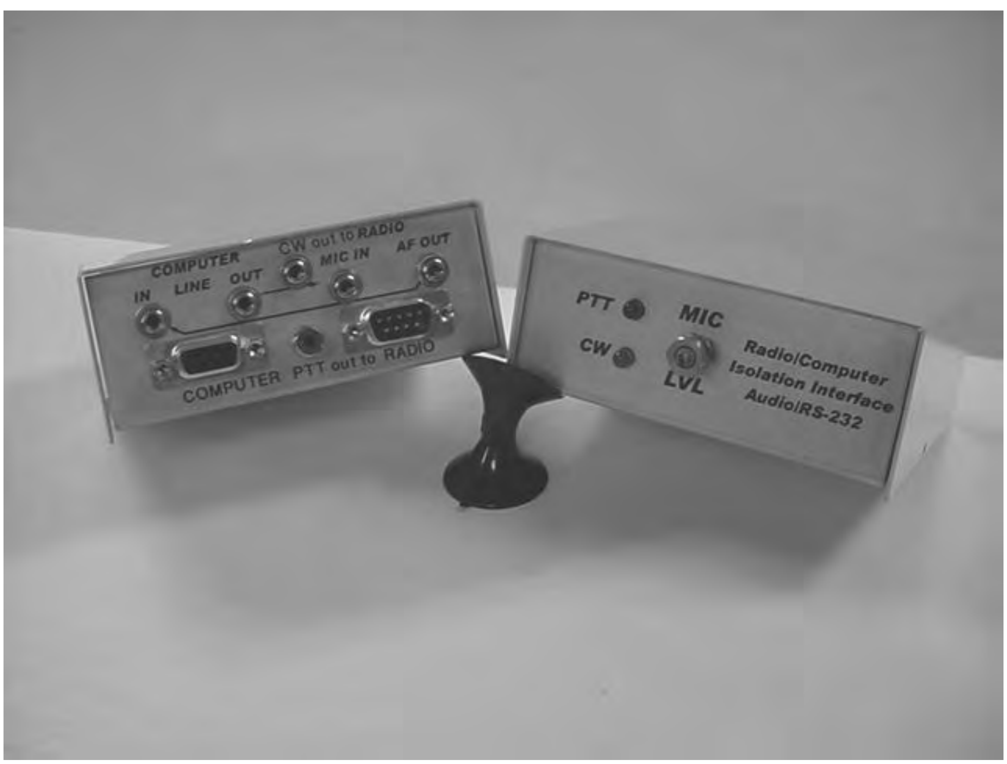


Photo 7: Front and Rear shown of latest version of interfaces.

Schematic same as Figure 2.

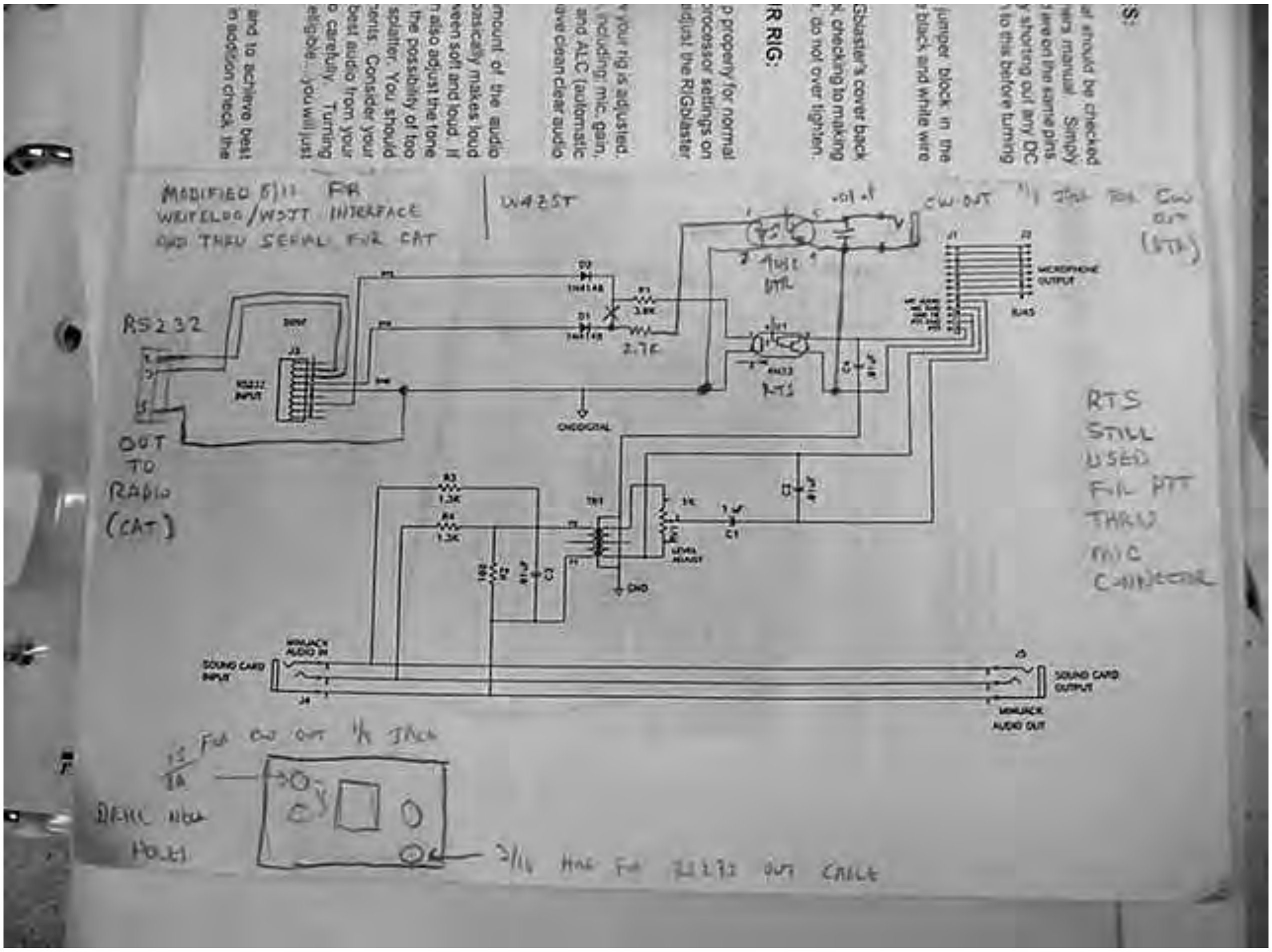


Figure 3: Modified RigBlaster NoMic schematic

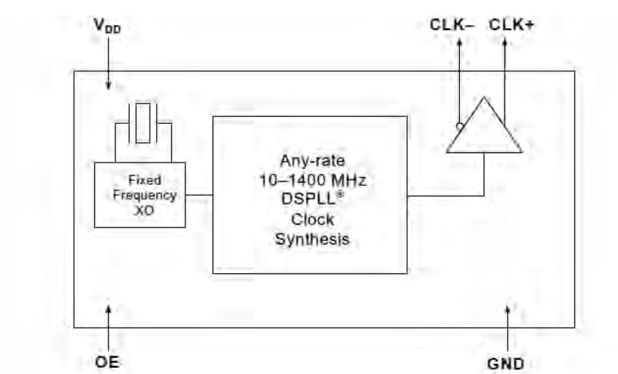
The Si530 XO and Amateur Radio

Bob Hillard WA6UFQ Austin, Texas/Region 2, 78739

Quite a few hams around the world are familiar with the Silicon Laboratories Si570 programmable XO chip. But not many hams are familiar with the Si570's younger brother, the Si530, and how it can be used in their construction projects.

The Si530 is not user programmable like the Si570 is. It is ordered on the user's desired frequency. The Si530 has the same frequency range as a Si570 chip (10 MHz through 945 MHz, and select frequencies through 1417 MHz). The Si530 can be used anywhere a crystal oscillator is used, and delivery time is much better than that typically encountered when ordering a crystal for your construction projects.

The Si530 functional block diagram below shows how Silicon Labs has simplified the clock multiplication and jitter attenuation circuitry using their patented DSPLL technology. Using a low frequency PLL reference crystal oscillator operating at 114.285 MHz, and a PLL synthesizer VCO operating at a nominal frequency of 5 GHz, the Si530 can be programmed to output a frequency between 10 and 1417 MHz. The use of a low frequency crystal results in improved aging, temperature stability and mechanical reliability.



The CMOS version of this chip can be programmed to operate at frequencies from 10 MHz to 270 MHz, and has one output port. The Si530 spec sheet shows the upper end of its frequency range to be 160 MHz, but the chip has a useable output up to 270 MHz. The output level at mid frequency range is +11dBm.

In addition to the CMOS version of the Si530, three other output formats are available: LVDS, LVPECL, and CML. These output formats are capable of frequencies through 945 MHz, with select frequencies up to 1417 MHz, and have two output ports; the second port being complementary. The output level at the mid frequency range of the LVDS version is –7dBm.

With the advent of the Si530, gone are the days of designing and building an oscillator string for your project that includes one or more multiplier stages, and the necessary filtering to reduce the various multiplier products generated in the process. Now this can all be accomplished with one stage using the Si530.

A few years ago, I designed and built a 23cm beacon that used a Si530 operating at 1296.40 MHz, and used CMOS RF switches to accomplish the coding and RF level stepping. The Si530 chip was ordered with a 20 ppm temperature stability option. The beacon stays at or very near that frequency as the repeater shack is warmed in the Texas sun, and then cool down during the evening hours. This beacon has been in service for over two years. A similar beacon, built by Roberto IK0XUH is in service in Rome, Italy.

Tom K5TRA has designed and built beacons that are currently in use at the Road Runners Microwave Group's beacon site located in Austin, Texas. These beacons operating on 2M, 1.25M, 70cm, and 33cm, all use a Si530 oscillator. In addition, Tom has also built a 6M beacon that is on the air in Canyon Lake, Texas.

At my home QTH, a Si530 operating at 470 MHz as the LO can be found in my 33cm transverter. My 23cm transverter uses a Si530 as the LO operating at 830 MHz.

On the lower frequencies, my home brew all band transceiver uses a Si530 operating at 80 MHz to clock a quadrature demodulator chip.

The Si530 can be ordered from Mouser, Digi-Key and other distributors. It can also be ordered directly from Silicon Labs using their ecommerce program. The Si530 is also available as an engineering sample.

Clicking on the link below brings up the silicon Labs on-line tool that is used to create a part number for the Si530 that is based on the options selected by the user.
http://www.silabs.com/products/clocksoscillators/pages/utilityintor.aspx

There are three speed grades available for the Si530:

- Grade A covers 10 to 945 MHz, 970 to 1134 MHz, and 1213 to 1415.5 MHz
- Grade B covers 10 to 810 MHz
- Grade C covers 10 to 280 MHz

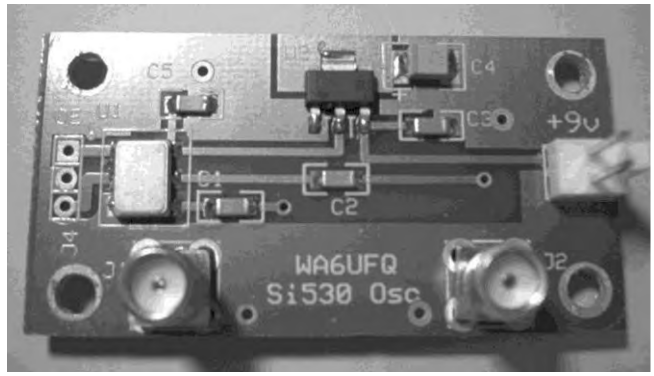
When ordering the Si530, in addition to selecting the desired output frequency, a number of other specifications such as supply voltage, output format, and temperature stability must be user specified. The user has a choice of three supply voltages: 1.8V, 2.5V, and 3.3V. Temperature stability can be specified as plus or minus 7, 20, or 50 ppm.

The chip can be ordered as a Si531 for the LVDS, LVPECL, and CML output formats. This version has the output enable port on pin #1 rather than on pin #2
A spec sheet for the Si530/531 chip can be down loaded from the Silicon Labs site by clicking on this link:
http://www.silabs.com/Support%20Documents/TechnicalDocs/Si530.pdf

Also available from Silicon Labs are a switch selectable two-frequency version (Si532), and a four-frequency version:

http://www.silabs.com/Support%20Documents/TechnicalDocs/Si532.pdf

http://www.silabs.com/Support%20Documents/TechnicalDocs/Si534.pdf



PC boards and partial kits (less the Si530) are available on my web site at:
http://home.roadrunner.com/~wa6ufq/si530xo.html.

Setting Up a Low Cost SMT Rework Station

Brian K. Straup

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Abstract — **a set of recommendations, hints and kinks on setting up your own surface mount rework station. A brief description of how commercial boards are assembled. A brief description of how to build your own SMD reflow oven. Pictorial of a commercial board assembled in the lab.**

Index Terms – **SMD, Rework Station, Reflow Oven**

I. INTRODUCTION

In the mid-1980s, Texas Instruments opened its surface mount expertise to outside manufacturers to promote the upcoming transition from electronic components mounted with leads that extended through the printed circuit board to those mounted on the circuit board. During my days as a lead engineer at Heath/Zenith, I made several trips to Texas to see what this surface mount technology was all about. The entire department had to rethink new design techniques and handling processes. For the first time, an engineer could take full advantage of both sides of the circuit board for placing components that lead to the development of some of the first laptop computers.

Today's IC packaging has progressed to parts that no longer have little legs on the side to solder to. The ball grid array has bumps of solder that melt and flow onto the circuit board. Many new RF components have ground pads and pins pads only accessible on the back side of the package. Elimination of the metal lead allows for very low ground impedances and improved thermal conductivity. For a large number of new devices, a fine tipped solder iron has no further use.

Commercially available SMT workstations capable of handling most SMT mounting and replacement are available in the $5000 and above price tag. But with some careful shopping and some improvising, an adequate rework station can be set up that can handle small components such as resistors or capacitors up to surface mount IC packages of 100 pins or so for a lot less. I would like to present a brief comment on SMT processes and a look at the tools, hints and kinks of setting up your own rework station.

II. COMMERCIAL ASSEMBLY PROCESSES

I would like to share how those parts made it to the PCB in the first place. It all starts with the blank PCB. Boards down to a given size are processed individually, but small circuit boards are combined onto a single board to be assembled as a group. At the end of the assembly process these assemblies are broken apart into individual assemblies. Small side extensions called rails are often added aid in holding the boards in place during assembly.

The board is placed under a thin piece of stainless steel referred to as a solder stencil. The stencil is cut to provide openings above the pads where the components are to be placed. Solder in the form of a thick past is drawn over the top of the stencil. A very small layer of solder the thickness of the stencil is deposited on the circuit board below. Solder stencils range from .004" to .008" thick. The paste contains the solder alloy in the form of microscopic balls suspended in a somewhat sticky flux material. This sticky goo holds the components in place after the parts are placed on the board and evenly distributes the solder material.

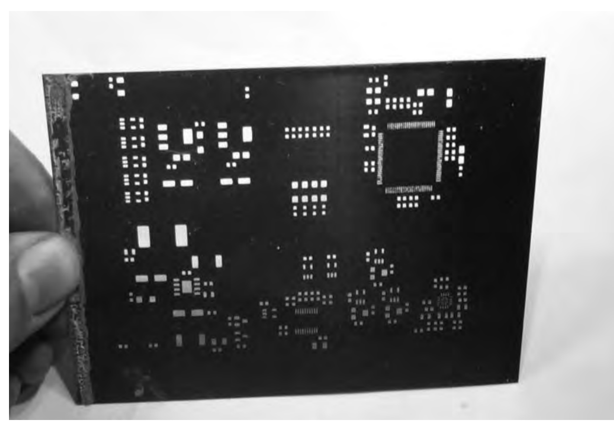

Fig 1. Commercial Solder Paste Stencil

The board is transferred to a machine that is referred to as a pick and place. The components are picked up from reels, sleeves, or trays of parts and placed in their respective locations on the board assembly. A small probe on the assembly head uses a vacuum to pick up the part from the paper tape and hold it until placed on the board. The component is lightly pressed into the solder paste and held by the sticky flux. The assembly head is constantly running between the component reels and the location on the PCB. Some assembly processes place a small drop of epoxy where the part is to be placed and actually glue the part to the board. This prevents parts on the bottom of an assembly from falling off prior to soldering. High speed large volume machines can place hundreds or more parts per minute. This process is multitudes faster than what I can do with a pair of tweezers!

Surface mount components often come in reels of paper tape that forms a small cavity that the component rests in. A thin plastic film seals the top of the tape and keeps the component in the cavity. Parts in plastic tubes are vibrated out and slide down to a holding area, large parts are picked up from plastic trays. After the parts are placed, the board is ready for the oven.

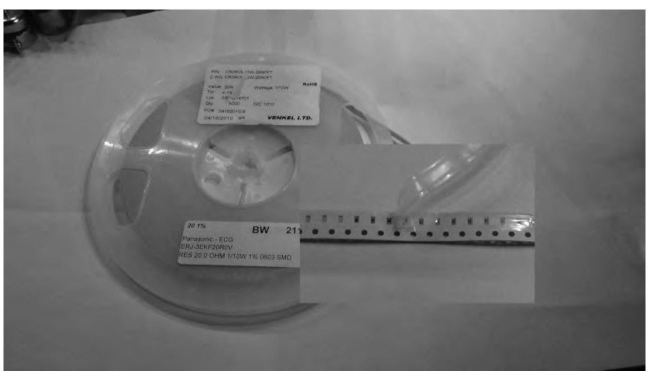

Fig 2. Parts on Tape and Reel

Ovens come in various processes depending on the nature of the PCB assembly. The original reflow oven at Heath /Zenith used a specialized Freon that condensed just above the melting point of the solder. As the board moved through hot gas, it would condense and melt the solder. This also washed away any remaining flux.

As environmental concerns with the use of Freon increased, ovens turned to Infar-Red heaters. As the board proceeds through the oven, the temperature is tightly controlled so the components and board reach thermal equilibrium and any residual water vapor in the components can boil off without damaging the parts or popping them off the board. Before the board temperature is raised to actually melt (reflow) the solder, it is held at a slowly rising temperature range to allow the flux to activate and clean the solder joint area. The board is then quickly heated to the reflow temperature. This melts the solder and bonds the components to the board. The actual temperature depends on what type of solder is used, but the time is typically less than 15 seconds. This seems like an eternity compared to touching solder and your iron to a pad and soldering a pin down. The board is quickly cooled with fresh air fans to just above room temperature where they are ready for cleaning.

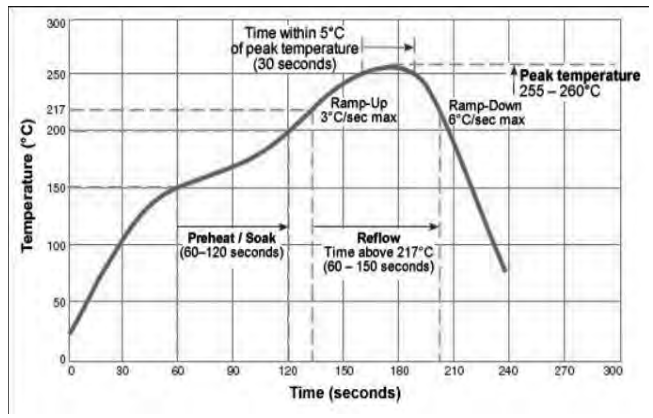

Fig 3. Typical No-Lead reflow Profile[3]

Many manufacturers use a no-clean flux skips the cleaning step. Others use simple clean water to scrub the boards. The cleaner looks just like a kitchen dishwasher. In the past, I have used a discarded appliance for this purpose. But for our needs, a toothbrush and hot water from that tap works wonders.

The boards are packed and ready for assembly and test. If there are any through-hole components such as connectors or power plugs required, they manually added at this time. If the board has parts on both sides, the process is repeated but with slightly different solder melting points that allow the second layer to reflow without melting the solder on the opposite side.

III. HOW BIG ARE WE TALKING HERE

I would like to give some indication of the size of surface mount components before we go shopping for the lab. Resistors and capacitors are often referred to by their package size. In the beginning, resistors were 1206 footprints. 1206 refers to the length and width of the component. In this case, 1206 is .12” x .06 “. Today’s smallest practical resistors are 0402 packages (.04” x .02”). Even with experience, hand placing these tiny parts is difficult. A pair of tweezers can impart enough energy into one of these components to make it fly across the bench. If you need to select components for your new project, I recommend 1206 or 0805 packages to start with.

In addition to the common resistor footprints there are an entire new designation of package with names like SOT, TQ, LQFP, and so on. It seems that new packaging technologies pop up every day. Rather than supplying 40 pages of tables and charts in the proceedings, I have found a fairly comprehensive surface mount nomenclature document published by Topline [1] that covers various packages and component types.

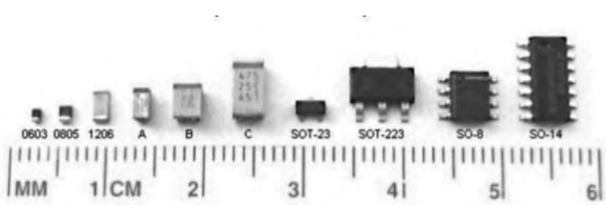

Fig 4. Sample SMD Component Sizes [4]

IV. THE SHOPPING LIST

I have listed the workstation items in order from most expense to lowest expense:

1. Stereo Binocular Microscope/boom/ring-light
2. Hot Air Station (No Paint Strippers)
3. 25W to 60W temperature controlled Soldering Iron
4. ESD Pad
5. Flux, Solder, and Wick.
6. Hand Tools

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1) Magnification: Stereo Binocular Microscope

The stereo binocular microscope is commonly called an inspection microscope and is commonly used in classroom biology labs for dissection. If you cannot see these parts, there is no way that you are going to be able to handle them. My recommendation is an instrument with 10x objective eyepieces with a variable magnification of .75 to 3.4. This is a very common configuration for educational purposes. Look for an instrument that can be mounted on a boom stand. Very low cost instruments are on a fixed platform and you just cannot get a larger PCB in the right place to see anything. For most tasks, you will be using the lowest magnification that gives the widest field of view. But if you are looking for a solder short between two pins that are 1.25 mm apart, the extra zoom in capability comes in handy. Look for wide field eyepieces if possible. This allows you to see more of the board when searching for a component. One of the limitations of the generic configuration is the focus height between the bottom of the microscope and the top of the circuit board. On my instrument, this was originally 3.25”. This made getting the hot air tool and soldering iron difficult to access the desired component. I was given a recommendation to obtain a 1/2X Barlow lens.

Fig 5. Example of a variable magnification inspection microscope with mount and ring light. [2]

The Barlow lens attached to the bottom of the objective assembly and reduces the magnification by ½. Since I already had plenty of magnification at 34X (10X eyepieces and 3.4X objective), a 50% reduction in magnification is hardly noticed. With the Barlow lens installed, the microscope head must now be moved up 2 times the normal height to obtain the correct focus. There is now 6-1/2" of room under the objective leaving plenty of space to get tools and soldering equipment above the board. The Barlow also acts as a protective cover to prevent solder fumes from reaching the objective lenses. The objective lenses are difficult to reach and require disassembly to clean. The Barlow can be unscrewed occasionally and cleaned with denatured alcohol and a soft lens cloth.

Fig 6. Example of a 0.5X Barlow Lens

I cannot stress the importance of having enough light. Increasing the light forces our pupils to contract and reduces the depth of focus. Just remember how much sharper things look on a sunny day. Having light equally on all sides of the component is also important. A single light source creates shadows that limits your ability discern small parts. I recommend a ring-light that fits over the objective lens and shines an even light straight down on the PCB. Most ring lights have some form of intensity controls so you can adjust to your preference. A light source from a high intensity incandescent bulb give a bright white with an even color spectrum. Most of the inexpensive import ring-light knockoffs use a very cheap white LED that result in a very harsh bluish light. Most of these that I have purchased have LEDS go out within a month of use. Some light designs use a circular fluorescent lamp but are less common due to solid state lighting. If you find one with a dead tube or a LED version with most of the LEDS out, pick it up for cheap. It can be easily reworked into a very good light by replacing the fluorescent lamp or LED PCB with three garden lamp solid state bulb replacements found at the big box stores. These modules produce a color spectrum close to natural sunlight. The power supply for the old LED assembly was already at 12V and required no modification to run these modules.

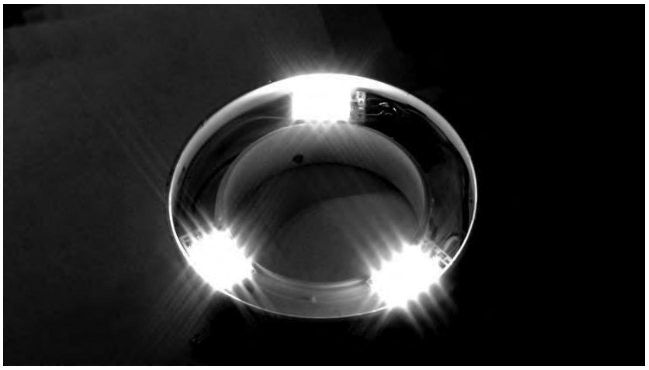

Fig 7. Ring Light Modified with LED Replacement Lamps.

If the stereo microscope is just not possible in your budget, the next best thing is a set of 5X to 10X flip down inspection visors. I use a pair of these for general board inspection and can be taken with me if I need to go offsite. The base for the microscope is 35 pounds and it is staying right there on the bench. Science fair singular objective microscopes can be used in a pinch, but they are tiresome and without the stereo view make coordination between hand and eye more difficult. Remember you are trying to guide a pair of tweezers with a part the size of a poppy seed onto a PCB pad covered with solder paste. There is no autopilot; you need visual feedback to get it right.

2) Hot Air Station

Although I listed the Hot Air Station and the Temperature Controlled Soldering Iron as separate entities, they can be obtained as a single unit. Most of the units surveyed prior to the writing of this document had digital readouts for the air and iron temperature in addition to airflow rate. I recommend a unit that you can accurately set the operating parameters especially of you have boards that use the higher temperature no-lead solders. On my old standby analog knob rework box, I inadvertently set the temperature about 25 degrees above the "max" for the component that I was attempting to salvage. The net result was a completely destroyed part and discoloration to surrounding components. Under no circumstances try and use a paint stripping gun to substitute for a hot air pencil. You have far more air than you will ever need and can reach temperature high enough to set the PCB on fire.

When building a surface mount project, the soldering iron can be used for most components. The hot air pencil is the tool of choice for leadless carriers and those parts with unexposed pads. Most units come with an assortment of typically round nozzles. You want to use one approximately the size of the part you are removing. Using a ¼" nozzle to remove a 0603 resistor will easily reflow the part you wanted and 20 of its neighbors. Specialty nozzles come in all shapes and sizes. The object is to put the hot air only where you need it. An example may be a square shaped nozzle for a 100 pin microprocessor that only directs air to the top of the pins. This avoids heating the package and the surrounding components. With a dab of flux, a pair of tweezers, hot air pencil, and a bit of practice, a SMT capacitor can be changed in just a few seconds.

Fig 8. Various Hot Air Nozzles.

3) Temperature Controlled Soldering Iron

Having the right temperature at the soldering iron tip is important when using SMT components. If you are using no-lead solder, you need a higher temperature. But just cranking up the heat past the reflow temperature may result in your PCB pads lifting right off the board. There isn't a lot of leeway between melt and lift. Although I really prefer the old 60-40 lead solder with its lower melting temperature, I often have requirements that the project be unleaded. Be cautious when using a soldering iron set for leaded temperatures with no-lead solders. The solder tends to behave like a glob of plastic rather than a flowing metal. The iron may not be hot enough to properly reflow the connection.

I set up my irons for 215C for lead solder and 230C for no-lead. Hint: If you are having difficulty in removing a component assembled with no-lead solder, try adding a touch of leaded solder to the joint. The lead will mix with the tin in the no-lead solder and lower the soldering temperature.

4) ESD Pad

If you are working with a Ga-As device such as a low noise FET or maybe a $50 power amplifier, the last thing that you want to hear is a tick sound from a static discharge. We can easily pick up thousands of volts of static electricity. Normally protection diodes are added to the pins of semiconductor devices to circumvent damage. Many Ga-As devices do not have protection diodes and break down around 2V. In many cases, the discharge to a pin may not result in immediate failure but degrade the device performance and or result in early failure. Murphy‘s law indicates that 10Ghz preamp will fail just after you install it at the top of the tower.

If you are not going to use an anti-static mat and a wrist strap, then try to avoid picking up active devices by the pins; stay on the component body. When selecting your soldering iron, check that the iron is ESD safe. This normally means the iron is grounded through the safety ground pin on the power cord. I have to admit that I'm somewhat lackadaisical on the wrist strap, but I always touch the ESD pad before using the workstation. From an aesthetic point, a nice bright blue ESD pad provides good visual contrast to find that part that just escaped the tweezers.

5) Flux, Solder, and Wick.

In a previous section, I mentioned the cleaning process that removed all traces of flux from the circuit board. When reworking a SMT component, flux needs to be reintroduced over the solder joint. Flux chemically removes oxides of the solder and allows it to reflow. Oxides of the solder tend to act as thermal insulation and force the use of additional heat to reflow. If you are immediately replacing a SMT part, you need the remaining solder to stay clean for the next part.

If you are using a small diameter rolled solder, the flux is imbedded in the center of the wire. If you are using solder paste, flux is used to suspend the solder particles. I have used both liquid and jell versions. My preference is the jell version that comes in a syringe and is dispensed via a large boar blunt hypodermic needle. The jell can be very sticky and works well to keep parts in place prior to heating. Try and keep the flux away from your tweezers. You will go to pick up a part and never be able to let it go. The liquid flux boils off as the part is heated; jell turns into a liquid slightly heavier than water. The past fluxes that I have found in electronics shops and big box electronics centers become inert (but even more sticky) when cold. Some liquid fluxes are listed as mildly active. These remain chemically active and may cause long term corrosion is not cleaned from the board. Look for no-clean where possible.

The largest diameter rolled solder I have on my bench is 20 gauge or .040". For small pins, I use solder that is .015" and .020". I have noticed that the 60-40 lead solder is becoming harder to find. It is being replaced with alloys of Tin-Silver-Copper and Tin-Copper. These new alloys have melting points 10 to 20 C higher.

For components with lead pitch less than 2mm, I use paste solder. The paste is made up of microscopic balls of solder suspended in a paste flux. The solder comes in syringe dispensers that contain 4cc of solder. It takes me about 6 months to use up a tube. These tubes have a shelf life once opened. Unopened tubes should be refrigerated to extend their usefulness.

Hint: To solder down fine pitch packages first align the part on the board and tack down opposite corner pins to hold the part in place. If you happen to create a solder bridge, fix it after soldering the remaining pins. Run a thin bead of past solder over the ends of the unsoldered pins, and I do mean thin. Gently warm the pins with your hot air over the paste until the solder solidifies into a grey crusty film. At this point, the flux is activated and the part is ready to reflow. Continue to move the hot air pencil closer to the pins and slowly melt the solder. The solder will flow to the pads and up on the pins. Allow the board to cool and inspect that all pins are soldered. You will have some solder bridges! Here is where you will need the solder wick.

Solder wick is a simple copper braid covered with flux. When heated, the wick draws solder into the braid. I do not recommend solder wick wider than 1/8" with fine pitch devices. You need the higher braid density to get small amounts of solder to flow. Now back to our solder bridge.

Add a touch of flux over the solder bridge and try and use the soldering iron to draw the bridge away from the pins. If that doesn't work, you will need to use the braid to wick the solder off the pins. Be careful not to draw all the solder off the pins, hold the iron and wick just long enough to fix the bridge.

6) Hand Tools

Tweezers are the workstations friend. I cannot stress the importance of a pair of stainless steel, non-magnetic, needle point tweezers. My favorite pair is 6” in length and 1.5mm at the tips. The contact area on SDM components is often a magnetic material. If your tweezers are even slightly magnetic, you will not be able to release part after you pick it up. Remember that these parts are .00x of a gram in weight. It doesn’t take much magnetism to hold on to a part. Small ferrite beads are particularly troublesome.

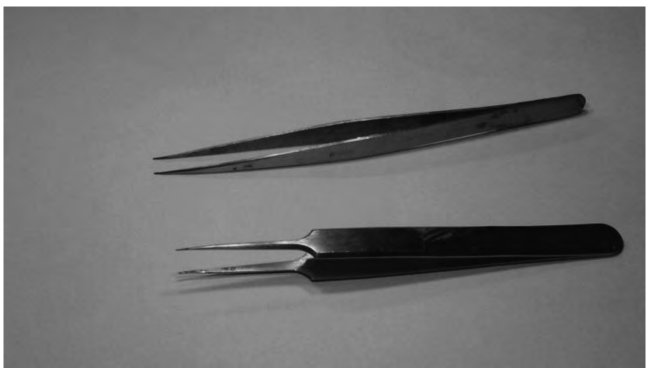

Fig 9. A Pair of My Favorite Tweezers

Toothpicks make an excellent probe to move and hold parts into place. They don’t handle hot air very well, use caution.

A fine tipped hobby knife is useful to straighten out the bent pins of dropped devices. It is also useful for making cuts in PCB traces.

Cotton swabs dipped in denatured alcohol or acetone are good for cleaning up patches of flux.

V. THE NEXT STEP- TOASTER OVEN

After spending eight hours soldering 175 components one at a time on a small board, I decided that a more efficient means was in order. What if I could place the parts and have the soldering all done at once. After all this is the way the big boys process a board. I started researching the feasibility of obtaining an oven capable of reflowing solder. The hot plate in the garage would get the board hot enough, but it wasn’t big enough do all of the board at once. But I did have an old toaster oven that I used to bake power coat paint.

I ran a 400 degree pizza bake cycle to see how fast the oven warmed up. It turns out that this oven didn’t have enough power to raise the oven temperature fast enough; especially at the reflow stage. The soldering profile has four stages as shown in Fig 2. : Pre heat, soak, reflow, and cool. The pre-heat stage raises the board to about 150C but no faster than 3C per second. This allows any water vapor to escape from the parts and the board. The Soak stage slowly raises the board up to about 200 C. During this period, the flux is activating and evaporating from the board. The solder paste reduces to a grey crusty power. The temperature is now raised to the peak reflow temperature again not exceeding 3C per second. For my no lead process, I limit the temperature to 240C. The board is held at the max temperature for about 15 seconds. It is critical that the temperature does not exceed this limit. At the end, it is important to get the board below 200C, but no faster than 6C per second. Components are limited to just over two minutes above the 200C temperature.

My garage oven took almost 5 minutes to get to the reflow temperature. OK for pizza, but not healthy for my components.

My use of the toaster oven is not unique. When I went out to look for suitable controller electronics, I found that the wheel had already been invented, packaged with software, and comes with a backlit display for under $40 dollars.[5] The addition of a thermocouple, solid state relay, and an off the shelf microprocessor board I was in business. I found a reasonable tutorial online that matched my electronics. [7]

Fig 10. Assembled Oven Controller

The microprocessor board is an Arduino UNO board [6] with an adapter board or shield that contains the display, buttons, and thermocouple amplifier.[5] All of the tools, compiler, and programming procedures are well documented and it took me less than thirty minutes to get the correct firmware onto the micro.

I procured another oven from a big box store that was 1400W verses the 800W unit. It was on clearance and had a dent in the top so I negotiated for a sub $50 price. The goal is to find an oven that can get close to the 3C rise per second rate. This turns out to be a smaller oven with higher overall power. In the U.S. at 110V, you probably will not be able to find a unit over 1400W.

I repeated the profile curve with this unit and it was better, but not ideal. At large amount of heat was generated on the sides of the cabinet. I decided to place a layer of home insulation between the inner baking chamber and the decorative chassis. The home insulation has a binding agent that keeps the fibers glued together. This is not designed to be a high temperature material and after the smoke cleared, the whole garage smelled like burnt sugar. In spite of the smoke test, the temperature curve looked like it was within range of being controlled. My final solution was to wrap some one inch thick high temperature fiberglass with extra heavy duty aluminum foil. I placed one of these rectangles on each surface of the interior of the oven. The shiny foil reflects the IR back into the interior of the oven, the insulation reduces the heat transfer to the exterior of the cabinet, and the added bulk reduces the internal area that has to be heated. Make sure that the fiberglass panels does not cut off any airflow to the heating elements or come in direct contact with the element guards. Figure 10. Is a graph of the the final temperature profile. Also when you procure your type K thermocouple, be sure that it has fiberglass insulation. My first one was plastic insulated and promptly melted. Since I cannot assume liability for your materials, make sure that anything placed in the oven has suitable temperature and flammability ratings.

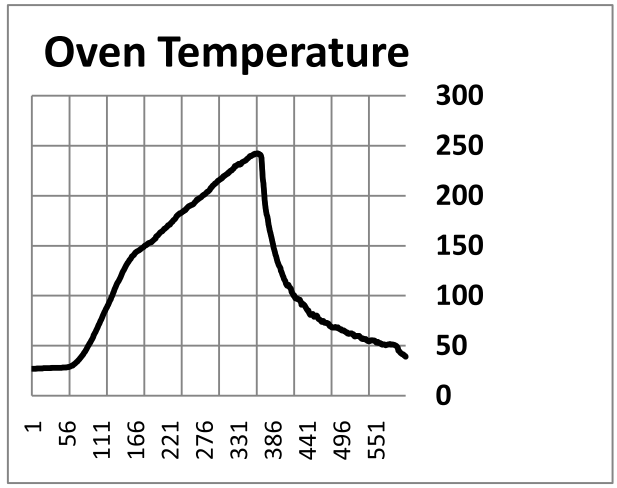

Fig 11. The Temperature Profile of the Working Oven.

VI. CONCLUSION

Once you have set up a rework station, I recommend practice, practice, practice, before starting on your first project. Find an old computer motherboard and try using the hot air to removing some of the bypass capacitors under the processor. More than likely they are connected to a heavy ground plane and the board will most have been assembled with no-lead solder. This is sort of a worst case test. If your teenager’s cell phone is generating an excessive bill, you may want to practice on that first. Keep an eye on the airflow from your hot air pencil; a gentle breeze is required not gale force winds. But you will remember this recommendation just after you have blown your first twenty parts off of the board. Flux, no matter how sticky, is your friend. Be ever so kind with the tweezers. It takes very little energy to pick up a part, but you can and will launch parts into near earth orbit by squeezing too hard. Do not curse at solder bridges, they are readily resolved. And you will know what I mean the first time you have a part tombstone.

Appendix A is a collection of photos of a small board project I designed and built for one of my customers. For me, spending $150 for a commercial solder stencil was money well spent. I produced twenty of the assemblies in less than two days. Without the stencil and the reflow oven, it would have been just short of one lifetime!

References

[1] www.topline.tv/SMT_Nomenclature.pdf

[2] www.amscope.com/sm-1bn-64s.html

[3] www.token.com.tw/image/typical-rohs-reflow-profile.gif

[4] http://www.fpga4fun.com/SMD.html

[5] http://www.rocketscream.com/shop/reflow-oven-controller-shield-arduino-compatible

[6] http://www.arduino.cc/

[7] www.youtube.com/watch?v=rZyP5G4Wfm0

APPENDIX A - THE PROCESS

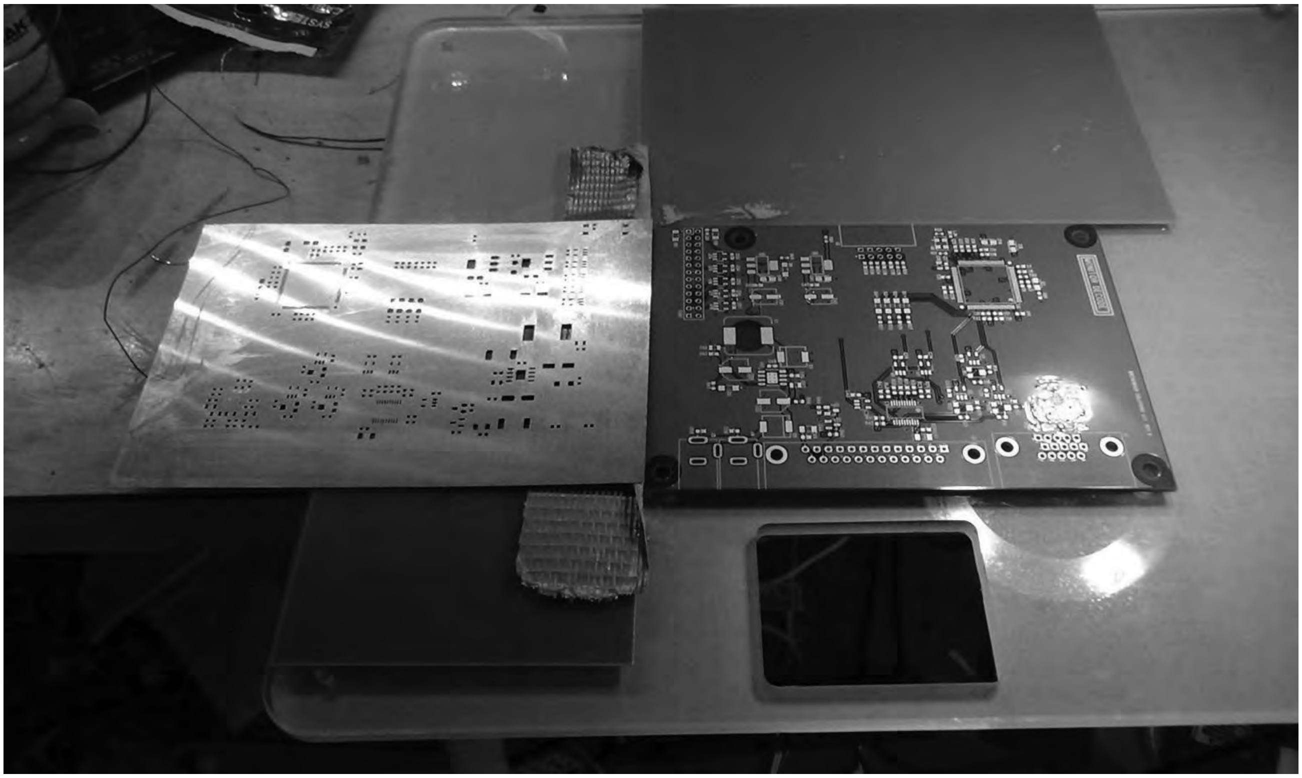

Photo 1. The blank PCB is ready to have paste solder applied.

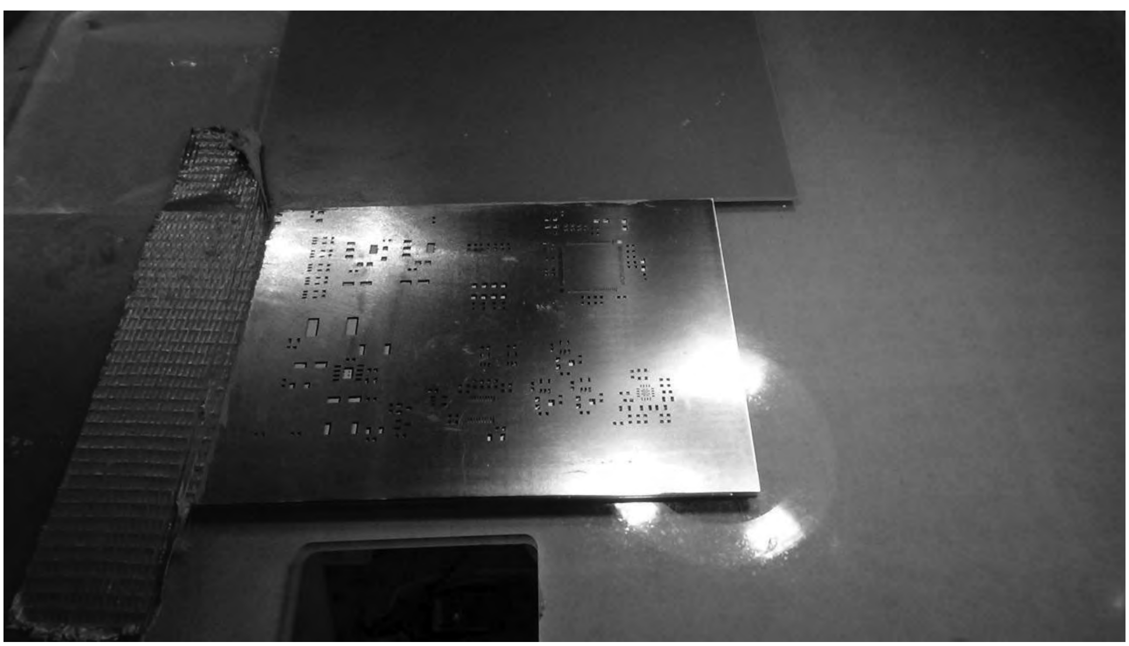

Photo 2. Aligning the solder stencil with the pads

Photo 3. Using an old hotel room key as a squeegee for the solder paste.

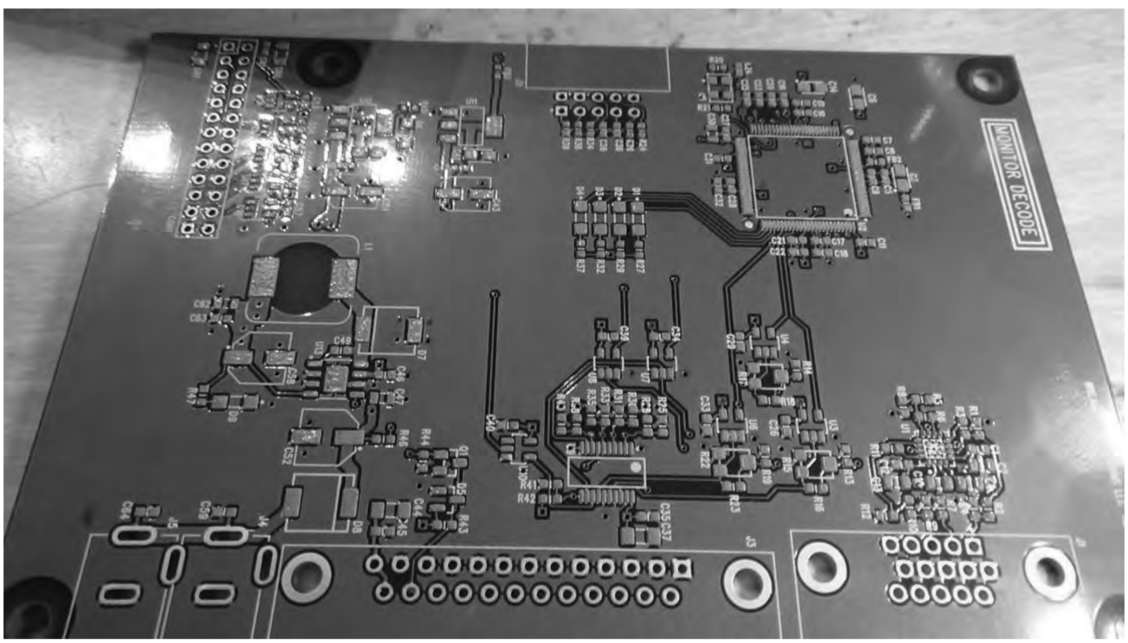

Photo 4. Inspecting the solder deposited on the board.

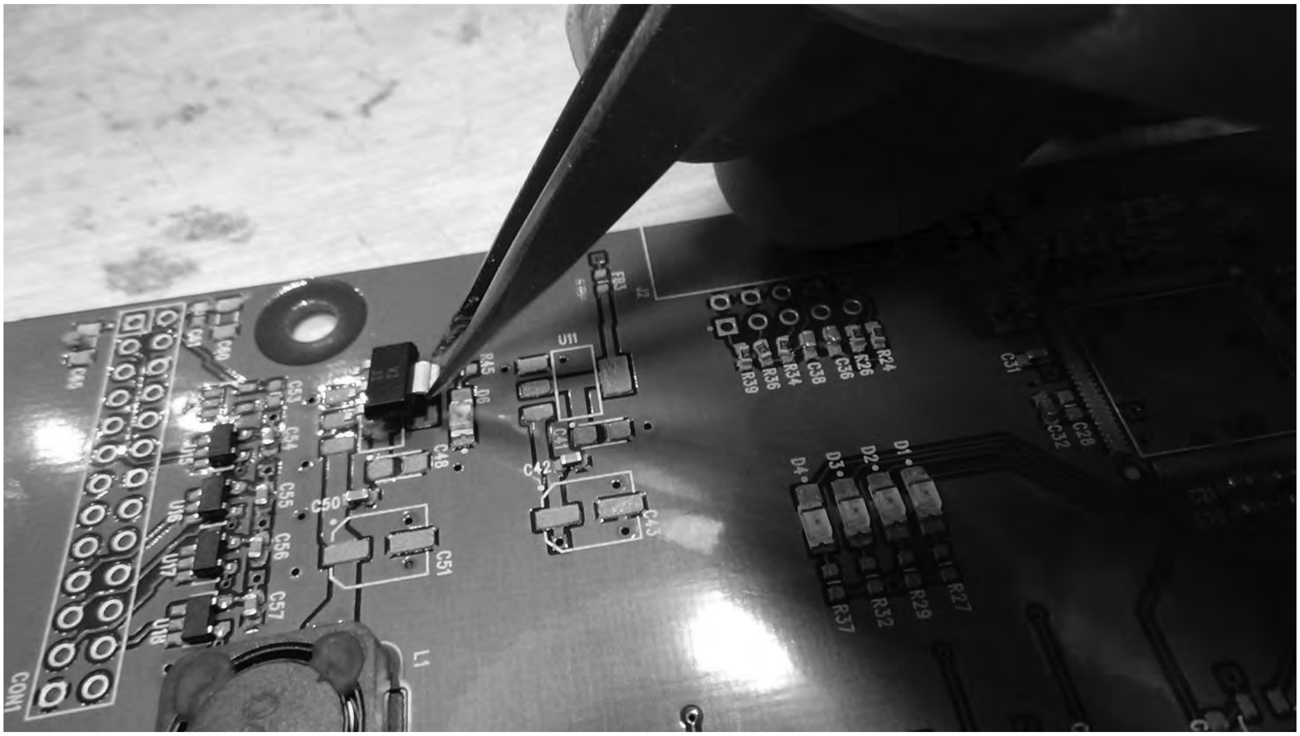

Photo 5. Hand placing components to the board.

Photo 6. Reflow oven.

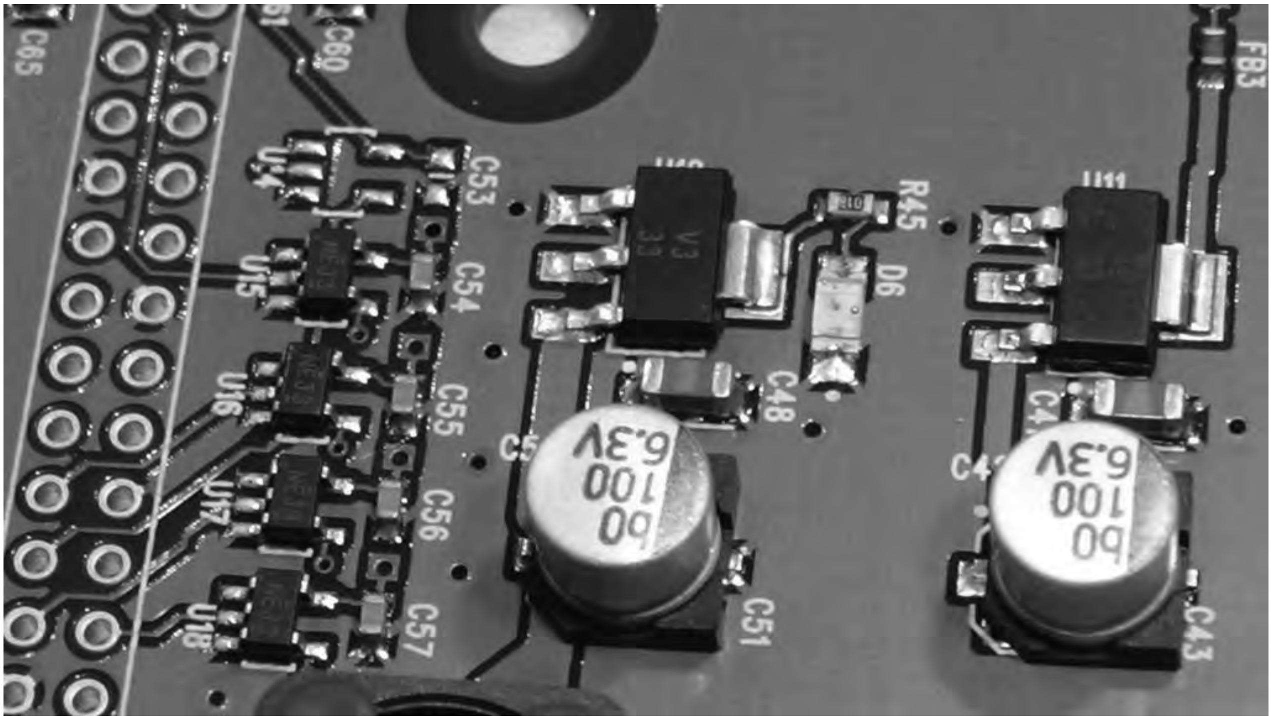

Photo 7. Soldered Parts

F-Region Propagation and the Equatorial Ionospheric Anomaly

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Introduction – Six meters has always been a fascinating place to study radio propagation. This is partly because ionospheric propagation is relatively rare, at least compared to lower frequency bands. As a result, when something does happen, usually it's easier to determine *what* happened. Despite the poor solar activity numbers, the long-awaited peak of the Sun's southern hemisphere has created a (perhaps brief) bump in six-meter F-layer propagation. This was especially obvious in the upsurge of DX paths during the northern fall of 2013 and spring of 2014. Much of this flurry of activity involved the geomagnetic equator and the *Equatorial Ionospheric Anomaly* (EIA).

The Equatorial Ionospheric Anomaly is a unique set of ionization pattern that forms in the E layer above the Earth's geomagnetic equator, specifically the *dip* equator. The dip equator is a line around the Earth showing where the Earth's magnetic field is exactly parallel to the Earth's surface.

The ionization patterns that form along this line provide for a number of variations of F-region propagation, including Transequatorial Propagation (TEP). These propagation types have been around for years. But for some, they are not broadly recognized as distinct forms, and though commonly referred to as TEP, in fact, not all of them are TEP. Nevertheless, like balls on a billiards table, the EIA and its effects can really bounce things around. Recently, six meters has displayed a number of these modes, and a few examples are shown in Figure 1.

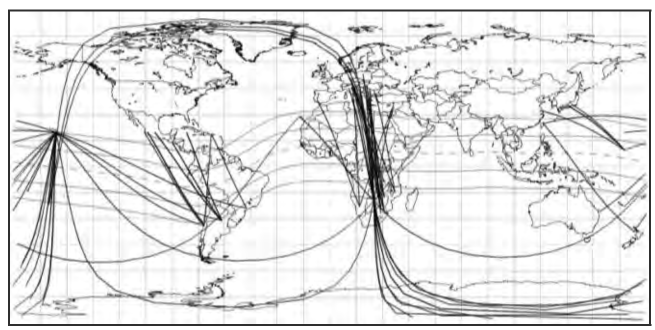

Figure 1: Several distinct F-layer paths are rooted in the Equatorial Ionospheric Anomaly. Five are shown: aTEP, eTEP, 1- and 2-hop F2, and transpolar long path (TPL). (*G.Projector map and overlays.*)

If the gloomy outlook for the next coming solar Cycle 25 comes to pass, as predicted by a number of prominent solar physicists, then some of the lessons learned at six meters may well become relevant, not only to 6 and 10 meters, but also 12, 15, and 17 meters, and maybe even 20 meters. The good news is that there is quite a variety of related, but different, F-region skip modes that vitally hinge on the rather special ionospheric conditions that occur in the general vicinity of the dip equator.

Basic Ionospheric Skip – The following review points out a few of the key components that make ionospheric propagation work, and which are important to understanding some of the propagation puzzles.

Ionization – The F2 region lies above about 250 km and goes upward beyond 1500 km. The ionization of the F layer is due primarily to extreme ultraviolet (EUV) radiation from the Sun. When a solar EUV photon collides with a neutral gas atom in the F layer (mostly single oxygen atoms) the photon knocks one of the outer electrons off the atom, leaving a rather heavy oxygen atom, with a positive charge of one, and a very light free electron, with a negative charge of one. From a radio propagation perspective, the key part is the light, very mobile, free electron. Of course, the more solar activity there is, the more free electrons there are.

If a radio wave is sent up into the ionosphere, when it encounters the free electrons, the oscillating electric field of the passing wave causes the electrons to move back and forth at the same frequency as the radio wave. Electronically, these oscillating electrons behave like an antenna, except the electrons are wiggling back and forth in nearly empty space, rather than on a metal wire. This means that a certain fraction of the up-going wave energy will be reradiated back downward towards the Earth by this "free-electron antenna". If the electron density is greater than a certain number, the *entire* radio wave will be reradiated back down, and skip occurs. The amount of ionization required to do this depends on the *frequency* of the upcoming wave, and the *angle* between the wave and the ionosphere itself.

Taking the simpler case first, suppose that a signal is sent straight up, vertically, to the ionosphere directly overhead. If N_e is the free-electron number density, the *maximum* frequency (in MHz) that can be bounced *straight back* down is given by:

$$f_c\,(\mathrm{MHz}) = \sqrt{N_e} \times \left(9 \times 10^{-6}\right) \qquad N_e = \mathrm{electrons/m^3}$$

The main point is simply that the *highest frequency* that a straight up signal can then be bounced straight back down (something called the *critical frequency*) only depends on the square root of the electron density, N_e, and a known constant value. Something else to note is that, for a signal to skip at *twice* the present critical frequency, the *electron density* must *increase* by a factor of *four* (because of the square root).

M Factor and the Angle of Attack – Of course, aiming signals straight up to have them skip straight back down won't produce much DX. In the real world, one aims at the horizon and that changes the *angle* with which the signal hits the ionosphere. The good news is that it makes the angle *shallower*, and the shallower the angle between the upcoming radio wave and the ionosphere, the *higher* the maximum usable (skip) frequency, or *MUF*, and the *longer* the skip distance. The angle between the wave and the ionosphere is sometimes called the angle of attack or α, as shown in Figure 2. The increase in the MUF that one gets from lowering the angle α is related to the cosecant of α. The cosec(α) term is called the *M Factor*, and it directly multiplies the effect of the critical frequency f_c. The value of the MUF is then given by:

$$f_{MUF}(\mathrm{MHz}) = \mathrm{cosec}(\alpha) \times f_c$$

When the symbol *M* replaces cosec(α), this becomes:

$$f_{MUF}(\mathrm{MHz}) = M\,\sqrt{N_e} \times \left(9 \times 10^{-6}\right)$$

Under *normal* circumstances, the M Factor depends on the height of the ionospheric layer. With an antenna aimed at the horizon, the typical F2 hop has a value in the vicinity of 3.4. However, we will see shortly that M, and therefore the MUF, can be *much higher* under the right conditions.

Specular Reflection – Another important consideration is how the skip process actually comes about. In an elementary picture of ionospheric skip, one imagines that the ionosphere presents a hard-surfaced radio mirror, as shown in Figure 2. Any upcoming radio wave simply bounces off the layer and returns to Earth. This is actually a fairly accurate view of what happens in *sporadic E* skip. In Es, there is a very thin layer of very dense ionization and the signal does experience a nearly mirror-like, or "specular", reflection. However, this is *not* the usual case for F-layer propagation.

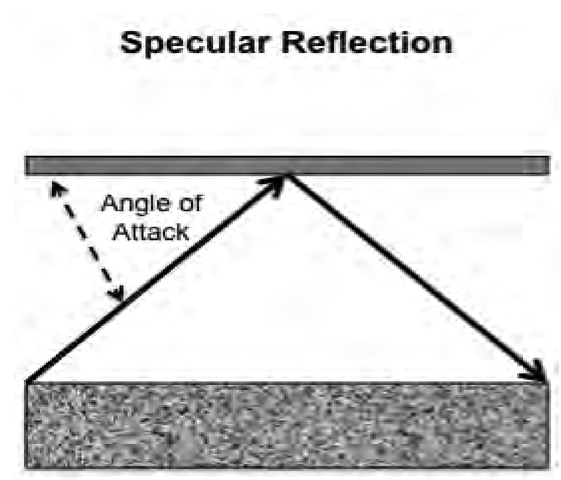

Figure 2: Es produces mirror-like *reflections*. Note also that the *smaller* the angle of attack the *higher* the MUF for a given electron density N_e.

Refraction – F-region ionization is spread over a large vertical expanse, usually extending upwards hundreds of kilometers or more. As a result, signals are not skipped by a mirror-like bounce, but rather they are gradually bent, like light travelling through a lens. Figure 3 depicts how a large vertical region of ionization refracts a wave path *gradually* until it points back downward again (if the MUF is high enough).

Since the F layer is three or more times higher than the E layer, it naturally provides a much longer single-hop skip distance than Es. In addition, once in the F layer, the signal can travel *horizontally* quite some distance *while* the refractive bending is taking place. Refraction can typically provides a longer skip distance than a specular reflection for the same layer height. Frequency is a factor, too. A good single F2 hop at HF is about 4000 km. At six meters, it can be as much as 20% longer.

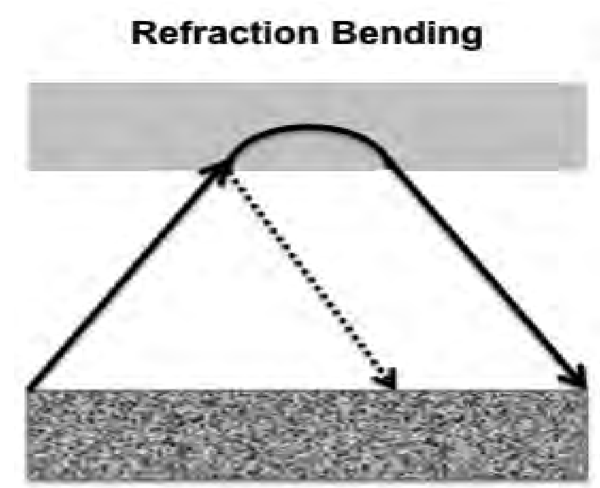

Figure 3: The large vertical extent of the F2 layer skips a signal by more gradual bending, or *refraction*. Refraction can provide longer skip distances than the specular reflection (here shown as a dotted arrow).

Ionospheric Environment – Simplified views of the ionosphere often show it as a smooth, flat layer. This is a good starting point for the beginner, but in the real world, the ionosphere is *neither* flat nor smooth. As a matter of fact, it's *not* even *spherical*.

These realities have significant impacts on the fine details of radio propagation. Generally, these are positive impacts, providing communications opportunities that would not otherwise exist. Nevertheless, making sense of them requires a little deeper look at our planet, and how it behaves.

Geomagnetic Field – The Earth's geomagnetic field interacts with the ionized electrons within the various layers, and this produces a range of interesting effects. One is that, like the ionosphere, the simplest pictures of the *magnetic* field can hide some of its most important characteristics. One of the more important features is that the Earth's magnetic field is *misaligned* with the Earth's actual rotation axis by about 10°. As a result, there are two different longitude-latitude systems, one based on the Earth's rotation axis (the *geographic* system), and the other based on the orientation of the geomagnetic field axis (the geo*magnetic* system). Of course, it is the rotation axis – the *geographic* system – that determines the time of day and the seasons of the year.

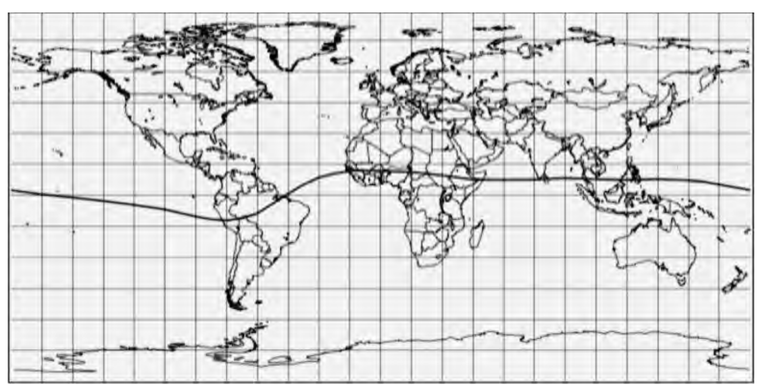
Figure 4: The black wavy horizontal line near the geographic equator is the geomagnetic dip equator. The odd bump over the Atlantic Ocean is caused by the magnetic field's center being displaced away from the Earth's center under the South Atlantic Ocean off Brazil, and in the direction of the Pacific instead. (*G.Projector map and overlays.*)

This is even more complicated because not only is the axis of the magnetic field *misaligned*, it is also *off center*. If the field were imagined as a simple bar magnet, the center of the magnet would *not be* at the center of the Earth. It would be several hundred kilometers from the center – toward the Pacific side. This weakens the field over the South Atlantic Ocean off Brazil, and causes an abrupt glitch in the geomagnetic dip equator.

The interaction of the offset field center with the Earth's interior structure also leads to distortions in the overall field, so that the magnetic field is *not* a true dipole. Some maps do show a magnetic-dipole longitude-latitude scheme, but this approximation is *not* at all *realistic* for *propagation* purposes. Figure 4 shows the location of the geomagnetic dip equator, that is, the line of points where the magnetic field lines are parallel to the Earth's surface. The abrupt distortion on the dip equator is clearly seen over the South Atlantic near Brazil.

Equatorial Electrojet – During the local *daytime*, in the E-layer around 100 to 110 km, directly over the dip equator, there is a very intense electric current called the *Equatorial Electrojet* (EEJ). This ribbon of flowing electrons is quite thin and confined to a very narrow north-south range across the dip equator (approximately from +3° to -3°). The electrojet is primarily driven by the Sun, which ionizes the daytime E layer and also drives a wind of neutral gases in an east-to-west direction, dragging the free electrons along with them. The interaction with the equatorial geomagnetic field, which is parallel to the Earth's surface, produces the ribbon of current. The current follows the dip equator throughout the year, even though the place-to-place, day-to-day, even hour-to-hour, *strength* of the current can vary strongly with the season, F10.7 solar flux, diurnal atmospheric tides, lunar tides, and perhaps even vertical drafts caused by tropospheric weather.

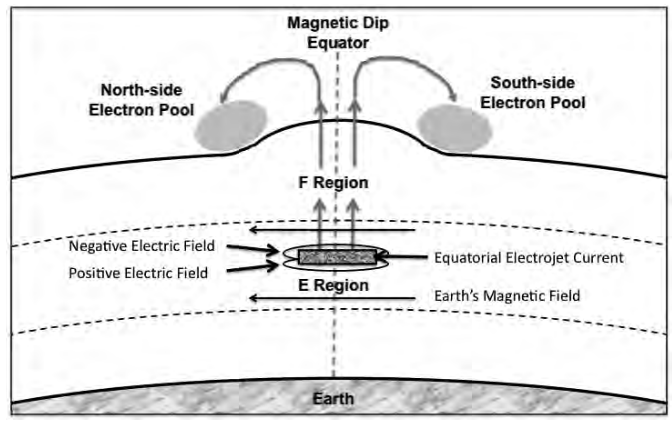

Figure 5: The *daytime* fountain produces two regions of enhanced ionization, one between 10°N and 20°N of the dip equator and the other from 10°S to 20°S.

Daytime Electron Fountain – When a current flows at right angles to a magnetic field, as it is here, the electrons are subjected to an electromagnetic force known as the Lorentz Force. With the Equatorial Electrojet, this force pushes electrons from the E and F1 layers *upwards* to great F2-region heights, at times more than 1500 km. At these heights, the electrons have *much longer lifetimes*.

As in the E layer, when the daytime Sun heats the F region, it drives the daytime neutral wind patterns. The F2 winds flow *outward* from the warmed area over the dip equator, and *towards* the cooler regions toward the nearest pole. These neutral winds carry the upcoming electrons with them. As a result, the electrons that are on the northern side of the dip equator are carried further northward, while those on the south side are carried further southward.

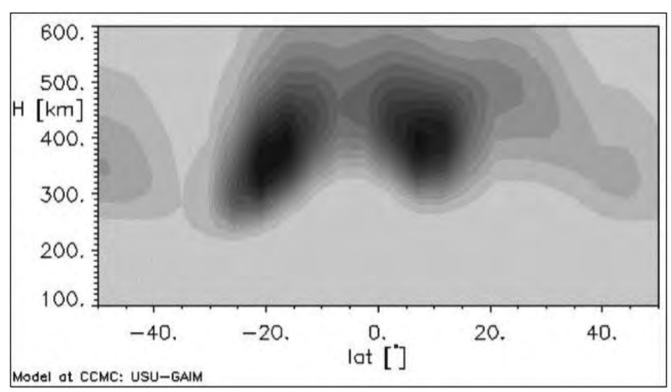

Figure 6: This electron density map, for 0315 UTC on April 2, 2013 at 85°W, shows both EIA pools have MUFs of about 57.5 MHz at about 390 km. Compare this with the diagram in Figure 5. (*USU-GAIM ionosphere.*)

Going north and south of the dip equator, the Earth's *magnetic field lines* gradually tilt downwards toward the Earth, and the fountain electrons follow these field lines. So, as they go north and south, they also must descend to lower F2 levels. Finally, the electrons collect into two ionization pools, often referred to as "crests", one centered around 17° north, and the other centered around 17° south, of the dip equator, at altitudes from 300 to over 450 km, as diagramed in Figure 5, while Figure 6 shows how these same features show up a USU-GAIM rendering. USU-GAIM is an ionospheric model developed at Utah State University that uses a wide range of real-world data to recreate the state of the ionosphere in three dimensions at a given time (Schunk, et al. 2004).

Nighttime Bubble Fountain – While the daytime electron fountain works well throughout the local sunlight hours, when the Sun sets on the E and F2 layers, the electrojet current drops dramatically to the much lower nighttime levels. However, just before the daytime fountain fails, there is a brief, but very significant *upward* surge in the fountain, called the *Prereversal Enhancement* (PRE). At this time, the vertical "pipeline" of daytime ionization is still *full*, from the E layer to the high F region.

The shock of the Prereversal Enhancement impulse is believed to trigger a set of atmospheric gravity waves (rather like ocean waves) within the standing vertical electron column. These gravity waves then produce a series of low-density ionization "bubbles" in the otherwise dense vertical column (e.g. Lin et al. 2005).

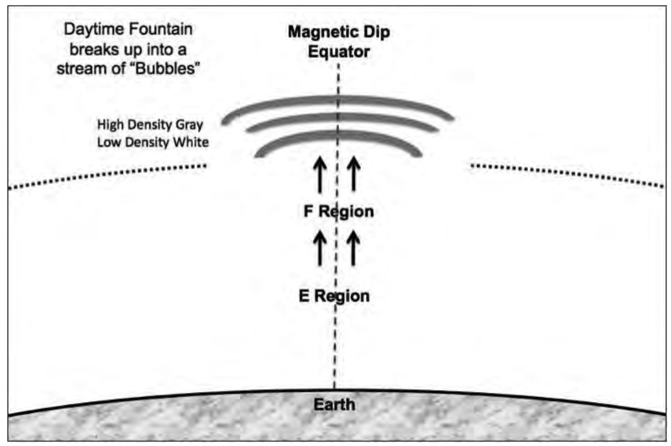

Figure 7: The dying daytime electron fountain is shocked into a series of standing waves of alternating high and low ionization. The stacked layers are buoyant and float upward.

These bubbles are 50 to 350 km thick sheets of *low*-density ionization, called *depletions*. They are sandwiched in between layers of the original *high*-density plasma (Chen et al. 2012). These *Equatorial Plasma Bubbles* (EPBs) can be more than 2000 km wide in latitude.

Like bubbles in a glass of water, or hot air in a balloon, these depletions are buoyant and they begin to rise, pushing up the denser ionization layers lying above them. Figure 7 shows a portion of this multilayer stack of alternating low- and high-density ionization layers as they float upward – as a nighttime fountain effect – typically between about 1900 and 0000 local solar time (LST). During periods of *high* solar activity, the bubbles have lifetimes of about three hours, increasing to as much as seven hours during *lower* solar activity (Huang et al, 2012). In latitude, the bubbles span a region from about 20° north to 20° south on the dip equator, with the bulk occurring between about 16° north and south (Burke et al., 2004).

Seasons, Times, and Ionization – Since ionospheric free electrons are initially produced by the Sun's EUV radiation, the more directly the Sun is shining down on a given place, the more the ions are produced. If the local time were noon at that place, then having the Sun *directly* overhead would produce the *most* ionization. Of course, the Sun's high-noon angle depends on the latitude of that place and the local season.

So, as the Earth goes through its various seasons, the noontime ionospheric Sun angle at a specific point slowly changes, as each of the Earth's two geographic poles alternately tips toward and then away from the Sun. Of course, this leads to the cycle of the seasons being reversed between the Northern and Southern (geographical) Hemispheres.

Summer and Winter – Since the Sun's noontime angles in a given hemisphere are greatest during the hemisphere's local summer, more free electrons are produced in the summertime. If the story stopped right there, then one would expect that the local summer season would be the best for F2 propagation. *However*, while *more* ions are produced in the *summer* ionosphere, another summertime effect in the F-layer chemistry causes these ions to have shorter *lifetimes*. That is, the electrons are recombined with the positive ions at a *much higher rate* than in the wintertime. So, the final effect is that there are *fewer net free electrons* in the local *summer*, than in the winter. So, at *midlatitudes*, F2 propagation is *best* in the local *wintertime*.

However, the real subject under discussion starts with propagation in the *geomagnetic equatorial latitudes*, and in particular, paths traveling *across* the geomagnetic dip equator. So, there is a lot more to the story.

Spring and Fall – In contrast to the extremes of summer and winter, the Sun shines more or less *equally* on *both* the northern and southern electron pools during the spring and fall. Even though the Sun angle is not optimum for either the northern or southern side, having them *balanced* makes skip *across* the dip equator much more likely. Since spring in one (north-south) hemisphere is fall in the other hemisphere, this means that there are *two* times a year when this kind of propagation reaches a peak.

Dates of Seasons – The dip equator sits at an angle to the geographic equator, at most longitudes there is a difference between their latitude values. The dip equator's peak-to-peak variation is about 24°. It is also not symmetric. For example, over the Atlantic, it makes that 24° latitude transition in only 70° of longitude (look back at Figure 4). Finally, the 24° peak-to-peak values are a significant fraction of the Sun's own annual 47° peak-to-peak north-south seasonal travel.

Strictly speaking, the *geomagnetic* equinox at a given geographic longitude would occur when the Sun was positioned directly over the *geomagnetic* dip equator (*not* the geographic equator). This happens on different dates at different geographic longitudes. So, the *magnetic seasons* are not exactly the same as the geographic seasons. Given angle between the dip equator and the geographic equator, this also means that on any given day, the magnetic season changes during the day, as the Sun passes over the various longitudes.

Again referring back to Figure 4, stations in the Northern Hemisphere located at geographic *longitudes* between the middle Atlantic eastward to the east coast of Australia have their dip equator between 8° and 12° north. As a result, their spring magnetic equinoxes occur 20 to 30 days *later* than the geographic equinoxes, and their fall equinoxes are 20 to 30 days *earlier*. Of course, stations at these same longitudes in the Southern Hemisphere have these same equinoxes at the same dates, but the names of the seasons are reversed.

The Northern Hemisphere stations located between geographic *longitudes* corresponding to the central United States eastward to the tip of Nova Scotia have their dip equator between 8° and 12° south. Their fall equinoxes occur 20 to 30 days *earlier* than the geographic dates, and their spring equinoxes are 20 to 30 days *later*. In the Southern hemispheres, the dates are the same, but again the seasons are reversed.

In principle, these equinox date shifts effect which weeks of the year are the best for propagation, based on one's longitude. However, there are also many other factors that influence when, exactly, propagation occurs, including short-term solar activity.

Times of Day – Since the Sun is the source of the ionization that drives the Equatorial Electrojet, which in turn provides the resulting propagation, when one talks about what the *time* is, it is the time at the points in the *ionosphere* where the skip actually takes place, an not either of the endpoints. That is, the time is the actual Local Solar Time (LST) at the skip points.

If one is talking about paths that are north-south, or nearly so, the skip points will be near the same longitude. In such cases, the times are essentially the same and one can talk simply about the path *midpoint* time. However, there are important cases where the paths have strong east-west differences and the different skip-point times have to be dealt with separately.

Many Flavors of Equatorial Ionospheric Anomaly F2 – Having set the stage, let's take a look at some of the many different ways that the Equatorial Ionospheric Anomaly can result in interesting F2-based propagation. One of the first things to notice is that many things that are routinely called TEP are really several *different* phenomena. In one way or another, they involve the Anomaly, and some aren't really TEP at all. So, the following is an effort to break these down to their more basic forms, and there is no doubt that this still is *not* the complete picture.

Classical Transequatorial Propagation (TEP) – This is perhaps the most commonly known form of Equatorial Ionospheric Anomaly F2 propagation. As the name implies, TEP involves skip paths that cross *over* the geomagnetic dip equator. TEP was "discovered" in late August 1947, as hams returned to the air after World War II, and in the US, on six-meters for the first time. The first contact may have been the one between W7ACS/KH6 at Pearl Harbor Hawai`i and VK5KL (Joly, 1990).

There are *two* main types of classical TEP, the *afternoon* and *evening* types. Although they have many basic similarities, in detail, they actually work somewhat differently. What they do have in common is that signals are first propagated up into the F2 layer on the nearside of the dip equator. Then, the signals propagate more or less *horizontally* across the dip equator, completely within the F region, *without* coming back to Earth in between. Finally, some distance from the farside of the dip equator, the signals leave the F2 layer and returned to Earth.

The total distance travelled, including *through* the F2-layer, corresponds to about an F2 "hop and a half", so the total distance between the north and south ground endpoints can be a good deal greater than 5,000 km. It is also a low-loss path. Since the signal doesn't come down at the midpoint, it avoids two passes of D-layer absorption and any mid-path ground effects that a normal double hop would have encountered. (The D-layer effects are negligible at six meters, but they would be a factor for HF propagation.)

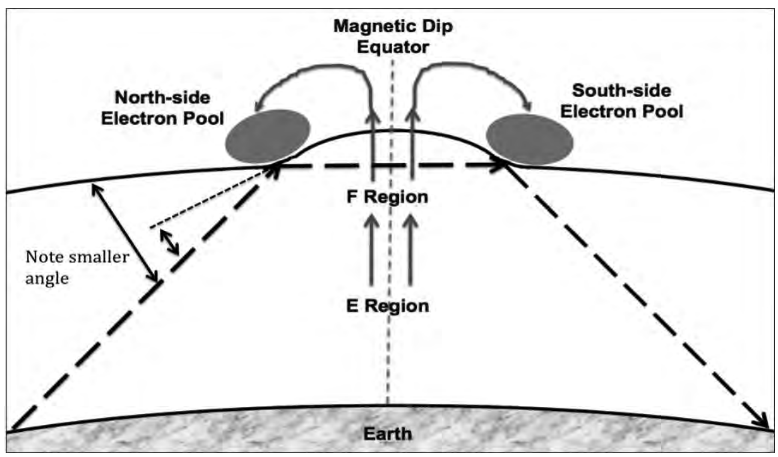

Figure 8: This diagram shows a transequatorial chordal hop off the tilted north and south skip points. These points each lie between about 10° and 20° north, and south, of the Earth's magnetic equator and clearly cause nighttime TEP in the magnetic tropics.

Afternoon TEP (aTEP) – As the world turns, the Sun progressively illuminates the daylight side of the Earth under it. This starts the previously discussed Daytime Fountain Effect. The Fountain pumps electrons upward from the E and F1 layers into the upper F2 region. This produces two regions where the ionosphere is systematically tilted *and* the free-electron density is enhanced by the pooling of electrons descending from the top of the fountain.

Generally, the morning hours are spent building up the amount of ionization transported into the F region. When the TEP crests or pools are sufficiently charged up, an upcoming radio wave hitting the *tilted* corner of the enhanced nearside ionization pool arrives at a *shallower angle of attack* than if it were a strictly spherical layer. So, not only are the electron densities higher than normal, the M Factor is *also* higher than the usual 3.4. Both factors conspire to produce much *higher MUFs* than the surrounding F2 layer. This happens again as the signal skips off the curved surface on the other side of the dip equator and heads back to Earth, as described in Figure 8.

During the period around the spring and fall *equinoxes*, the solar ionization is more or less equal in both the northern and southern TEP pools. Generally, this balanced amount of ionization is favorable to aTEP propagation. Although there are some subtler details, aTEP is much more common around the equinoxes.

Ionization Lanes – For aTEP to work by the afternoon, both the north and south F2 skip points, which straddle the dip equator, must be ionized at, or above, the effective MUF required for the frequency involved. These two ionization pools move around the Earth daily, following the Sun. This leads to two "lanes" or pathways that the ionization pools follow, day after day, on the daylight side of the planet. These lanes lie mostly between 10° and 20° north of the dip equator, and between 10° and 20° south of the dip equator, as illustrated in Figure 9.

Common Paths – aTEP paths are largely *magnetic* north-south paths. They usually cross the dip equator within ±15° of the perpendicular, and can reach out to distances of about 7500 km. Figure 10 shows the general appearance of these paths and *some* of the common geographical regions where they are found. Although, there are *some* paths that have significant east-west components, these are special cases that will be discussed in later sections.

Times of Day – As aTEP ionization builds up in the morning daylight hours, it often reaches high enough levels for propagation in the early afternoon. This propagation mode then collapses shortly after the *path midpoint* E-layer sunset, because the daytime electron Fountain shuts down. So, the aTEP time period is about 1300–1900 path midpoint LST.

Figure 9: Bright patches show F2 ionization pools at 315 km at 0915 UTC, March 20, 2013 (the March Equinox). Solid white lines show the nominal daily paths, or lanes, that the pools follow from east to west. The large peaks left of center show the north and south electron levels are about equal. Those are the afternoon TEP peaks (aTEP). The two weaker peaks right of center are the evening TEP peaks (eTEP). The maximum MUFs are 53 MHz, over India and the Indian Ocean. (*USU-GAIM ionosphere; G.Projector overlays.*)

Seasons – Since aTEP works best with equal ionization on both sides of the dip equator, it normally occurs during the two annual spring-fall equinox seasons. This usually peaks during March and April, and then again during October and November. The exact dates may be earlier or later, or longer or shorter, depending on the location of the dip equator, the timing and amount of solar activity, and other effects.

Evening TEP (eTEP) – The second classical form of TEP is *evening* TEP, or eTEP. After the Sun sets on the path midpoint E layer, the daytime fountain shuts down, and the *nighttime* fountain begins producing bubble layers. The bubbles consist of sheets of high-density ionization separated by very weakly ionized sheets called depletions. These sandwiched combinations of high – then very low – then high conductivity plasma layers are the key to making eTEP work.

As Figure 11 shows, the north and south ends of the depletion layers have openings on each side of the dip equator. A radio signal approaching the bubble stack will find it difficult to penetrate the highly conducting layers, but find it quite easy to *enter* the low ionization deletion layers. As a result, the depletion layers can act like signal ducts or tunnels through the bubble stack.

So, *instead* of *skipping* the signal from a dense cloud on one side of the dip equator, to another cloud on the farside of the dip equator (like aTEP), a depletion duct carries the signal in a continuous curved path though the F layer bubbles, following the Earth's magnetic field lines (Kennewell and Wilkinson 2004). Once a radio wave gets into the duct, it slides along making very high M-Factor grazing incidence skips off the *top wall* of the duct, guiding the signal around its curvature until it exits the duct on the other side of the dip equator.

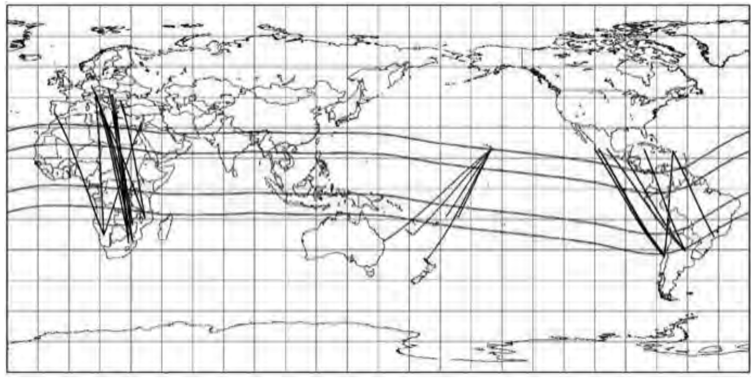

Figure 10: Both afternoon TEP (aTEP) and evening TEP (eTEP) can produce paths that are approximately perpendicular to the *dip equator*. The map shows common examples of these mostly north-south paths. (*G.Projector map and overlays.*)

Since the size of the bubble stacks can extend from about 20° north to about 20° south of the dip equator, the general locations of the entrance and exit regions are similar to skip points seen in aTEP.

Since the vertical span of the individual ducts are in the 50 to 350 km range, the ducts are fully capable of transporting signals from at least as high as 432 MHz, and then well on down into the HF range.

With the family of bubbles being stacked up vertically, an upcoming signal can enter *more than one* guided path at the same time. So, there can be many paths over the dip equator. As a result, even with strong eTEP signals, there are often obvious, profound at times, multipath effects, including deep fading, and/or echoes.

Common Paths – Usual eTEP paths include the mostly north-south paths, as also seen in aTEP (see Figure 10). The observed maximum range is a bit longer than aTEP, going out to about 8800 km. There are at least two *other* modes that have some characteristics of eTEP, but are or may not be eTEP, as will be discussed shortly in the section on Oblique TEP and Single-Lane F2.

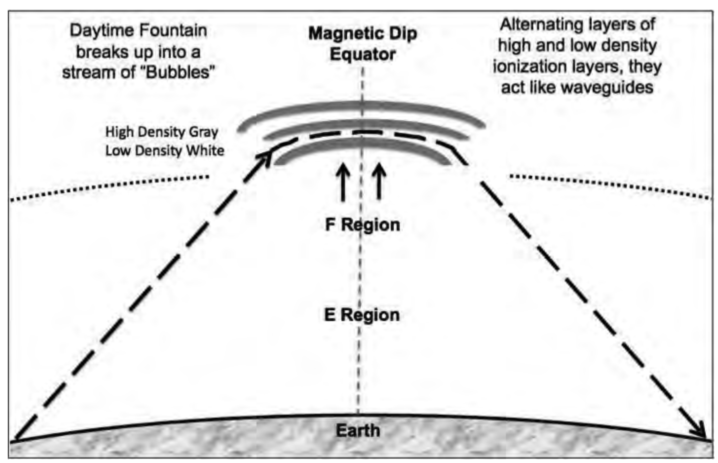

Figure 11: Stacked layers of weakly conducting regions in between highly conductive regions form a duct that guides upcoming radio waves through the dip-equator F region, and back to the ground on the other side. If more than one duct is illuminated, even strong signals can show noticeable multipath effects, as multiple ducts pass the signal.

Times of Day – The evening bubble fountain gets underway shortly after the path midpoint sunset and the collapse of the daytime fountain. Various studies of the equatorial plasma bubbles themselves suggest that their active periods are about 2000-2300 LST at the path midpoint. However, propagation observations indicate that they can be effective from about 1900-0100, and in some cases, even later. It is not uncommon to encounter north-south paths that are open in the mid-path afternoon with aTEP, and then later after mid-path sundown, pick up again in the evening hours by eTEP.

Seasons – The eTEP and aTEP seasons are about the same, spring and fall in both hemispheres. Both are facilitated by roughly equal ionization of the E and F layers on both sides of the dip equator.

"Oblique" TEP – The classical picture of aTEP and eTEP outlined above really applies to paths that are largely oriented (magnetically) north-south. In these cases, there is only modest east-west difference in magnetic longitude, and this presents no mystery. However, paths that cross the dip equator at very large *oblique* angles must be much *longer* than nearly north-south paths. Even though the *latitude differences* between the stations about the dip equator are about the same, the *longitude differences* can be *very* large.

These include recurring paths between Hawai`i and South America. Figure 12 shows common examples of several of these paths. The longest is over 13,000 km, the shortest over 10,000 km, and most are over 11,000 km.

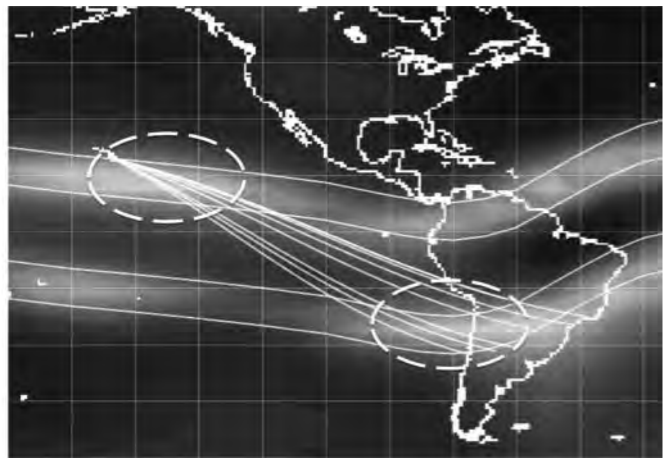

Figure 12: Dashed ovals are the paths' north aTEP (left) and south eTEP (right) ionization peaks. The ionization lane boundaries are also shown. The south aTEP (left) and north eTEP (right) peaks are visible, but *not* involved in the path. (*USU-GAIM ionosphere; G.Projector overlays.)*

The Figure also shows an overlay of a typical USU-GAIM ionization map for that time of day and season. The dashed ovals show the paths' northern aTEP (left) and southern eTEP (right) skip-point ionization pools (white) at 400 km. Their corrponding southern aTEP and northern eTEP pool are also visbile.

These longer paths pose at least two interesting challenges. The first is that the distance *in between* the *nearside* lane skip point and the *farside* lane skip point is simply *too long* for a chordal or ducted hop.

This "middle" segment would have to be about 5400 km for the shortest path, and about 8500 km for the longest. The basic problem is that the curvature of the Earth would cause the signal path to run into the ground about 2300 km downstream, destroying the path. Even under the most ideal conditions, the paths are 900 km to 4000 km short of the mark.

Getting the Distance Right? – The challenge of going long distances around the curvature of the Earth, *without* hitting the ground has come up in other contexts. For example, at least some types of 50 MHz long-path propagation show evidence indicating that the very long central portion of the path has one or more segments (some perhaps longer than 11,000 km) that never come to Earth (Kennedy 2003; and the Transpolar Long path section below).

In the present case, one possibility is a variation of the guided wave scenario. In this hypothesis, the signal skips off, say the west-end ionization peak, as an aTEP hop, and then going into the region between the two lanes. There it starts nearly parallel to the Earth's surface, and going forward, the horizon moves up to meet it. However, long before it hits the ground, it encounters the topside of the E layer at grazing incidence. MUFs resulting from such skips are typically twice that of normal skips (Davies 1990).

This skip sends the signal further on down the path, edging *upwards* toward the F layer again. From there, F-layer refraction along the path eventually returns the signal path back downward again, to either another topside E skip, or carrying the signal all the way to the east-end TEP peak, and from there back to the ground at the end of the path.

A simpler varation of this scheme might be to propose that F-layer refraction simply bends the signals around the curvature of the Earth, from one end to the other, all the way to the east-end TEP peak. Whatever the case, the paths do happen, and do so frequently when TEP is around. The above effects have been observed on other contexts, and they offer plausible explanations here as well, and there may be other explanations as well.

Oblique: aTEP and eTEP? – In addition to the length of the path, the time of day patterns raise another question. The extended paths separate the two end-point stations by five or six time-zone hours – so their Local Solar Times are very different. The observed propagation usually occurs during the *west-end mid afternoon*, while it is *evening* at the *east end*. Adjusting for first and last skip points, the west is still in the afternoon TEP regime and the east is well into the evening TEP regime. The simplest conclusion is that the west end is getting an aTEP hop and the east end is getting an eTEP hop. That may well be what's happening. If so, it is interesting that the two different mechanisms, which work in rather different ways, seem to make such a good connection.

The issue here is that aTEP requires a separate hop on *each side* of the dip equator, while the usual view of eTEP is that signals are piped *all the way across* the *whole space* from the north lane to the south lane, while *buried inside* the depletion ducts. So, the question would be, how did the aTEP signal from the north side – traveling *in between* the two lanes – get into the *middle* of a *closed* eTEP depletion duct, in order to get over to the south side lane and down to Earth?

The most likely answer is that as the bubbles rise, they *also have open edges* pointed into the region *between* the north and south lanes. Recalling that, in eTEP, all the guiding of the wave comes from high-M skips off the *ceiling* of the duct. In other contexts, eTEP has been observed to "leak" signals out the bottom of the ducts. So, if a signal coming from the north side can find a hole in the bottom of a duct, or a duct *without* a bottom altogether, then it could complete the journey on the south end as an eTEP hop.

Common Paths – Highly oblique paths are very common in the Pacific region during the TEP seasons. They may occur in other regions as well, though the combination of the hook-shaped dip equator region over South America, followed by a rather straight, gently northward flowing line out toward Asia may play a role in the frequency of its appearance there.

Times of Day – On the west end they occur during the local afternoon. On the east end they occur in the local evening.

Seasons – Like other true TEP forms, the path seems to favor the equinoxes. The span, from the beginning to ending date, seems somewhat shorter than some other paths.

Single-Lane F2 – While much attention has been given to TEP propagation *across* the dip equator, there is another Equatorial Ionospheric Anomaly propagation mode that is simply east-west F2 occurring off only *one* of the two ionized lanes. The dip equator is not crossed and the farside lane is not involved at all in a given path.

What many don't realize is how high the MUF can be for this mode. The USU-GAIM model shows that the east-west MUF can be well over 66 MHz, *without* any special angles and M Factor values. It also need not be near an equinox. The models also show high local wintertime values. In this last regard, the Wake Island (KH9) beacon was into Hawai`i almost daily from October 2013 until late April 2014.

Of course, taking advantage of this form of propagation generally requires that the two end-point stations must be on within about 2000 km of the *same* ionization lane peak. If the path is north-south, then they have to be on opposite sides of the lane. If they are more or less aligned *along* the lane, then double hop also occurs. That places a lot of constraints on where one has to be and whom one will be able to talk to. Nevertheless, this mode happens quite frequently in certain parts of the world, where there are landmasses in the right positions for the require end-point station alignments. Figure 13 shows some actual examples from the western Pacific and the central Atlantic during March and most of April 2014.

Common Paths – From Hawai`i these paths go westward toward the northern hemisphere islands including Wake, Guam, Taiwan, the Philippines, Japan, and mainland China. As can be seen in the Figure, these kinds of paths show up in between the northern part of South America (and its maritimes), and northwestern Africa (and martimes) and southern Europe.

Times of Day – The midpoint time in that example was about 1800. While midpoint times seem to run from 1330-0000 for single hop and 1330-2000 for double hop, earlier times have been seen.

Seasons – Equinoxes generally are best, if not for the positive impact of Fountain ionization, then at least because more people are on the air. Those associated with the northern spring seems to perform better, but the amount of data is small.

There is some evidence suggesting that this sort of propagation should be available in seasons no one is expecting it, *such as local winter*.

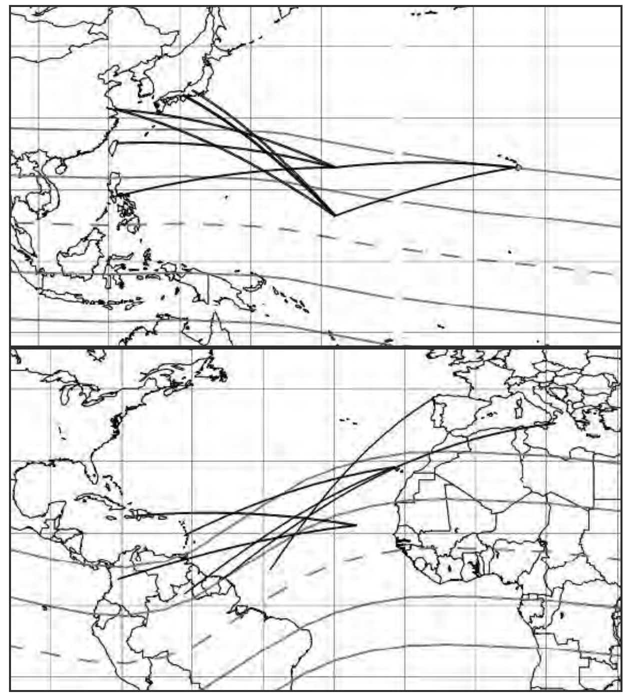

Figure 13: These are several examples of single- and double-hop F2 along, and across, the north lane during evening TEP hours. Note that the skip points all fall within the north lane. (*G.Projector map and overlays.*)

Non-Great Circle Paths – Nature is an equal-opportunity propagation provider. She is not restricted to using any one propagation mode to move a signal between point A and point B. It is perfectly possible to have one kind of propagation mechanism hand over a signal to some other kind of propagation mechanism, and the signal keeps on going.

In some cases, this results in paths that do *not* appear to follow a *single* Great Circle path from end to end. Rather, each of the different modes follows a Great Circle, but not necessarily the *same one* as the other, due to the different character of the two (or more) modes involved in the end-to-end path.

Skewed Paths – Of course, there is nothing new about skewed paths, but it is interesting to look at how they might come about. However, understanding the possibilities is often hampered if one takes the simplified two-dimensional skip pictures too seriously, because, the ionosphere is a three dimensional world. So, not every reflection, refraction, skip, or hop occurs in the *vertical* plane. Things can be bent or bounced sideways, as well.

The Equatorial Ionospheric Anomaly is, by its very nature, a three-dimensional structure. This creates all sorts of ways interesting things can occur. Whether the lanes are looked at from the side (north-south) or down along their long dimension (east-west), they provide a family of high-electron-density surfaces that skip signals at many different angles – not just straight ahead, but to the side as well.

It is also interesting to see how even a *small* deflection of the signal direction can make a profound difference in the signal path that then follows. When this happens, hybrid paths, can be generated that, in the whole, are not Great Circle paths, even though the segments that make it up may well be. Figure 14 shows two examples of this effect.

The first is a variation of a path that, although completely a surprise when it first showed up decades ago (SA-JA), has continued to create excitement under good conditions. This recent example occurred on February 22, 2014 at 0052 UTC with an opening between several LU/CE and BA/BV stations. They are represented here as a single CE-BA path for clarity. The dashed line that runs down toward the South Pole shows the equivalent Great Circle path. However, these were not the directions that the antennas were aimed.

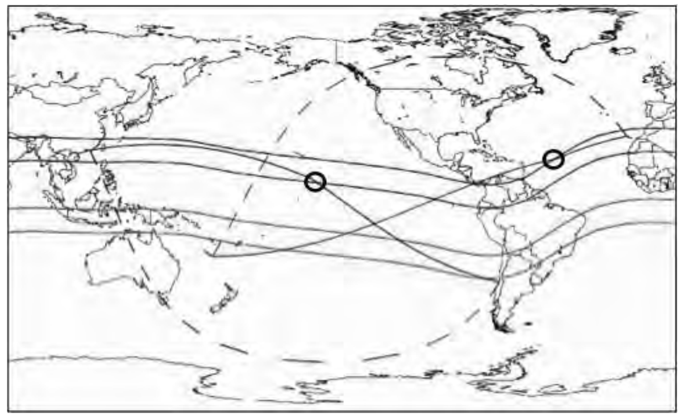

Figure 14: Both skew paths start as south-lane TEP and then are redirected upon entering a later lane (circles). The path from CE then does a 2F2 hop in the north lane to BA. The FK8 path crosses the north lane and runs into it again, and is redirected to EA8. (*G.Projector map and overlays.*)

The first path segment from SA westward took almost exactly the same frequent eTEP path from SA to KH6 seen in Figure 12. As in that path, it occurred during the local SA evening. The path from the nearside lane to BA very closely follows a known single-lane double-hop F2 path from KH6 to BA/BV. The circle on the plot shows the approximate point that the new path appeared to deviate from the other. The deflection angle is to the left about 14°. The deflection was away from the centerline between the two lanes, suggesting that refraction might have played a role.

The other example is the contact between FK8 and EA8 on November 10, 2013 at 0055 UTC. Again, the plot shows a reasonable estimate of the path actually followed, and also the normal great circle route, this time up toward the North Polar regions. As before, the key information was the station beam headings. FK8 was beaming east and did actually swing the beam looking for the best signal direction.

One interesting thing here is that the local time in FK8 was about 1300, which is consistent with the first segment starting as an aTEP link, looking toward later times to the east. Plotting a Great Circle for this segment suggested that the path appeared to first make a TEP hop to the northern side of both lanes.

Due to the abrupt northward swing of the dip equator over the SA, a little farther downstream it then encountered the north side lane a second time, this time *in* from the north. From there, it seems likely to have deflected to the left (as was the case in the CE-BA path above). The deviation point in that path's circle is about 13°, and as in the previous example, to the left, away from the lane centerline. After the deflection, the path is consistent with a single-lane one-half-hop F2 path down to EA8.

Common Paths – These are the only two paths for which data are currently available.

Times of Day – Both involved very oblique eTEP hops in the night near longitude 75°W.

Seasons – One occurred in late northern fall and the other in the early northern spring seasons.

TransPolar Long-path (TPL) – Late in the evening on 9 October 1988, on the rapidly rising leading edge of Cycle 22, a six-meter station in Greece (SV1DH using the special 6-m call, SZ2DH) worked JG2BRI in Japan. What was especially amazing was that it was nearly midnight in Greece and SV1DH was beaming southwest, *away from Japan*, toward the southeastern reaches of South America! The Japanese station was beaming *southeast*, at the other side of the south end of South America.

The two stations completed a nearly 31,000 km long-path contact from north of the magnetic equator southwestward encroaching on the Antarctic near the South Pole, and then back north across the magnetic equator again and landing in Japan. The actual signal traveled about three-quarters of the way around the world! (Fimerelis, 2003; Joly, 1990)

There were many TPL openings from KH6 to the Mediterranean and southern Europe near the Cycle 23 solar cycle maximum, and a few more occurred in Cycle 24 in early 2014. KH6 was on the east end of the link (at night) and Europe was on the west end (in their morning).

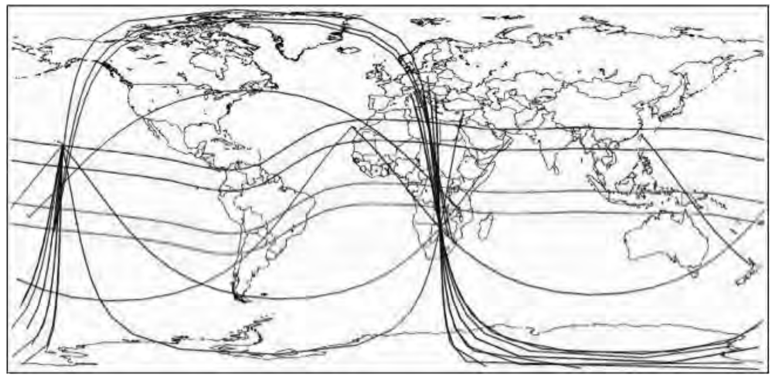

Figure 15: Various transpolar long paths are shown between KH6 and the Med and A45; KH8 and 5H3; E51 and ZS; and BV and EA8. (*G.Projector map and overlays.*)

In KH6, the openings occurred in the late evening usually after 2200 *station* LST, when TEP was already in evidence over the usual paths (such as VK4), though the TEP was generally sporadic and not particularly intense or widespread. Quite strong backscatter was often heard from headings of about 195°, suggesting lots of ionization and tilted layers. Often the signals were very weak, though a great many SSB contacts were made. On a few occasions, the signals were very loud, allowing contacts with modest power and small antennas.

KH6 also saw the other side of the TPL path, as well, in Cycle 23 and again in early 2014. In these openings, the KH6 stations were on the west end of the path between 0830 and 1100 *station* LST, beaming around 140° and the path went into A45 and thereabouts in their late evening. Other recent examples include openings between EA8 and BV, and between E51 and ZS (see Figure 15). While there are many other example paths for this mode, but there are also some geographical limitations, too. A great many mathematically possible paths end up with one end or the other being in an ocean.

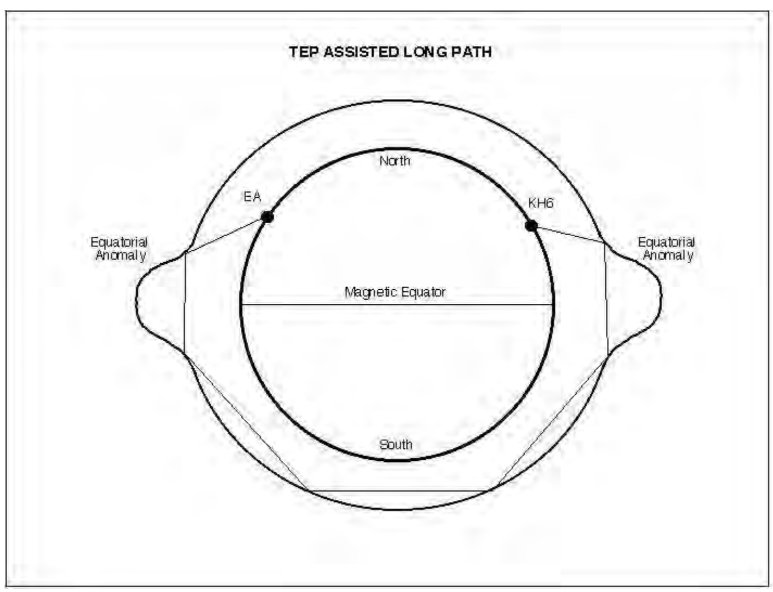

Figure 16: TEP may provide launching points for high-M shallow attack angle grazing hops that cover long distances, with higher than normal MUF's and low absorption.

Whether going around westward or eastward, there was no evidence of the signals coming back to Earth in between the two ends of the path. (Of course, these paths cover a lot of water and sparsely inhabited land.)

Nevertheless, it gives the impression that the signals started off as "ordinary" TEP. But, when the signal skipped off the *farside* lane, instead of coming back to Earth (say, in VK), some of the signal energy continued at a much shallower angle off the curved surface. This "launched" the signal into a series of high-M skips off the F2, over and over – like a whispering gallery – until the signals hit the anomaly lanes on the far end of the path over northern Africa. At that point, the farside lanes reversed the "launching" process and brought the signal back to Earth (Figure 16).

Midmorning TEP Curiosity

One interesting observation is that the east ends of the circuits, in both the eastern and western hemispheres, seem to systematically be in their *evening* TEP period. This necessarily means that the western ends of the paths are in *midmorning*. Normally, this would be *too early* for aTEP and *too late* for eTEP. Nevertheless, hundreds of contacts were made in Cycles 23 and 24.

The mechanism for this effect might be associated with various observations that indicate that the ionization bubbles, such as associated with eTEP, sometimes have very long lifetimes (Pautet, et al. 2009; Huang, et al. 2012). Referred to as *fossilized* bubbles, they may play a role in facilitating this unusual TEP connection.

Common Paths – The paths from Hawai`i to the Mediterranean, southern Europe, and the Near East is well known. There have been credible reports between South America and Australia, Polynesia and India, China and the Canaries, and a number of others.

The paths here are generally constrained by the placement of the landmasses within the Earth's oceans. Besides the fact that the stations have to be within access of the TEP ionospheric system, the paths are very long. So, from a given point at one end of the circuit, there are only a limited number of viable places at the other end of the proposed circuit. Nevertheless, some DXpeditions to carefully-chosen islands can produce designed-in opportunities.

Times of Day – Looking west, 2130-0130 *station* LST. Looking east, 0830-1100 *station* LST.

Seasons – This propagation seems to be confined to high solar activity and the equinox periods. There are indications that the April time frame is better than the October time frame.

Linking to TEP from Afar – It's reasonable to ask just how far from the TEP lanes can one be and still connect to the various TEP-like modes. The obvious requirement is that the station must be close enough to be able to illuminate the nearside TEP ionization lanes with its signal. This, in turn, is a function of the height of the lanes themselves. For peak regions at 300 and 450 km, these distances are about 2000 and 2500 km respectively. Figure 17 shows the TEP lanes and outer boundary dashed lines. In principle, stations *within* these outer boundary lines should be able to connect directly to the TEP nearside lane.

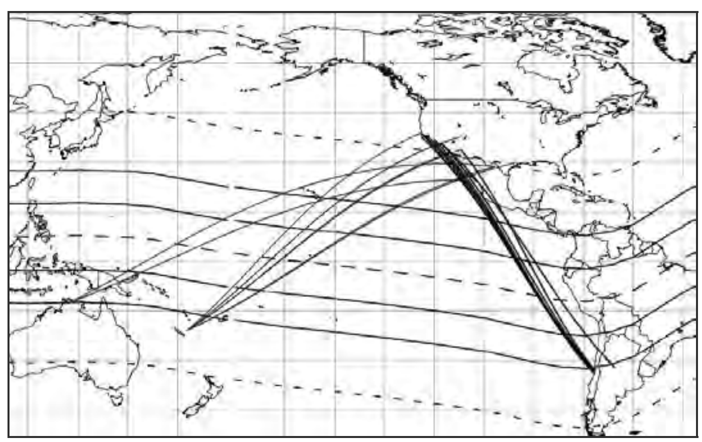

Figure 17: The outer dashed lines are the nominal limits for direct access to the TEP lanes pairs of solid lines). Access from beyond the "direct" boundaries will require some additional mechanism, such as Es, to reach inside an outer boundary and link to the TEP. (*G.Projector map and overlays.*)

However, it would also be possible to make a less direct connection from *beyond* the outer boundary using some *different* propagation mode to cross over the boundary from the outside. The most likely opportunity is having a sporadic E cloud in just the right place.

If the Es link brings the incoming signal down *inside* the outer boundary line, then it can *begin* a second hop. If things are properly lined up, then that second hop can become an F hop going up to the nearside TEP lane, and then complete a full TEP hop. Since single-hop Es can have a range of 1000-2000 km, this has the capacity to stretch the "TEP" range well beyond the direct connection limit. What's more, these paths really happen, as shown in Figure 17. It will be noted that a number of those paths actually link across the boundary line, some from quite a distance. In all likelihood, many of the paths starting inside the boundary line were also Es links.

Common Paths – In the Western Hemisphere, the most common paths are between the US and both the Pacific and South America.

Times of Day – While there are exceptions, this is dominantly an evening affair, suggesting that the TEP component is eTEP.

Seasons – In the Northern Hemisphere the Es links to the TEP system are usually seen in mid to late April, at the time when the ending of the TEP season and the beginning of the Es season overlap for a while. In the Southern hemisphere this would be in early to middle October.

Summary – The Equatorial Ionospheric Anomaly defines the behavior of radio propagation that originates, terminates, or passes through the vicinity of the Earth's geomagnetic dip equator. The daytime core of the EIA is the Equatorial Electrojet, a powerful electron current flowing in the E layer between 100 and 110 km, straddling the dip equator centerline between ±3° of latitude.

During the day, the electrojet and the Earth's magnetic field produce an "electron pump" which drives E and F1 layer electrons upward in a fountain carrying them high into the F2 layer. The fountain overflow settles into two crests or pools, one centered on about 17° north and the other about 17° south of the dip equator, still in the F layer at 300 to 450 km. The ionization peaks in those two pools follow the Sun daily, but lagging behind the Sun by a few hours.

From local afternoon until sunset, these ionization pools facilitate radio propagation called afternoon TEP, or aTEP. Afternoon TEP skips signals from the ionization pool on one side of the dip equator, to the pool on the other side, allowing signals to cross over the dip equator with paths out to 7500 km.

When the Sun sets, the electrojet loses its energy source and the current ribbon abruptly stops, but a sudden last gasp sends an upward shock wave through the standing column of fountain electrons. This shock creates a series of large, flat "bubbles" of alternating layers of very-highly, and then very-weakly, ionized plasma. These bubbles are buoyant and they rise upward to great heights in the F2 layer, sometimes over 1500 km.

The bubble regions extend outward as much as 20° north and south of the dip equator. They are open at their edges. The weakly ionized layers act as ducts that can guide radio waves from one side of the dip equator to the other, providing evening TEP or eTEP propagation out to a total path length of about 8800 km.

The majority of this propagation is along largely north-south paths, which limits the maximum path length. However, there are variations that provide propagation across the dip equator, but with a very large east-west component as well. This Oblique TEP can produce paths out to 13,000 km or more. It generally involves a west-end station in its afternoon TEP regime and an east-end station in its evening regime.

The afternoon electron pools and nighttime plasma bubbles also support *single-lane* F2 skip from just *one* pool (either north or south), such as single-hop north-south paths *across* the lane. If the two stations *and* the lane are all aligned with each other east and west, then east-west single- or even double-hop F2 can occur.

In addition, there are forms of propagation that involve a mixture of two or more of these modes in different segments of the same path. One example is very long, skewed paths, which do not follow a single Great Circle path. Another variation is Transpolar Longpath or TPL, which generally are not skewed, but involve TEP twice in the path, with something else different in between. Still another variation occurs when a station, far from the dip equator, uses an Es hop to link into range for a following TEP hop.

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BUILDING
A
VHF/UHF STATION

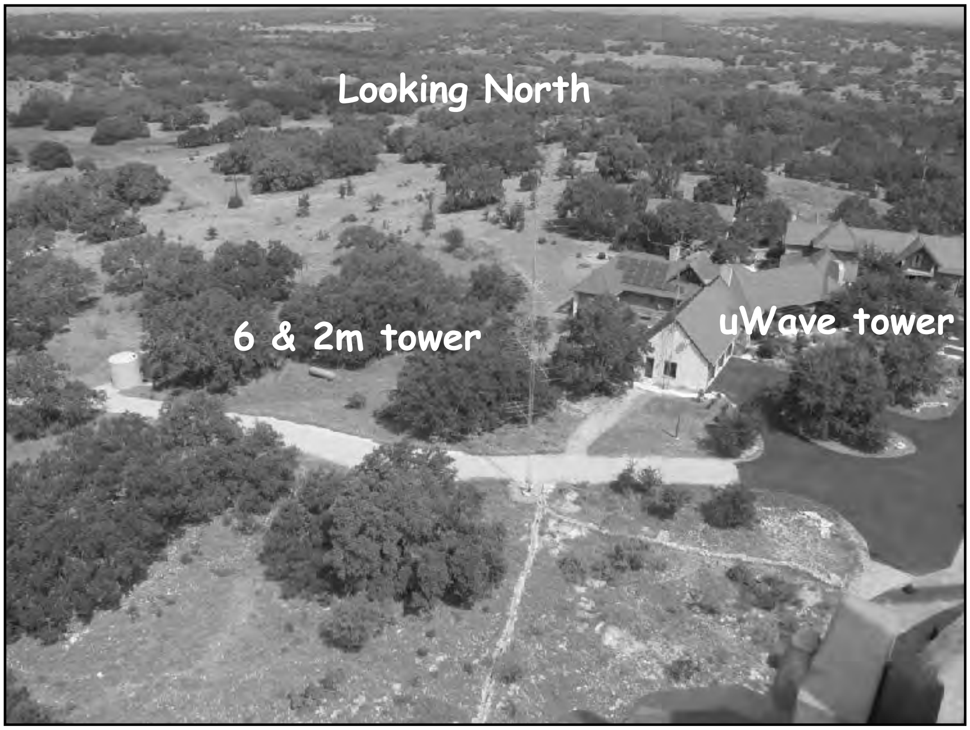
K5AND

When we lived in Atlanta from 1980-2006, my antennas were never higher than the surrounding trees! Being at lake level on Lanier was great for watersports, but terrible for radio!

Tower base Base in EM73 (Cumming) was 20' above lake at full pool. Top of 100' tower was still 10' below big hardwood/pines ☹

Moving to Austin, TX, in EM00 changed everything. Hilltop (1240') with 360 degree view.

Our last QTH before the 'home' beckons……



20 & 10m stacks

(added 12m 3 el)

40m & 15m stack

(added 17m 3 el with
2el 30m coming)

80 & 160m vertical with elevated radials

8-circle array for receive only

The Station

ELECRAFT K3 (RX/TX IF)

TRANSVERTERS:
ELECRAFT 2m, 1.25m & 70cm

DEMI 33, 23 & 13cm; with
ApolLo synthesizer and external
10MHz Rubidium standard

MY STATION LAYOUT IS SUCH THAT THE 50-432 GEAR IS IN MY 'SHACK'. THE 902-2304 GEAR IS REMOTED IN MY ATTIC, 20' FROM ANTENNAS. SO…. MUST CONTROL ALL THE ATTIC GEAR FROM THE SHACK: TURN GEAR (POWER SUPPLIES ETC) IN ATTIC OFF/ON, SWITCH PTT LINES (NOT SO EASY WITH K3), AND SWITCH ANTENNA RELAYS.

WHAT WAS NEEDED WAS A K3 "INTERFACE" WITH REMOTE (ATTIC) SWITCH TO ACCOMPLISH THESE TASKS. TOM APEL, K5TRA, DESIGNED TWO BOXES TO DO THIS.

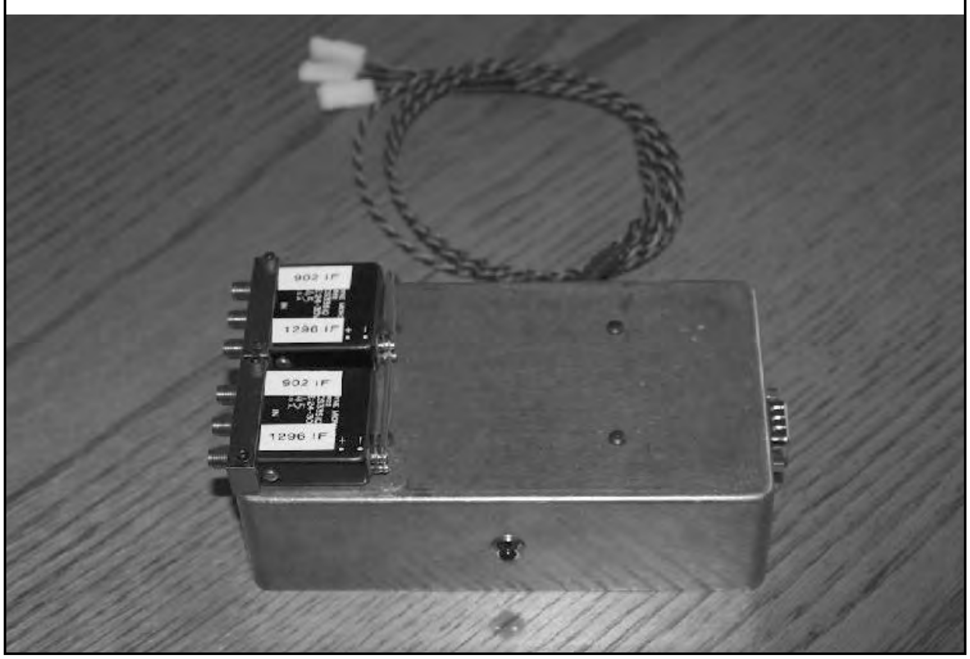
1) PROVIDE PROPER IF FREQUENCY TO THE TRANSVERTERS (28 OR 144 MHZ)
2) SWITCH PTT LINE TO THE SELECTED BAND
3) PROVIDE FOR PTT FUNCTION FOR AMPS
4) PROVIDE FOR ANTENNA RELAY SWITCHING ON 33-13cm AMPS

CHANGING BANDS FROM HF THRU UHF WOULD NOW BE A SINGLE BUTTON-PUSH ON THE K3


magic box


K3 DIGITAL INTERFACE
(it *is* magic)
K5AND
PWR 144 222 432 902 1296 2304

DEMI INTERFACE in ATTIC



AMP WALL

144 222 432

HF Remote 50

AMPLIFIERS

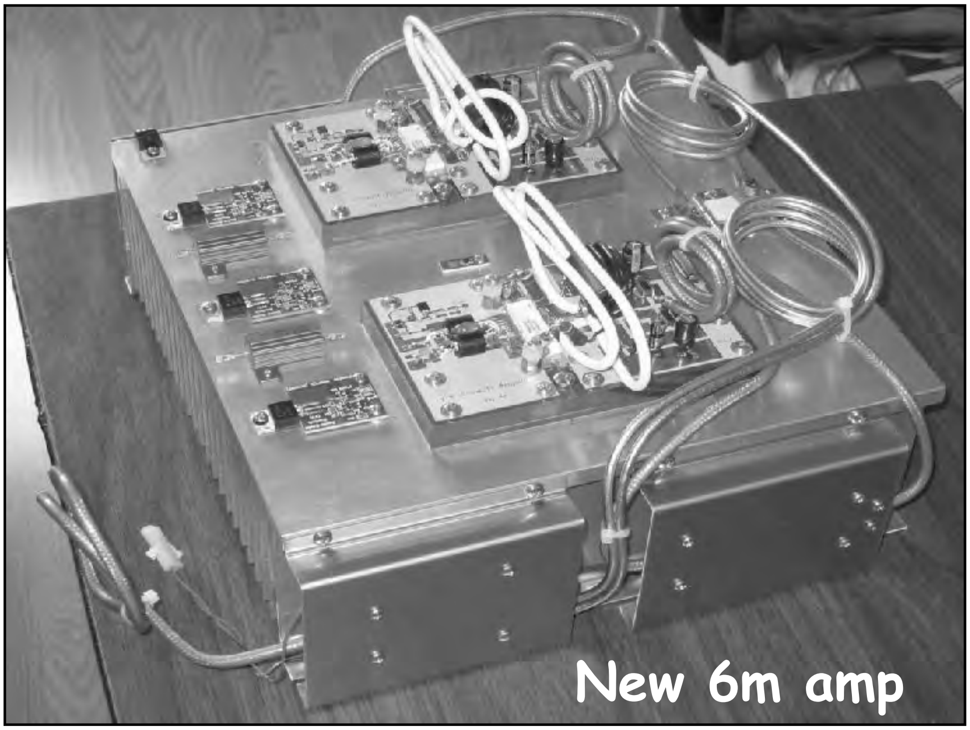
ALPHA 8406 6m….1.5KW **

KLITZING 2m/1.25m/70cm….1KW

PAIR MOTOROLA 33cm….400W

KLITZING 23cm….250W

SPECTRIAN 13cm….150W

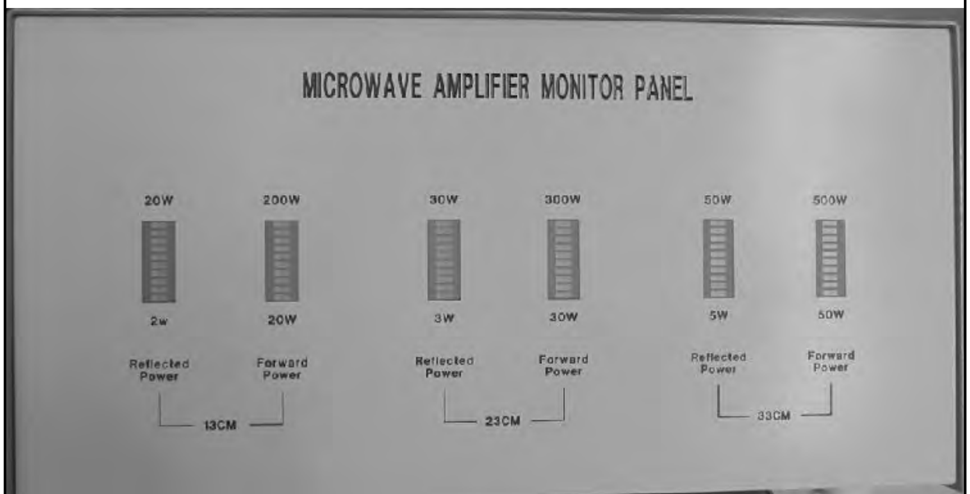


OOPS!!

EASY ENUFF TO 'WATCH' THE 6M THRU 70CM AMPS; BUT WHAT ABOUT THE 13-23CM AMPS UP IN THE ATTIC??

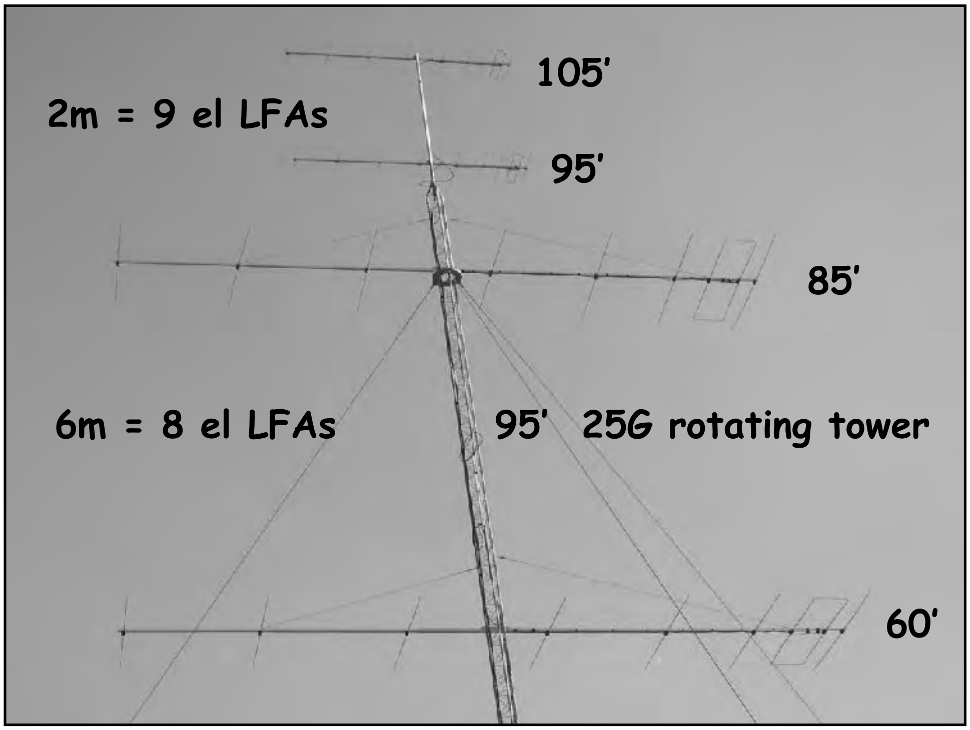
WOULD NEED SOME SORT OF REMOTE READOUT CAPABILITY

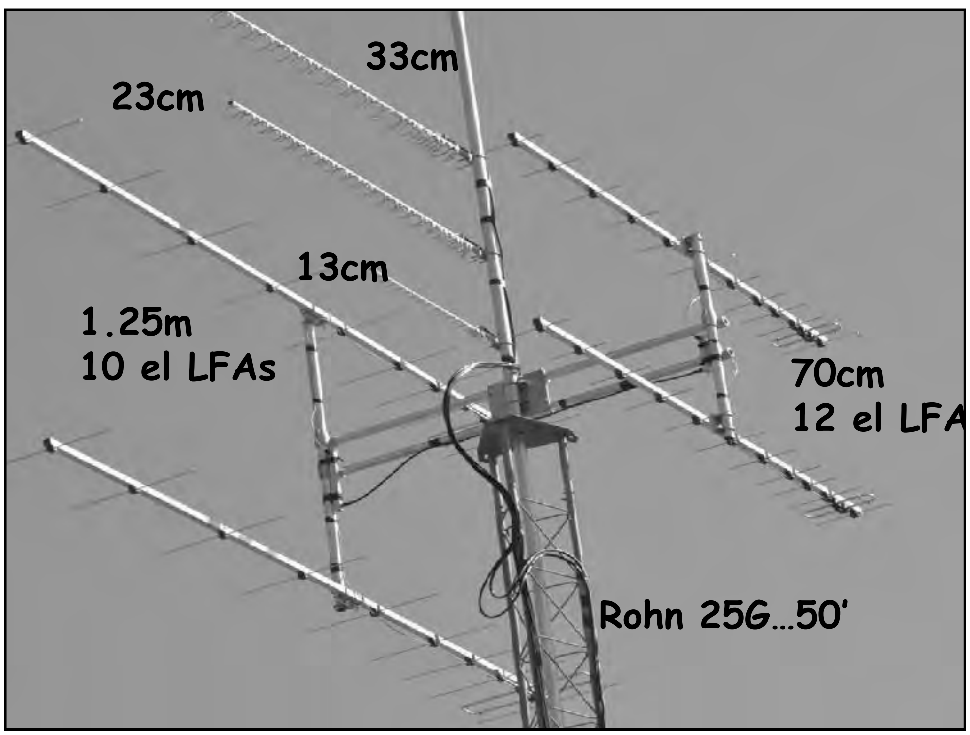
KLITZING MONITOR PANEL



6 & 2m ANTENNA SWITCHING:
via K3 INTERFACE

ANTENNA CHOICES:
6m YAGIS
2m YAGIS
2m K5DDD LOOPS


105'
2m = 9 el LFAs
95'
85'
6m = 8 el LFAs
95' 25G rotating tower
60'

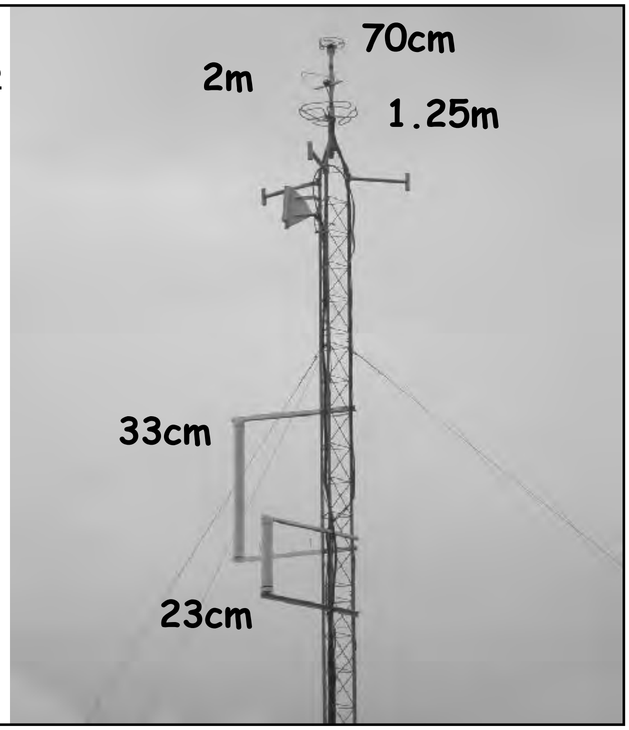

33cm
23cm
13cm
1.25m
10 el LFAs
70cm
12 el LFA
Rohn 25G…50'

K5RMG BEACONS

AT K5AND QTH

AVG ASL = 1300’

(400’ from my Station; remote power on/off via Internet)

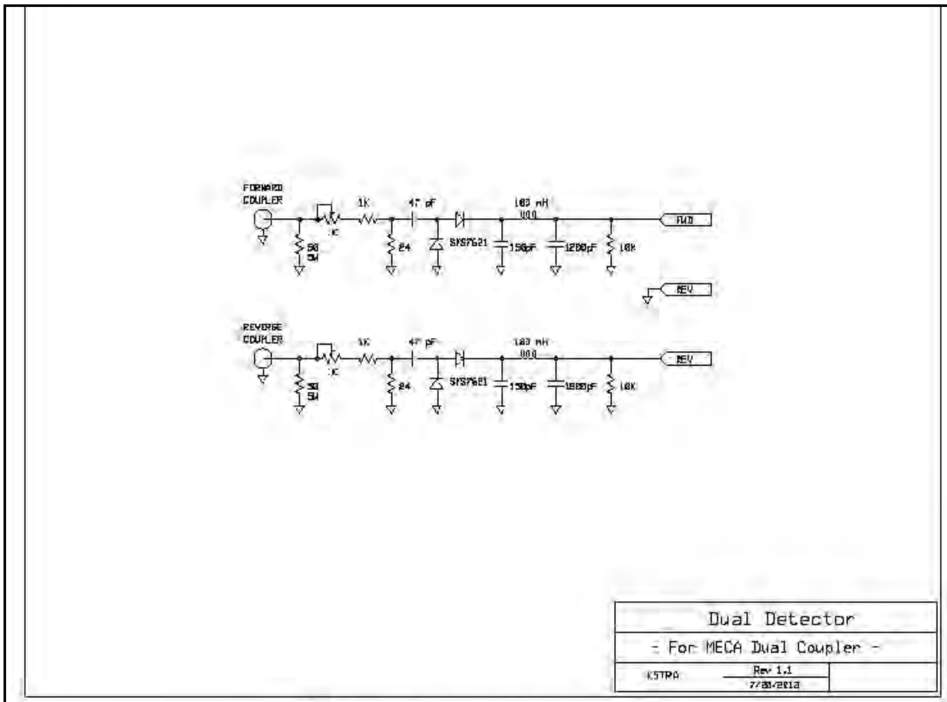


KLITZING 902 HYBRID COUPLERS

COUPLER REAR VIEW

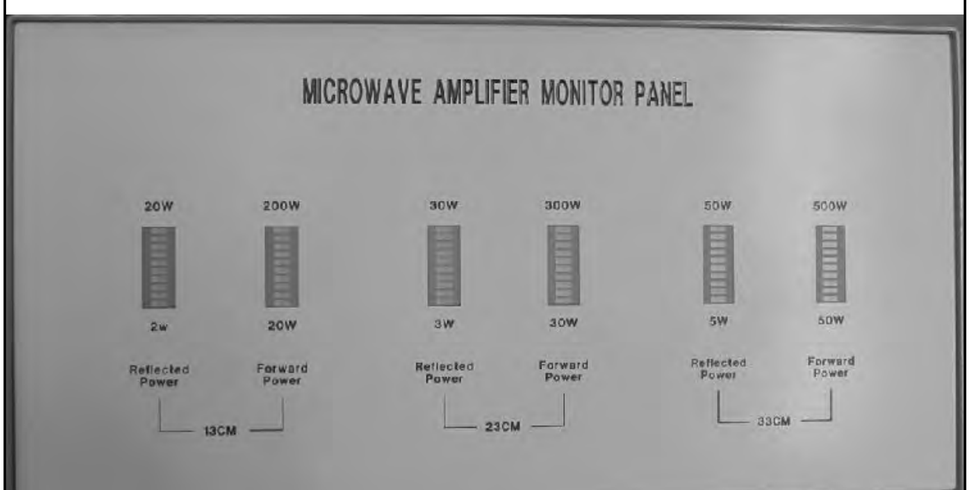
K5TRA DETECTORS FOR 902/2304

THESE DRIVE THE REMOTE MONITOR PANEL LED READOUTS

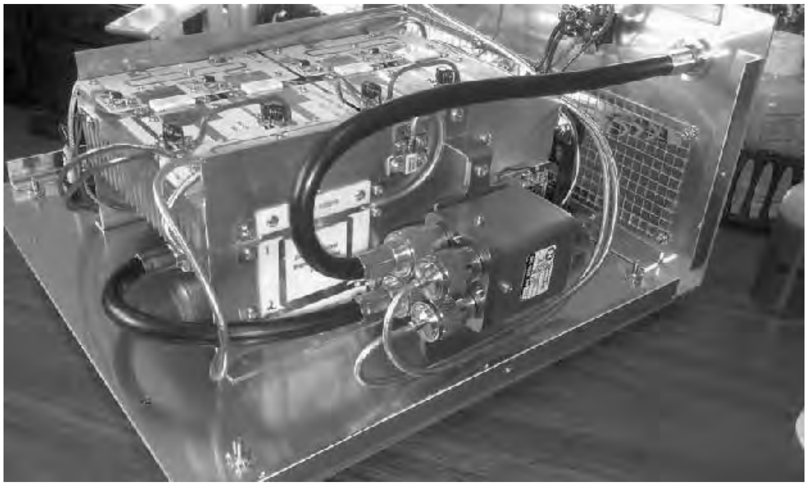


C:\files\ExpressPCB\dual detectors\dial detectors.sch - Sheet1

REMOTE MONITOR PANEL



INTERIOR OF 23 CM AMP

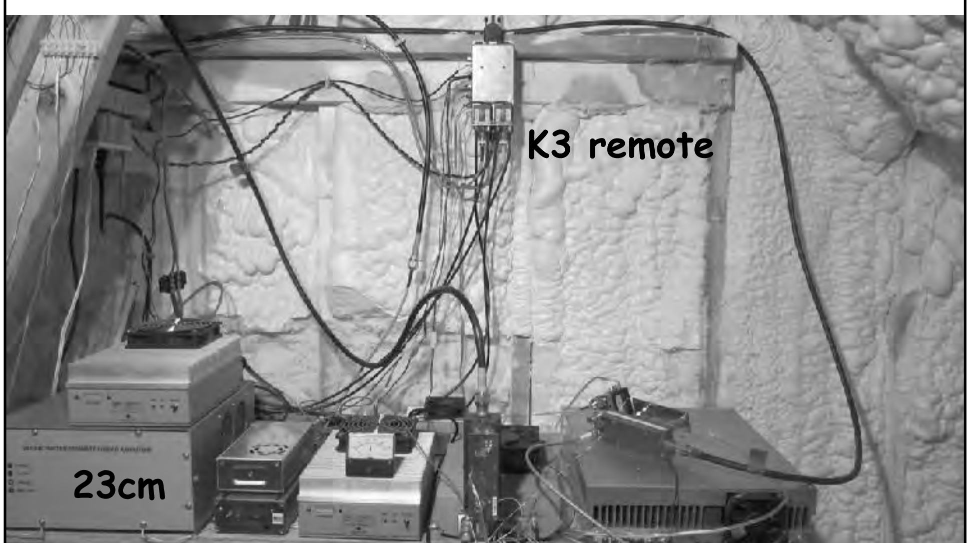


DEVICES ARE MRF-286

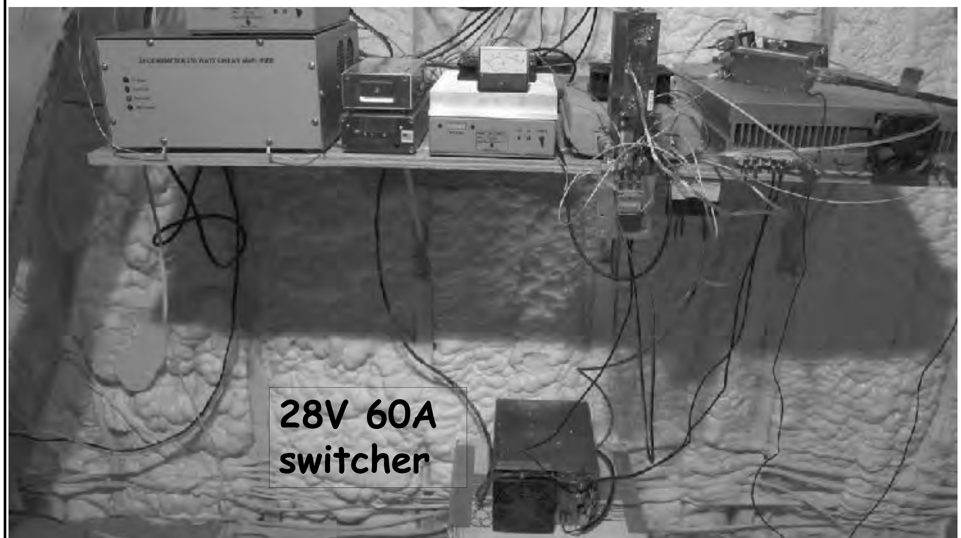
ANOTHER INTERIOR SHOT OF 23CM

902-2304 AMPS & 28VDC
60A POWER SUPPLY
LIVE IN CONDITIONED
ATTIC SPACE (80F max)

FEEDLINES FROM
AMPS TO ANTENNAS
ARE 20' LONG



13cm 33cm 13cm


28V 60A
switcher


10G……soon!
W8ZN
Directive Systems

LOTS OF 'ELMERING' FROM:

STEVE:	N5AC	STEVE:	K4RF
STEVE:	N2CEI	CHARLES:	K4CSO
TOM:	K5TRA	GEORGE:	K5TR
AL:	W5LUA	TERRY:	AB5K
LARRY:	K5OT	*KATHIE HANSON*	

THANKS SO MUCH!!

THAT'S

ALL

FOLKS!

Solid State Kilowatt Amplifiers

Jim Klitzing
WWW.W6PQL.COM

A tutorial on how to annoy your neighbors with modern LDMOS

First, a little background on myself…

From the time I received my first license in 1964, I was always interested in building amateur radio equipment. My first transmitter was a 6146B crystal oscillator, a nice chirpy little rig that burned up the crystal when I pushed it too hard.

My first "high-power" amplifier was an 813 taken from an old military surplus transmitter…it probably put out a whole 250 watts, but at the time I thought that was incredible. High voltage, oil-filled capacitors and swinging chokes reigned supreme.

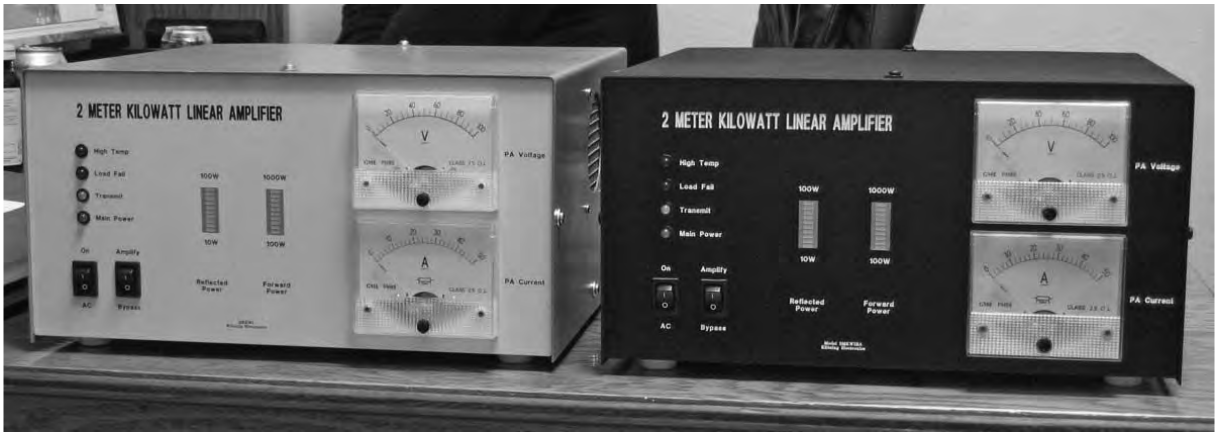
I retired from HP/Agilent 8 years ago and quickly tired of just playing golf and tennis…I'm only an average tennis player, and much worse at golf, so I decided to do something else to boost my morale. I had a small business venture in the late 70's building 12v "brick" linear amplifiers, enjoyed it until my first born came along, but had to wind it down as the family grew and other matters pressed. Besides, I realized I was only making about a dollar an hour at it.

But this time I decided to cater mainly to the home builder. As I built things for myself, I realized there were others wanting to make the same things; getting the right parts for the job can be difficult and expensive in small quantities, and reinventing the wheel is often not worth the time it takes, so it seemed there would be some value in providing these things to others.

What a difference 40 years makes…about 4 years ago, the first of the really big and affordable 50v LDMOS transistors appeared on the scene; these devices are capable of outputs exceeding a kilowatt, cost less than equivalent tubes, and are extremely rugged. That doesn't mean you can't kill them…we amateurs are good at that, but they'll take quite a bit of abuse before giving in.

To date, I've been able to build KW amplifiers for all the VHF and UHF bands (my primary interest) using these devices, and hope to share some of the particulars with you here; most of this material is targeted at 6 meters through 70 centimeters.

I've also experimented with HF amplifiers spanning 160 through 10 meters, and hope to have the various parts and assemblies for legal-limit versions available in the fall.



Shown above are a couple of KW amplifiers for 2 meters; they are identical except for color scheme. If you want it to match your other black radio equipment, and you have good eyes, you would probably want to use the darker scheme.

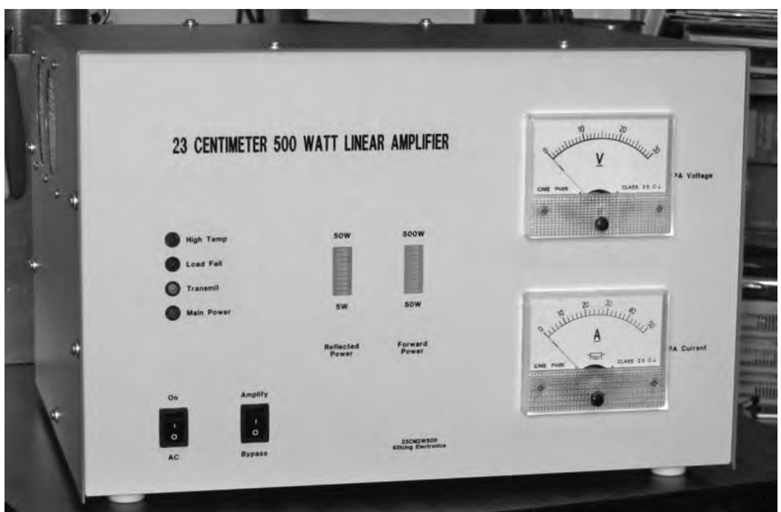
But I like the lighter colors myself…and I can actually read the text on the panels with my ancient eyes, and it does seem to brighten things up a bit…to each his own.

The whole point here is to show the flexibility a builder has; you can really get crazy with this…there are a whole range of gaudy finishes available as well as the traditional ones.

I used to make all of the cabinet pieces myself; I still make the wrap-around cover and the internal support brackets, but now I have the front panel, rear panel and floor plate made for me by FrontPanelExpress. These pieces have most of the time-consuming holes and cut-outs in them; a wide variety of power-coat, anodized or chromated finishes are available, as well as engraved lettering.

Front Panel Express has a web site where you can download their software for free. This software is used to create your panels, and is easy to learn. When you’re done designing your panel or other piece, you can order directly from them with a credit card (the software allows you to do this electronically), and it shows up on your doorstep about a week later.

Just showing a couple of other things here…above, a rack-mount version of that same 2m KW amp, and below a couple of 23cm amplifiers, a 500w and a 150w version, the latter having it's own internal power supply.



Above is a tray full of one of my favorite KW parts (NXP BLF188XR). There are several devices I've worked with worthy of your consideration:

- 1 KW LDMOS (HF to ~350MHz)
  - BLF188xr (NXP)
  - MRFE6VP61k25h (Freescale)
  - BLF578xr (NXP)

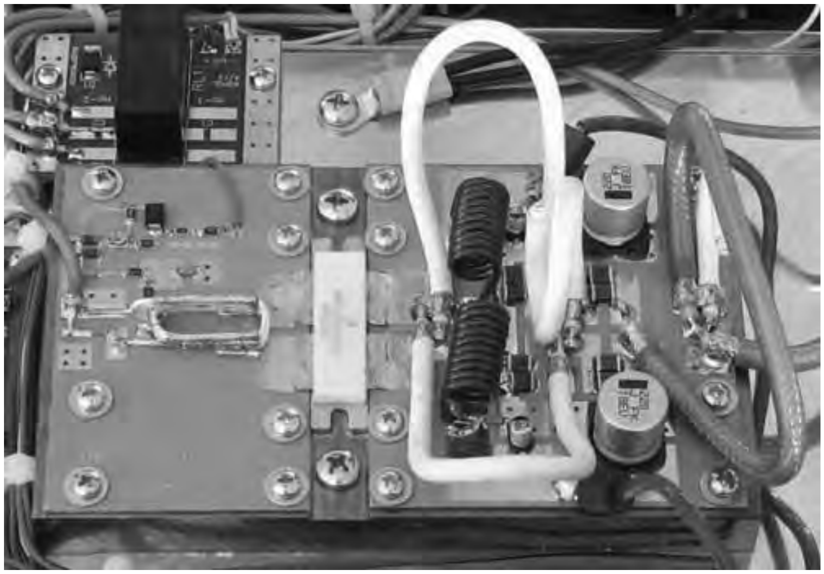
- 600w LDMOS (HF to 500MHz)
  - BLF184xr (NXP)
  - MRFE6VP5600h (Freescale)

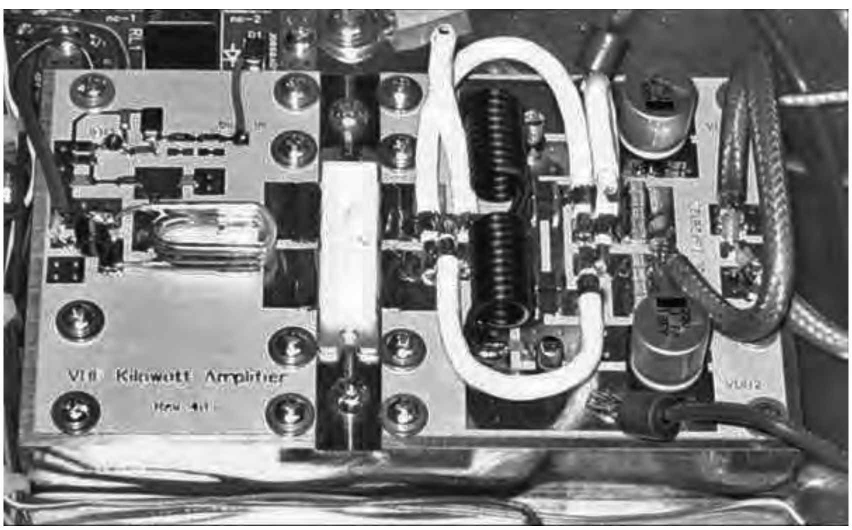
You probably noticed I limited the upper frequency range on those KW parts to about 350MHz…even though the manufacturers claim they work to about 500MHz, I haven't been able to get them to play very well up there. The best performer for me was the BLF188xr…at 432MHz it did about 750w, but was only 35% efficient. Turns out the impedances are so drastically low at UHF, you wind up dissipating most of the power in the matching components, which tend to go out in a blinding flash.

So at 70cm, I use a pair of the 600w parts to get to a KW+; there are two advantages to this; they are easier to match, and by using two devices you have double the footprint, allowing you to draw heat away from the devices much more quickly, which is an advantage at lower efficiencies. At VHF (50-222MHz), all of these devices are capable of efficiencies exceeding 70%; at UHF (70cm), even using the 600w parts, the best efficiencies are just North of 50%.

But I'm certain we haven't seen the last of these great devices.

Here's a look at a couple of KW RF decks, 2m and 222MHz, as installed in their respective amplifier systems. You probably noticed there is no real difference between the two of them, save for the length of the transmission lines and the matching capacitors. These two bands are close enough in frequency to allow such scaling.



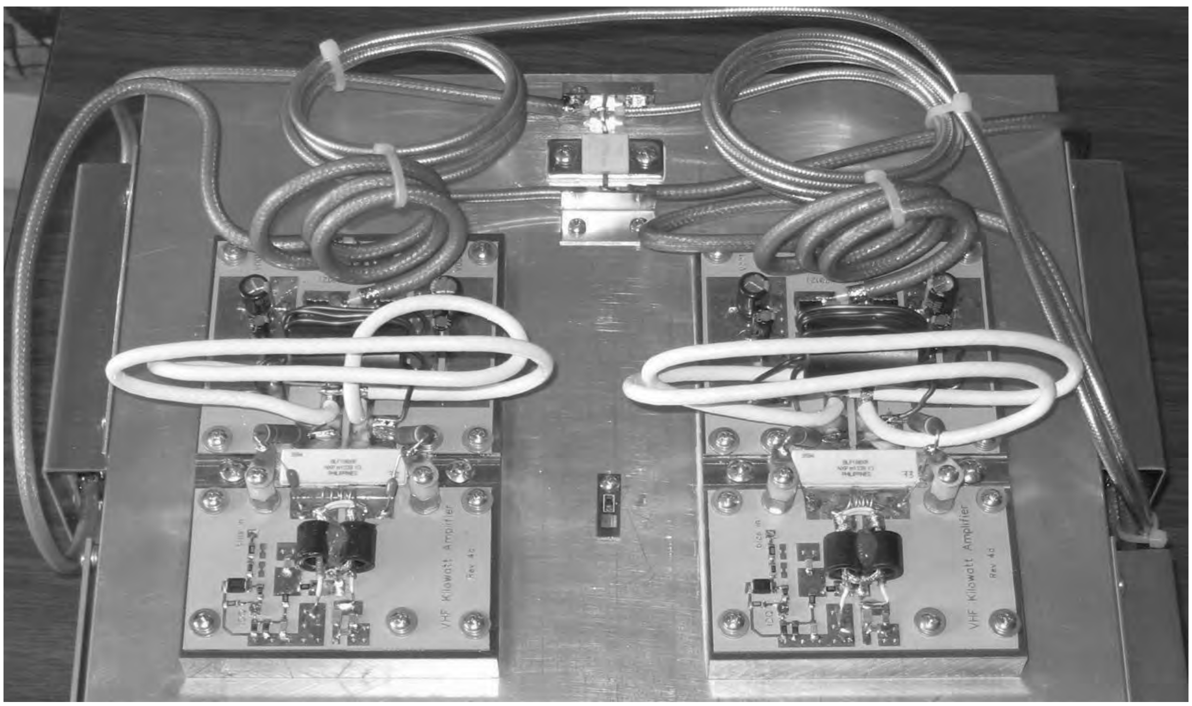


One other thing you probably noticed is that I'm not bolting the LDMOS devices down to the copper spreader…the devices used here do have mounting feet designed for that, and I could have done it, but I chose a different method I believe to be much better. The LDMOS is flow-soldered to the copper. There have been many discussions on email reflectors about the pros and cons, but reading the manufacturers application notes convinced me…if done properly, you get better heat transfer and also better RF grounding on the source connection doing it this way, and it does no harm to the device. Besides, if it were not a proper thing to do, one would have to wonder why manufacturers also supply these parts in the "solder-in-only" package.

Here’s a photo of a prototype legal-limit rf deck assembly for 6 meters, showing two of the 1kw rf decks and some of the supporting components (filters, combiners, etc).

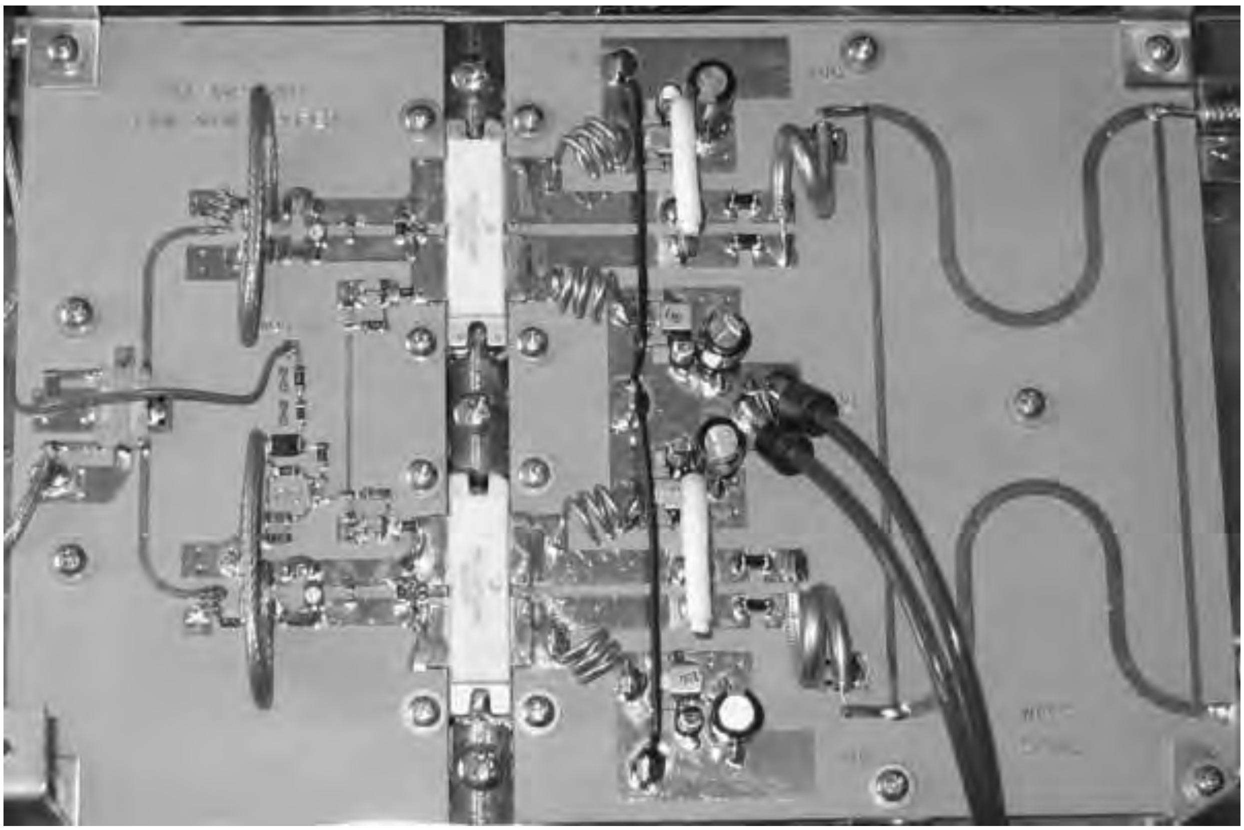
On 6 meters, we can still use the same PC board, but the basic design is somewhat different, and the length of the transmission lines is much longer. We also have to use a ferrite core on the input transformer to get that component to work properly at this lower frequency, and this creates a potential hazard for self-oscillation (more on this later).

The method used for combining RF decks is nothing new…at UHF and microwave frequencies, the preferred method is usually a branchline hybrid combiner, which lends itself well to inexpensive 50 ohm terminations for the isolation port. At VHF, this type of combiner is just too large physically to be practical; the Wilkinson combiners used here also have excellent isolation, ensuring that the failure of one side of the amplifier will not cause the destruction of the other side. It becomes necessary to use a 100 ohm 500w isolation resistor (top center), but these are available, even if they are a bit pricey.



This is a KW rf deck for 70cm, and is a good example of how big the branch-line hybrid output combiner can get…it takes up the half of the entire output board, and is the reason 70cm might be the lowest band where you'd want to use this type of combiner. The input hybrid, which only has to handle 10w, is much smaller…it's a commercial "Zinger" type made by Anaren.

As noted before, to get to a KW with acceptable efficiency on this band requires combining the outputs from two 600w devices.

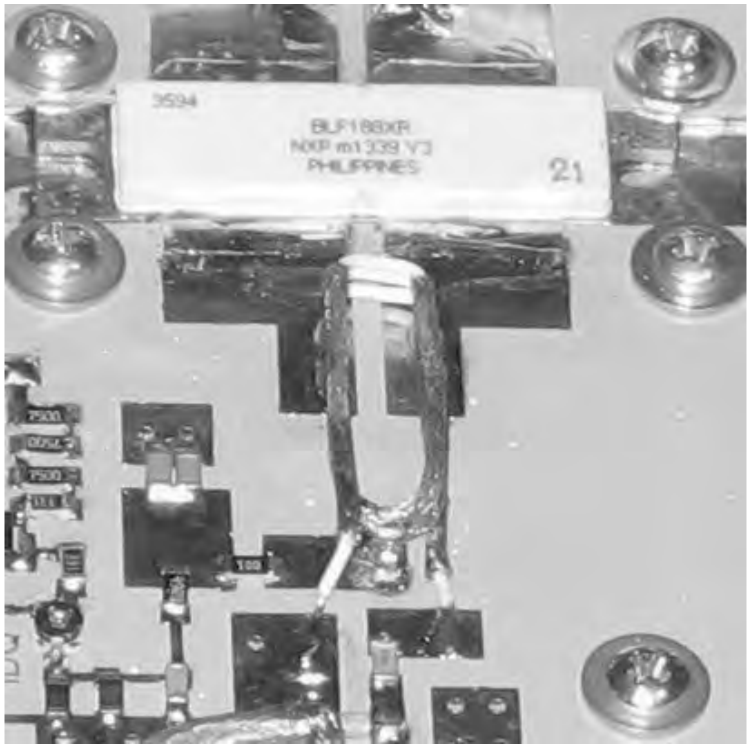


This might be a good time to mention stability; these devices have incredible gain at lower frequencies…30db is not uncommon at 6m, and even at 70cm the gain is still a bit over 20db. Below VHF, it's even higher than 30db, and this can cause us lots of trouble. It's a great segway into the next subject…how to ensure unconditional stability.

If the device self-oscillates, it can develop so much power it will usually destroy bypass capacitors and vaporize board traces; when it's done with that, it often goes out with a blinding plasma arc that blows the top off of the device, causing innocent bystanders to duck and weave.

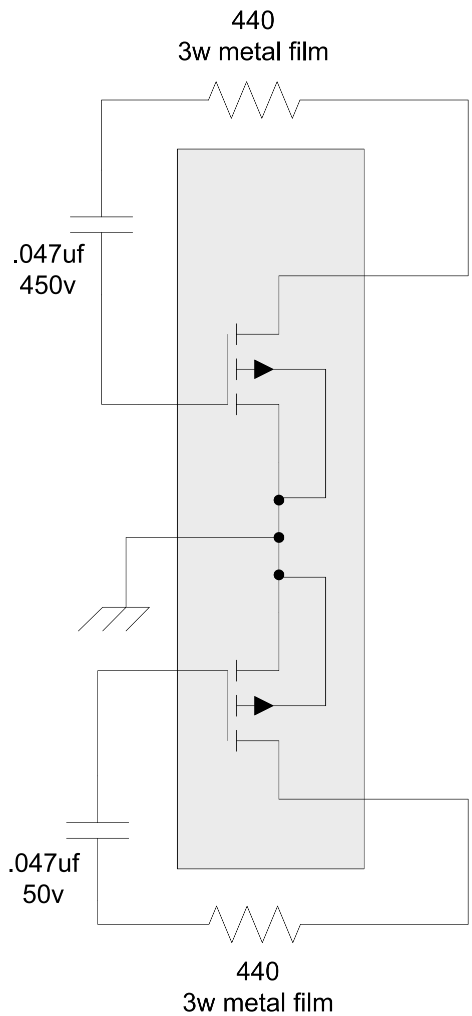
But there is hope…

We must kill all of that extra low frequency gain. The design I'm using for 2m and 222 has an ally in that battle, the input transformer. It's nature at lower frequencies is to short the gates together; I've never seen an instability on either of these bands using that input transformer.



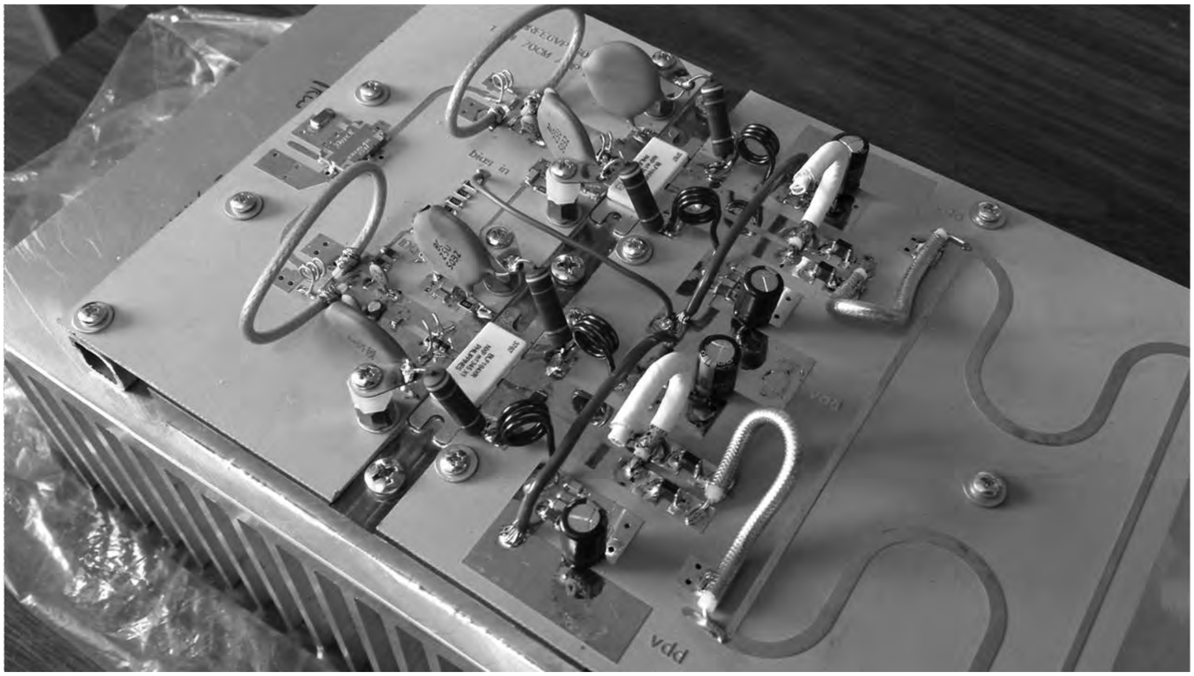
However, once you “improve” that transformer with a ferrite core, as we did on 6 meters, we once again have excessive low frequency gain all the way down to 1 MHz and below. This is also the case at 70cm, where the input circuit is different, and we have nothing shorting the gates together at lower frequencies. I used to use a small inductor to kill the LF gain on this band, but now I also use the method below.

The cure is to use degenerative feedback, and the most common method is to use a resistor and capacitor in series from drain-to-gate.



The resistor determines the amount of degenerative feedback, and should be a low enough value to slightly lower the gain of the device at your operating frequency. The capacitor is just there to block DC, but it must be of sufficient value to allow passage of those lower frequencies where the gain is excessive. The values shown here work well at 6 meters; the resistors could be even lower for 70cm, but 440 ohms is also OK there. I’ve seen values as low as 100 ohms, but this is more than we need, and requires the use of expensive high power non-inductive resistors.

Degenerative feedback components installed on a 70cm KW board



Other Design Considerations

- The use of a good quality PC board material is best; I see FR4 used at 2 meters by well-known manufacturers, and even though it works, it's right at the upper limit of power-handling capability at 1kw.

  The reference designs provided by Freescale and NXP usually employ more robust material, such as Arlon TC350, Taconic RF35 or Rogers 4350. These materials are less lossy and more stable. Granted, they are more expensive, and unless you are able to make your own PC boards, you cannot economically make just one or two to try out a design.

  I'm able to do my own prototyping for these more exotic materials (make my own boards), and when the design is verified, have them made 100 at a time at one of the PC board houses. These are also available on my web shopping page for those without this capability, should you want to use one of these boards.

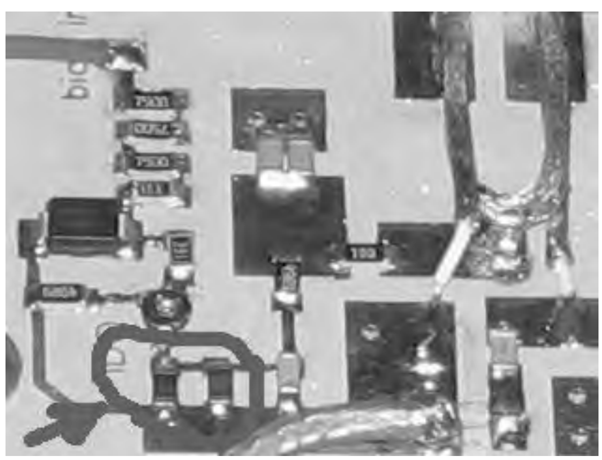
- The matching components, usually capacitors, must handle very high RF currents and voltages. Metal mica types, and even the newer CDE MC type RF capacitors rated to 500v or better, are suitable for testing as matching components…but not for long-term use. Too many of them eventually fail.

At 50, 222 and 432 MHz, I've gone to capacitors made from the same 12 ohm coax used in the matching transformers (TC12). This coax has a large amount of capacitance for a given length, and as long as you keep that length under 1/8wl, the effect of an open-ended piece is capacitive, and is absolutely indestructible at the KW level. The longest piece I've needed to use (at 144) was well under that length.

ATC capacitors, ceramic capacitors, etc. are fine for general bypassing. For high current DC blocking, or high RF current bypassing, metal micas or MC type micas are recommended. I even double those up to be safe.

- Thermal drift can be a problem, particularly using JT65 or other high duty-cycle modes that tend to get things hot. Without thermal bias compensation, the idling current (IDQ) will drift up from a nominal 2 amps to over 5 amps, and has the potential to go even higher. At 5 amps, the device is idling at 250w, generating more heat than necessary.

The two most common methods of controlling this involve lowering the bias voltage as the device heats up. I use the simpler of the two (life is complicated enough), which uses a thermistor to lower the bias voltage as things warm up. I mount the thermistor on the board near the LDMOS, and as it warms, it's resistance decreases, dragging the bias voltage lower. Tracking is pretty good, rivaling the other method (active bias compensation using a transistor amplifier); you just have to use the right value thermistor. It turns out the right value is not one that is commonly made, so I just put two different values in parallel to arrive close to that optimum value.



These are sources for reference designs:

- Freescale and NXP Web sites
- Dubus managine
- QST and QEX magazines
- F1JRD
- www.w6pql.com – full project information and technical articles

These next few pages list sources for many of the hard-to-get parts you will need:

1. LDMOS devices
    - Newark Electronics (Freescale)
    - RFMW Limited http://www.rfmw.com/ (NXP)
    - Digikey www.digikey.com
    - Mouser www.mouser.com
    - Richardson RFPD www.richardsonrfpd.com (Freescale)
    - www.w6pql.com

High power RF capacitors

- Metal Micas
    - Mouser
    - Digikey
    - Communication Concepts www.communication-concepts.com/
- SMT micas (CDE MC series)
    - Mouser
- Coaxial matching capacitors
    - Self-made

- Inductors and transformers
  - Communication Concepts
  - Mouser
  - Self-wound RF chokes and transformers

- Coax (special stuff, 10, 12, and 25 ohm)
  - Communication Concepts
  - RF Elettronica www.rfmicrowave.it
  - EBay (50 Ohm RG401,RG402, RG316, RG142)

- Terminations
  - Richardson RFPD
  - RFMW Limited (Florida RF labs terminations)
  - EBay

- High power RF resistors and attenuators
  - Richardson RFPD (ATC attenuators)
  - Newark (Johanson attenuators)
  - Mouser (high power resistors for attenuators)

- Relays and transfer switches
  - RFPARTS (www.rfparts.com) - Tohtsu, Dow Key
  - Surplus Sales of Nebraska - Tohtsu, Dow Key
  - EBay
  - WWW.W6PQL.COM (input relay board)

PC boards

- Communications Concepts
- RFHAM
- WWW.W6PQL.COM

Copper spreaders

- RFHAM
- WWW.W6PQL.COM – fully machined, fly cut for flatness on the surface that mates with the heat sink, with all mounting holes drilled/tapped

Aluminum heat sinks

- www.heatsinkusa.com – these will come in fairly raw form, often warped like a saddle. For proper heat tansfer from the copper spreader, they must be fly-cut for flatness
- WWW.W6PQL.COM (fully machined to accept spreaders), and drilled/tapped for them

Cabinets and panels

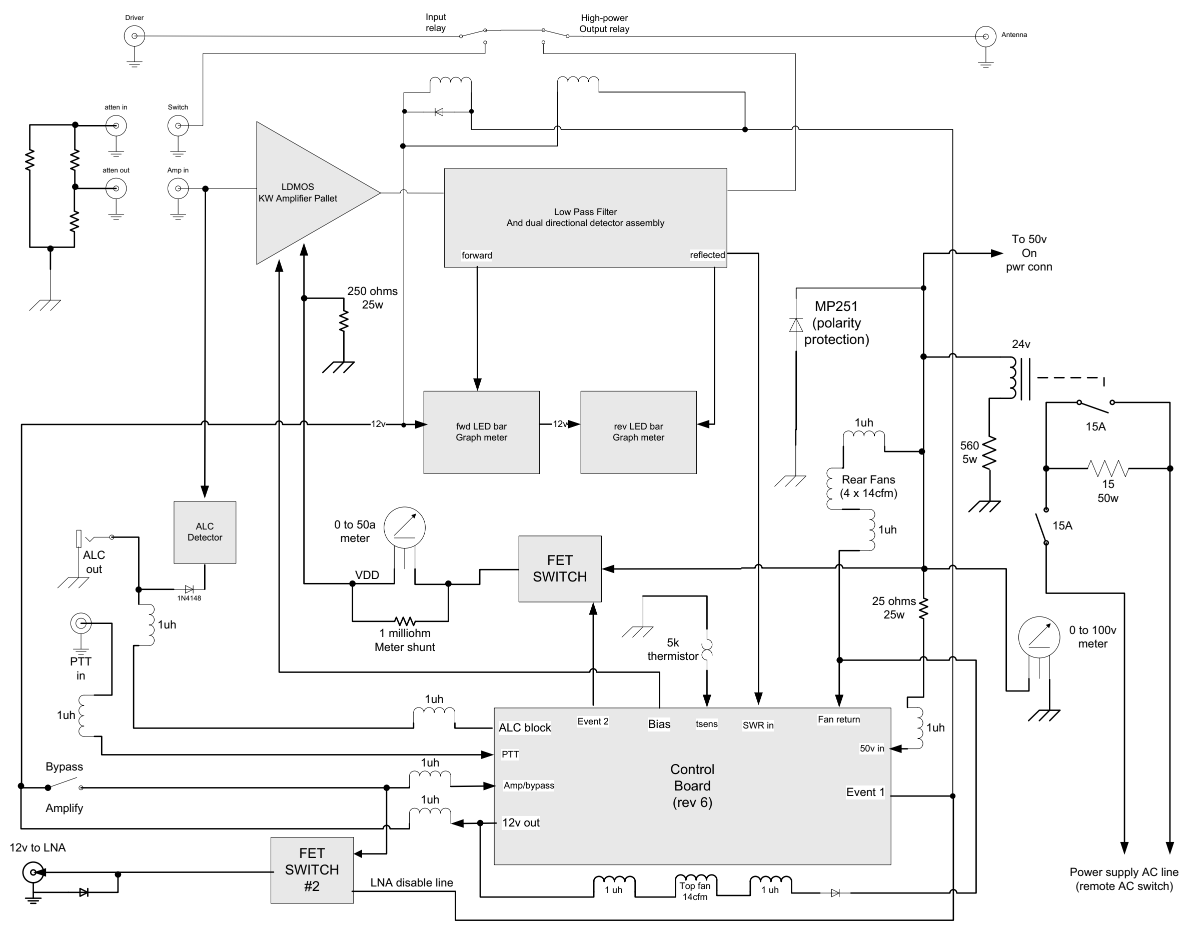
- www.frontpanelexpress.com

Complete RF deck kits are available on the w6pql web site

OK, so let's imagine you bought an RF deck kit, and some time later you now have a working amplifier assembly.

Now what?

This is akin to buying one of the surplus Larkin TV amplifiers…we need a lot of other things to make a complete working amplifier system. Here's a block diagram of a complete system the way I currently build them:



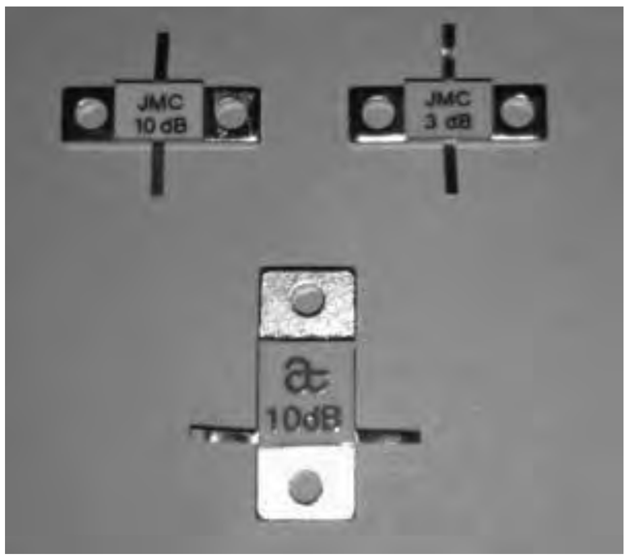
The RF deck is that little triangle in the upper left corner, and as you can see, there's a lot more that needs to be in the box to give you a safe and reliable system with some desirable features:

- Overdrive protection
- High SWR and high temperature lockout, cooling fans
- t/r relays capable of handling the power
- Sequencing for those relays to prevent hot-switching
- ALC feedback to the driver (for those who use it), and driver RF hold-off
- Reverse polarity protection
- Metering, and a sequenced LNA power feed (usually 12v)
- A control board to manage all of this and prevent chaos

Let's start at the beginning, the input drive requirements. Most of these rf decks need only a fraction of the drive you may have available…for example, the 2m amp develops full output with a bit under 2w drive. If you have a 50w radio to drive it, and forget to leave the power turned down (come on, we've all done it), the LDMOS will be killed.

The safest way do deal with this is to use an attenuator at the input of the rf deck; it should be placed out of the receive path, and there should be some means of bypassing it should you want to drive the amplifier with a low power radio, like the FT-817 or a KX3 with the 2m option. It also needs to have enough attenuation to reduce the maximum output of your driver below the input damage level of the device…in the case of the 50w radio, 4w; so a 13db 50w attenuator is about right, and will leave about 2.5w max drive available.

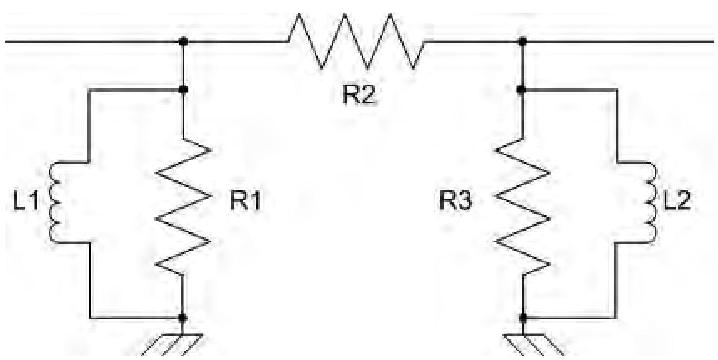
If you can find them in the right value (or at all), the easiest way to do this is to use one of the flange-mounted 100w attenuators made by ATC or Johanson (shown below).



I've found these to be available at distributors in the 3, 10, 20 and 30 db values, but not all the time; the 10db ones seem to be the easiest to get.

Since I usually need 13db and 16db for the 50 and 100w radios, I decided to make my own attenuators using “non-inductive” tab-mounted power resistors. The one shown below is a 100w 16db attenuator.

All that is required is a small PC board to connect the parts…and even though these resistors are non-inductive, they do have some capacitance to deal with that will make a good match difficult above 50 MHz. To neutralize that stray capacitance, small shunt inductors are used on the input and output, which tunes out the distributed capacitance at the operating frequency, leaving only the resistive component active. If you need to use this on a different band, just change the value of the inductors.



The table below can be used to set up this type of attenuator using Caddock MP series resistors:

432 MHz	3db	6db	10db	13db	16db
R1	300 – 15w	100 - 15w	100 – 30w	75 -30w	
R2	15 -15w	50 – 15w	75 – 15w	100 – 15w	
R3	300 -15w	Not used	100 – 15w	75 – 15w	
L1	27nh	3 turns #22 3mm dia, space-wound input inductor; position across R1 terminals near body	8.5nh inductor 3 turns #22, 3mm id, 8mm long; position across R1 terminals near body	8.5nh inductor 3 turns #22, 3mm id, 8mm long; position across R1 terminals near body	
L2	27nh	33nh	27nh	27nh	

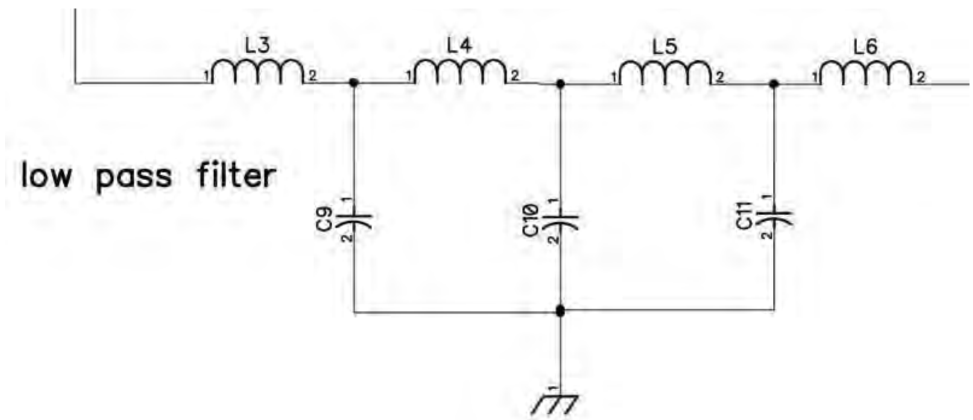
222 MHz	3db	6db	10db	13db	16db
R1		100 – 15w			
R2		50 -15w			
R3		Not used			
L1		120nh			
L2		220nh			

144 MHz	3db	6db	10db	13db	16db
R1	300 – 15w	100 – 15w	100 – 30w	75 -30w	75 – 100w
R2	15 -15w	50 -15w	75 – 15w	100 – 15w	150 – 30w
R3	300 -15w	Not used	100 – 15w	75 – 15w	75 – 15w
L1	330nh	270nh	220nh	220nh	120nh
L2	330nh	560nh	330nh	330nh	270nh

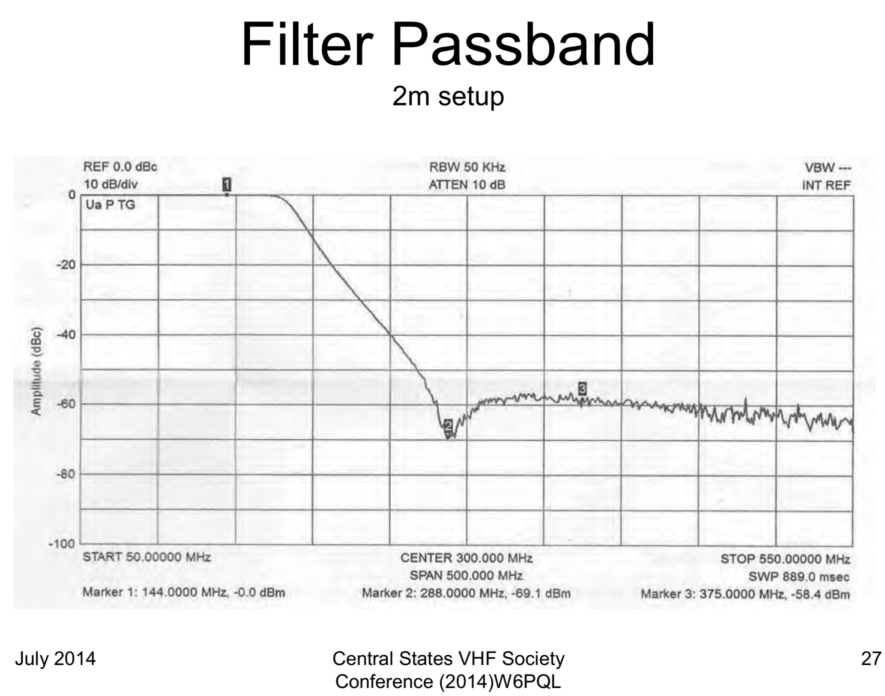
50 MHz	3db	6db	10db	13db	16db
R1	300 – 15w	100 – 15w	100 – 30w	75 -30w	75 – 100w
R2	15 -15w	50 -15w	75 – 15w	100 – 15w	150 – 30w
R3	300 -15w	Not used	100 – 15w	75 – 15w	75 – 15w
L1	Not used	Not used	Not used	Not used	Not used
L2	Not used	Not used	Not used	Not used	Not used

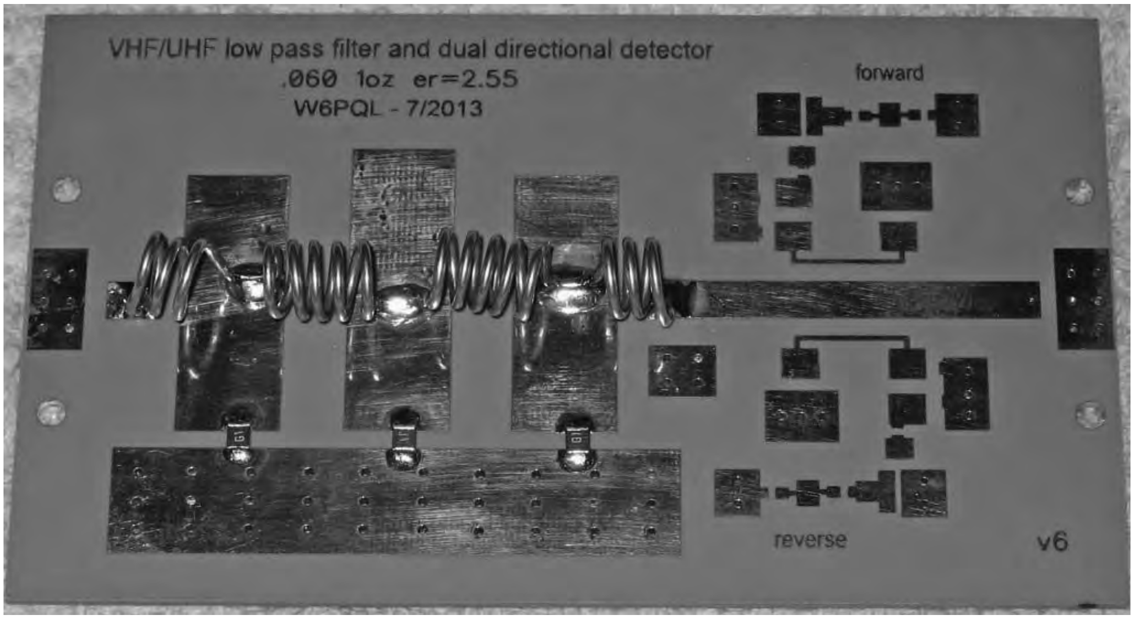
Since we had so much fun dealing with the input requirements, let's do the output next. Harmonic content can be a real problem, particularly since the FCC requires them to be suppressed by at least 60dbc.

On 2m, the second and third harmonics can be as high as -27dbc, so we need a good low pass filter to keep us in good graces.



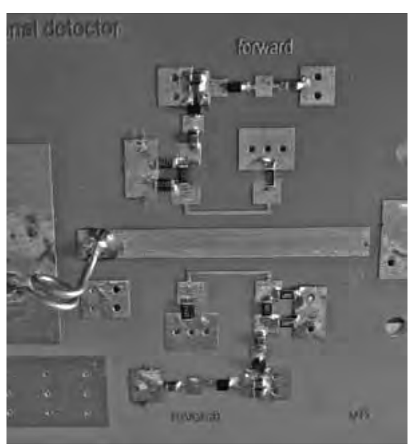
This can be done with the filter shown above, using 3 capacitors and four inductors. An analyzer plot of the filter performance is shown below. This type of filter typically reduces all harmonics to -65dbc or less.



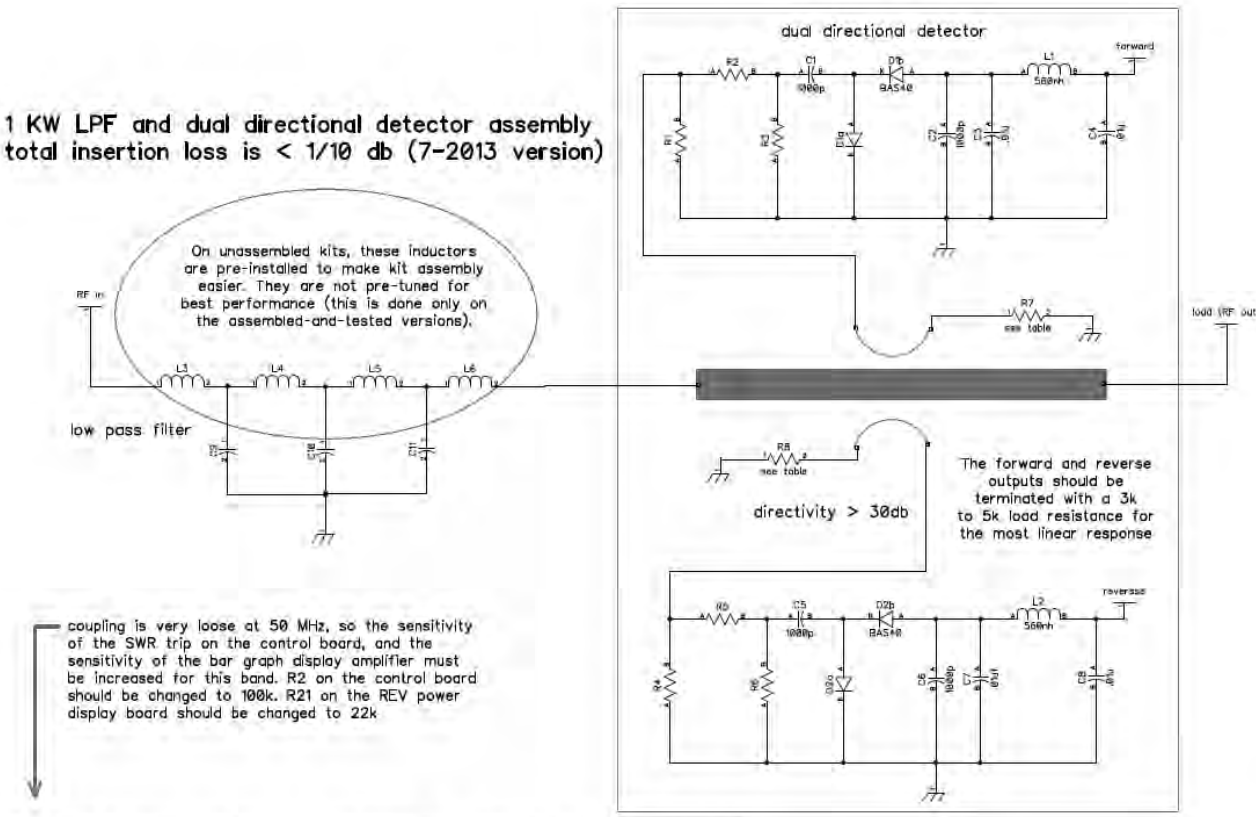


This is one of the filter boards I developed for use from 70cm through 6m, printed on Teflon material; for clarity here, only the filter components are installed on this one (2m components shown). On 70cm, you'd only need to install the inductors…the capacitance required for the filter is provided by those thick vertical islands; for all other lower bands, additional capacitance is added in parallel to be used with the appropriate inductors for the band in use, as shown by those small green 1kv high current mica capacitors at the bottom.

This board has an additional feature, a dual directional detector shown on the right side, currently devoid of components. That part allows both forward and reflected power to be sampled, detected, and the signals routed to power meters. The reverse power signal is also routed to the control board, where it is monitored by the high vswr lockout circuit. Here's that section loaded with components:



This is a setup table for this board showing the correct components to use for the various bands it was designed for.



50 MHz	70 MHz	144 MHz	222 MHz	432 MHz	component
-53db	-50db	-43db	-40db	-34db	coupler forward sample level
4 turns #16 .25 ID, .310 long	4 turns #16 .25 ID, .5 long	3 turns #16 .25 ID, .375 long	2 turns #16 .195 ID, .187 long	2 turns #16 .165 ID, .250 long	L3, L6
10 turns #16 .25 ID, .75 long	7 turns #16 .25 ID, .70 long	5 turns #16 .25 ID, .500 long	4 turns #16 .195 ID, .375 long	4 turns #16 .165 ID, .375 long	L4, L5
60pf metal mica	50pf metal mica	18pf metal mica	10pf metal mica	pcb only	C9, C11
75pf metal mica	60pf metal mica	22pf metal mica	13.5pf metal mica	pcb only	C10
3 db	6 db	13 db	16 db	20 db	forward attenuator
0 db	0 db	3 db	6 db	10 db	reverse attenuator
120 ohms	120 ohms	100 ohms	100 ohms	75 ohms	R7, R8

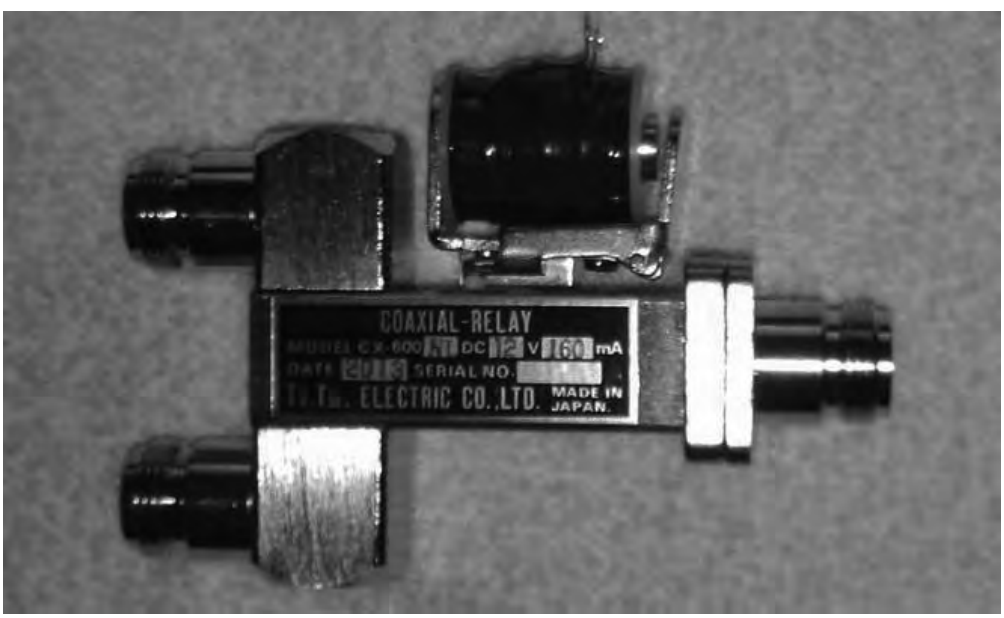
Attenuation	R1, R3 or R4, R6	R2 or R5
0 db	not used	jumper (zero)
3 db	300	17
6 db	150	33
10 db	100	69
13 db	82	100
16 db	69	150
20 db	62	250

The values in the table above have been optimized for best performance, and are different than the ones shown in the online web article

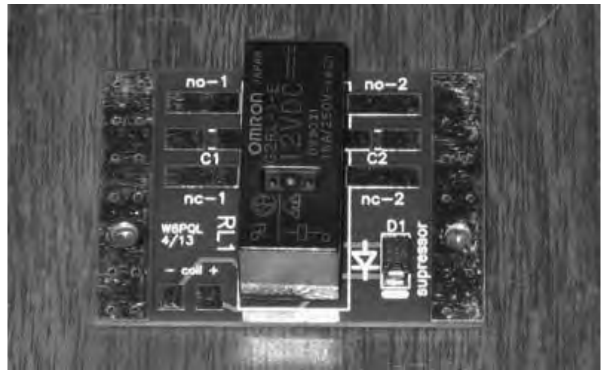
Transfer switch
Dow Key model 412

SPDT model 402

Let's deal with the t/r switching next; on the output side, what's needed is a relay capable of handling high power with good isolation to the open ports; the Dow Key ones shown above are the best I've found, but they are also the most expensive. And the transfer switch on the left is the easiest to use, eliminating the need for an input relay (it does both jobs at the same time). Shown below is a Tohtsu CX600NL, an economical alternative useful at the kw level through 222 (about $110 compared to many hundreds for the Dow Key units).



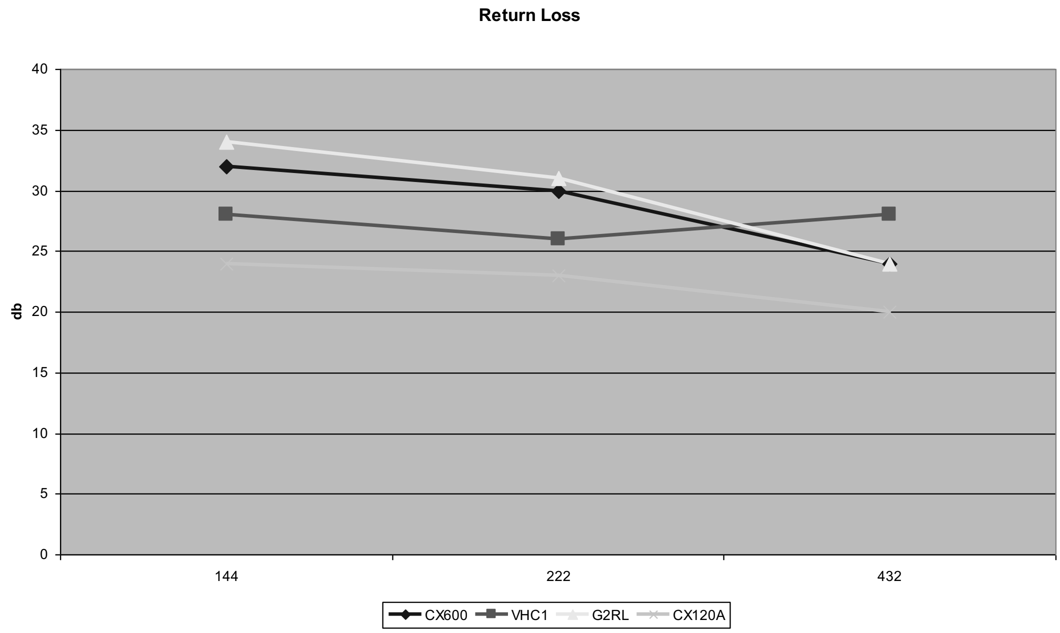
Vacuum relays like this one are available for even less, though they require some unique mounting, and should not be used above 2 meters. They don’t have a lot of isolation above 2m, and this can cause you some trouble, particularly if your input relay also has low isolation (more on this in a moment).



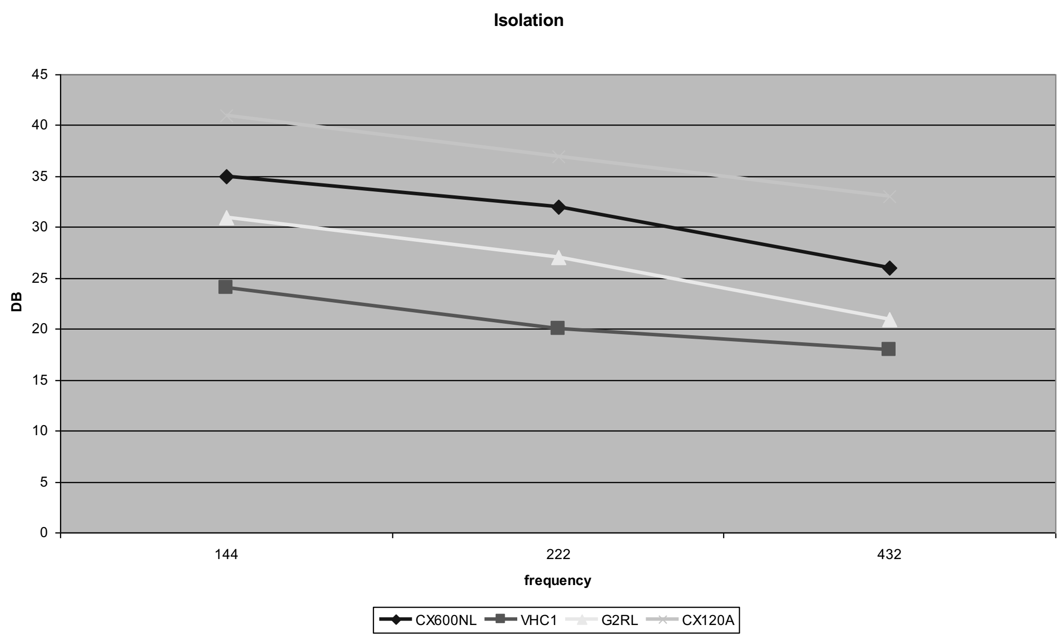
These two relays are suitable for the input side; the one on the left is made by Tohtsu, and is a direct-solder type (about $35). The one on the right is one available for about half of that…it uses an inexpensive general purpose relay and a small PC board to facilitate connections. Both have very low insertion loss, and one is better in the vswr department, the other in the isolation department. Matching one of these to the correct output relay requires a little more information, so this is probably the right time to share some measurements.

Except for the Dow Key units…these measured so well all the way through microwave frequencies that they are not worth discussion or worry. If you can use one of these type N relays, you'll be in the best position possible.

As for the others tested here, they all have good insertion loss through 70cm, so no need to examine that; but let's look at return loss and isolation…



The real job here is to match an input relay with an output unit; looking at worst case with regard to return loss (above), the only real loser is the CX120A at 70cm…it's marginal there, but could still be used.



On the other side of the fence, you do have to be aware of isolation; too little and your amplifier will oscillate through the t/r switch. A good general rule of thumb is to have at least 15db more isolation that you have amplifier gain. The biggest loser in this department is the vacuum relay at 70cm. If you were to use this one on that band, you'd have about 16 watts coupled to the open port going back to the input relay. Married with the CX120A, it would be OK so long as you can accept it's input VSWR of 1.25 to 1.

We're coming down the home stretch now, so let's talk about Chaos and Control…you remember our old friend Maxwell Smart? Yes, I know I'm dating myself…

The control board does a lot of things, and serves as the conductor of the orchestra in there. It has the following features:

- Sequencer
  - Prevents hot-switching the antenna output relay
- DC power gate
  - VDD gating with an external FET switch, and bias (on event 2)
- Fan control
- Reverse power lockout (high VSWR)
- Over-temp lockout
- Sequenced LNA power feed and drive power gating if required (event 3)

1. The first thing it does upon receiving a PTT signal from your driver is switch the antenna relays and turn off the 12v available for a remote LNA (if you use one)
2. 50 milliseconds later, it turns on the 50v going to the RF deck, and also it's bias
3. 50 milliseconds after that, it releases the driver ALC line, upon which it had placed a blocking level, allowing the driver to reach full power. This last feature protects your remote LNA (if you use one) from your driver, and it's use is optional.

All of this is done in reverse order as soon as your driver releases PTT. The control board also runs any fans you may have, turning them on when transmitting, or when your heat sink reaches about 110F. It also locks out the amplifier if it senses higher than recommended reverse power levels, or if it senses the heat sink to be above 135F. It does this by disconnecting the PTT signal until these conditions are no longer present.

Finally, the generous use of ferrite beads, rf chokes and shields inside your enclosure is highly recommended. RF interference to your control circuits, fans and other components can come from many points, and like a hose with lots of holes in it, leaks until you plug the last one. Chokes or beads should go to most connections to the control board, and to the connections on the filter board, right at the output pads of the detectors. Larger beads need to go on the FET switch output(s) and to the power leads where they enter the cabinet, along with bypass capacitors on the connectors.

Looking to the future, there are others working on interesting things: K2OP just completed a 160 thru 6m 1kw amplifier

- 1kw+ on 160m thru 10m
- 850w on 6m
- Broadband transformer design

There are very complex switching and filtering requirements, as you can imagine – the third harmonic content is as high as -9dbc on some bands, and a complex output filter is required…his prototype is working well now, however, using a combination LPF and diplexer. More to come this year for certain…

1296 MHz Remote 100W PA and LNA

Tom Apel K5TRA

AUSTIN, TX

I. INTRODUCTION

This paper details the development of a remote mounted PA and LNA unit. It is keyed by detected RF drive. It is intended for operation near the antenna for improved transmit power and receive system noise figure. The construction presented here was not weather proofed for external operation because the author's amplifiers are mounted in the attic of his house and power supply is remotely controlled by network browser interface.

II. BACKGROUND

Remotely operated amplifiers can provide significant performance benefits at VHF and higher frequencies. This is due to increased feed-line losses as the operating frequency is increased.

Consider first the contribution of coaxial cable losses to receive signal to noise ratio. For more about noise-figure and noise in two port systems, see references[1,2]. A good front-end with a 0.5 dB noise figure is capable of hearing a SSB signal 10 dB above the noise floor with only 0.08uV (-129.2 dBm). A CW signal 6 dB above the noise floor can be heard from 0.02uV (-140.5 dBm). When attenuation is placed in front of this receiver the desired signal is attenuated while the thermal floor is constant. At 1296 MHz, 100 ft of LMR400 has greater than 5 dB of loss. The required input signal for the same signal to noise performance must increase by 5 dB. This translates to SSB and CW sensitivities of 0.14uV (-124.2 dBm) and 0.037uV (-135.5 dBm), respectively. Loss degrades the signal to noise ratio. The degraded system NF is 5.5 dB.

Now consider placing a LNA with 0.5 dB NF and +18 dB gain in front of the 5 dB coax loss. The cascaded result is +13 dB of gain and 0.6 dB NF. The corresponding SSB and CW sensitivities are now 0.08uV (-129.1 dBm) and 0.021uV (-140.4 dBm), respectively. Clearly, the overall NF is set by the remote LNA. The relationship between RX sensitivity and NF is shown in Figure 1.

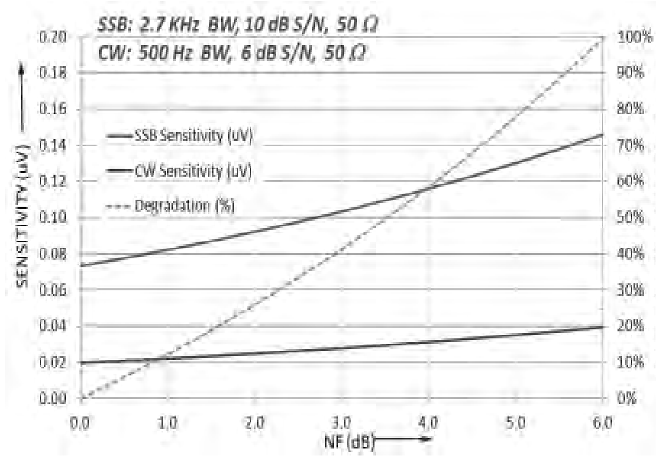


Figure 1 RX sensitivity vs noise figure

The benefit of a power amplifier placed after line losses is a direct increase in ERP by an amount equal to the loss of the coax. For example, by moving a PA to the antenna end of a 100 ft run of LMR400 results in a 5dB increase in ERP at 1296 MHz.

The remote PA and LNA effort reported here was preceded by two earlier projects. The first was simply a remote LNA with RF sensed switching control. A photo of this can be seen in Figure 2.This worked extremely well.

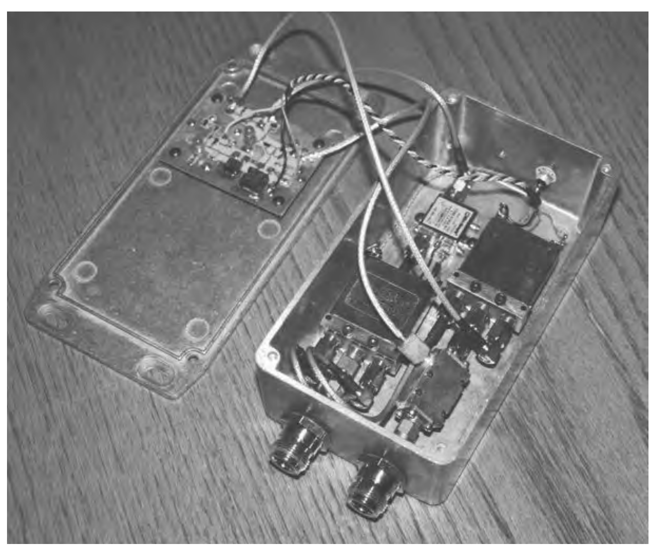


Figure 2 Remote 1296 MHz LNA

The addition of a power amplifier to the remote unit was the second step. The basic detector and control from the remote LNA could be reused in a remote PA/LNA combination. Initially, a much modified 860 MHz MASTR-III PA was used. The original PA utilized a MRF899 pushpull BJT. The modification to that amplifier included replacing the MRF899 with a MRF186 pushpull LDMOS device, modifying the bias circuits to accommodate the device technology change, and significant PC board surgery and retuning to make the change to 1296 from 860. This early PA/LNA unit in a MASTR-III housing can be seen in Figure-3. This worked very well and was used for more than a year. The PA to be presented here is a new design that replaces the modified MASTR-III board.

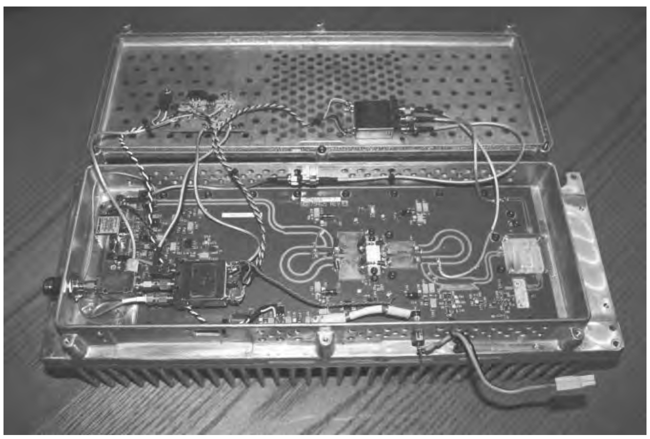


Figure 3 Initial 1296 MHz remote PA/LNA

III. CONTROL CIRCUIT

The key to realizing a remote RF keyed amplifier, whether PA, LNA , or both, is in the detector and control circuit. The detector must be sensitive to react to the rising edge of transmitter RF, yet able to survive peak transmitter drive. The control circuit provides several functions:

- Protect the LNA in the unpowered state
- Switch the LNA on when in powered state
- PIN protect the LNA when drive RF is detected
- Switch coaxial relays to TX state when drive RF is detected
- Power off LNA when drive RF is detected
- Apply gate bias to PA when drive RF is detected
- Delay switching to receive state for 1 second after RF drive is removed

The one second delay is essentially an rf vox to minimize unnecessary TX/RX switching and relay abuse. Figure 4 shows the PC board with SMT components and Figure 5 illustrates the schematic of the control and detector circuits.

Coaxial relays were 24v non-latching type with low current 5v logic control. The control circuitry can be easily modified to accommodate relay drivers to switch more standard 24v relays directly. Latching relays were avoided to provide additional insurance of proper switching and LNA protection.

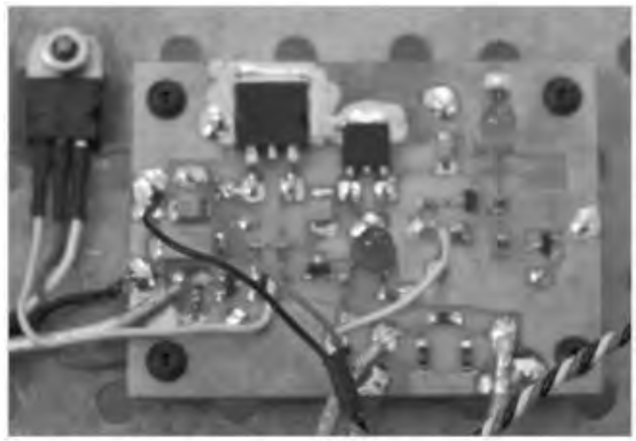


Figure 4 Control board

IV. LNA

A Minicircuits ZX60-P162LN+ is used as the LNA. It is relatively inexpensive SMA module that provides a NF of 0.5 dB and high IP3. Figure 7 shows a photo of the LNA.

LNA protection is paramount. Since the LNA's output port is normally connected to the transceiver during receive, transmitter RF will toast the LNA if it is not protected, powered off and quickly switched out of line when transmitting. We have already discussed the need for a highly sensitive detector. Several LNA protection measures are taken at it's output port. First, in order to tolerate more RF level on the rising edge of the drive envelope, a 6 dB pad is placed in the output path of the LNA. This LNA typically has greater than +20 dB of gain, so the overall NF won't be significantly degraded. Secondly, the shunt PIN diode is turned on to "crowbar" protect port-2. Since this PIN is in parallel with the LNA side of the π-pad, attenuation jumps to around 50 dB. Of course, the relays are also quickly switched and the LNA is powered off.

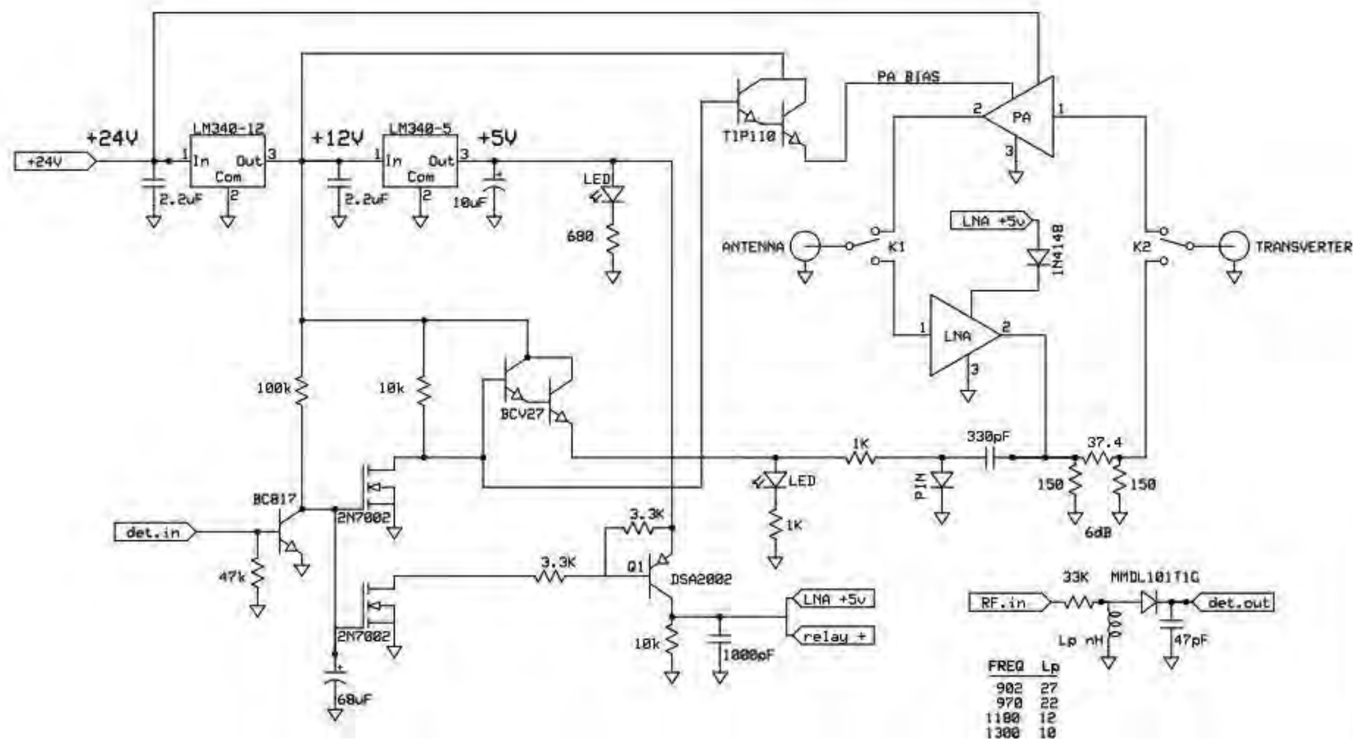


Figure 5 Control and detector schematic

The detector circuit shown in Figure 5, provides high sensitivity to drive RF. Typically, the control circuit can be keyed by 10 to 15 dBm. The module assembly is constructed in a surplus air strip-line housing and can be seen in Figure 6. Construction uses 0804 SMT components in free standing "ugly" form. The 33K resistor simply taps along the 50 ohm strip-line. The high resistive value and low body capacitance provide a very small perturbation to the input RF line. Under high peak RF drive, this hign impedance coupling provides current limit protection to the detector. The key to achieving high sensitivity to low drive signal levels is by tuning the parallel inductor to resonate with the schottky diode and circuit capacitance. This is accomplished by test selecting the correct chip inductor. The high-Q resonance boosts the RF voltage at the detector. At high drive levels, when the diode and NPN input transistor are turned on, the loaded Q is considerably lowered.

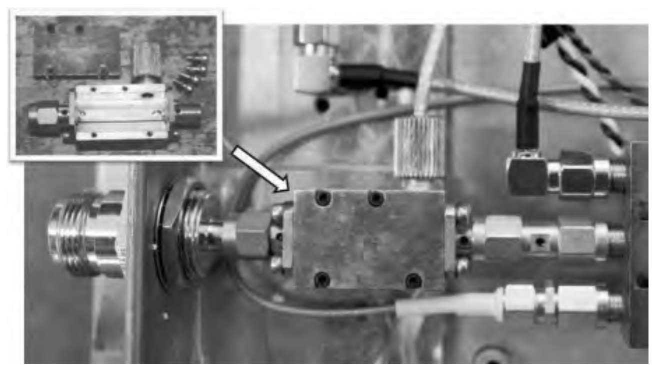


Figure 6 Detector module

Figure 7 ZX60-P162LN+ LNA module

V. PA

The PA board, shown in Figure 8, contains a single pushpull LDMOS final and bias circuitry. At lower out of band frequencies, negative feedback enhances stability. The collector supply voltage is +26V. The gate bias regulator runs from a switched +12V line.

Usually 23cm power amplifiers that operate at power levels above 30W use thin (< 0.032”) circuit boards. Low impedance interface to the power transistor and ground return inductance are the dominant reasons for this. Pushpull operation provides a differential impedance interface 4x higher than with a single-ended design at the same power level. This allows the possibility of using relatively inexpensive PC board shops such as ExpressPBC, where standard material is 0.062” FR4. Boards for this project utilize this vendor.

Device selection for solid-state 23cm power amplifiers is made difficult since LDMOS transistors usually have internal LC input matching; but tuning is always for other bands. The common choices are 800 MHz, 900 MHz, 1 GHz, 2 GHz and 2.4 GHz. Use of a part that is designed for a lower frequency can encounter low gain, due to lower f_T, while use of higher frequency parts can lead to stability challenges. Input matching can be a challenge in both cases, since 1296 MHz impedance data is virtually never published.

In contrast the output match impedance targets are relatively easy to predict based on loadline (supply voltage and output power), output capacitance, and package parasitics. More about this can be found in Cripps[3], chapters 2.5 and 2.6.

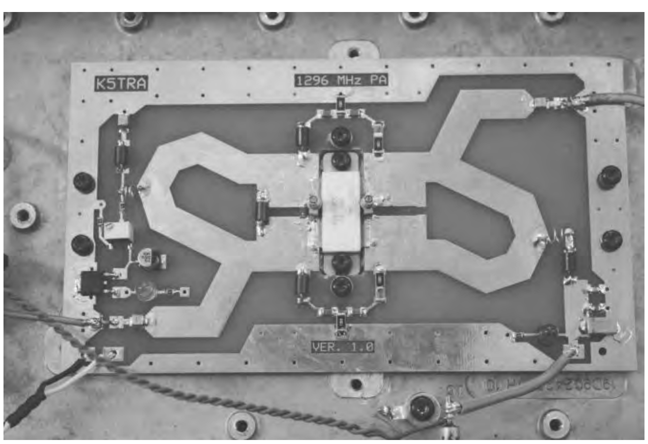


Figure 8 Pushpull 100W PA board

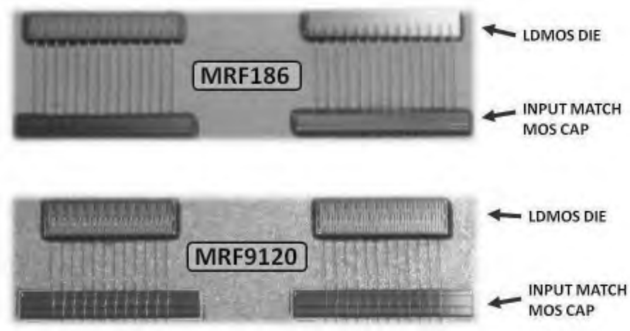


Figure 9 LDMOS internal view

Two Freescale LDMOS parts were considered for this PA: MRF9120 and MRF186. A photo of the chip and wire internal assembly of these two parts can be seen in Figure 9. The 9120 is a more rugged device; but, the input matching has a lower corner frequency. The MRF186 has more parallel input wires for lower series inductance. The MOS cap is also a bit smaller. This is all consistent with the MRF186 being a nominal 1GHz part and the MRF9120 being a 880 MHz part. The lower frequency part is more VSWR rugged to 10:1 compared with 5:1 for the MRF186 (both at 120W CW).

Both transistors were tested in the PA. Based on overall tunability and stability the MRF186 was selected. More on the subject of stability will be discussed in the circuit details.

Input and output matching networks are similar. A 50 Ω 1:1 balun is formed by a pair of 25 Ω lines. Between the two differential terminals is a ½ λ line. The line that interfaces with the external 50 Ω port is a ¼ λ line that acts as an impedance transformer to 12.5 Ω. The ½ λ portion is the same as the familiar coax (4:1) balun. Overall, this structure provides a 50 Ω differential feed to the lower impedance (wide) lines. From that point each side of the network can be equivalently viewed as an impedance match from 25 Ω to one side of the final. This balun technique is also used in Motorola 150 W cellular and GE/Ericsson MASTR-III 860 MHz (110 W) power amplifiers.

Figure 10 shows the circuit details for input and output network simulations. The transformer at port-1 is simply used as an ideal balun in order to allow a view of the transistor's differential load (or source) impedance. Tuning is done with high-Q piston capacitors. The series inductance of these capacitors cannot be neglected in the simulation. Figure 11 shows the simulated transistor interface impedances. The real part of the load is just under 4 Ω. The input source impedance is approximately 7 - j7 Ω.

The overall PA schematic can be seen in Figure 12. DC feeds are at differential balance (virtual ground) points at the electrical center of the ½ λ balun lines. Gate bias is set from +5V regulator with 5K pot. LDMOS transistors designed for 1 GHz operation have excessive gain at HF and VHF frequencies that can lead to stability problems. In order to avoid this, negative feedback and low frequency loading branches using ferrite beads have been added. Power output of 100 W is easily achieved. PA gain is set by gate bias to around +13 dB (quiescent current is approximately 800 mA).

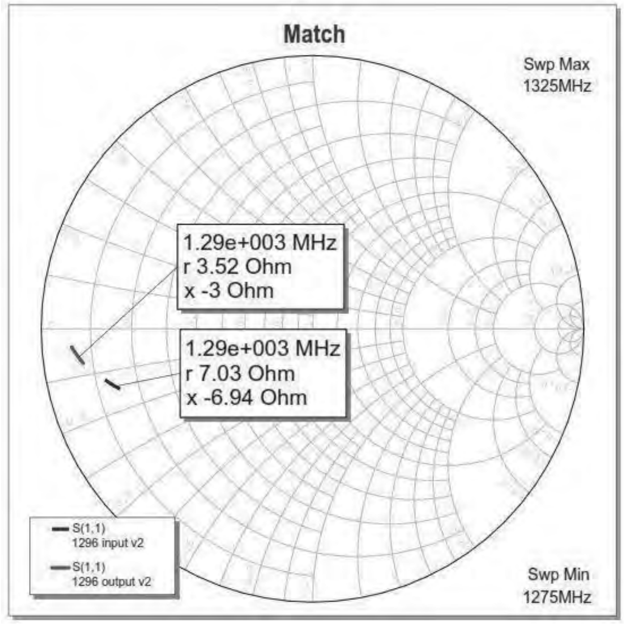


Figure 11 PA match simulation

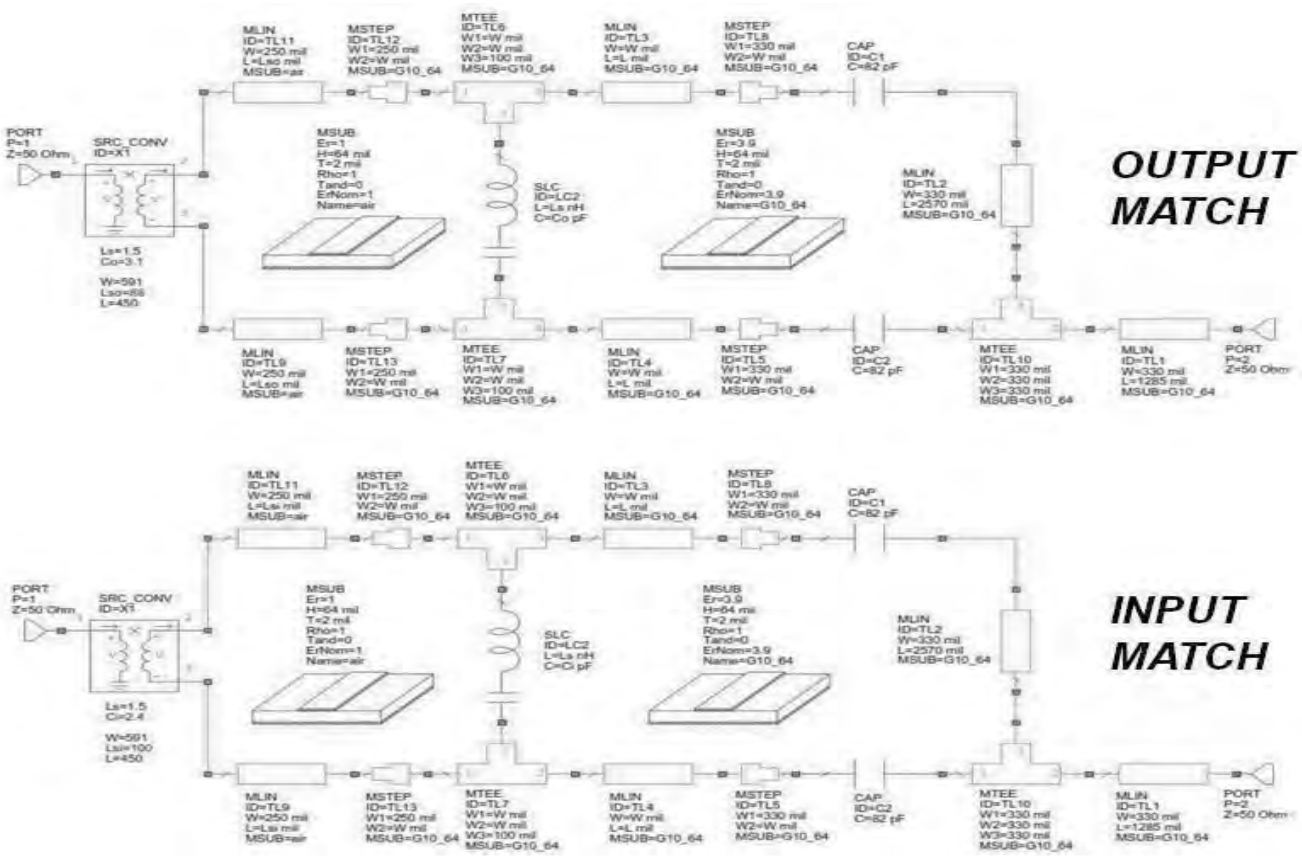


Figure 10 PA match design

VI. SUMMARY

The development of a remote RF keyed PA and LNA has been presented. Advantages of remote amplifier operation, both for receive and for transmit performance were discussed. Since this work was preceded by a remote RF keyed LNA and it's control circuit was reused here, it was also discussed. The earlier modification of an 860 MHz MASTR-III PA for 1296 MHz operation formed the basis for the new PA board design presented; so, it too was discussed. The PA LDMOS selection and impedance matching details were presented. On the air results have been very good.

REFERENCES

[1] S. Adam, "Microwave Theory and Applications," *HewlettPackard, Prentice-Hall.*, 1969, chapter 6.3, pp. 490-499.

[2] G. Gonzalez, "Microwave Transistor Amplifiers Analysis and Design," *Prentice-Hall.*, 1997, chapter 4.2, pp. 295-298.

[3] S. Cripps, "RF Power Amplifiers for Wireless Communications," *Artech House.*, 1999, chapters 2.5 and 2.6, pp. 24-35.

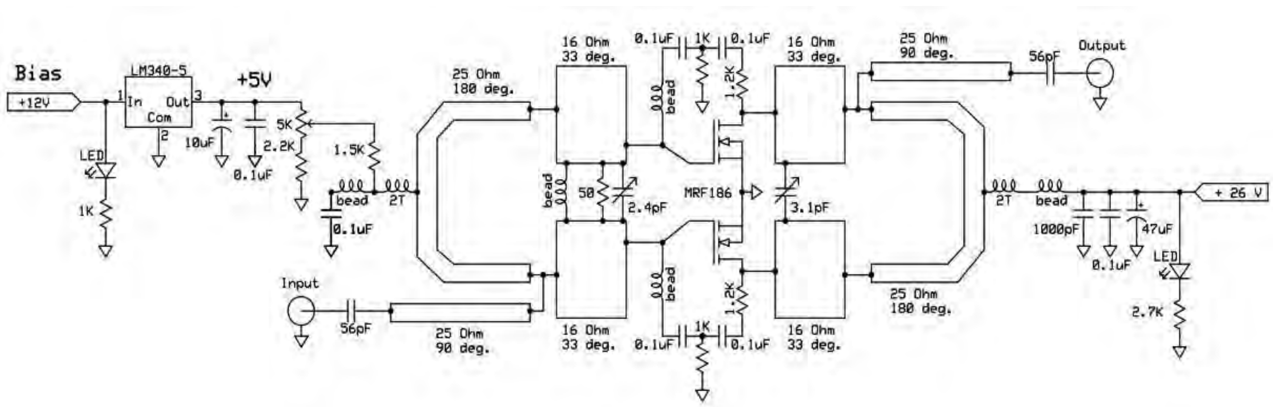


Figure 12 PA schematic

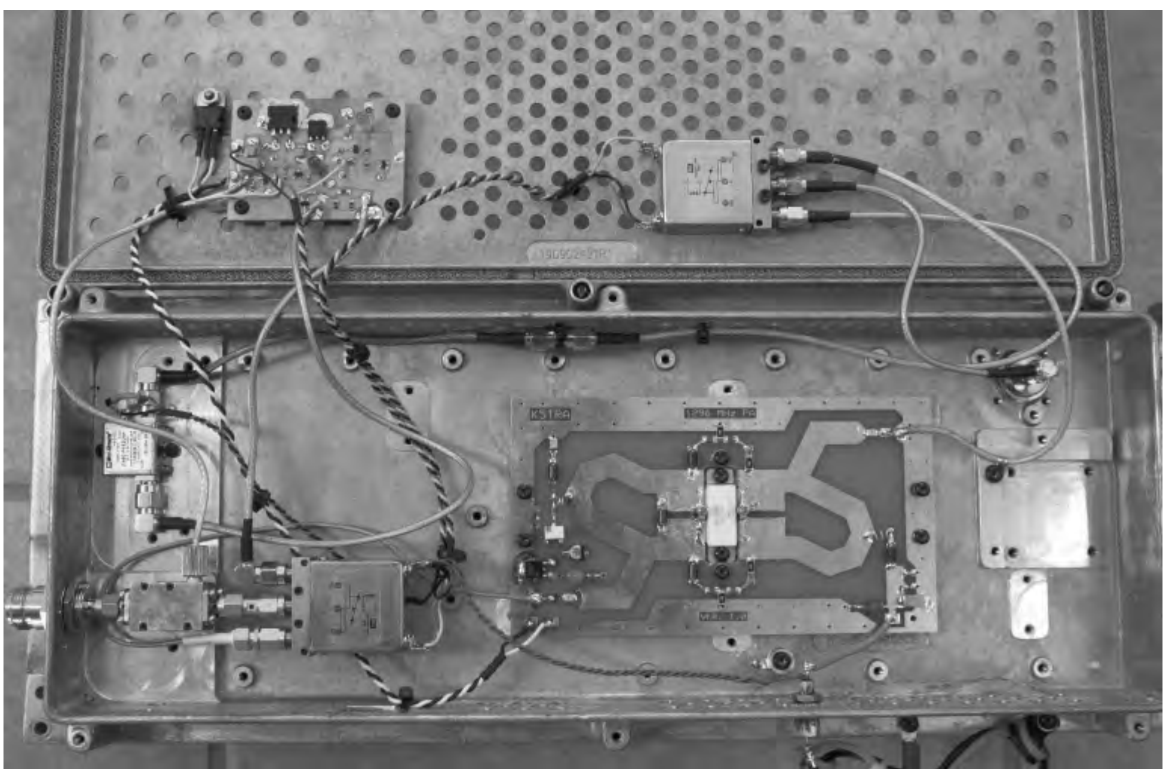


Figure 13 1296 MHz remote PA and LNA

GaN PAs for 3.4, 5.7 and 10GHz

Charlie Suckling, G3WDG

Introduction

Gallium Nitride (GaN) FETs show great promise for use in solid state power amplifiers (SSPAs) for microwave tropo and EME applications. This article will discuss what GaN technology has to offer and why it is of interest to us. It will attempt to review what kind of devices are available and the performance they are capable of achieving. Some examples of home made SSPAs using GaN devices will be described, including basic information on how they were designed and the results obtained, both on the bench and on the air.

GaN Technology – What does it Offer?

GaN has received a lot of professional attention in recent years since it offers many potential advantages over GaAs, and is leading to the replacement of TWTs (and magnetrons) in many applications. A number of companies in the US, Japan and more recently in Europe are now offering GaN discrete (unmatched) devices for general sale and these can be purchased by individuals in a large part of the world. Some MMICs are also available, but these are quite expensive and in most cases not available outside their country of origin.

Like GaAs, GaN is also a III/V semiconductor and is a good material for building microwave power devices. Compared to GaAs, it offers much higher 'power density' which means that for a given physical size of device up to four times the power output can be obtained, and many tens of watts can be obtained from a single die. GaN is also capable of higher efficiency than the majority of GaAs devices available to us amateurs. A GaN PA will typically have >50% efficiency compared to 25% or less for GaAs.

Another advantage is that GaN devices usually operate with considerably higher voltage, and along with their higher efficiency this means that the DC current drawn for a specific power level may be up to 8 times lower, cutting down I^2R losses in the DC cables and again resulting in more output power.

Unlike many GaAs devices, GaN FETs operate well in Class AB, with relatively low zero-signal drain current. The drain current may increase by a factor of 5 to 20 under RF drive, but little heat is generated during 'key up' periods so this helps to keep the average dissipation low compared to a Class A GaAs amplifier. Coupled with the higher efficiency, this means that for a given output power the amount of heat dissipated will be considerably lower than for a GaAs PA, allowing smaller heatsinks and lower mass per watt of RF power (0.6 g/W has been achieved for one of the amplifiers described below).

All of this means that GaN PAs are ideal candidates for mounting at or near the antenna feedpoint, giving a further performance advantage by cutting feedline losses to a minimum.

From a design point of view, GaN devices are generally easier to match to 50 ohms than GaAs. The higher operating voltage means that output impedances are higher and the smaller size of device (for a given power) reduces the input capacitance.

The vast majority of GaN devices are depletion mode FETs. Like most GaAs devices therefore, they require a positive drain voltage and a guaranteed negative gate bias. GaN devices will die almost instantly if drain voltage is applied without gate bias. Sometimes you can get away with this with GaAs devices, but not with GaN. Power supply sequencing is therefore very important! Generally GaN devices do not draw much gate current until they are driven really hard, so the negative voltage generators that we are familiar with can also be used with GaN.

Available GaN Devices

GaN devices are available in bare die form and in packages. This paper will focus on packaged devices, since these can be readily used by amateurs. However, the parasitic reactances associated with packaged devices do restrict the maximum frequency on which they can be used. However, some experimentation has been done using packaged devices above the manufacturer's recommended maximum frequency of operation, with promising results (see below). In such cases, the design method was simply to match the device using tuning tabs!

There are two basic types of GaN devices available. Devices intended for cellular base stations with power levels of hundreds of watts exist, which could be used for 1.3 and 2.3GHz, but these are very expensive and don't offer much performance advantage to amateurs compared to the silicon LDMOS devices in surplus PAs. The other family of devices are single transistors with output powers of up to 70W at 3.4GHz and 40W at 5.7GHz, and these were of most interest to me.

The number of suppliers of GaN devices is increasing all the time. At the time of writing, about 8 companies are offering GaN devices.   Three suppliers were contacted and kindly agreed to supply devices for this work – Cree and TriQuint Semiconductor from the US and UMS from Europe.

Studying the Data Sheets

A good place to start looking at GaN devices is to study datasheets. These can be found on the manufacturers' websites, and if a full data sheet is presented it generally means that devices are available.

All manufacturers state the frequency of operation, output power, small signal and power gain, efficiency, DC operating conditions, whether the device is suitable for pulse or cw, absolute maximum ratings, source and load impedances for power operation, s-parameters, gain and stability information, applications circuits and package drawings. The package drawings need to be studied VERY carefully, since there is no standardisation of connections! The FET source is always the package ground tab or flange, but the chamfered lead can be either gate or drain according to the manufacturer's preference. Getting these reversed would be an expensive mistake!

There is usually a table of 'Main Features', from which the basic device information can be obtained, such as that shown in Fig. 1 (Ref 1)

Main Features

- Wide band capability: up to 3.5GHz
- Pulsed and CW operating modes
- High power : > 45W
- High PAE : > 55%
- DC bias: V_{DS} =50V @ I_{D_Q} =300mA
- MTTF > 10^6 hours @ Tj=200°C
- RoHS Flange Ceramic package

Fig.1: Main features of UMS CHK040A-SOA device

From this, we learn that the device is suitable for use up to 3.5GHz, so it is good for 9 cm. It can be used for both pulse and CW, so is OK for amateur modes (pulse-only devices generally are not suitable). Expected output power would be a minimum of

45W in a properly designed circuit, with a high Power Added Efficiency [(output power – input power)/DC power] of 55% minimum. The device is intended for use with a drain voltage of 50V and a quiescent drain current (ie with no RF drive) of 300mA. The mean time to failure is > 1 million hours with a device junction temperature of 200°C; and the device is supplied in a lead-free flanged ceramic package.

Most of this information is self-explanatory and tells us how the device should be biased and what performance can be expected. Other performance tables show the small signal gain (15 dB in this case) and the power gain when the device is driven into near-saturation where the efficiency is at its highest (power gain falls to 12 dB). The near-saturated power gain is important to know, since it allows the required drive power to be estimated.

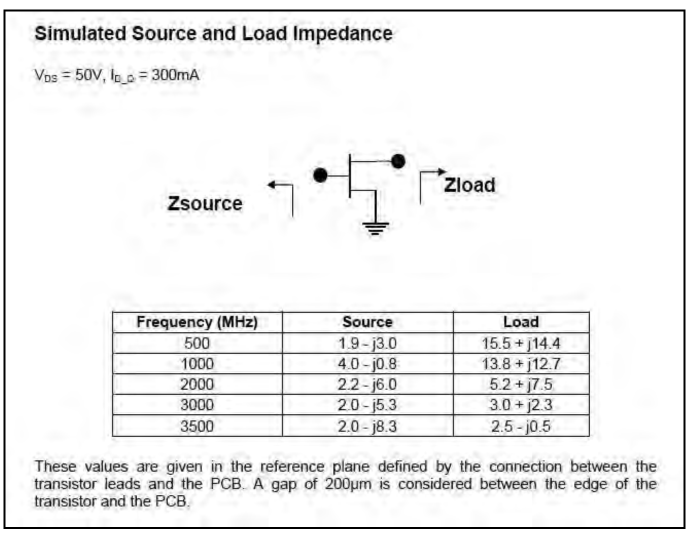
Other relevant information that can be gleaned from the datasheet is the expected gate bias voltage (only a typical value, which will vary from device to device) and the thermal resistance Rth. Knowledge of Rth is important, as it allows the device junction temperature Tj to be estimated, based on the dissipated power Pdiss and the temperature of the device flange (Tb) using the formulae:

Pdiss = [(DC input power) + (RF drive power) – (RF output power)]

Tj = Tb + (Pdiss * Rth)

A value for Tj is quoted (200°C for this device) which is usually chosen to ensure a given lifetime (eg 1 million hours). Some manufacturers also provide a graph showing how the lifetime is affected by the junction temperature. Often an absolute maximum value for Tj (220°C in this example) and a maximum for Tb are given. It is wise to follow the manufacturer’s recommendations for all absolute maximums, including Tj and Tb, to avoid blowing up the device. Often there is a disclaimer that states that not all maximums can be applied together!

Information will also be provided in the datasheet that allows an amplifier to be designed with the device. There is usually a table of source and load impedance data, such as that shown below in Figure 2.


Simulated Source and Load Impedance

V_{DS} = 50V, I_{D_Q} = 300mA

Frequency (MHz)	Source	Load
500	1.9 - j3.0	15.5 + j14.4
1000	4.0 - j0.8	13.8 + j12.7
2000	2.2 - j6.0	5.2 + j7.5
3000	2.0 - j5.3	3.0 + j2.3
3500	2.0 - j8.3	2.5 - j0.5

These values are given in the reference plane defined by the connection between the transistor leads and the PCB. A gap of 200µm is considered between the edge of the transistor and the PCB.

Fig.2: Source and load impedance data for CHK040A-SOA

The source impedance data can generally be ignored; what is of interest is the load data. This shows the impedance that needs to be presented *to* the drain of the device for it to work at the desired frequency. To obtain data at other frequencies (eg 3.4 GHz) it is necessary to interpolate. A linear approximation is usually accurate enough for practical purposes, since at the end of the day most amplifiers will need some tuning!

There will also be either a table of s-parameters or a link on the manufacturer's website to download them. These are used in the design process to design the input matching circuit, check stability and predict the (small-signal) gain response.

Finally, the datasheet will probably show some kind of demonstration amplifier. There may be a temptation to try to copy these, but generally what is shown is physically larger than needed, since demonstration amplifiers are usually designed to cover a broader bandwidth than we need. Usually some performance data of the amplifier is given, which can be taken as a good target for expected performance, but sometimes it is possible to do better over a narrow bandwidth.

Designing a GaN PA at Home

As noted above, there is enough information in the datasheet to design a workable amplifier. If care is taken and the manufacturer's data is good, it has proved possible to design amplifiers that need little or no tuning for optimum performance. The following few paragraphs outline the method that I have used successfully without the need for expensive design software, non-linear models etc.

The first stage in the amplifier design is to design an output matching network that presents the correct load impedance, as specified in the datasheet. Often, a single microstrip element of the correct width and length is all that is needed. A good start is to design the element as a quarter-wave transformer of the required impedance to match the real part of the load impedance to 50 ohms. A microwave circuit design program can then be used to predict the impedance exactly and if it is capable of optimization, the program can also be used to adjust the width and length of the microstrip to get the required impedance. If the program allows, include discontinuity models for any changes in line width, as these can affect the impedance presented to the device. If the program is not able to optimize, cut-and-try methods can still be used to get the correct result. Of course more sophisticated methods can also be used, eg Smith Charts or network synthesis methods.

A suitable microwave design program that can be used for this kind of work is *QUCS* (Ref 2). I have so far only used it to analyse circuits, and Figure 3 shows the results for the output network I designed for the TriQuint T1G6001528-Q3 device (Ref 3). The datasheet gives a required output load of 8.85 – j7.85 ohms at 3.4GHz.

The microstrip line length of 5.2mm and width of 2.8mm (MS1 In Figure 3) were designed initially using other software.

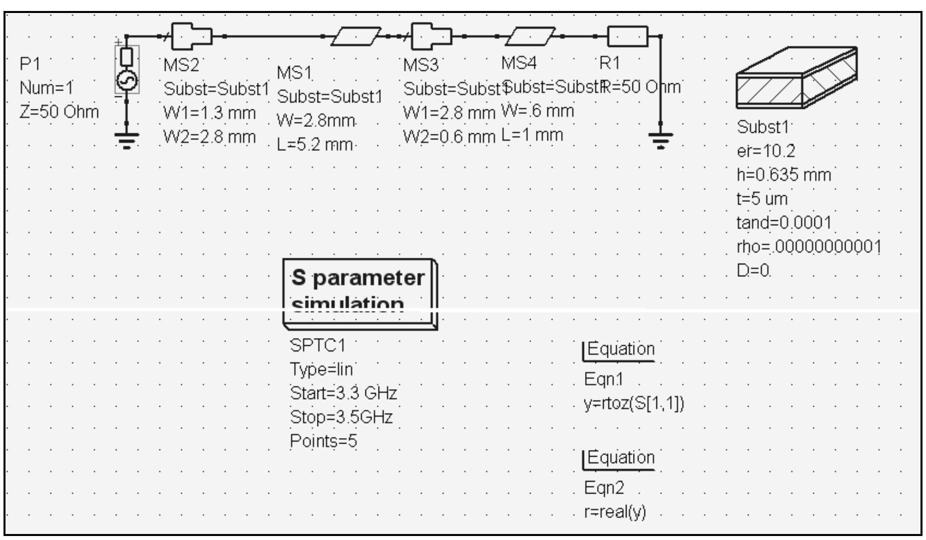


Fig.3: QUCS simulation for T1G6001528-Q3 output match at 3.4GHz

The results of the *QUCS* simulation are shown in Figure 4.

frequency	S[1,1]
3.3e09	0.693 / -159°
3.35e09	0.697 / -160°
3.4e09	0.7 / -160°
3.45e09	0.703 / -161°
3.5e09	0.706 / -162°

frequency	r	x
3.3e09	9.36	-9
3.35e09	9.22	-8.7
3.4e09	9.08	-8.4
3.45e09	8.96	-8.1
3.5e09	8.84	-7.8

Fig.4: QUCS simulation results for T1G6001528-Q3 output match

The results of the *QUCS* simulation agreed quite well with the original simulation. Depending on the complexity of the networks, and especially if wide micropstrip lines are used, the results from the simulator may not be sufficiently accurate. it is possible to use another software package called *Sonnet*, a free version of which is available to anyone (Ref 4). This is a very accurate way of simulating microwave circuits with many different applications for amateur radio, and I have used *Sonnet* for designing different kinds of microstrip circuits including branched arm couplers, filters and matching networks. It analyses the electromagnetic fields and currents of structures from first principles using Maxwell's Equations, and has proved to be highly accurate. Figure 5 shows the layout of the same network in *Sonnet* format, and the results are given in Figure 6.

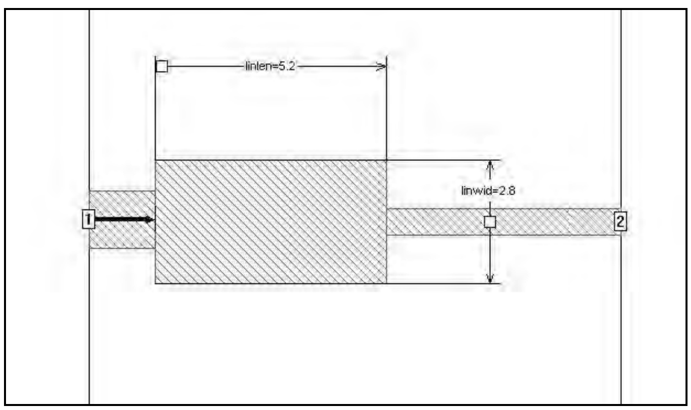


Fig.5: Sonnet *layout of output network*

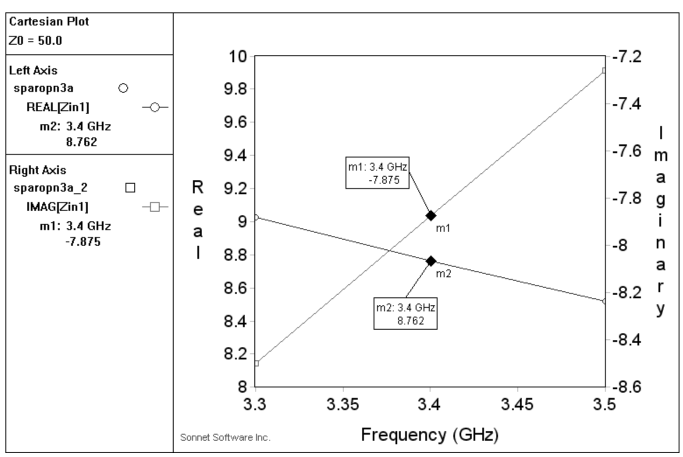


Fig.6: Sonnet *prediction of output load impedance*

The input circuit was designed using a similar method to the output circuit, using the device s-parameters and including the output matching circuit as described above connected to the device drain. The input microstrip was designed to achieve a low input VSWR, which also provides the maximum gain.

The final amplifier was built on a 39 x 32 mm aluminium plate, 6mm thick, which provides good heat transfer to the heatsink. A photograph of the amplifier is shown in Figure 7.

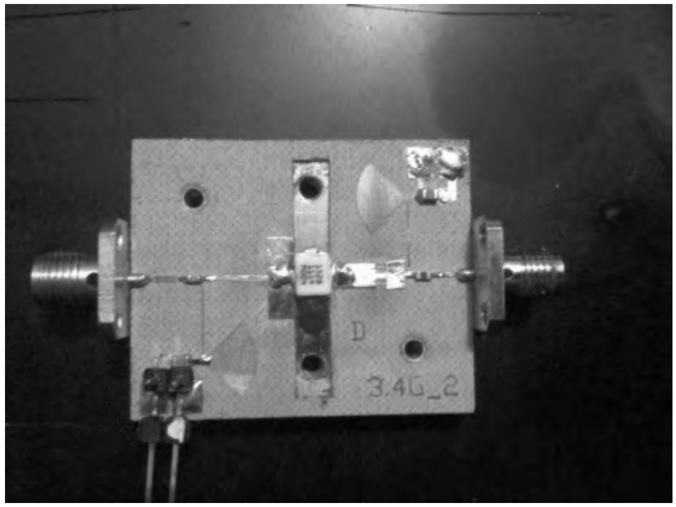


Fig.7: 25W GaN SSPA for 3.4GHz using TriQuint T1G6001528-Q3 device

The measured performance of this amplifier is given below. The performance of the device in the datasheet is shown in brackets, for comparison.

Test frequency	3400 MHz
Small signal gain	14.75 dB (13.9 dB)
Power output	25.5 W (21 W)
Power gain	12.7 dB (12.3 dB)
PAE	58% (56.7%)
Drain voltage	30 V
Drain Current (RF off)	250 mA
Drain Current (RF on)	1450 mA

More Examples of GaN Power Amplifiers

Following on from the good results obtained with the TriQuint T1G6001528-Q3 device on 9 cm, a number of other amplifiers have been developed as shown in Figures 8 to 13 below.

The black dots on some of the devices are matt black paint, to allow temperatures to be measured using a handheld infra-red thermometer.

52 W on 3.4 GHz

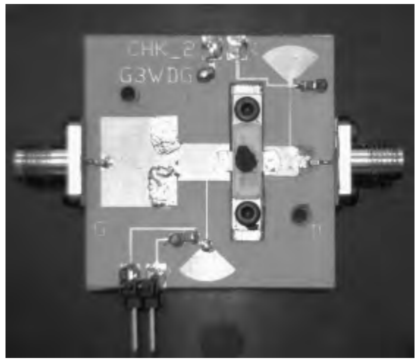


Fig.8: 3.4GHz PA using UMS CHK040A-SOA

Test frequency	3400 MHz
Small signal gain	16.1 dB (15-17 dB)
Power output	52 W (40-50 W)
Power gain	13.4 dB (12 dB)
PAE	54% (50-55%)
Drain voltage	50 V
Drain Current (RF off)	300 mA
Drain Current (RF on)	1946 mA

70 W on 3.4 GHz

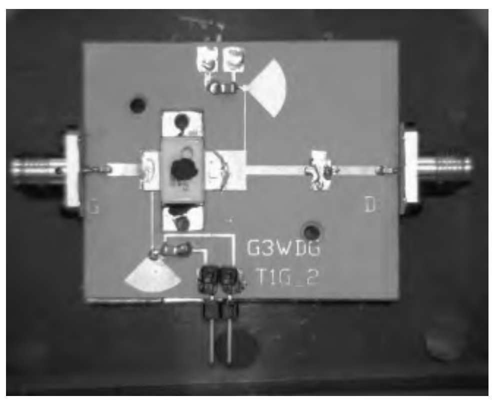


Fig.9: 3.4GHz PA using TriQuint T1G4005528-FS

Test frequency	3400 MHz
Small signal gain	16.5 dB (15.1 dB)
Power output	68 W (66 W)
Power gain	14 dB (12 dB)
PAE	54% (49%)
Drain voltage	28.5 V
Drain Current (RF off)	200 mA
Drain Current (RF on)	4225 mA

21 W on 5.7 GHz

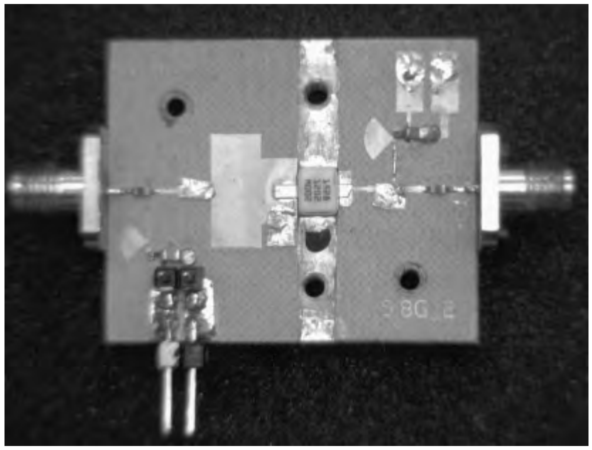


Fig.10: 5.7GHz PA using TriQuint T1G6001528-Q3

Test frequency	5760 MHz
Small signal gain	12 dB (11.9 dB)
Power output	21 W (20 W)
Power gain	9.0 dB (8.9 dB)
PAE	53% (51%)
Drain voltage	30 V
Drain Current (RF off)	220 mA
Drain Current (RF on)	1160 mA

26 W on 5.7 GHz

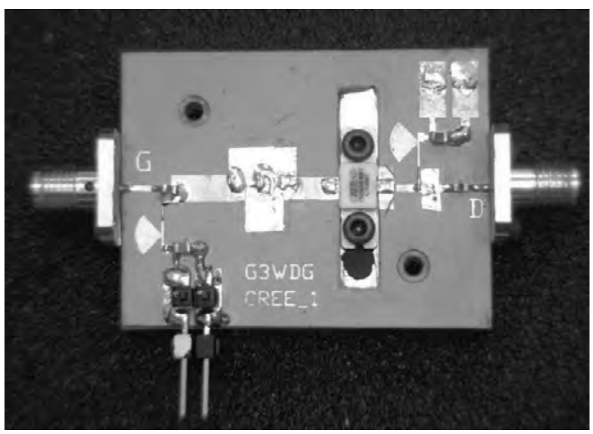


Fig.11: 5.7GHz PA using Cree CGH55030F2 (Ref 5)

Test frequency	5760 MHz
Small signal gain	11.3 dB (9-11 dB)
Power output	26 W (20-30 W)
Power gain	8.7 dB
Drain Efficiency	60% (50-60%)
PAE	52%
Drain voltage	28.5 V
Drain Current (RF off)	250 mA
Drain Current (RF on)	1521 mA

40 W on 5.7 GHz

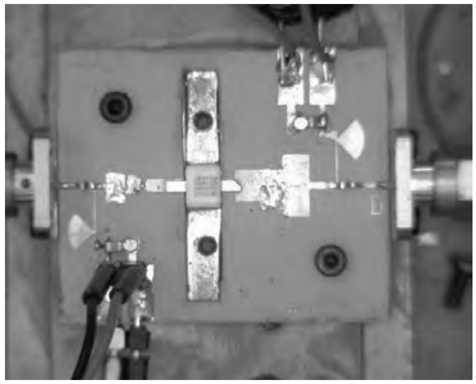


Fig.12: 5.7GHz PA using TriQuint T1G6003028-FS

Test frequency	5760 MHz
Small signal gain	14.7 dB
Power output	40.4 W
Power gain	12.2 dB
Drain Efficiency	55%
PAE	52%
Drain voltage	30 V
Drain Current (RF off)	200 mA
Drain Current (RF on)	2450 mA

12W on 10.4GHz

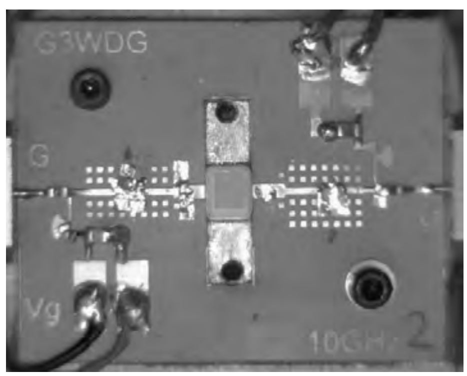


Fig.13: Early prototype 10GHz PA using a packaged 6GHz device

Test frequency	10368 MHz
Small signal gain	10.8 dB
Power output	12 W
Power gain	7 dB
Drain Efficiency	45%
PAE	36%
Drain voltage	29.5 V
Drain Current (RF off)	350 mA
Drain Current (RF on)	910 mA

Combining GaN PAs

The feasibility of combining two GaN PAs was investigated. A second 70W PA was constructed using a randomly selected Triquint T1G4005528-FS device (but with the same date code as the transistor in the other amplifier) , and assembled with the original PA and two branched-arm 90^{o} hybrids, to form a balanced amplifier, as shown in Figure 14.

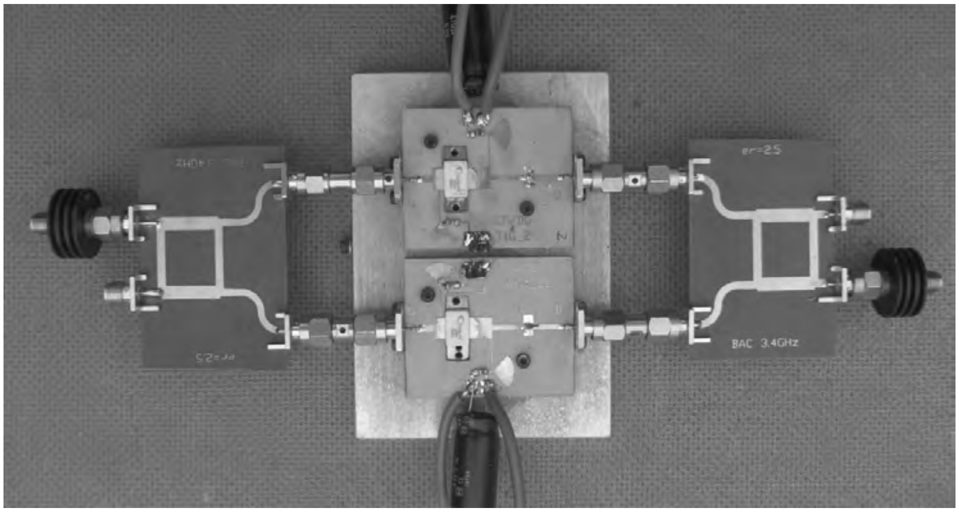


Fig.14: Balanced amplifier using 2 x 70W GaN amplifiers

The performance obtained from this configuration is shown in the table below.

Test frequency	3400 MHz
Small signal gain	15.5 dB
Power output	131 W
Power gain	13 dB
PAE	45%
Drain voltage	30 V
Drain Current (RF off)	400 mA
Drain Current (RF on)	9100 mA

Can a feedhorn be used as a heatsink?

One of the potential advantaged of GaN's high efficiency is to remove the need for large and heavy heatsinks, allowing the possibility of mounting the PA directly at the feedpoint. It occurred to me that it might even be possible to use the feedhorn itself as the heatsink under certain circumstances. To test this idea the prototype 3.4 GHz 25 W PA was mounted on the rear of a DJ3FI septum feed, as shown in Figure 15 (the photo shows the 70W PA). The feed is constructed out of relatively thick aluminium and some tests were performed to see if it could act as the heatsink for the PA. The PA was driven to 25W RF output (into a dummy load) and was dissipating 16W of heat. The amplifier was run for about 10 minutes until the temperature of the PA chassis had stabilized. A temperature rise of 23˚C above room temperature was measured. The thermal resistance of the horn was calculated as 23/16 = 1.44 ˚C/W.

For an ambient temperature of 15˚C and a maximum chassis temperature of 85˚C (typical of many devices) this means the feed would be and adequate heatsink for GaN PAs dissipating up to nearly 50 W continuously (or more under normal operating conditions with <100% duty cycle).

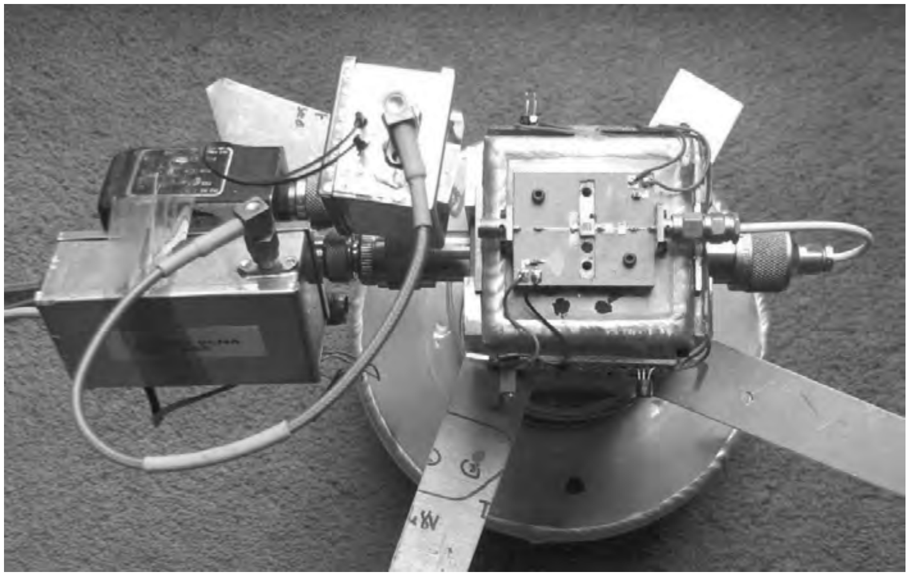


Fig.15: 70 W 9 cm GaN PA mounted on rear of DJ3FI feedhorn

EME results on 9 cm with a GaN PA

Having established the thermal resistance of the feedhorn as a heatsink, the 25W PA was replaced with a 70W output PA and tried out on-air. Good echoes were obtained, as shown below in Figure 16. On the following evening six QSOs were made using the GaN PA , and very good reports were obtained.

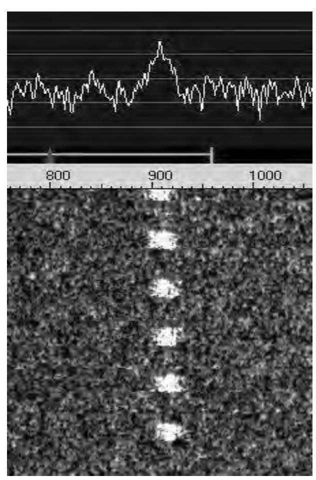


Fig. 16: EME Echoes obtained on 25 June 2012 using a 70W GaN PA and 10 ft dish

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5. http://www.cree.com/rf/products/gan-hemts/packaged-discrete-transistors/cgh55030f2-p2

SSPA Amplifiers for 6M, 2M and 432Mhz: Details and Construction Summary

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Columbus, IN

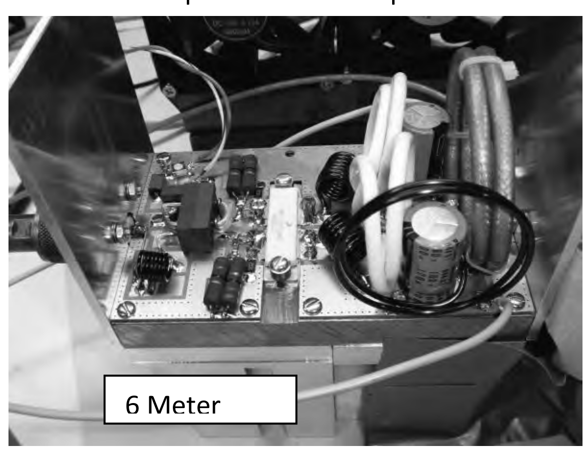
The "SSPA" RF amplifiers, based on the Freescale MRFE6Vx series of dual LDMOS transistors, has been a real boon to VHF/UHF builders. I have built 4 separate amplifiers; one each for 6 and 2 meters and two units for 70cm. This paper will provide a brief recap of the new SSPA RF amplifiers, my overall results and experiences and detail on construction and test methods and a bit of tweaking experience.

My first exposure to these amps was in DUBUS, 4/2012, which detailed a 1.2KW version for 50MHz. This article and the specs on the transistor were pretty exciting as it was, but to top it off, parts kits with circuit boards were available for all 3 bands from RFHAM in France. So I bought all 3. Since my French is really poor, I used Google Translate to write to them. They responded immediately (in English). I had the kits in 2 weeks. Transistors were purchased from DigiKey. At $265 for the 1.2KW version, these things are cheap. A 3CX1000 costs 3-4 times that much. And it can electrocute you. The transistor comes in 3 power levels: 1.2KW, 600W and 300W. I used the 600W ($160) version for all.

The RFHAM website has a link to the DUBUS article. Very useful.

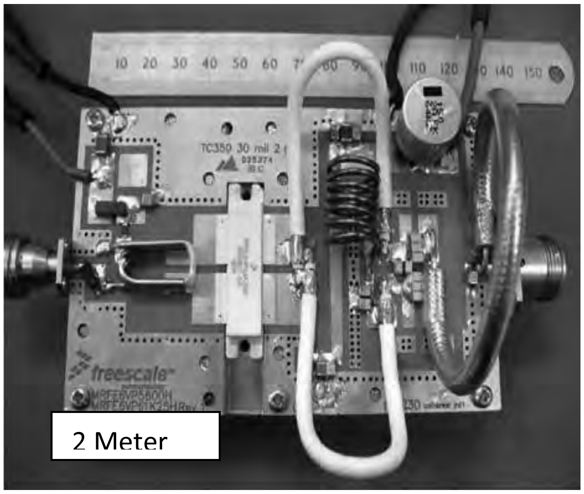
The boards are 3" x 5". The RFHAM versions use the same board for 6M and 70cm. A universal board makes some lumpy assembly in that several lines have to be jumpered with foil cut to the same width as the lines. But it works. The 2M board is a direct copy (or maybe the actual board) of the board shown by Freescale in a detailed article on how to make a 2M amplifier here: http://www.freescale.com/RFbroadcast . Look up the 2M amplifier in reference designs. Use this article as a construction guide.

The circuit boards are easy to build. The most cumbersome part of the whole construction process is the need for a copper heat spreader. These transistors are small; 2" long x .4" wide and simply cannot transfer enough heat directly to an aluminum heatsink. The transistor is either screwed or soldered to the copper block, then the block bolted to the heatsink. The block requires a 1mm deep slot milled for the transistor to bring the I/O leads flush with the circuit board. Any machine shop can do it. I did mine on a home milling machine. W6PQL sells pre-machined blocks. Soldering the transistor to the block is preferred and easier than it sounds. Set the transistor in place with a little flux and a squiggle of .020 solder, heat the block on a hot plate. As soon as the solder melts and the transistor settles, transfer the copper to a large heatsink to cool it quickly. Works. W6PQL has a nice video of the process.



6 Meter

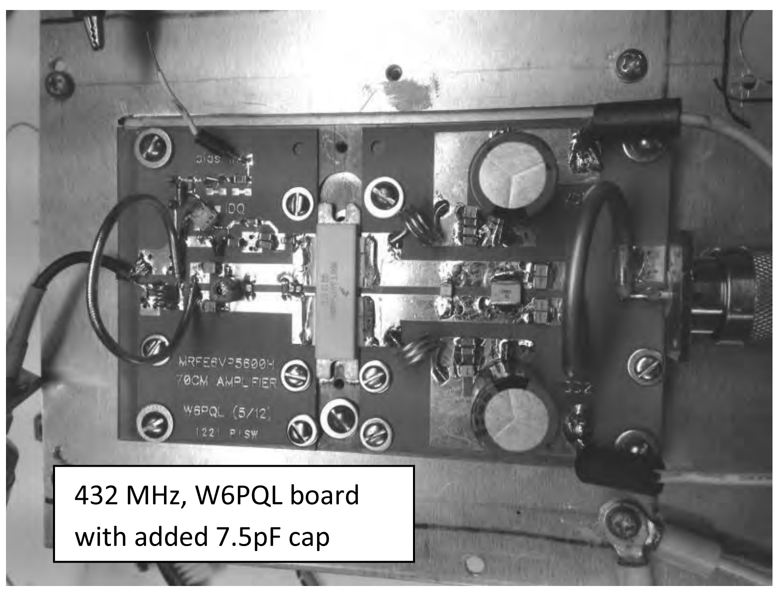
I built the 6M version first. It is a bit tedious to get the output transformers, which are made from coaxial cable, formed and attached correctly. Pay attention to the schematic as what end goes to what. Listed cable lengths are for the braid. It worked, first time.



2 Meter

The 2M version is by far the easiest to build. It's a 1-evening job once the parts are together. And it worked, first time, no tweaking.

The 70cm version (DUBUS 1/2012) was a bit more involved to assemble, and the lumpiest to make work properly. This board required flashing copper jumpers in the tuned lines. Also, the coax that serves as the output transformer works better at 10cm (shield length) instead of 11cm. The "standard" output tuning configuration uses a large 18pF chip cap (TEMEX CLX) and ceramic piston trimmer across the output lines. It works, but you may have to adjust the position of the large chip cap. As a construction technique, I move soldered chips with 2 soldering irons equipped with chisel tips, one on each side of the chip. Power off, of course. Internet research and a subsequent DUBUS article (2/2012) showed that others have had problems with this output arrangement. A preferred arrangement removed the large chip cap and replaced it with a series of 4 pcs 5.1pF ATC100B chips, standing on edge, starting 9mm from the transistor. I tried that; it also worked. But I wondered if I could come up with something better. And in the process of tinkering, I burned the output DC blocking caps and some trace right off the board. 900+ watts of DC will do that. The board was toast.



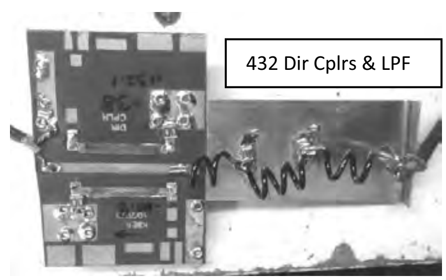
432 MHz, W6PQL board with added 7.5pF cap

Since I didn't consider the universal board a particularly elegant solution for 432, I found that W6PQL was selling his own version of the 70cm board. No flashing copper jumpers and simplified circuitry. Bought one. Easy to build. Used the same transistor. This is one tough device to be simply unfazed after the abuse I handed it. I didn't buy the kit as I have a pretty good junk box. Jim recommends 10cm shield length on the output coax. While I had burned the end of output transformer, it was simply 50 ohm coax. I used UT-141. Jim has gone through several iterations of output line tuning. His latest version uses a capacitor made from 10 ohm Teflon coax. Probably indestructible. Being fresh out of 10 ohm coax (I'd never even heard of 10 ohm coax), I used the well-used large 18pF chip from the original RFHAM package. I cleaned it; all the soldering and unsoldering doesn't seem to have hurt it. I placed the chip on the line as W6PQL specified. Board fired right up and worked. Jim's board has a revised input network. The best S11 (input return loss) I could get from the original RFHAM input network (I rewound the input coil several times) was about -10dB. The new input network (with a 10.5cm shield length input transformer) exceeded -25dB. Note that when measuring S11, the amp needs to be operating. Bias changes the capacitance of the transistor.

W6PQL strongly recommends adding a small inductor across the two input network lines at the transistor to prevent low frequency oscillation. My amp did not oscillate but I added it anyway.

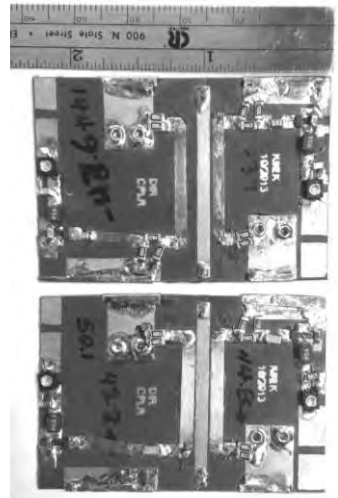
This package did well, putting out 550W with 19 Amp@48 VDC for 60% efficiency. And that was with 4 Watts in. Driven to full output by an FT-817. But can it do better? I took a 7.5pF ATC100B chip cap and pressed it against the board (bamboo skewers, again) and slid it along the output traces. It didn't affect the output power, but at the optimum point, current dropped to 17.5 Amps, raising the efficiency to 65%. Good enough.

All of these amplifiers have harmonic-rich outputs. Freescale states this as a normal condition. You must add low pass filters. I designed low pass filters with W7ZOI's LadPak design software, included as part of the ARRL RF Design book. Filter designs were tweaked so the 3dB point was the correct distance above the desired pass frequency to put the best return loss at the fundamental. For the 6M version, the -3dB point was 62 MHz. For the 2M version, it was 195 MHz. For the 70 cm version, it was 520 Mhz. The 6M filter used #12 house wire coils and capacitors made from .060 brass clamped to .010 Teflon on an aluminum plate. The 2M version used capacitors made from etched pads on Teflon circuit board. Note the tweaking with an Xacto knife. The 70cm version used paralleled ATC100B chip caps standing #16 wire coils above circuit board. All worked and none burned up.

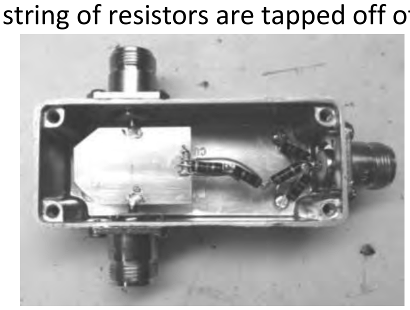


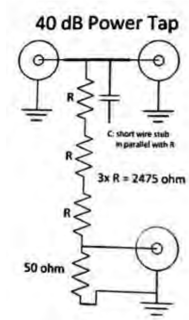
I packaged the 70cm amp with protection and sequencing circuitry, based on W6PQL designs. While I built my own low pass filters, forward and reverse directional couplers for output power monitoring and fault protection, I bought his sequencer/protection board. It is good value. His sequencer addresses a problem in most sequencer designs that only sequence relays. This board has a negative voltage generator that is part of the sequence. Most transceivers have an ALC input that can be used to inhibit the transmitter, even if the PTT is pushed. The ALC output on the sequencer board hooks right into the transceiver ALC input and makes sure that the transmitter does not transmit until all the other sequences are properly completed.

Output directional couplers presented a problem. I etched several on .032 Teflon board at various distances from the through line. The intent was to get a coupled signal level sufficient to allow on-board attenuators to provide enough signal to the diode rectifier to get required voltage for the output forward power and reflected power indicators. Nothing really worked right and I was tired of etching circuit boards. So I etched boards with all the attenuator and detection circuitry (shamelessly borrowed from W6PQL's schematic) but with 2 open 50 ohm printed lines, 1" apart, at 90 degrees to and approaching but not touching the through line. I then cut a .005" thick copper strip the correct width for 50 ohms, and slid it along the two 90 degree lines, changing the coupling distance to the through line. I did this under power, holding the copper with long bamboo skewers. Once I got a coupling that I liked, I soldered the ends of the moveable strip to the side lines, superglued it down and tested it again. This actually worked quite well. I did not measure the directionality of the couplers. Also, this DC voltage is fed back to the sequencer board and used to trigger the output fault (SWR protection) circuitry. That level is not critical as the sequencer board has an adjustment pot. I calibrated the reflected power level by transmitting into a paralleled pair of 50 ohm dummy loads. This 25 ohm load is 2:1 SWR, so I adjusted the protection circuitry trip point slightly beyond the 2:1 point.



Testing high-power transmitters is always a problem to us mortals with home labs. I stumbled onto a W7ZOI design for an attenuating line power tap. A string of resistors are tapped off of a 50 ohm through microstrip-type line. This 100:1 resistive divider gives a 40dB attenuator. It is flat within .5 dB from 10 MHz to 540 MHz. Extremely useful. A caution: build it with 3W thick-film resistors (DigiKey). I built my first one with 1/2W carbons and burned them up. Along with an HP 8478B power head. Painful lesson.





Although I verified testing with as many different power meters (2) and power heads (4) that I have, such measurements are always suspect. One can make the same mistake in several different ways. So, to verify that I was in the ballpark, I took an old oil-filled Cantenna, put a temperature sensor inside, then wrapped it in insulation. Its S11 is lousy at high freqs, so I used the 6M amplifier. Put a brick on the key for 6 minutes at the 340 Watt level (power supply limited at that point), then calculated the amount of power it would take to get the measured temperature rise from the measured oil quantity. I got a 24F rise and calculated that to require ~300 watts. Considering inaccuracies and inadequate insulation, etc. that number appears right in the ballpark. I should verify this with DC current. The conclusion is that there is nothing radically wrong with my other, less cumbersome power measurement techniques.

A note on power supplies: while 48VDC at high amps seems hard to get, in reality it is cheap and easy. Use the HP DPS-2500AB computer "blade" server power supply. This long, skinny wonder is rated at

51VDC @ 39 Amps out and is nearly indestructible. It runs on 200-240VAC, 50/60Hz. And costs <$40 on eBay. A note: How to wire these things is not well documented. This works: The two solder-jumpered pads (there is a slit between them) in the picture of the underside are an Enable circuit. You can connect those through a toggle switch (milliamp power) to switch the DC output on or off. In the OFF (open) position, the PS goes into standby, the output turns off immediately and the cooling fan slows down. The DC output should be connected to pads on both sides of the strip as should the AC input. No other connections are required.

Great, fun project.

www.rfham.com (kits & all three DUBUS articles available here)
www.freescale.com/RFpower (2 meter version is very well documented)
www.w6pql.com (many devices & sophisticated output protection circuitry. Excellent)
www.f1te.org (don't let the French language scare you off; great stuff here!)
www.f5cys.eklablog.com
www.vk4dd.com
www.qsl.net/f1jrd/
www.nd2x.net/k8cu-lpf.html
http://w7zoi.net/Power%20meter%20updates.pdf (notes on -40dB power meter tap)
http://www.arrl.org/files/file/Product%20Notes/Experimental%20Methods/Ladpac-2008(1).zip (LadPac RF design program for filters, etc.)
www.communication-concepts.com (2M amplifier kit)

A GPS Disciplined Oscillator Utilizing a Modern GPS Module

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***Abstract* — A GPS disciplined 10MHz oscillator development was undertaken to provide an accurate frequency standard for my lab equipment. A frequency locked loop approach was used with a modern GPS module providing a 1 pulse per second signal with 10ns RMS accuracy. A PIC32MX microcontroller was used to implement the FLL and user interface.**

***Index Terms* — GPS, GPSDO, 10MHz, FLL, PIC32.**

I. Introduction

Most commercial test equipment and some modern radios provide the capability to lock their internal timebase oscillators to an external timebase signal. Usually the internal timebase oscillators in these products are temperature compensated crystal oscillators (TCXOs) or oven controlled crystal oscillators (OCXOs) which are calibrated at some point in time. Crystal aging and changes in temperature result in drift from their calibration frequency. Since the frequency synthesis phase locked loops and direct digital synthesizers in these products use the timebase oscillator signal to develop their references or clocks, an error in the timebase frequency results in instrument frequency accuracy degradation.

After feeling the need for an accurate frequency standard for my test bench for several years and not finding a good enough deal on eBay for a Trimble Thunderbolt or HP Z3805A, I happened to see an advertisement from Mouser Electronics for a new GPS receiver module from Linx Technologies. What got me interested was the accuracy specification on its one pulse per second (1PPS) output signal. Most specs I had seen for other GPS receivers available on eBay were in the 100ns to 1us range. The Linx RXM-GNSS-GM receiver was specifying its 1PPS accuracy at 11ns. I found the specifications for the chipset used in this receiver and the chipset manufacturer was specifying the 1PPS accuracy at 10ns RMS. This sounded pretty good, and the price in single unit quantities at Mouser was $31.88 so I decided to build my own GPS disciplined oscillator.

Besides wanting to end up with a good quality GPS disciplined oscillator, I had several other goals in mind when I launched this project. First, I wanted to get some experience with the DipTrace[1] PCB design software I had decided would be my main PC design software package. Second, while I have had quite a bit of experience using Microchip Technologies 8-bit micro-controllers programmed in assembly language, I wanted to get some experience using the PIC32MX family of microcontrollers with the firmware written entirely using the C programming language. Finally, I wanted to get as many parts as possible from my fairly well stocked junk box.

II. Design Approach

The block diagram of my GPS disciplined oscillator is shown in Figure 1. This implementation is similar to others which have been documented[2] in that it uses the 1PPS signal from a GPS receiver to develop gate periods which are used to count the timebase signal frequency using a timer peripheral in the microcontroller. Frequency errors so determined are then used to adjust the tune voltage applied to the oscillator tune port to bring the oscillator frequency to the desired frequency (10MHz.) My approach differs in that extra attention is paid to minimizing power supply and load induced drift in the OCXO, as well as maintaining the integrity of the OCXO phase noise and spurious performance.

A. Oscillator Power Supply and Buffering.

To avoid drift due to variation in the supply voltage of the OCXO, a three terminal regulator (LM317MBDT) was used to develop the +12V required by the oscillator and the first buffer amplifier. The LM317's temperature stability is not that great, about 56ppm per degree C. This was improved to about 3ppm per degree C by referencing the regulator output to a high stability AD586 voltage reference. Appropriate noise filtering was used to keep the noise level on the supply as low as possible (approximately 100nV/rtHz).

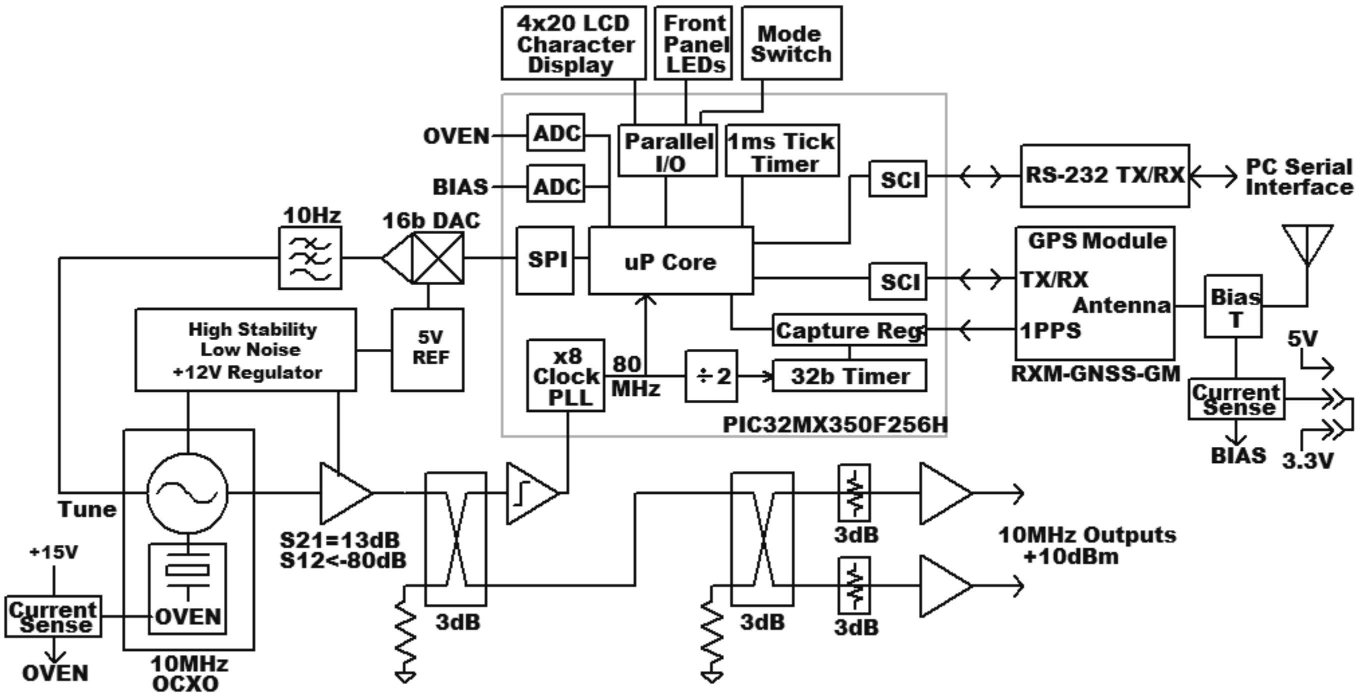


Figure 1. GPS Disciplined Oscillator Block Diagram

To avoid output load induced frequency shifts a high isolation cascode amplifier buffers the output of the OCXO. The power supply for this amplifier is the same as that for the OCXO. The 10MHz output amplifiers are on a separately regulated supply (another LM317MBDT which is not referenced to the high stability voltage reference.) Hybrid splitters are used to provide some isolation from output to output. Total reverse isolation from the 10MHz outputs back to the OCXO output is in excess of 100dB.

B. Avoidance of Spurious Signals

To avoid a possible source of spurious signals and to reduce the number of clock domains, I decided to develop the microcontroller clock from the OCXO frequency rather than use an unrelated clock frequency. The PIC32MX processor family has a PLL clock multiplier which can be used to increase the clock frequency. In this implementation the 10MHz timebase frequency is multiplied to 80MHz to provide the system clock for the microcontroller core. The 80MHz clock is then divided by 2 to 40MHz to provide the clock which is used by the microcontroller peripherals. This 40MHz clock is what is counted to determine the OCXO frequency. Counting 40MHz instead of 10MHz has the advantage that OCXO frequency measurement resolution is increased by a factor of 4. For example a 1 second gate time can resolve the 10MHz OCXO frequency to 0.25 Hz instead of the 1 Hz which would have resulted if 10MHz were counted directly.

C. Tuning Resolution

An external (to the microcontroller) 16-bit digital to analog converter is used to develop the tune voltage for the OCXO. The amplifiers and filters following the DAC were designed to support two different OCXOs. One is a board mounted oscillator from my junk box made by Vectron and the other is an HP10811D. Both support 10V tune ranges with the Vectron requiring a 0 to 10V range while the 10811 requires a -5V to +5V range. A jumper selects which range is provided.

The Vectron OCXO has a tune sensitivity of 3.5Hz/Volt. The 16-bit DAC provides a tuning resolution of about 530 micro Hz which represents 53 parts per trillion (5.3e-11). The 10811D has a tune sensitivity of about 0.25Hz/Volt so the tuning resolution is about 4 parts per trillion (3.8e-12). Both should be sufficient for my needs.

D. GPS Module Interface

The GPS receiver module interfaces with the microcontroller through a serial two-way data link (TX/RX) and the 1PPS signal. The serial data connection is used to configure the GPS module and to receive data from the module. As I have it configured, the data received includes time, position, velocity and the number of satellites being used in the GPS solution (NEMA GGA and GLL messages). This data is delivered once per second via one of the microcontroller's serial communications interfaces.

The 1PPS signal drives one of the microcontroller's capture inputs. When a rising edge happens on 1PPS, the value of a free running 32-bit timer (counter) is captured. This timer is counting the 40MHz peripheral clock. Since the 1PPS signal is not truly synchronous with the 40MHz clock, it must cross clock domains and this can result in a possible 1 count error when the 1PPS and clock edges are nearly coincident.

E. PC Interface

Another of the microcontroller's serial communications interfaces is used to provide an RS-232 connection to an external computer. This interface can be used to log data and control the instrument remotely. It isn't required for normal operation.

F. Front Panel User Interface

The front panel user interface is fairly simple. A 4-line by 20-character LCD display module is used to present data relating to the operation of the system or data from the GPS receiver. Two LEDs indicate the presence of a good 1PPS signal from the GPS (1PPS is only present when the GPS has a 3D position solution) and if the firmware frequency lock loop (FLL) is in its tracking state. A single push button allows selection of the data being displayed on the LCD as well as a means to switch the operating mode to fix the DAC setting so that the OCXO frequency can't change abruptly during sensitive measurements.

G. Diagnostics

The microcontroller monitors the OCXO oven current and the GPS active antenna bias current. This information is displayed on the LCD display. The oven current is also used at power-up to delay the system from trying to correct for large oscillator frequency errors when the oven is cold. For example, the Vectron OCXO at a cold start is about 350Hz off frequency. If the system were to try to correct for this error, there would not be enough tune voltage range available to correct for the error. At a cold start, the oven draws approximately 450mA. This drops to about 62mA (at an ambient temperature of 68F) when warm and stable.

III. Construction

A. Printed Circuit Board

A 4x6-inch two-sided FR-4 printed circuit board was fabricated utilizing mostly surface mount components. Exceptions include larger value aluminum electrolytic capacitors and some film capacitors used where settling time and microphonic performance are important (ceramic capacitors with X7R dielectric can develop piezoelectric potentials). The loaded board is shown in Figure 2. With the exception of a few bypass capacitors near the OCXO and the microcontroller, all components are on the top side of the board. A solid ground plane is used on the back of the board. Some backside jumper wires are used to route DC power to sections of the board to avoid cutting the ground plane. The jumper wires were preferred over going to a 4-layer board for cost reasons.

The RJ-11 connector just to the right of the microcontroller is used to connect the Microchip ICD3 in-circuit programmer/debugger to the board for development purposes.

A fair amount of LC filtering on the power supplies is provided since the board is powered from an AC/DC switching power supply. The 6-pin molex connector in the upper right on the picture is the connection to the switching supply. Care was taken to make sure switching noise stayed off of the ground plane and away from sensitive circuitry. The filter capacitor grounds return to the power supply cable ground directly through a path independent of the ground plane under the rest of the board.

B. Chassis and Enclosure

Having worked for HP and Agilent before I retired, I have been partial to the HP system II cabinets into which we designed our products. Many trips to the junk bins over the years resulted in a collection of parts I am still using. Figure 3

Figure 2. Loaded GPS disciplined oscillator PC board

Figure 3. GPSDO board installed in the System II cabinet

shows the GPSDO board mounted in a System II cabinet that is 8.5”x3.5”x10.5” (WxHxD).

Airflow in the cabinet is restricted to the power supply section. A small fan is mounted on the rear panel to pull air over the power supply heat sinks.

To avoid air currents causing fluctuating ambient temperatures in the vicinity of the OCXO, a wall is placed between the power supply and GPSDO sections of the enclosure. All heat from the GPSDO board is conducted to the chassis by the mounting screws which are placed near the major heat sources.

C. Front Panel

Figure 4. Front panel view of the GPSDO.

I decided to bring the 10MHz signals out the front panel because I have routed most of the timebase inputs for my various pieces of test equipment to the front of the racks in which the equipment is mounted. Another consideration was that the rear panel access is a bit limited due to the proximity of the power supply.

D. Rear Panel

The rear panel is shown below in Figure 5.

Figure 5. Rear panel view of the GPSDO.

IV. Operation

The microcontroller must handle multiple simultaneous processes during operation of the GPSDO:

1. The frequency locked loop process to control the OCXO frequency.
2. Capturing and parsing data messages from the GPS receiver module.
3. Receiving, parsing and responding to PC serial commands.
4. Recognizing, de-bouncing and responding to user interaction from the front panel mode push button.
5. Monitoring oven and antenna bias currents, and in the case of the antenna bias current, shutting it down if excess current is flowing.
6. Updating the LCD display.
7. Controlling the LED indicators.

To handle all of the processes simultaneously a series of state machine routines were created. These routines get called, one after another, every time a tick timer fires an interrupt. The tick timer fires once every millisecond so the jobs these processes require must be broken up into states that can execute in fractions of a millisecond. This might sound like quite a challenge but the PIC32MX microcontroller is pretty fast. In my implementation, I dedicated a parallel I/O line to be an indicator that goes high at the start of the loop that calls all of the state machines and then goes back low after all of the state machines have finished running and the processor is waiting for the next tick. On most ticks, the indicator is only high for about 5 microseconds. The longest period of activity occurs as the data from the GPS module is being parsed and a large number of internal variables updated. In this case the indicator is only high for about 80us. In this case the processor is only 8% loaded at the 1ms tick rate. Writing to the LCD display takes about 43us per character (limited by a relatively low frequency clock in the display module) so the LCD state machine only writes a single character to the display each 1ms tick. Even at this slower rate, it only takes 80ms to write the entire display and no discernable delay can be seen as the display’s optical response time is typically 120ms.

A. OCXO Frequency Control

There are six states defined for the timebase frequency lock loop (FLL) state machine. These are:

1. INIT: This state initializes the variables associated with the state machine and transitions immediately to the WAIT state.
2. WAIT: This state watches the 1PPS signal and the OCXO oven current. The exit criteria for this state are that there have been at least 16 consecutive good 1PPS periods and the oven current must be below the warm threshold defined for the OCXO in use. When these criteria are met, the machine state transitions to the SLEW state.
3. SLEW: This state makes coarse adjustments to the OCXO frequency based on one second measurements of frequency. The state machine stays in this state until the measured frequency error is zero for four consecutive one second measurements. An error of one count represents 0.25Hz error at 10MHz so by the time this state is exited the error is less than 0.25Hz. When the coarse tuning is complete the state machine transitions to the TRACK state.
4. TRACK: This state is where the state machine spends most of its time. While in this state, measurements at gate times of 1, 16, 64, 256, 1024 and 4096 seconds are made concurrently. Thresholds are set for each of the measurement durations. When an error is above a threshold, the setting of the tune DAC is changed to correct the frequency error and all measurements restart after a 2-second settling delay. There are two sets of thresholds. One is used if the measurement causing the change is the longest measurement to complete and the other is used if a shorter measurement sees an error after a longer measurement has completed (e.g. if a sudden shift in frequency is detected.) The TRACK state will transition to the HOLD state if an interruption in the 1PPS signal is detected or if a bad 1PPS period is detected (see more on bad 1PPS detection below.) User interaction (via front panel or PC serial) also can cause the TRACK state to transition to the FIX state when it is desired to prevent any changes in the tune voltage DAC.
5. HOLD: This state is entered when something unusual happens – usually something with the 1PPS signal. The state machine will stay in this state until 16 consecutive valid 1PPS signals are detected. When this occurs, if the 1 second measurement is within 0.25Hz the state machine will transition back to the TRACK state. If the 1 second measurement error is greater than 0.25Hz the state machine will transition to the SLEW state.
6. FIX: This state is usually entered as a result of a user request to fix the DAC setting while a sensitive measurement (e.g. phase noise measurement) is running. It can also be entered if a serious error occurs (e.g. a DAC number setting that is beyond the range of the 16-bit DAC.) This state can only be exited via user interaction, and when exited the state machine returns to the INIT state.

Since the determination of OCXO frequency depends entirely on the accuracy of the GPS 1PPS signal, the system must detect when there are problems with the 1PPS signal. This is done in two ways. First, a determination of missing 1PPS pulses is done by counting the number of tick timer (1ms) ticks between rising edges on 1PPS. Since the tick timer and the 1PPS signal are asynchronous, the 1PPS is determined to be present if the number of ticks between pulses is 999, 1000 or 1001. Once the state machine has entered the TRACK state, the OCXO should be adjusted to better than 0.25Hz accuracy. The OCXO frequency is computed every second (every period of 1PPS) so if the 1 second frequency measurement is off by 0.5Hz or more ($\geq$ 2 count error in one second) the 1PPS signal is determined to be bad and the state transitions to HOLD to wait for the 1PPS to become good again. The system keeps track of these errors and they can be displayed on the LCD display. I must state that once the state machine has entered the TRACK state, I have NEVER seen a single error reported. The 1PPS specification of 10ns RMS seems to really be true! The only 1 second measurement errors seen are due to the coincidence of the 1PPS rising edge and the 40MHz peripheral clock rising edge. When one of these errors occurs on one 1PPS period (say +0.25Hz) the next period has the opposite error (−0.25 Hz). I have never seen two errors of the same sign occur consecutively while in the TRACK state, and they always occur in +/− pairs.

B. LCD Display Information

One piece of information I have always wanted to see on a GPSDO is an estimate of the current accuracy of the oscillator. Of course the only reference for such an estimate is the GPS 1PPS signal. Even so it is useful to know how accurately the oscillator has been adjusted to that standard.

Currently I have three different sets of data presented in the LCD display. The default power up set of data shows the FLL state machine data, GPS mode, the number of satellites being used in the solution and the oven and antenna currents. An example of this display is shown in Figure 6.

Figure 6. Default data display

The GPS data screen is shown in Figure 7. The velocity data (labeled V:) is only there so I can see if the GPS solution is stable (not moving!)

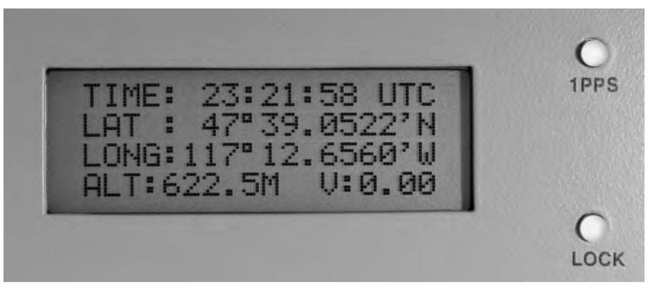


Figure 7. GPS data display

The final display, shown in Figure 8, contains some FLL state machine data along with the 1PPS error count and the most recent 1 second frequency error measurement.

Figure 8. 1PPS error / 1sec freq error display

Accuracy values can be positive, negative or prefixed with ‘<’. The sign indicates the direction of the error while a number prefixed with the less than sign indicates that there was no error in the count whatsoever. Note from Figures 6 and 8 that the FLL has reached an error smaller than the tune step size (Vectron OCXO step is 5.3E-11).

C. LED Indicators

The two front panel LED indicators (1PPS and LOCK) were added to make it easier to see if the GPSDO is operating normally from across my lab. If both LEDs aren’t illuminated I will walk over and investigate further using the LCD data. The lock LED probably should have been labeled “TRACK” but my dry transfer label set didn’t have that word and “LOCK” was close enough…

V. PERFORMANCE

A. Phase Noise

I measured the phase noise of the 10MHz outputs using an HP11848A phase noise interface, an FFT analyzer, and some software of my own design which has most of the features of the HP3048 phase noise measurement system. The GPSDO was warmed up and operating in its locked state. The reference source was an HP10811D which has better phase noise specifications than the Vectron OCXO mounted on the GPSDO printed circuit board. Table 1 shows the specified noise from the OCXO data sheets as well as the noise level measured.

Offset	Vectron OCXO	HP10811D	GPSDO Measured
1Hz	No Spec	-100 dBc/Hz	-92.2
10Hz	-120 dBc/Hz	-130 dBc/Hz	-122.8
100Hz	-140 dBc/Hz	-150 dBc/Hz	-144.4
1kHz	-145 dBc/Hz	-157 dBc/Hz	-151.9
10kHz	-150 dBc/Hz	-160 dBc/Hz	-154.4
100kHz	No Spec	No Spec	-155.9

Table 1: OCXO Phase Noise Specs and measured values

The actual phase noise plot is shown in Figure 9. I have added slope lines to the plot to identify the floor, 1/f, and $1/f^3$ regions. The amplifiers that follow the OCXO should exhibit a noise floor near -170dBc/Hz so the measured noise is mostly the OCXO here. The OCXO’s oscillator or buffer amplifier has a 1/f corner in the vicinity of 1.5 kHz. The transition between 10dB/decade and 30dB/decade occurs at about 40Hz. This is the half bandwidth of the oscillator resonator so the operating Q of the crystal is about 125,000.

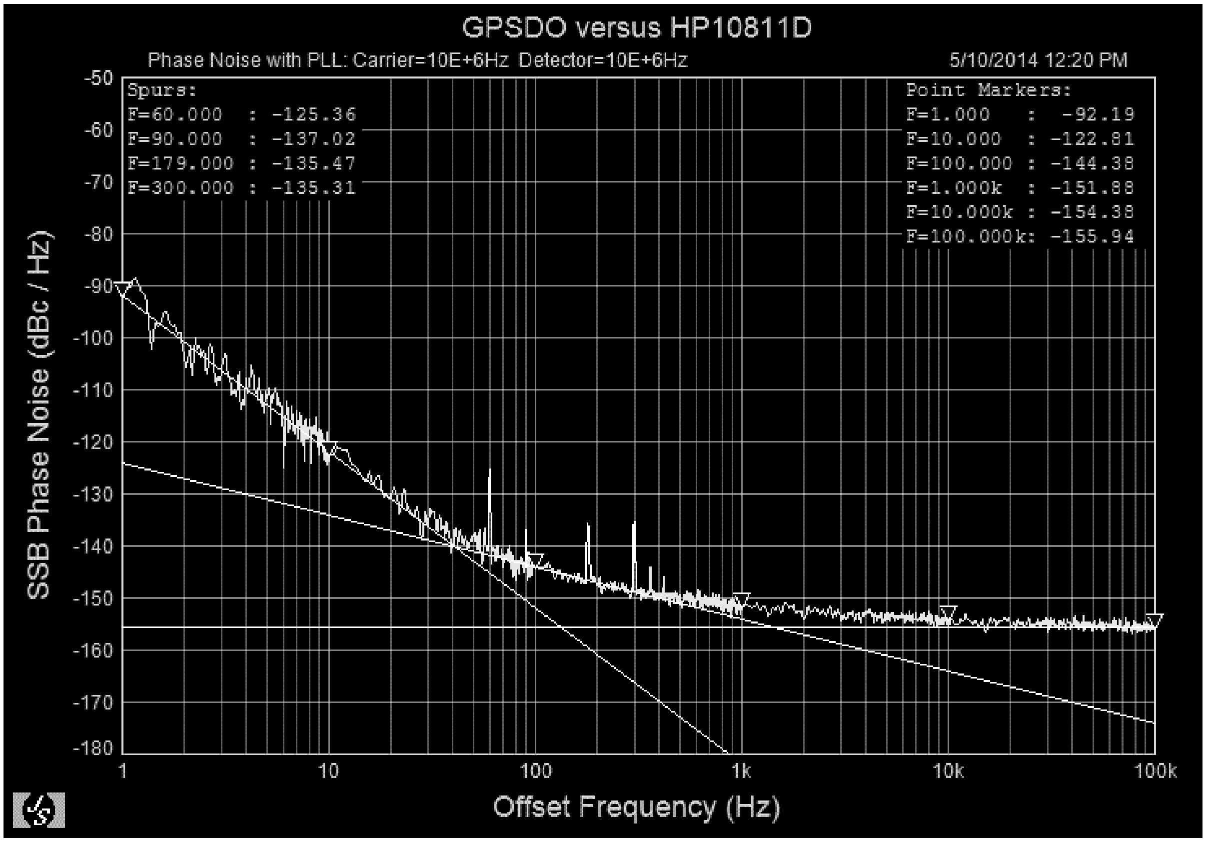


Figure 9 GPSDO output phase noise.

B. Spurious Signals

Spurious performance is fairly good. Most of the spurs are odd harmonics of the 60Hz line frequency and I know that my measurement system has some flux leakage from its DVM and counter into the 11848A which may account for some of the line-related spurious. I suspected that the 90Hz spur could be related to fan vibration but I didn't have the foresight to put a switch on the fan so I could turn it off and the spur is low enough that I didn't feel motivated to unsolder a wire to find out. As I was writing this paper I realized I had another diagnostic tool at my disposal – my computer sound card. I recorded the fan noise and calculated an FFT on the resulting data. The result is shown in Figure 10. There are two major components here. One is definitely at 90Hz and the other at 450Hz. Not surprisingly, the fan has 5 blades and the majority of the noise from the fan is being created by the fan blades passing near the support struts for the fan motor at a rate 5 times the rotation rate. An imbalance in the fan will create vibration at the rotation rate of 90Hz (5400 rpm) and no doubt the fan current drawn from the +5 supply will also have a component at the rotation rate. Due to the filtering and regulation on the supplies, I suspect the main spur mechanism in this case is the fan vibration modulating the OCXO microphonically.

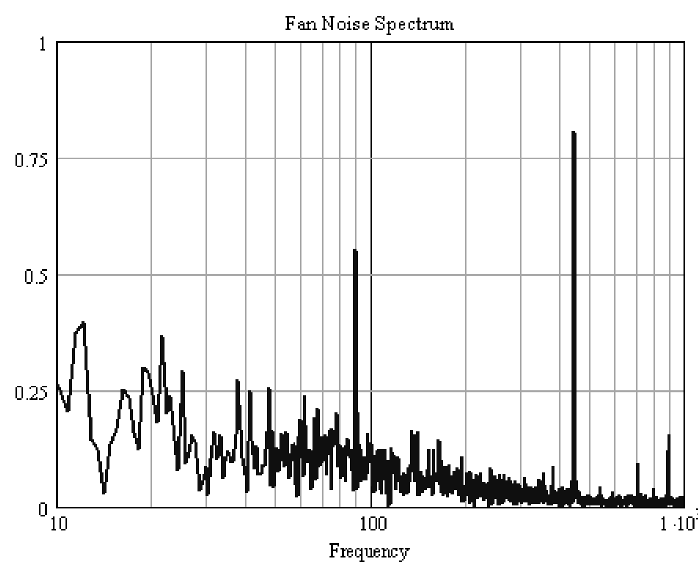


Figure 10. Fan acoustic noise spectrum

The Artesyn NFS40-7610 switching supply, which powers the GPSDO, uses a switching frequency between 20 kHz and 100 kHz. It would appear from the phase noise plot that the supply filtering is sufficient to prevent spurious signals from this source.

C. Frequency Accuracy and Stability

Of course the main horsepower performance specification for a GPS disciplined oscillator is frequency accuracy and stability. I haven't been a member of the Time-Nuts group so I haven't (yet at least) put an Allan Variance measurement capability into my phase noise software. I have no access to Cesium or Rubidium references. Thus my data in this area is, to say the least, a bit thin.

What I have done is to look at the carrier frequency of WWV at 10MHz using a receiver in CW mode with a signal generator locked to the GPSDO generating a CW tone several Hz away from 10MHz. Then I digitized the audio from the receiver and analyzed it with the Spectrum Lab[3] software package. This has given me confidence that the GPSDO is operating as intended, however I am not within ground wave range of WWV and, as a result, shifts in the ionospheric propagation path result in Doppler spreading of the WWV carrier signal which makes measurements closer than about 10 mHz difficult (with my experience level at least).

As I was finishing this project the April ARRL frequency measuring test was held. I decided to give it a try since I now had an accurate frequency reference with the GPSDO. As a rookie I was able to take second place. Those FMT guys are pretty serious about measuring frequency so I guess my path's Doppler conditions must have been better (Oklahoma to Spokane) than those for the propagation paths to the more experienced FMT guys.

D. Output Level and Harmonics

The two front panel outputs were designed to deliver +10dBm (1V peak) into 50 ohms. One output ended up at +10.1dBm and the other at +9.7dBm. I used standard value capacitors in the 10MHz LC hybrid splitters and the split wasn't exactly equal between the two output paths at 10MHz. The harmonic performance for one of the outputs is shown in Figure 11. (The other output's performance is essentially identical.) The second harmonic is greater than 40dB below the fundamental and the third is better than 65dB below the fundamental.

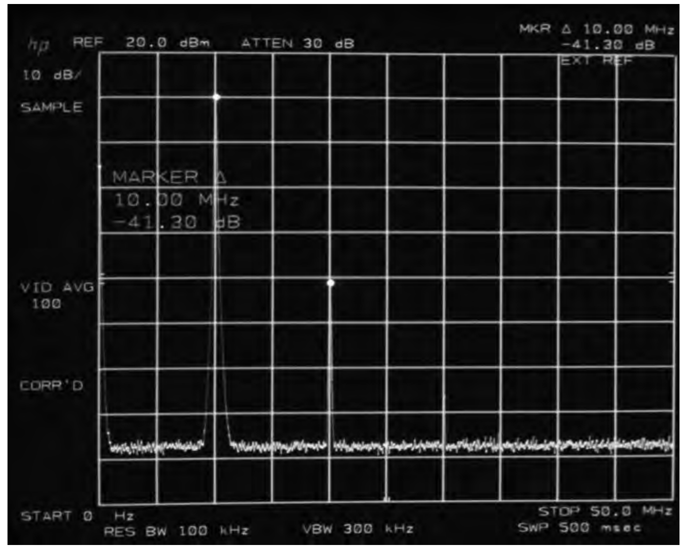


Figure 11. Harmonic performance at 10MHz output

VI. Conclusions

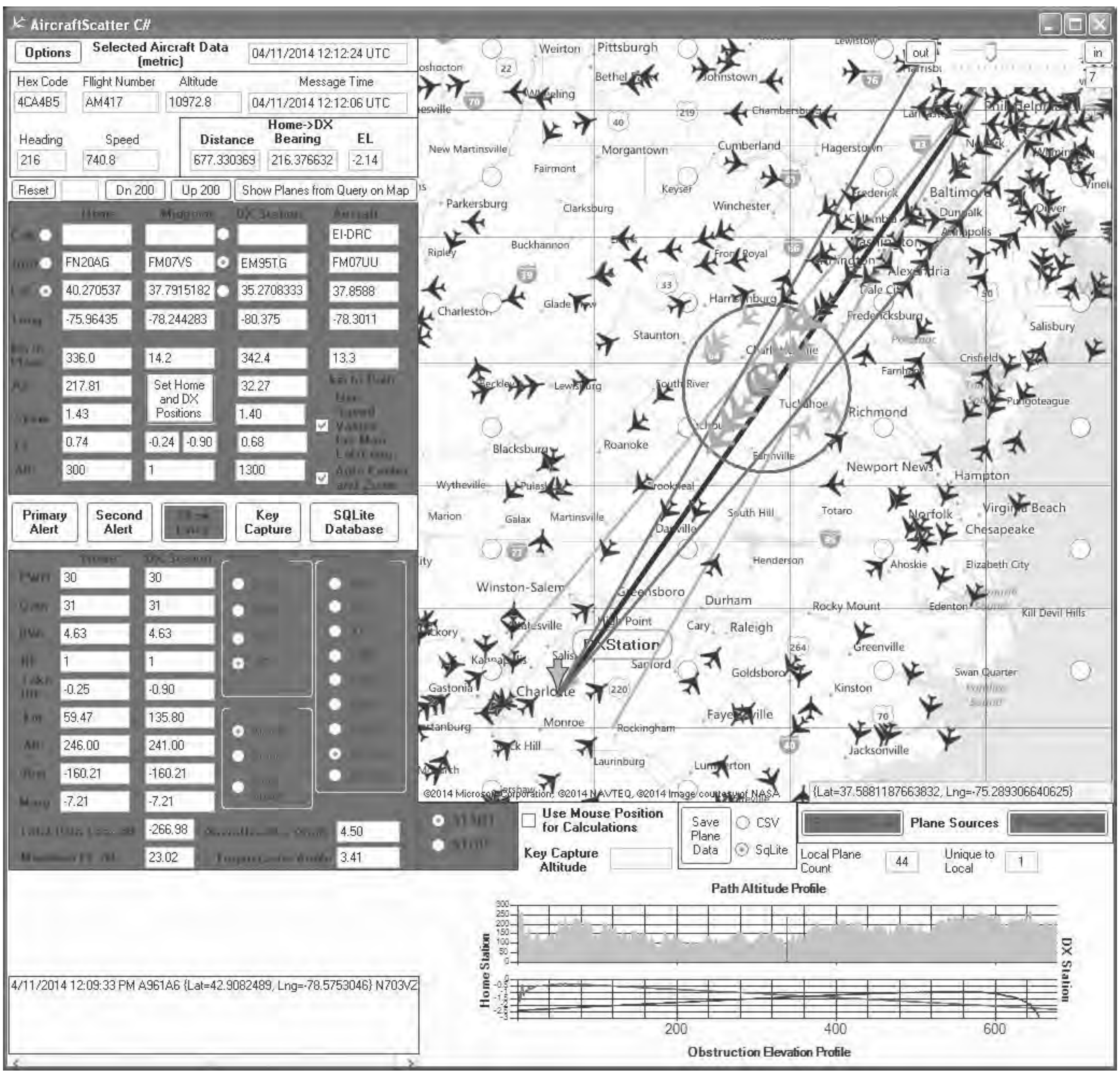
This project has been very successful when measured against my original goals. I became very familiar with DipTrace schematic, layout, and library part creation and the PC board was successfully fabricated from Gerber and Exelon files at Advanced Circuits[4] in Colorado. The board was loaded by hand using a Metcal soldering iron under a stereo microscope and it turned on and worked as expected. Firmware development using Microchip Technologies free development tools (MPLAB X IDE and the XC32 C compiler) went smoothly and the ICD3 (not free) integrated with the board without any problems. Most of the parts came from my junk box but I did have to order the GPS module, the PIC32MX microcontroller, the LCD display module and a few other SMT components. Most importantly, I think the GPSDO instrument that was developed will suit my needs in the lab quite nicely.

References

[1] Go to www.DipTrace.com for a description of the DipTrace PC layout software.
[2] Bertrand Zauhar, "A Simplified GPS-Derived Frequency Standard," QEX, pp. 14-21, Sept/Oct 2006.
[3] Spectrum Lab software by Wolfgang Buscher DL4YHF Go to www.qsl.net/dl4yhf/spectra1.html for more information.
[4] Advanced Circuits web page: www.4pcb.com

AircraftScatter Sharp

A Windows program to assist with aircraft-scatter by Roger Rehr, W3SZ



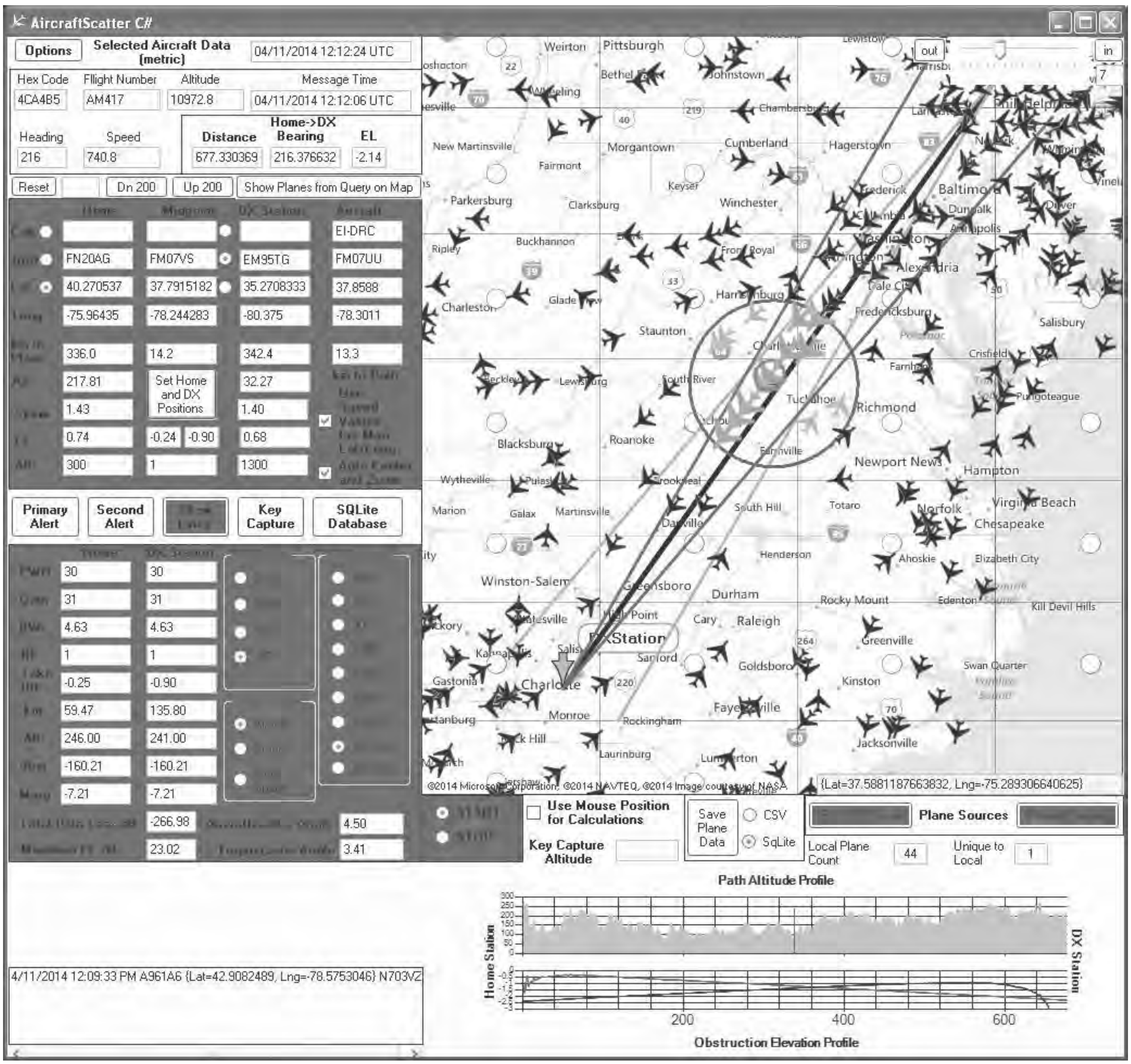
AircraftScatter Sharp is a new program that I wrote using C# to assist those wanting to do aircraft scatter work. It is an improvement upon and an extension of the software I had previously written to work with PlanePlotter. Unlike the old program, AircraftScatter Sharp requires no auxiliary programs, but runs as a stand-alone program. It has several important capabilities:

1. Real-time capture and display of plane position data derived from internet servers, from a local RTL1090 server, or both
2. Display of the direct path line between two stations, along with skew lines to allow a quick assessment of the angular deviation of an aircraft position from the direct path line for both stations, and a midpoint circle to show when an aircraft is within a specified distance from the midpoint of the path. Path altitude and elevation/obstruction profiles are also shown.
3. Highlighting of aircraft near the ideal position for "reflection", based both on distance from the midpoint of the path as well as angular deviation from the path
4. Real-time calculation of path loss/received signal at both locations based on plane location and user-adjustable station parameters, using either bistatic aircraft scatter, troposcatter[1 2] or free path formulas
5. An integrated SQLite database that allows you [1] to save information on all planes appearing on your screen for however long you want [minutes, hours, days, weeks, months] and [2] to then analyze that data to determine when aircraft scatter opportunities will most likely occur. You can analyze the data without interrupting its collection, and powerful SQL search functions are automatically included and easily selectable using only mouse-clicks to generate the SQL query statements. There is no need for the user to know the SQL query language. The program takes care of all of that behind the scenes.

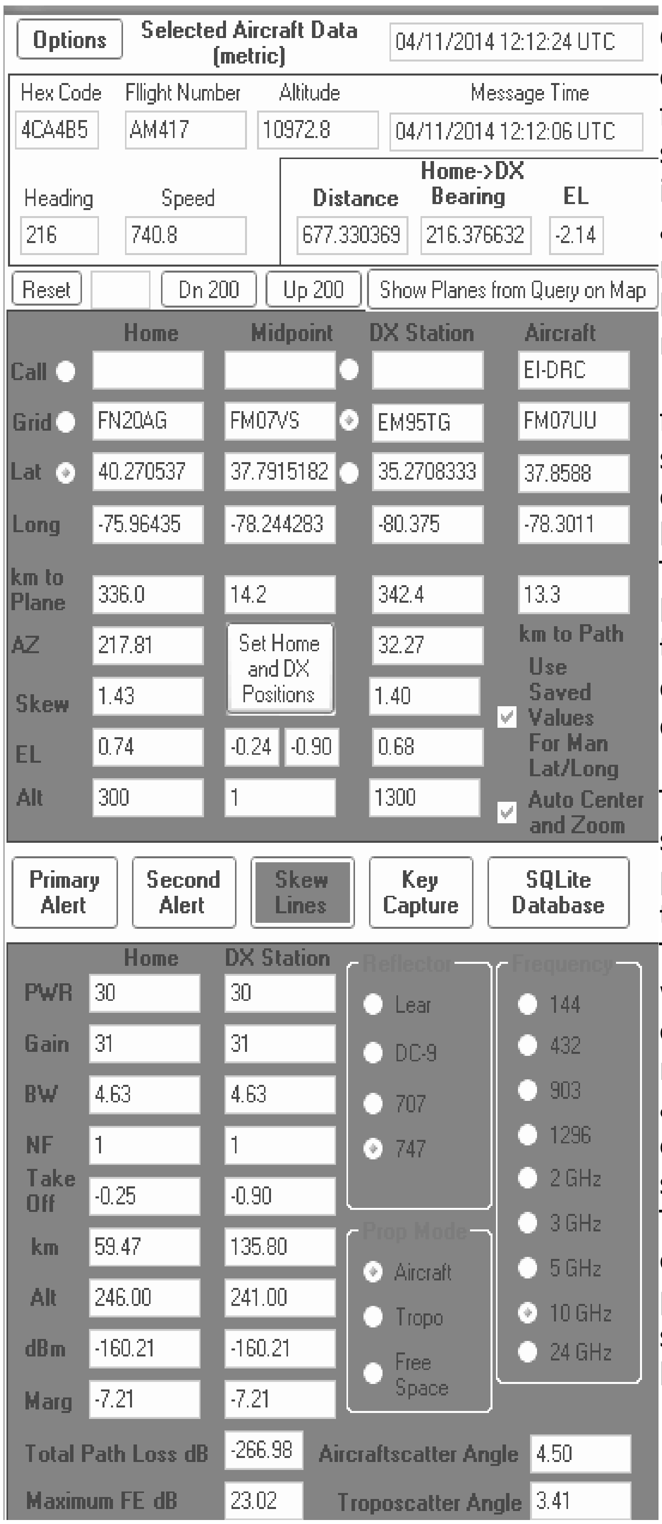
This last piece described above, the SQL database, provides what has been missing from previous aircraft-scatter software (except for my earlier program mentioned above, which also included this feature). For EME we have software predictors of when the moon will be "available" to us as a reflector. For rain-scatter we have RainScatter, by Andy Flowers, K0SM[3] to give us this information. But there has been nothing similar for aircraft scatter until now.

Below I will describe the program in some detail. For "Getting Started" instructions on installing and using it, go to the appendix.

AircraftScatter Sharp's main form, shown below, has a map on the right side of the form which contains a real-time display of all aircraft downloaded from the server[s]. The aircraft icons shown on the map accurately represent aircraft positions and headings. Planes from the internet server as shown in black, red, or green depending upon their position, and planes from the local server are shown in brown. Below the map is a path altitude profile and a path elevation profile for the path between the home and DX stations. On the left is the data and calculator area. The path between W3SZ and W4DEX shown on the map has been selected by entering the appropriate 6 digit grid square for W4DEX, and entering latitude and longitude directly for W3SZ into the text boxes on the left. This causes the direct path line, the skew lines, and the midpoint circle to be drawn on the map along with markers and labels for the Home and DX stations. If grid square is entered, latitude and longitude are calculated, and vice versa, as determined by user selection. The program also contains the call3.txt file and can use it to supply grid information for stations included in it. New stations can be added to it via this program. Thus you can also enter position information for either the Home or DX station by typing that station's call. The path altitude profile will only appear if SRTM3 data files have been installed[4] [5].

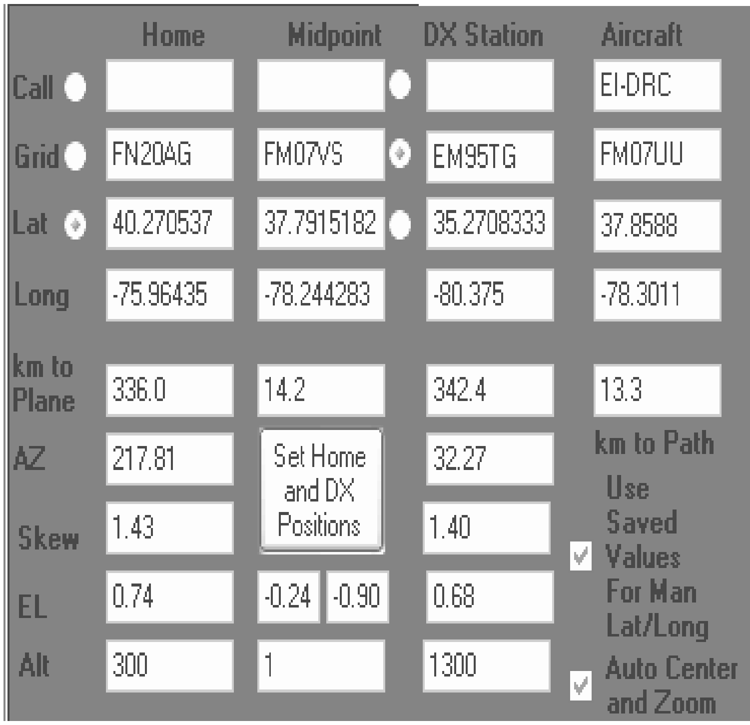


Before making the screen shot shown above, I selected a plane by left-clicking it with the mouse. This action put a black ring around the plane icon for easier identification. You can easily see the selected plane near the center of the map. It is colored red because it is both within the "secondary alert" circle and within the skew lines. Selecting this plane in this manner also placed additional information about the plane into the data area on the left side of the form.

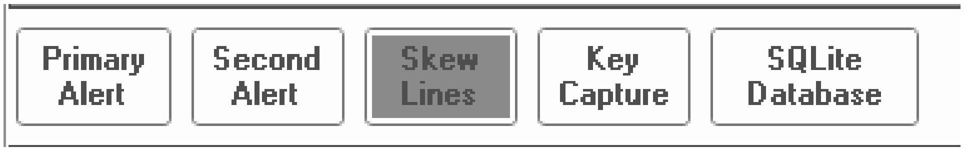


On the left is an enlargement of the data area from the left side of the main form shown above. Across the top it shows the ICAO hexcode for the plane, its flight number, altitude in meters, and the time at which its data was received. Just below that are its heading and speed in km/hr. To the right of that is a description of the length in km and bearing of the path from the home station to the DX station, along with a notation of the elevation of each station relative to the horizon, as seen from the other station. The next portion of the form has four buttons and a textbox. These are used to display planes from the stored SQLite database on the map, and will be discussed more fully below.

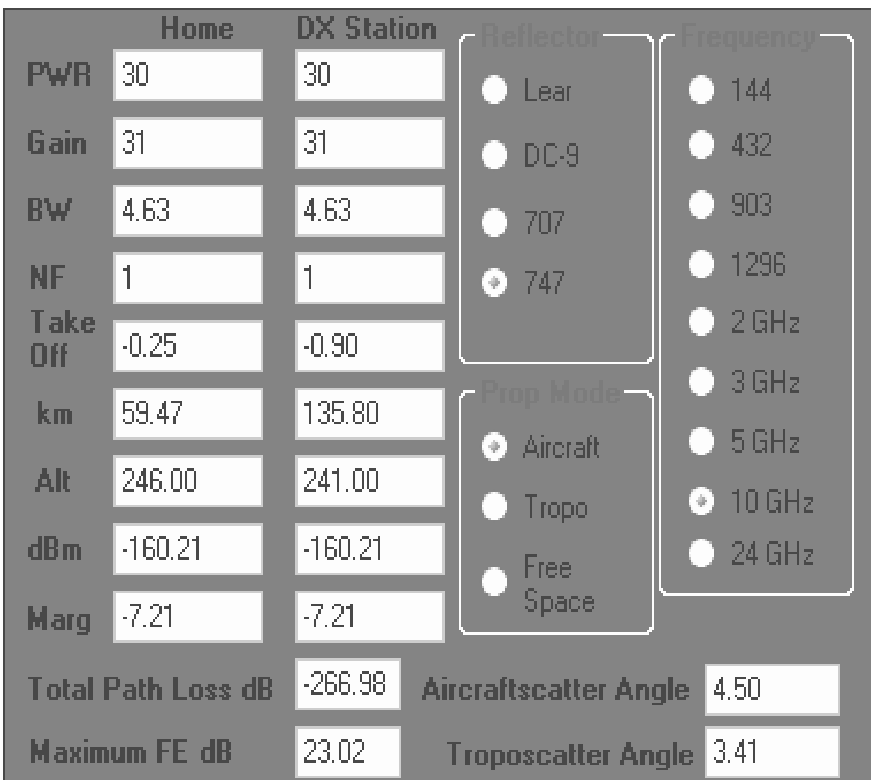
The portion of the form just below this section is colored red because there is a plane (in this case the selected plane) that has activated the secondary alert. This alert is activated when a plane is within the user-defined "optimal range circle" that is drawn around the midpoint of the path (the radius is user-adjustable). This red color provides an easily visible indication that the secondary alert has been activated. This section of the data area has 4 columns. These respectively give positional information about the Home station, the midpoint of the path between the Home and DX stations, the DX station, and the selected aircraft.



This information includes for the Home and DX stations callsign (optional), grid square, latitude, longitude, km to plane, azimuth to plane, skew angle of the plane position from the direct path as seen from that station, elevation of plane as seen from that station, and altitude of the location (must be entered by user). Callsign, grid square, latitude, longitude, and altitude are user-adjustable. Radiobuttons allow the user to specify home station location by selecting either direct entry of callsign, grid square, or latitude and longitude. A check box allows one to recall previously stored data for latitude and longitude rather than entering those values manually. Another check box causes the map to automatically center on the midpoint of the selected path and zoom to include both the Home Station and the DX Station when "Set Home and DX Positions" is left clicked or if the "Enter" key is typed. If Key Capture is turned on, one can use the latitude and longitude of a point on the map to position the Home station by selecting manual lat/long entry by clicking the "Lat" radio button for the Home Station, and then positioning the mouse cursor over the desired position and then hitting <Clt>F1. One can similarly position the DX station by positioning the mouse cursor over the desired position and then hitting <Clt>F2 after the "Lat" radio button has been selected for the DX Station. The small text box just to the right of the Home Station Elevation text box gives the take-off angle of the path from the Home Station to the aircraft. Similarly, the small text box just to the left of the DX Station Elevation text box gives the take-off angle of the path from the DX Station to the aircraft. Unless the elevation of the aircraft as seen from the Home Station is greater than the Home Station to aircraft take-off angle, and the elevation of the aircraft as seen from the DX Station is greater than the DX Station to aircraft take-off angle, aircraft-scatter will not be possible. If because of these geometric constraints aircraft-scatter is not possible, then the El text boxes will all be colored red, as will be the "max FE dB" and "Aircraftscatter Angle" text boxes in the RF calculation section, which will be discussed below. In addition, the Max FE dB and Aircraftscatterangle angle boxes will display asterisks rather than numerical values if aircraft-scatter is not possible for geometric reasons as just described.



The next portion of the display, reproduced above, contains buttons that activate or deactivate the audio primary and secondary alarms (but do not affect the panel color changes that accompany these audio alerts), the skew lines and midpoint circle display, and key capture, and it also contains a button that brings up the SQLite database analysis page. The secondary alert sounds when any plane enters the midpoint circle. The primary alert sounds if at least one plane is both within the midpoint circle and also within both sets of skew lines. A plane turns from black to green when it enters the midpoint circle (i.e., if it activates the secondary alert), and it turns red if it is also positioned between the skew lines (i.e., if it activates the primary alert). Both the angle of the skew lines and the radius of the midpoint circle are adjustable from one of the options page tabs, as will be discussed below.



The next section of the display is used for entry and display of RF-related information. As shown on the left, it is red because a plane was both within the midpoint circle and also within the skew lines when this screen capture was performed (i.e., the primary alert was activated). To perform the RF calculations, the user first selects plane size (Lear, DC-9, 707, and 747 as examples of very small, small, medium, and large aircraft) and frequency, and then enters transmit power in watts, antenna gain in dBi, and the receiver noise figure (in dB, of course) for both the Home and DX stations. Once this has been done, the program continuously calculates and displays the received signal level in the “dBm” textbox, signal margin in the “Marg” textbox, and total path loss in the “Total Path Loss dB' texbox for both stations in real time. The signal margin value displayed assumes a 100 Hz filter width. The texboxes labeled “BW” give the calculated beamwidth in degrees for the antenna gains entered by the user, for the specified frequency. The textboxes labeled “Take Off” give the take off angles for the direct path for the Home and

DX Stations respectively, as calculated based on the station elevations entered by the user and the path profile calculated by the program from the SRTM3 data. If the user has not downloaded the SRTM3 data and placed it in the correct directory, then this calculation cannot be performed. The textboxes labeled “km” display the distance to the obstruction that determines the takeoff angles for the direct path for the Home and DX Stations respectively. The textboxes labeled “Alt” display the altitude of the obstruction that determines the take off angles for the direct path for the Home and DX Stations respectively. A check box located below the map display and labeled “Use Mouse Position for Calculations” is provided so that all of the aircraft-scatter calculations can be made for any user-selected point on the map, rather than using actual aircraft data. This allows path analysis to be performed for any given map position in the absence of any aircraft at the desired position. To use this function, check this box and then double-left-click on the map position for which you want calculations to be performed. Make sure that you have the altitude you want to use entered into the Altitude textbox which as noted above is located in the aircraft data section at the top of the data area.

A set of radiobuttons allows one to substitute free-space path or troposcatter loss calculations for the aircraft-scatter calculations. The troposcatter calculations use Yeh's method, as discussed in references 1 and 2.

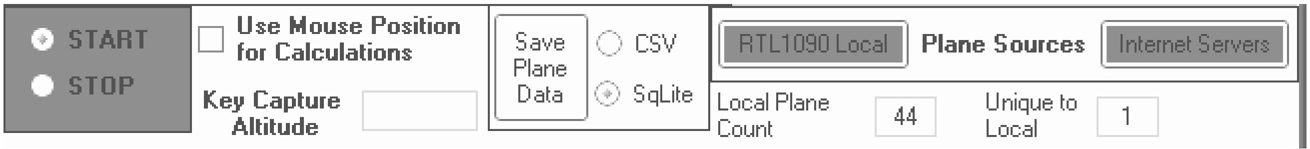
This portion of the form also contains at its bottom right corner a text box labeled “Troposcatter Angle” that indicates the scattering angle that is used for troposcatter calculations. This value is calculated by the program for the direct path between the Home and DX Stations. Above that textbox is a textbox labeled “Aircraftscatter Angle”. This gives the deviation of the actual aircraft-scatter angle from perfect forward scatter, or 180 degrees, taking into account both the vertical and horizontal deviations of the Home Station – Aircraft – DX Station path from a straight line. This angle is used to calculate the value shown in the “Maximum FE dB” text box. It turns out that for 180 degree forward scatter, there is substantial signal enhancement above the expected signal level that is derived from the bistatic radar equation. This is due to diffractive scattering / constructive interference. This enhancement is inversely related to wavelength squared, and directly related to the area of the scattering object. The beamwidth of the forward scattered signal is directly related to wavelength and inversely related to the radius of the scattering object, and thus as one moves away from the 180 degree angle, the forward enhancement decreases as determined by this beamwidth. Thus is it possible to calculate the expected maximum forward enhancement for the actual geometry of the Home Station – Aircraft – DX Station path for the specified frequency, and it is this value that is shown in the “Maximum FE dB” textbox, which is positioned just below the “Total Path Loss dB” text box. The value in the “Maximum FE dB” box can be added to the signal margin as displayed in the “Marg” text box to give the maximum received signal level that can be realized if maximum forward enhancement is achieved.

Below this section of the main form is a textbox, shown on the left, that displays a small portion of the data for the unique “local” aircraft (i.e., aircraft seen only by the local RTL1090 server, and not by the internet server), in order to provide a visual indication of the status of the local RTL1090 server connection. If no unique local aircraft information is available, then this textbox remains blank. In this example there is one unique local aircraft.

The map portion of the form has a few features that should be noted. Boundary lines for the Maidenhead grid squares are shown by default. These can be turned off using one of the tabs on the Options form, which is accessed by clicking the Options button at the top left of the main form. A grid square label pop-up for a given grid is activated by hovering the mouse over the marker placed in the center of that grid, as is shown on the left. A tab on the options form allows one to turn this function on or off, and to make the grid square center markers more or less visible.

At the top right of the map are controls for zooming the map in and out.

At the lower right edge of the map is a box that displays the latitude and longitude for the point over which the mouse is hovering, as shown on the left.

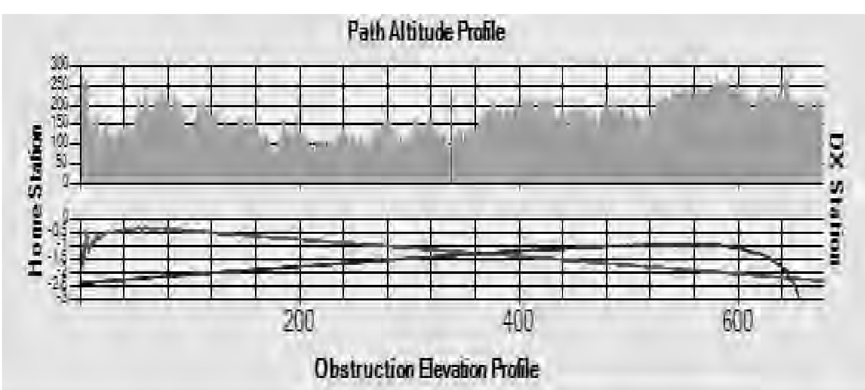


Below the map are several additional control/display groups, as shown immediately above. Below the left bottom edge of the map are the radiobuttons used to either start or stop aircraft data download from the internet server and/or the local RTL1090 server, labeled “START” and “STOP”. It is necessary to click on “START” to initiate downloading of aircraft information from either source.

To the right of the START/STOP control group is the checkbox described above that allows one to use the mouse to select the map location that will be used as the scattering point, instead of an actual aircraft. The textbox below this, labled “Key Capture Altitude” will display the altitude for any point on the map if one has key capture enabled and hits <Ctl>F3 while the mouse is over the selected point. This feature, like the path altitude profile feature, requires that SRTM3 height files be installed in the appropriate directory. Hitting <Ctl>F4 will display a Message Box containing the position and altitude of the point last referenced by hitting <Ctl>F3.

To the right of these objects is the SQL Database control group. Included in this control group are buttons used to activate the function to save all aircraft data to a file, labeled “Save Plane Data”, and to select between CSV file or SQLite database file storage (labeled “CSV” and “SqLite” respectively). The SQLite database file is the default and is strongly recommended.

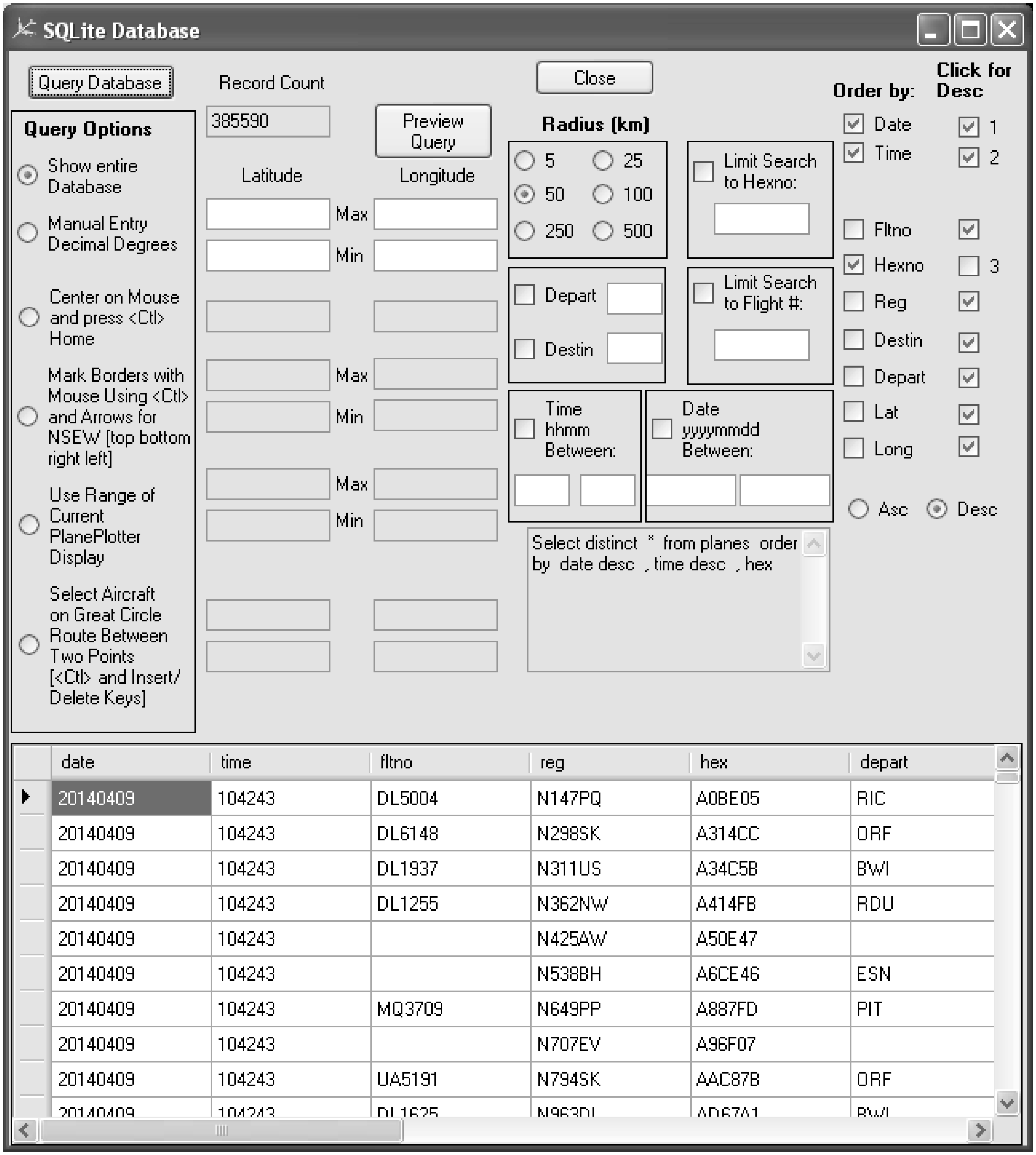
To the right of this button group are two buttons, used to select for downloading, display on the map, and for analysis aircraft from the RTL1090 server, from the internet server, or both. These buttons are labeled “RTL1090 Local” and “Internet Server”, respectively. Either one or both of these can be selected. Below this are two textboxes. The textbox on the left is labeled “Local Plane Count” and it displays the total number of aircraft currently “seen” by the local RTL1090 receiver (if used). The textbox on the right is labeled “Unique to Local” and it gives the number of these local aircraft that are “unique”, and not “seen” by the internet aircraft server.



Positioned below the above text boxes and buttons is the Path Altitude Profile for the direct path between the Home Station, on the left, and the DX Station, on the right. The vertical red bar near the center of the profile shows the position of the selected aircraft. The Obstruction Elevation Profile below this shows the obstruction angles for the Home and DX Stations. These profiles will only be displayed if the user has downloaded the SRTM3 data as outlined above.

If one hovers the mouse over an aircraft, information for that aircraft will pop up whether or not that aircraft is the "selected" aircraft, as demonstrated in the MessageBox on the left. However, to conserve computer resources, certain data such as the skew angle is only calculated for the selected aircraft and for aircraft within the midpoint circle. The image on the left was obtained by hovering over an aircraft that was not within the midpoint circle. Thus skew information is not available, and is displayed as "NaN" (shorthand for "Not a Number").

VII. **Getting Historical Aircraft Position Data.** Below is the SQLite database analysis form that is accessed by clicking on the “SQLite Database” button on the main form of the program. This form shows at the top left that 385,590 plane records have been saved in this database.



Information about each plane in the database includes date, time, flight number, registration (whether FAA or other), ICAO hexcode, departing airport, destination airport, latitude of plane, longitude of plane, altitude, bearing, speed, airframe type, squawk, and vertical speed. You can see by the checkboxes near the top right of this form that the entries in the search that is displayed here were specified to be ordered by date, then time, and then by the ICAO hexcode. The "Query Options" box on the left shows that "show entire database" has been selected, so the table contains all 385,590 planes.

In order to plan an aircraft-scatter session, one enters the Home and DX station 6-digit grid squares into the primary form and left-clicks the "Set Home and DX Positions" (labeled as "Calculate Lat/Long from Home/DX Grids" or "Calculate Lat/Long or Home/DX Grids" on some older illustrations) button. That places the direct path line and the midpoint circle and skew lines onto the map, to help one decide on exactly what geographical area to explore with the database. One then opens the SQLite database form by either left-clicking the "SQLite Database" button, thus bringing up the SQLite database form, or by clicking on the "Show Planes from Query on Map" button, which will bring up the SQLite database form and also display the first 200 planes in the selected dataset on the map, where they can be analyzed and viewed just as if they were "live" planes. From the SQLite database form, one can then select a region from which to display aircraft records in one of several ways.

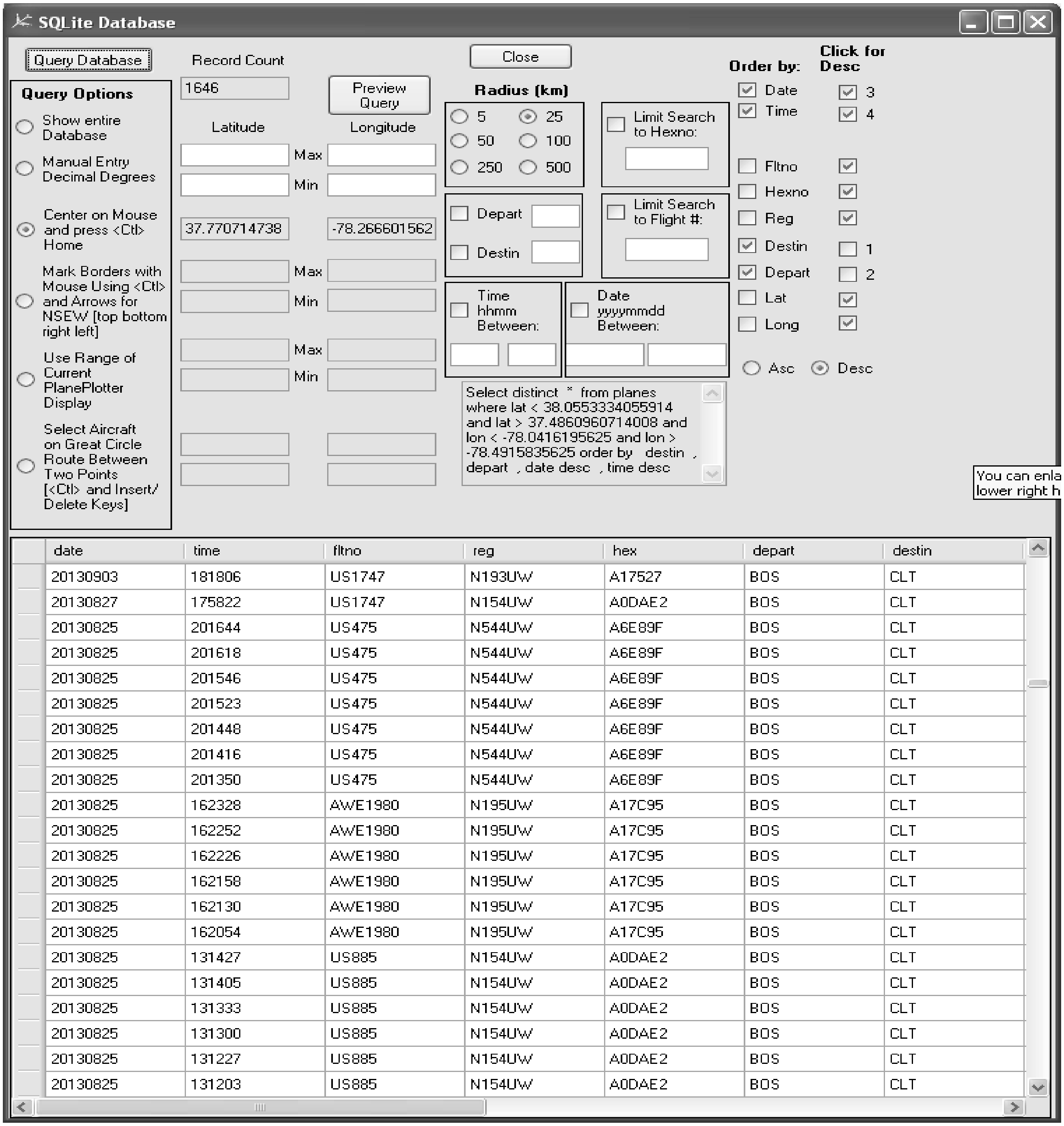
If one wants to see when aircraft are likely to be within a 5, 25, 50, or 100 km square centered on the midpoint of the direct path, one clicks the appropriate radio button on the SQLite database page to set the radius desired. With the key capture function activated, one uses the mouse to place the cursor over the midpoint of the direct path and hits <Ctl>HOME on the keyboard. This puts the coordinates for the midpoint into the appropriate text boxes on the SQLite database page, as shown in the illustration below. One then left clicks the RadioButton labeled "Center on Mouse and press Home Key" on the database page to choose this method of location selection for the database query, and finally one left clicks the "Query Database" button. This sends the appropriate query to the database, and the data returned to the data grid includes only planes that are within this region. One can order the display of these planes by date, time, etc. as described below and quickly see what aircraft are likely to be available for use, and when.

There are 4 other, alternative methods of limiting the geographic region from which planes are returned in the query. These are also shown in the "Query Options" panel, located both above and below the RadioButton for the option just described. These include (1) manual entry of the maximum and minimum latitude and longitude for a rectangle from within which all planes will be selected, (2) setting the borders of a rectangle using the map and the mouse, (3) using the display area of the map itself to set the boundaries, or (4) selecting a great circle route between any two points (such as the Home and DX stations) and using the

“Radius” radiobuttons to specify a distance from that path from within which planes will be selected.

One can also, and simultaneously, limit the search query by date and/or time, and by the ICAO hexno, which is a unique identifier assigned to every plane that is put into service worldwide, and which stays with the plane for its entire life, or by the airline-assigned flight number, or by departing airport, destination airport, or both.

The searches can also have the data returned by the query ordered by up to 9 additional parameters. For the first example above, with 385,590 planes, you can see that the search displayed was first ordered by date, then by time, and finally by hexno. Date and time were ordered in descending fashion, and hexno was ordered in ascending fashion.

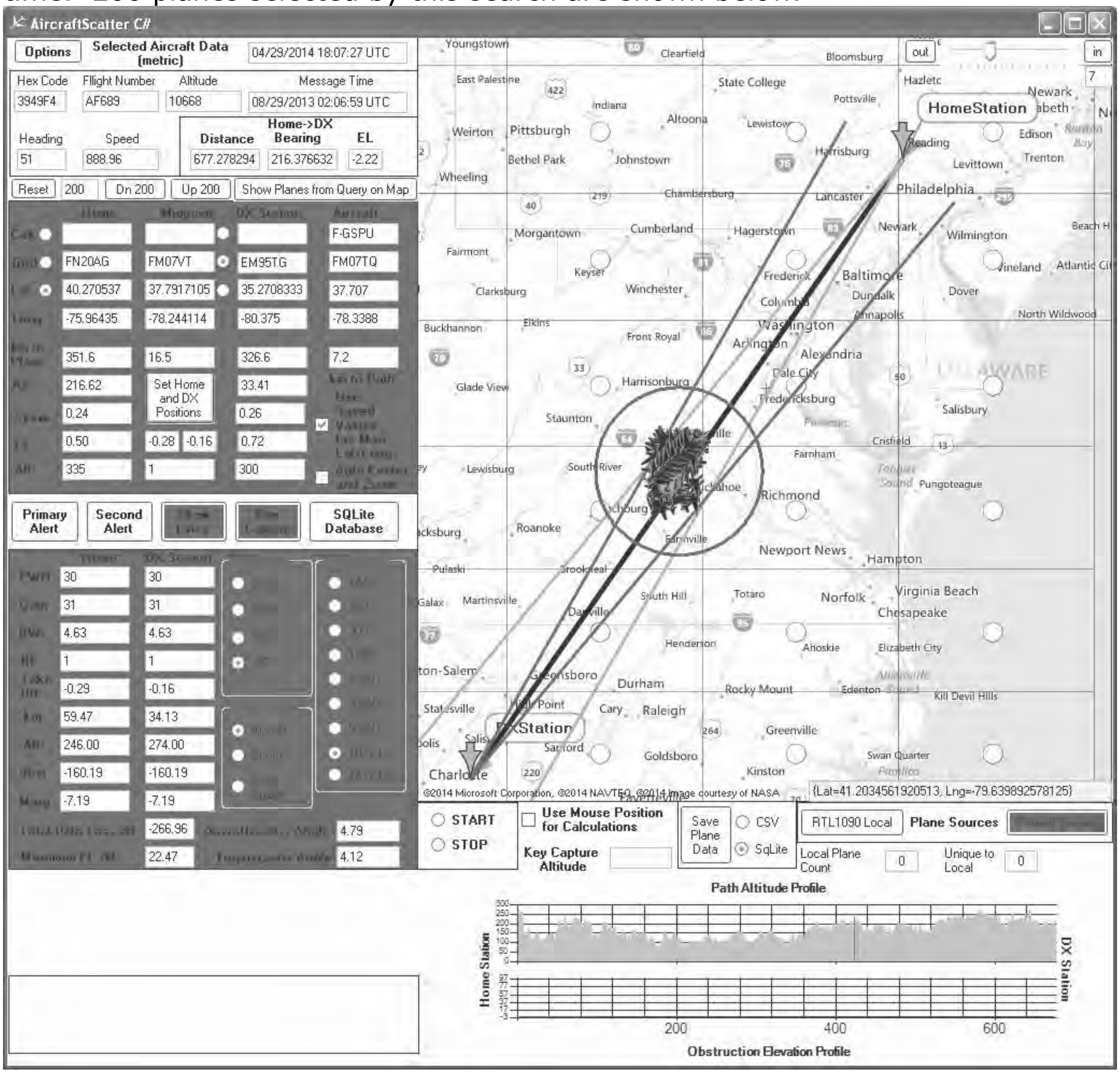


date	time	fltno	reg	hex	depart	destin
20130903	181806	US1747	N193UW	A17527	BOS	CLT
20130827	175822	US1747	N154UW	A0DAE2	BOS	CLT
20130825	201644	US475	N544UW	A6E89F	BOS	CLT
20130825	201618	US475	N544UW	A6E89F	BOS	CLT
20130825	201546	US475	N544UW	A6E89F	BOS	CLT
20130825	201523	US475	N544UW	A6E89F	BOS	CLT
20130825	201448	US475	N544UW	A6E89F	BOS	CLT
20130825	201416	US475	N544UW	A6E89F	BOS	CLT
20130825	201350	US475	N544UW	A6E89F	BOS	CLT
20130825	162328	AWE1980	N195UW	A17C95	BOS	CLT
20130825	162252	AWE1980	N195UW	A17C95	BOS	CLT
20130825	162226	AWE1980	N195UW	A17C95	BOS	CLT
20130825	162158	AWE1980	N195UW	A17C95	BOS	CLT
20130825	162130	AWE1980	N195UW	A17C95	BOS	CLT
20130825	162054	AWE1980	N195UW	A17C95	BOS	CLT
20130825	131427	US885	N154UW	A0DAE2	BOS	CLT
20130825	131405	US885	N154UW	A0DAE2	BOS	CLT
20130825	131333	US885	N154UW	A0DAE2	BOS	CLT
20130825	131300	US885	N154UW	A0DAE2	BOS	CLT
20130825	131227	US885	N154UW	A0DAE2	BOS	CLT
20130825	131203	US885	N154UW	A0DAE2	BOS	CLT

In the second example above we have limited the search to a circle with radius 25 km centered on the midpoint of the path between W3SZ and W4DEX. This query returns 1646 flight records, and in this case I ordered the query by alphabetically ascending destination, then alphabetically ascending departure airport, and then by descending date and descending time. Reviewing the data, you can quickly see that the flights crossing this point in this time span shown were all flights from BOS to CLT. A review of the remainder of the 1646 flights captured by this query would show many other departing and destination airports as well. A careful inspection of the form will show the choices I made to direct the query, and the text box below the time and date check boxes shows the query that the program automatically formed based on the selections I made with just a few clicks of the mouse.

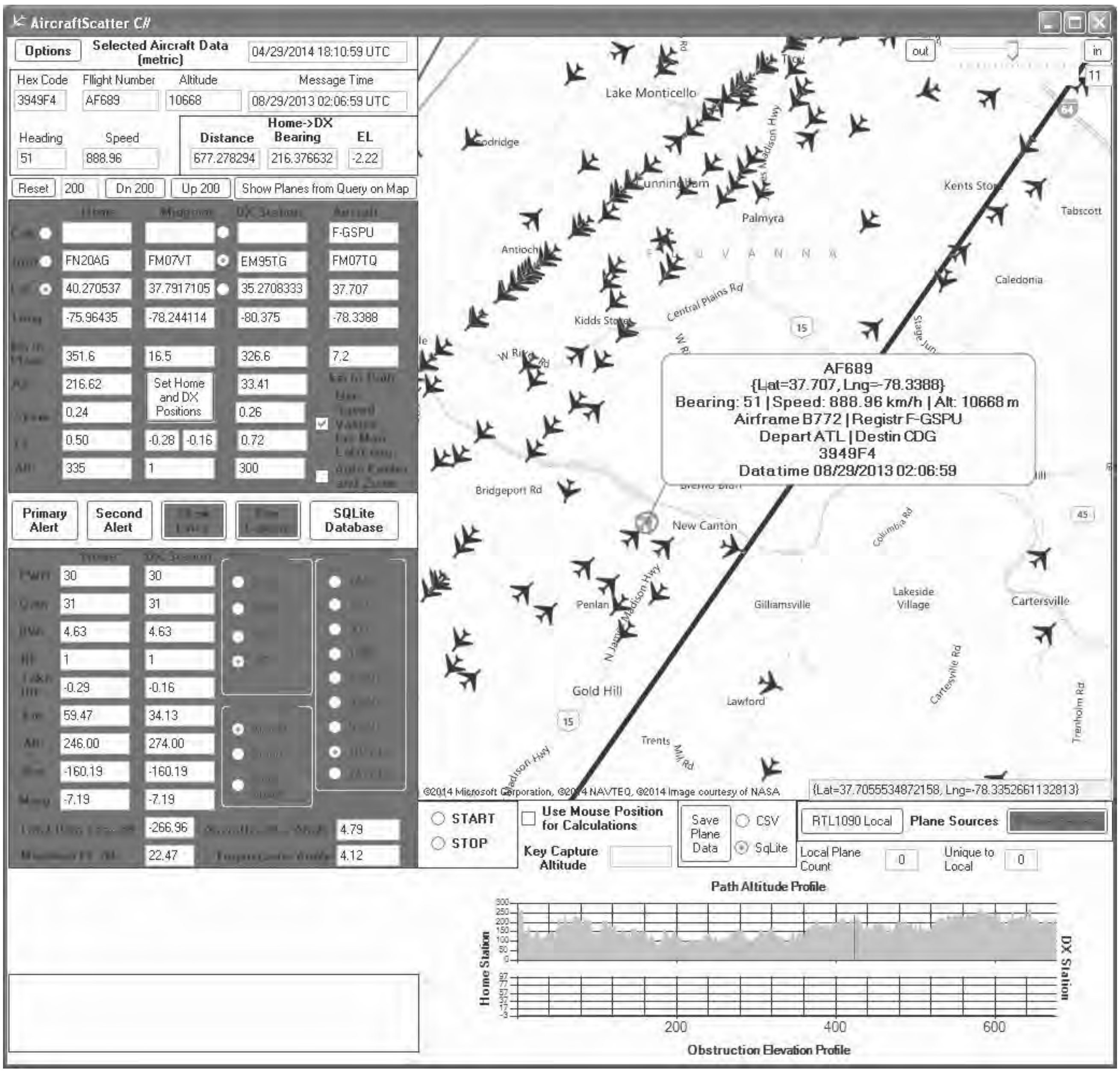
The order of the plane record display can also be changed by clicking on the heading for any column of the display itself.

Clicking on the “Show Planes from Query on Map” will display, 200 planes at a time. 200 planes selected by this search are shown below.

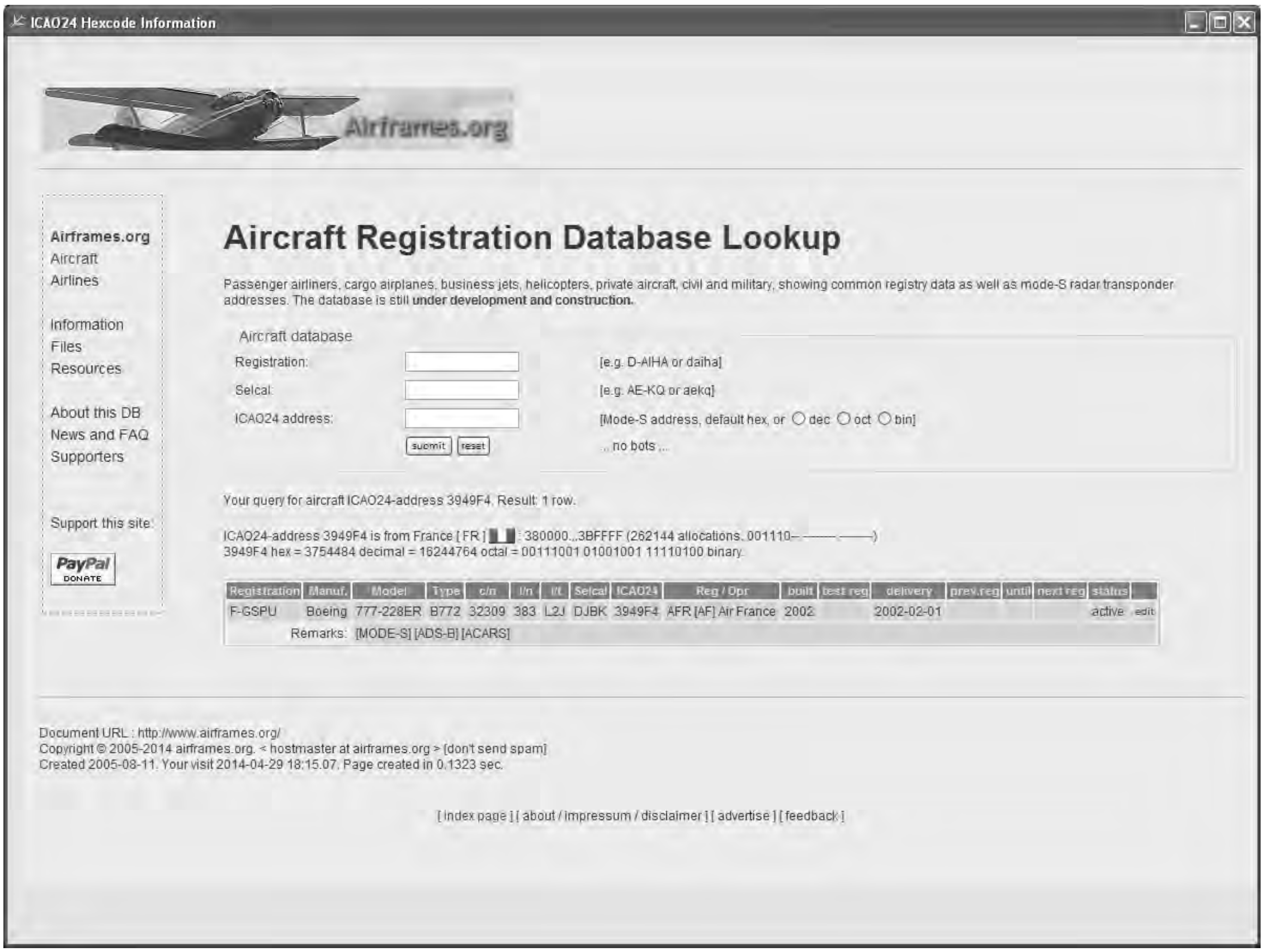


The planes are clearly too densely packed to provide any useful information, so we need to zoom in. With zooming in, we can easily see individual planes, and click on them (or hover over them with the mouse) to get more information on them. As you can see below, zooming in separates the planes nicely. I have both left-clicked and hovered over a plane near the bottom center of the display. As a result, you can see its information both in the tooltip displayed on the map and also in the data/calculator panels to the left of the map.

You can see below that is has flight number AF689 and ICAO hexno 3949F4. You can also see that it was recorded at 02:06:59 UTC on 08/29/2013 and see all of its position and RF calculation parameters, just as if it was a "live" plane.



You can get more information about the aircraft with this ICAO hexno (3949F4) by clicking <Ctl>F7, which will bring up information for its hexno at airframes.org. This is shown below.



By clicking <Ctl>F8 you can bring up flight information for this plane provided by FlightAware.com, as is shown below, using the airline-assigned flight number AF689. This gives you a history of several weeks of arrival and departure times, that you can use to get an idea of how much variability there is in flight times, to supplement the data you acquired with Aircraft Scatter Sharp. This is shown below. Note that there is an option to click on a link that will show ALL flights by ALL airlines that run between the same two airports. This can be very helpful!

Date	Aircraft	Origin	Destination	Departed	Arrival	Duration
09-Feb-2014	B772	Hartsfield-Jackson Intl (KATL)	Charles de Gaulle/Roissy (LFPG / CDG)	09:10PM EST	11:05AM CET (+1)	Scheduled
08-Feb-2014	B772	Hartsfield-Jackson Intl (KATL)	Charles de Gaulle/Roissy (LFPG / CDG)	09:10PM EST	11:05AM CET (+1)	Scheduled
07-Feb-2014	B772/L	Hartsfield-Jackson Intl (KATL)	Charles de Gaulle/Roissy (LFPG / CDG)	09:17PM EST	10:21AM CET (+1)	7:04
06-Feb-2014	B772/L	Hartsfield-Jackson Intl (KATL)	Charles de Gaulle/Roissy (LFPG / CDG)	09:20PM EST	10:37AM CET (+1)	7:17
05-Feb-2014	B772/L	Hartsfield-Jackson Intl (KATL)	Charles de Gaulle/Roissy (LFPG / CDG)	09:22PM EST	10:22AM CET (+1)	7:00
04-Feb-2014	B772	Hartsfield-Jackson Intl (KATL)	Charles de Gaulle/Roissy (LFPG / CDG)	09:27PM EST	10:51AM CET (+1)	7:24
03-Feb-2014	B772/L	Hartsfield-Jackson Intl (KATL)	Charles de Gaulle/Roissy (LFPG / CDG)	09:20PM EST	10:33AM CET (+1)	7:13
02-Feb-2014	B772/L	Hartsfield-Jackson Intl (KATL)	Charles de Gaulle/Roissy (LFPG / CDG)	09:21PM EST	10:33AM CET (+1)	7:12
01-Feb-2014	B772/L	Hartsfield-Jackson Intl (KATL)	Charles de Gaulle/Roissy (LFPG / CDG)	09:19PM EST	10:35AM CET (+1)	7:16
31-Jan-2014	B772/L	Hartsfield-Jackson Intl (KATL)	Charles de Gaulle/Roissy (LFPG / CDG)	09:30PM EST	10:45AM CET (+1)	7:15
30-Jan-2014	B772/L	Hartsfield-Jackson Intl (KATL)	Charles de Gaulle/Roissy (LFPG / CDG)	09:17PM EST	10:40AM CET (+1)	7:23
29-Jan-2014	B772	Hartsfield-Jackson Intl (KATL)	Charles de Gaulle/Roissy (LFPG / CDG)	09:10PM EST	11:05AM CET (+1)	Cancelled
28-Jan-2014	B772/L	Hartsfield-Jackson Intl (KATL)	Charles de Gaulle/Roissy (LFPG / CDG)	11:03AM EST	12:56AM CET (+1) (?)	7:53
28-Jan-2014	B772/L	Hartsfield-Jackson Intl (KATL)	Charles de Gaulle/Roissy (LFPG / CDG)	10:53AM EST	01:07AM CET (+1)	8:13
26-Jan-2014	B772/L	Hartsfield-Jackson Intl (KATL)	Charles de Gaulle/Roissy (LFPG / CDG)	09:19PM EST	10:33AM CET (+1)	7:14
25-Jan-2014	B772/L	Hartsfield-Jackson Intl (KATL)	Charles de Gaulle/Roissy (LFPG / CDG)	09:14PM EST	10:20AM CET (+1)	7:06

More Past Flights →

Registered users (registering is free and easy!) view 4 months history. Join

However, because plane schedules are NOT like clockwork, and because airlines do reuse flight numbers for more than one route, using published schedules and estimating when a plane will be in a given area can be unproductive. But using Aircraft Scatter Sharp to gather large amounts of data over a period of days or weeks or longer allows one to make statistically-based decisions on when aircraft are most likely to be in the region of interest, by examining the historical data obtained using this program. Using the various functions on the database form, one can select which data from the database is to be displayed, and by analyzing that data, one can then devise aircraft-scatter operating schedules that will be most likely to be productive. Further suggestions on using Aircraft Scatter Sharp are contained in the appendix, which precedes the list of references.

If you have any questions, please contact me by email at mycall at comcast dot net. You may download a copy of the program from the web page listed below.

There is also a copy of this document plus additional information at
http://www.nitehawk.com/w3sz/AircraftScatter.htm

Roger Rehr W3SZ
4-29-2014

Appendix. Suggestions for getting started.

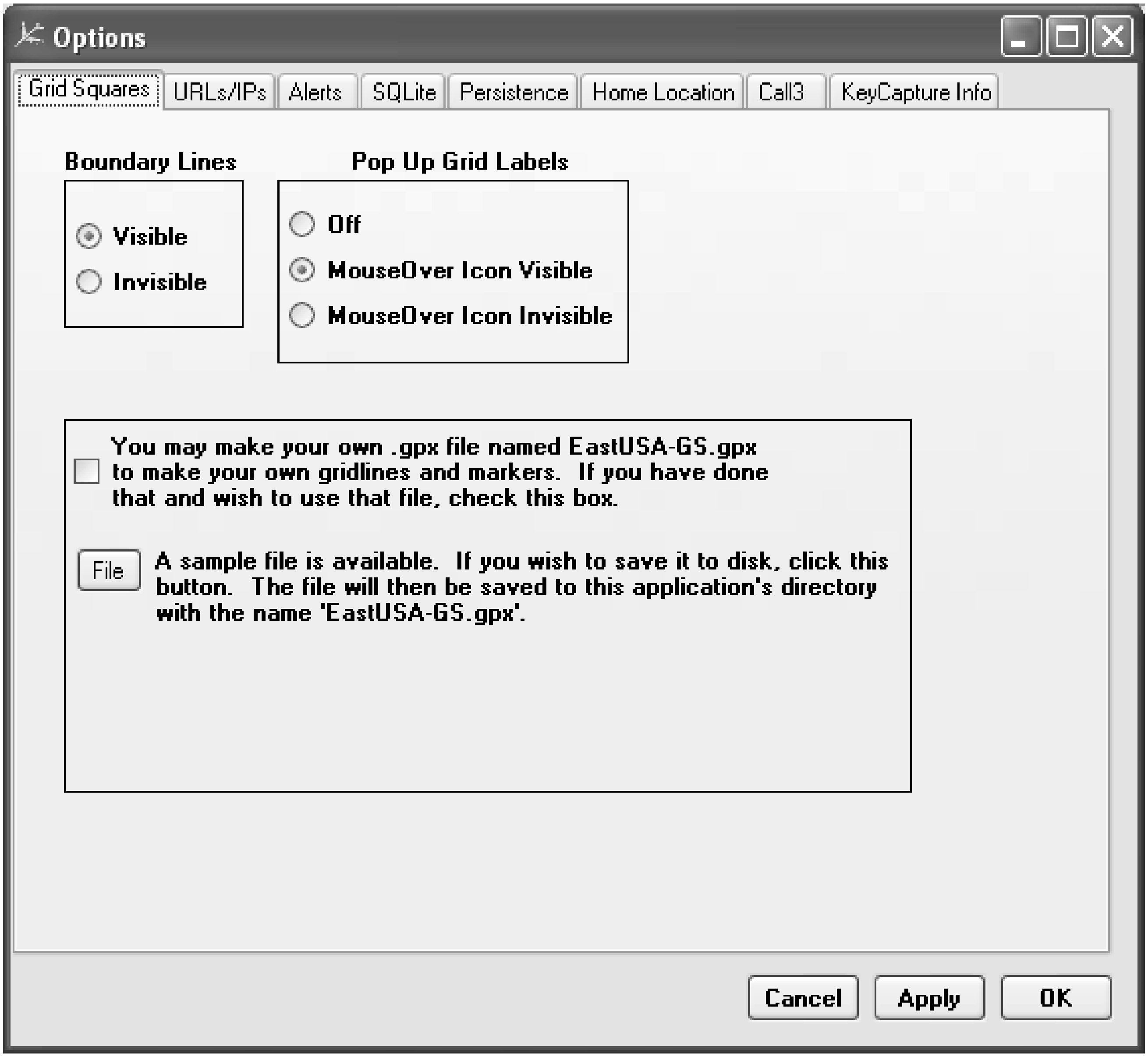
1. The program has been tested and works with Windows XP 32 bit and both the 32 and 64 bit versions of Windows 7. It has not been tested with other operating systems.
2. Download Aircraft Scatter Sharp from: http://www.nitehawk.com/w3sz/AircraftScatterSharp.zip
3. Unzip it.
4. Double-left-click “Setup.exe”
5. When installation completes, the program will start immediately.
6. When it starts it will tell you that it is writing to disk the initial dBplanes.sqlite database file and the call3.txt file. It will also remind you that you need to go to options to set up the URL, Directory, and File to use for the Internet plane servers, using the “URLs/IPs” tab on the “Options” form, if you want to change these from the default options.
7. While on the Options form, you should also go to the “Home Location” tab and set the home latitude, longitude, and altitude. After you have entered the appropriate data, click the “Set Home Station” button for each and then click “OK” to close the Options form.
8. There are numerous ToolTips which appear when you hover over the various controls, textboxes, etc. to guide you as you learn the program.
9. After you have entered the URL and Directory and File for the internet plane server, you can start downloading plane data from the internet by left-clicking the “START” button near the bottom of the data/calculation form.
10. Buttons turn RED when activated, and return to their baseline color when deactivated.
11. Using the internet plane server is selected by default. You can deselect it by clicking on the “Internet Servers” button. When you exit the program, your choice will be remembered.
12. You can additionally select to display local plane data, sent using the port 30003 server of an RTL1090 by clicking on the “RTL1090 Local” button.
13. To save plane data to the SQLite database, click the “Save Plane Data” button.
14. Hover over a plane with the mouse to see its ToolTip data. You need to hover near the “3 o'clock” to “6 o'clock” quadrant below the plane to activate the ToolTip.
15. Left-click a plane to make it the “selected” plane and put all of its data into the data/calculation portion of the main form. You need to click near the “3 o'clock” to “6 o'clock” quadrant below the plane to select it.
16. In order to use the Hotkeys, you need to turn on key capture, using the “KeyCapture” button near the middle of the data/calculation portion of the main form. The hotkeys are F1-F9 combined with the <Ctl> key.

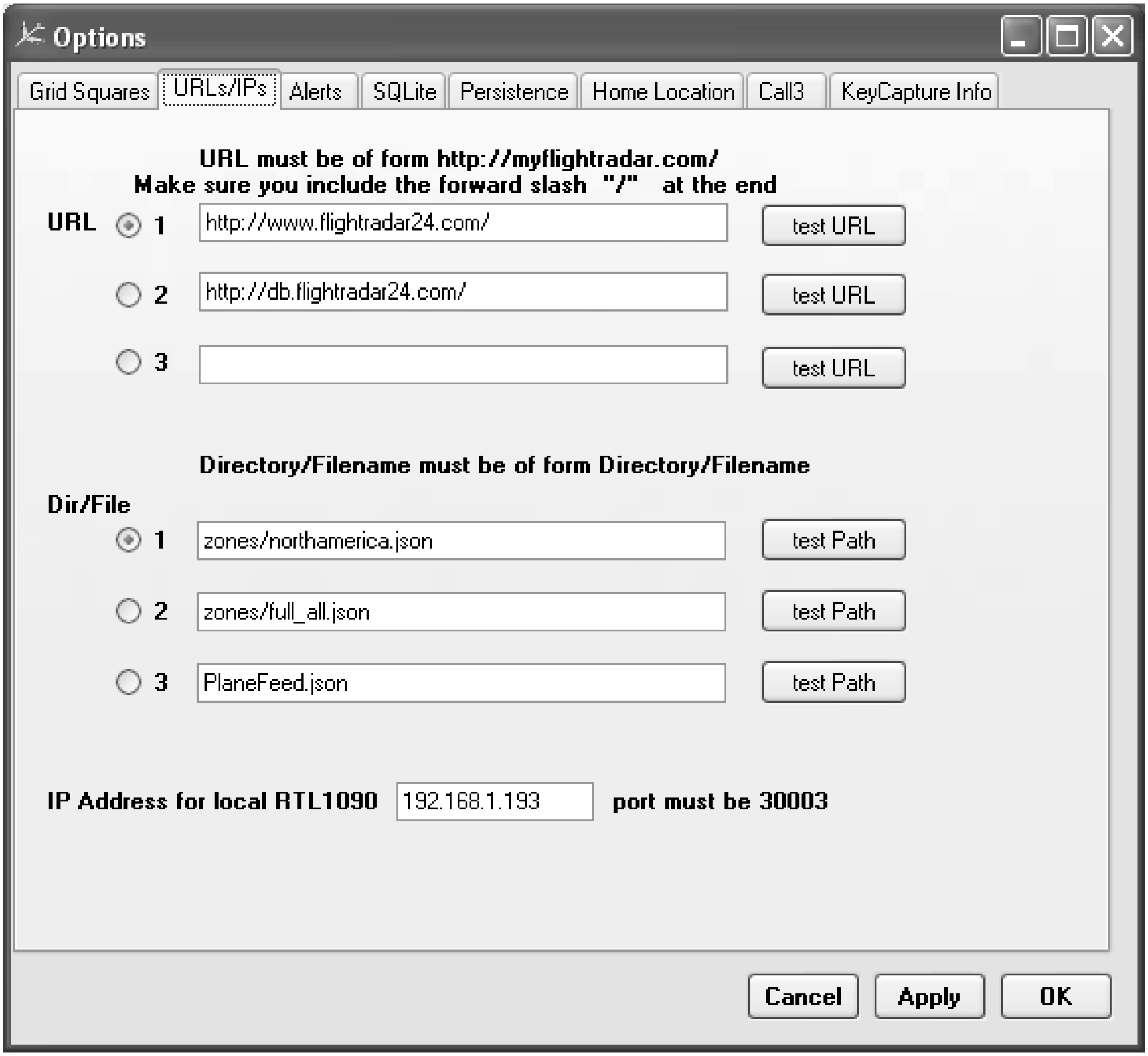
    <Ctl>F1 Put the Lat/Long of the point under the mouse pointer into Home Station Lat/Long [need to have Lat/Long for the Home station selected by the radio button]

    <Ctl>F2 Put the Lat/Long of the point under the mouse pointer into DX

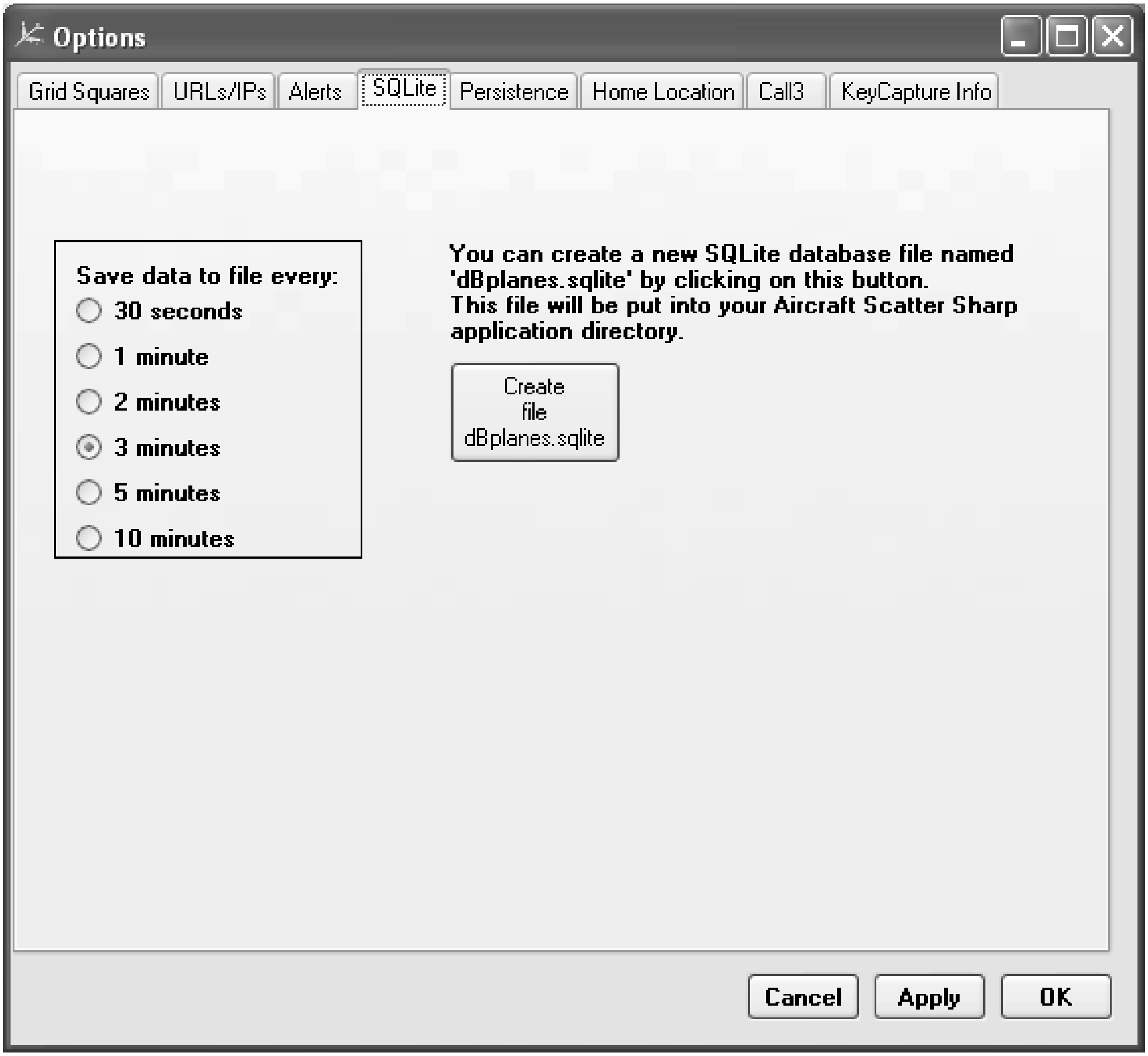
Station Lat/Long [need to have Lat/Long for the DX station selected by the radio button]
<Ctl>F3 Put the altitude of the point under the mouse pointer into the small textbox at the lower right corner of the data/calculation portion of the man form
<Ctl>F4 Pops up a message box with the Lat/Long/Altitude of the point last obtained with the <Ctl>F3 combination
<Ctl>F5 Turn on all helpful tooltips [does not affect plane tooltips]
<Ctl>F6 Turn off all helpful tooltips [does not affect plane tooltips]
<Ctl>F7 Gets plane data for the selected plane from airframes.org, using ICAO hexno
<Ctl>F8 Gets flight data for the selected plane from FlightAware.com using flight number
<Ctl>F9 Shows the list of Hotkeys

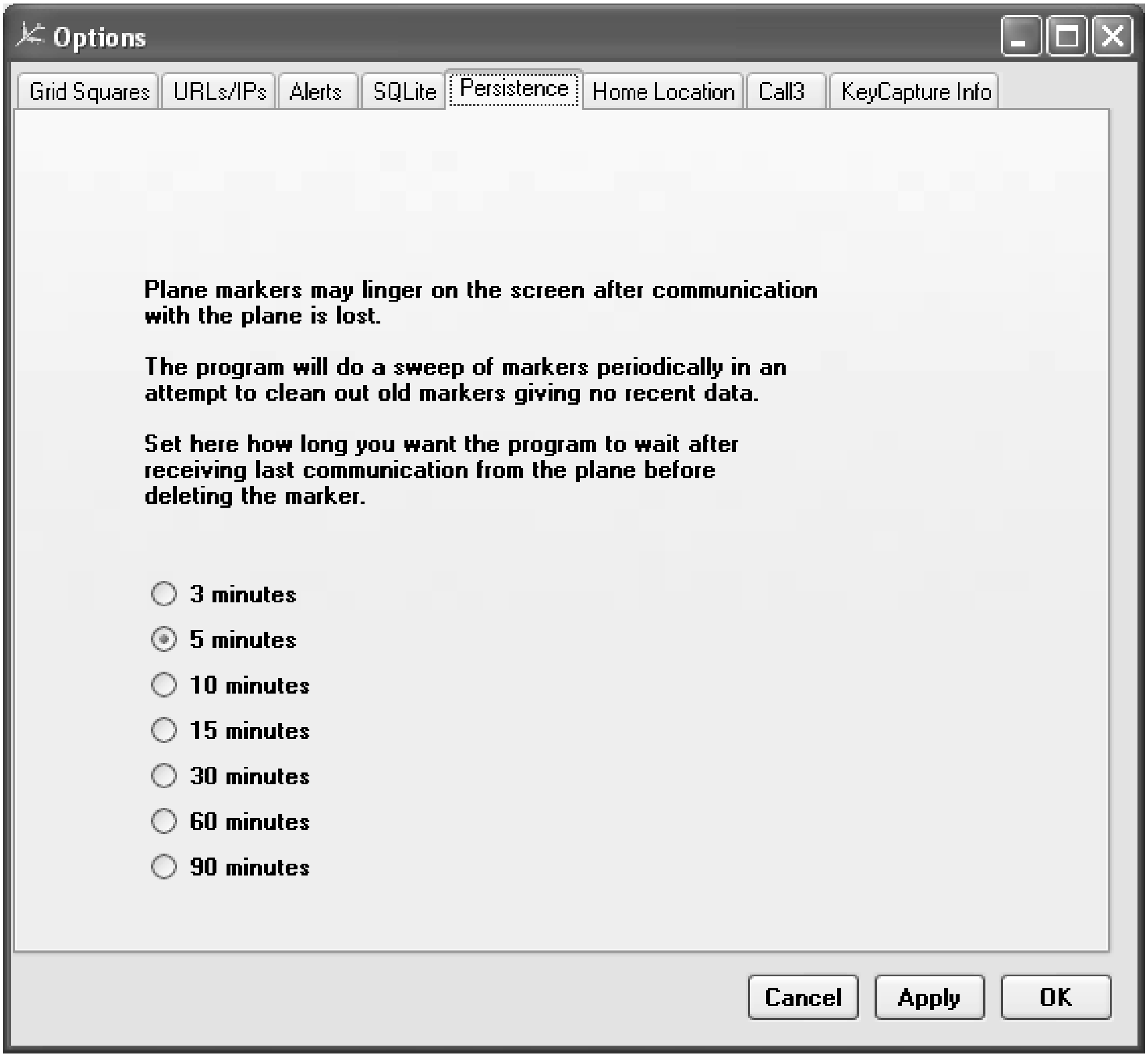
17. Zoom the map in and out using the "in" and "out" buttons at the top right of the map.
18. You may drag the map to a new center by rightclicking while you are dragging the map with the mouse pointer.
19. If you have "Auto Center and Zoom" clicked [the default] then each time you click "Set Home and DX Positions" (labeled as "Calculate Lat/Long from Home/DX Grids" or "Calculate Lat/Long or Home/DX Grids" on some older illustrations), the map will center itself on the midpoint of the path you have created.
20. You can enter Home and DX station position data one of 3 ways:
    - Click on the "Call" radio button and type in a call. If that call is contained in the call3.txt database, its grid and Lat/Long information will be entered.
    - Click on the "Grid" radio button and type a 4 or preferably 6 digit grid
    - Click on the "Lat" radio button and enter the latitude and longitude values
21. Once you have entered the position data for Home and DX stations as described above, left-click the "Set Home and DX Positions" (labeled as "Calculate Lat/Long from Home/DX Grids" or "Calculate Lat/Long or Home/DX Grids" on some older illustrations) button to calculate the path between the home and DX stations.
22. The Path Altitude Profile will only be displayed if you have downloaded all of the necessary SRTM3 data files from http://dds.cr.usgs.gov/srtm/version2_1/SRTM3/North_America/ and put it into the %localAppData%/W3SZ/ElevationData/SRTM3 directory. This is most likely of the form x:/Documents and Settings/Username/Local Settings/Application Data/W3SZ/ElevationData/SRTM3/ (where "x" is your Windows disk).
23. Read the tooltips and the Options pages for more useful information.
24. I have reproduced the Options pages from my installation below, in case you have trouble with them at your site:

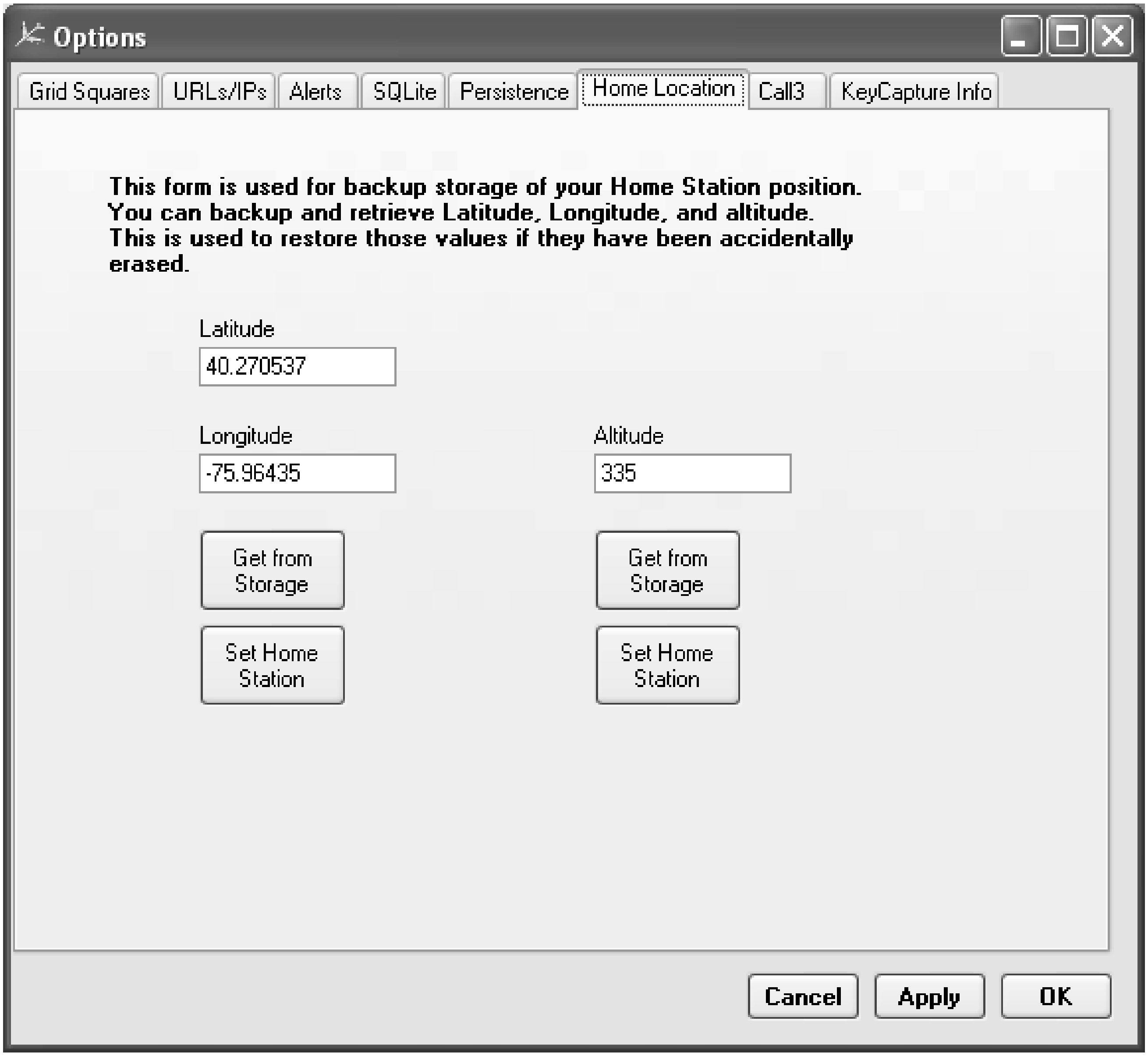

Options
Grid Squares
URLs/IPs
Alerts
SQLite
Persistence
Home Location
Call3
KeyCapture Info
Boundary Lines
Visible
Invisible
Pop Up Grid Labels
Off
MouseOver Icon Visible
MouseOver Icon Invisible
You may make your own .gpx file named EastUSA-GS.gpx to make your own gridlines and markers. If you have done that and wish to use that file, check this box.
File
A sample file is available. If you wish to save it to disk, click this button. The file will then be saved to this application's directory with the name 'EastUSA-GS.gpx'.
Cancel
Apply
OK

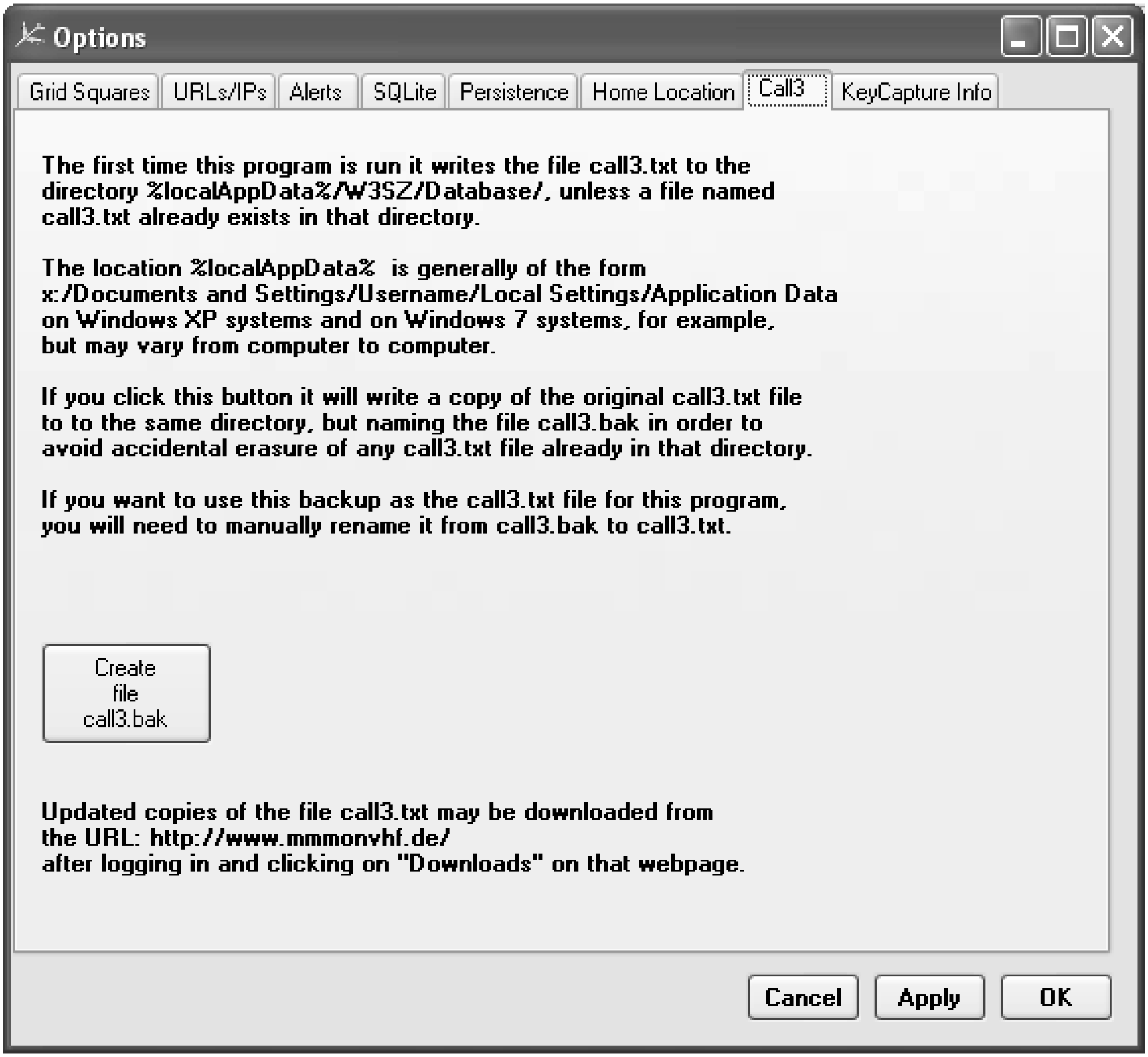

Options
Grid Squares
URLs/IPs
Alerts
SQLite
Persistence
Home Location
Call3
KeyCapture Info
URL must be of form http://myflightradar.com/
Make sure you include the forward slash "/" at the end
URL
1
http://www.flightradar24.com/
test URL
2
http://db.flightradar24.com/
test URL
3
test URL
Directory/Filename must be of form Directory/Filename
Dir/File
1
zones/northamerica.json
test Path
2
zones/full_all.json
test Path
3
PlaneFeed.json
test Path
IP Address for local RTL1090
192.168.1.193
port must be 30003
Cancel
Apply
OK

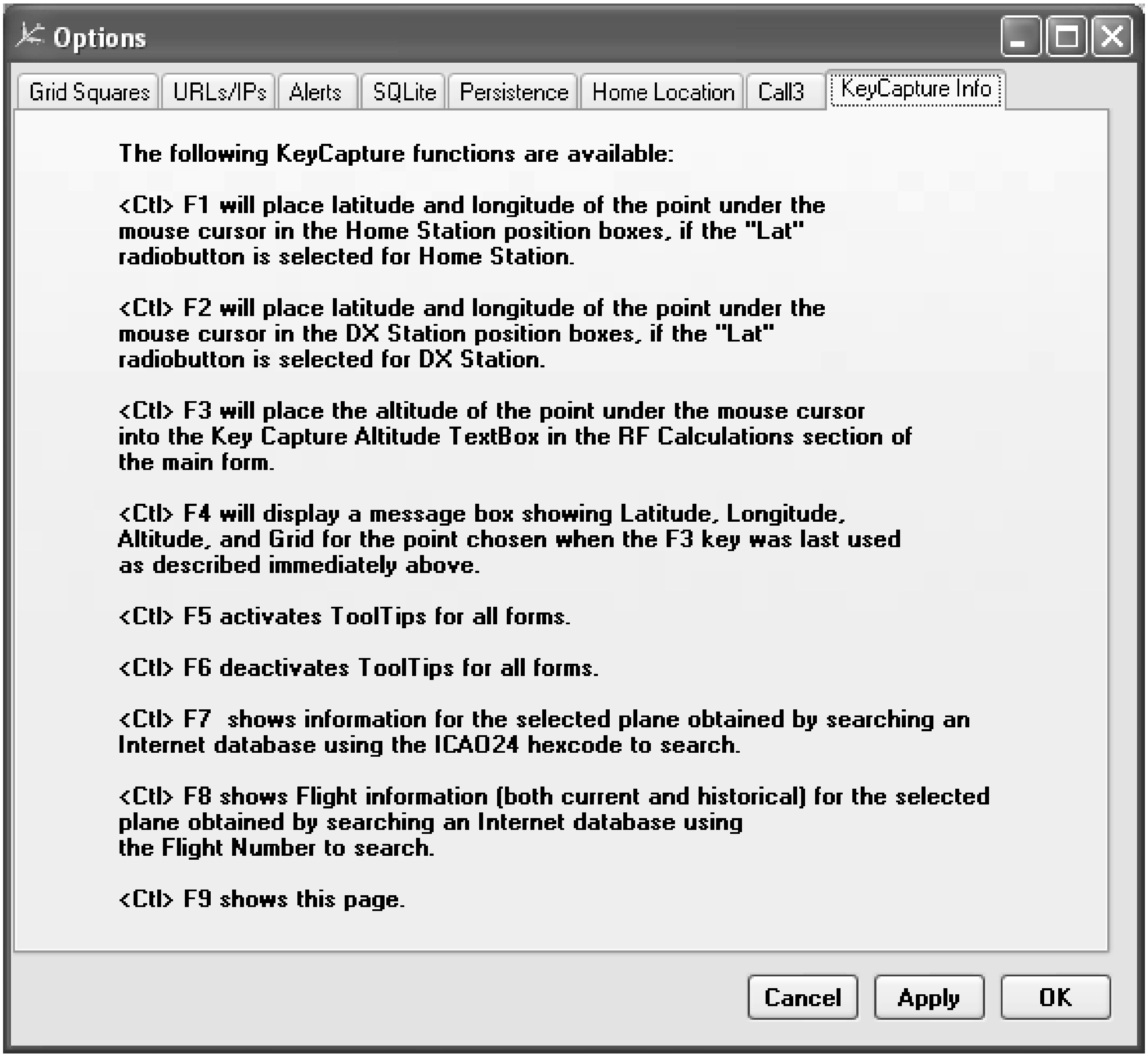

Options
Grid Squares
URLs/IPs
Alerts
SQLite
Persistence
Home Location
Call3
KeyCapture Info
Set Parameters for Primary and Secondary Alerts
Secondary Alert triggers when any plane within
75
km of Midpoint
Primary Alert triggers when skew from path is ALSO less than
5
degrees
Aircraft Alert symbols are as below. They cannot be changed.
Selected Aircraft Primary Alert
Unselected Aircraft Primary Alert
Selected Aircraft Second Alert
Unselected Aircraft Second Alert
Selected Aircraft No Alert
Unselected Aircraft No Alert
Cancel
Apply
OK


Options
Grid Squares
URLs/IPs
Alerts
SQLite
Persistence
Home Location
Call3
KeyCapture Info
Save data to file every:
30 seconds
1 minute
2 minutes
3 minutes
5 minutes
10 minutes
You can create a new SQLite database file named 'dBplanes.sqlite' by clicking on this button.
This file will be put into your Aircraft Scatter Sharp application directory.
Create file dBplanes.sqlite
Cancel
Apply
OK


Options
Grid Squares
URLs/IPs
Alerts
SQLite
Persistence
Home Location
Call3
KeyCapture Info
Plane markers may linger on the screen after communication with the plane is lost.
The program will do a sweep of markers periodically in an attempt to clean out old markers giving no recent data.
Set here how long you want the program to wait after receiving last communication from the plane before deleting the marker.
3 minutes
5 minutes
10 minutes
15 minutes
30 minutes
60 minutes
90 minutes
Cancel
Apply
OK


Options
Grid Squares
URLs/IPs
Alerts
SQLite
Persistence
Home Location
Call3
KeyCapture Info
This form is used for backup storage of your Home Station position.
You can backup and retrieve Latitude, Longitude, and altitude.
This is used to restore those values if they have been accidentally erased.
Latitude
40.270537
Longitude
-75.96435
Altitude
335
Get from Storage
Get from Storage
Set Home Station
Set Home Station
Cancel
Apply
OK


Options
Grid Squares
URLs/IPs
Alerts
SQLite
Persistence
Home Location
Call3
KeyCapture Info
The first time this program is run it writes the file call3.txt to the directory %localAppData%/W3SZ/Database/, unless a file named call3.txt already exists in that directory.
The location %localAppData% is generally of the form x:/Documents and Settings/Username/Local Settings/Application Data on Windows XP systems and on Windows 7 systems, for example, but may vary from computer to computer.
If you click this button it will write a copy of the original call3.txt file to to the same directory, but naming the file call3.bak in order to avoid accidental erasure of any call3.txt file already in that directory.
If you want to use this backup as the call3.txt file for this program, you will need to manually rename it from call3.bak to call3.txt.
Create file call3.bak
Updated copies of the file call3.txt may be downloaded from the URL: http://www.mmmonvhf.de/ after logging in and clicking on "Downloads" on that webpage.
Cancel
Apply
OK


Options
Grid Squares
URLs/IPs
Alerts
SQLite
Persistence
Home Location
Call3
KeyCapture Info
The following KeyCapture functions are available:
<Ctl> F1 will place latitude and longitude of the point under the mouse cursor in the Home Station position boxes, if the "Lat" radiobutton is selected for Home Station.
<Ctl> F2 will place latitude and longitude of the point under the mouse cursor in the DX Station position boxes, if the "Lat" radiobutton is selected for DX Station.
<Ctl> F3 will place the altitude of the point under the mouse cursor into the Key Capture Altitude TextBox in the RF Calculations section of the main form.
<Ctl> F4 will display a message box showing Latitude, Longitude, Altitude, and Grid for the point chosen when the F3 key was last used as described immediately above.
<Ctl> F5 activates ToolTips for all forms.
<Ctl> F6 deactivates ToolTips for all forms.
<Ctl> F7 shows information for the selected plane obtained by searching an Internet database using the ICAO24 hexcode to search.
<Ctl> F8 shows Flight information (both current and historical) for the selected plane obtained by searching an Internet database using the Flight Number to search.
<Ctl> F9 shows this page.
Cancel
Apply
OK

1 Atkins, R. Radio Propagation by Tropospheric Scattering. Communications Quarterly Winter 1991, pp 119-127.
2 Yeh, LP. Simple Methods for Designing Troposcatter Circuits. IRE Transactions on Communications Systems September 1960, pp 193-198.
3 Flowers, A. RainScatter 1.61. http://www.frontiernet.net/~aflowers/rainscatter/
4 Jet Propulsion Laboratory, California Institute of Technology. http://www2.jpl.nasa.gov/srtm/
5 SRTM3 files for North America can be downloaded from http://dds.cr.usgs.gov/srtm/version2_1/SRTM3/North_America/

Altoids Tin Filters

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Several years ago, I described a series of "Multiband Microwave Transverters for the Rover - *Simple and Cheap* " (www.w1ghz.org), with several later enhancements. These have proved popular; I hope they have gotten some hams on new microwave bands. I did warn that they were adequate for a simple QRP station, but would need more filtering when augmented with amplifiers.

My suggestion was for "real metal filters," but no concrete suggestions. Unless you are lucky with surplus finds, good filters are hard to make or expensive to buy. Even with some decent machine tools, filters take time and care, though the results are usually rewarding.

I was recently inspired by bad weather and too much broken equipment needing repair to try building some simple, inexpensive filters. The goal is a filter with good performance with minimal cost that can be built in a couple of hours with modest tools.

Filter design

Filter design software, no matter what the cost, yields a set of dimensions that meet some performance specifications. This is only half of the problem; the other half is making it realizable within practical limitations – can I build it? The practical limitations and capabilities could range anywhere from a shop with a 6-axis CNC machine to a drill and soldering iron on the kitchen table. Most hams are somewhere in between, but closer to the latter.

Since these transverters are QRP rigs, aren't we required to use an Altoids tin somewhere? Can we build a decent filter in an Altoids tin?

A good filter type for UHF and microwaves is the combline filter. I use a printed version in my LO boards. The combline filter uses parallel transmission line resonators less than a quarter-wave long, loaded by capacitance at the open end. This allows tuning over a range of frequencies by varying the capacitance. Typical electrical length of the resonators is between 30 and 60 electrical degrees; a quarter-wavelength is 90 degrees.

Once the resonator length is chosen, the type and impedance of the transmission line resonators is estimated. Then the resonator spacing and required tuning capacitance may be calculated – usually by software except in very simple cases. If we are trying to fit into an available enclosure, like the Altoids tin, the choices may be limited and require some trial-and-error tradeoffs to fit.

Altoids filter

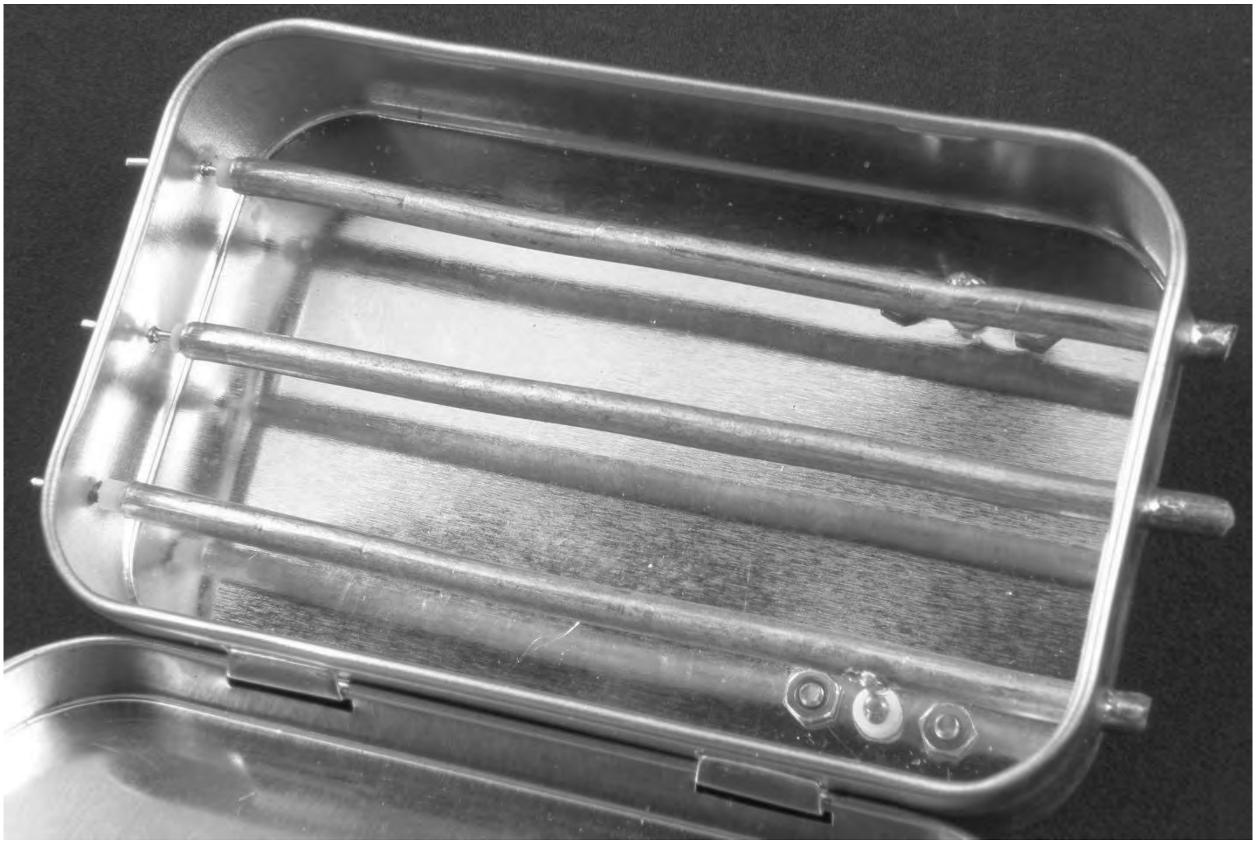

Figure 1 – 432 MHz Combline filter in Altoids tin

A simple way to make a transmission line resonator is a cylinder between two flat plates, known as slabline. For the cylinder, I use the outer conductor of common semi-rigid coax, 0.141 inches in diameter, such as UT-141. Then the inner conductor provides the capacitor, sliding out to adjust the capacitance – approximately 2.4 pf per inch. The outer conductor is soldered to the tin wall at one end, and the inner conductor to the other end after tuning, making a reasonably rigid assembly.

Several configurations of input and output connections are commonly used, but most straightforward is to tap the end resonators near the ground end. This configuration does not permit easy adjustment, but once the correct tap point is known, adjustment is not needed.

The minimum number of resonators for decent filter shape is three. More resonators provide better filter shape but make tuning more difficult, especially with limited test equipment.

A few trial calculations suggested that the lowest ham band frequency that would fit in an Altoids tin is about 432 MHz. The resonators are about 46 degrees long, and require about 4 pf to resonate. Lower bands would require more capacitance than the coax can provide. Calculated characteristic impedance of the semi-rigid coax resonators is 116 ohms. A lower impedance might be desirable, but would require larger, more expensive coax than the readily available 0.141 inch diameter.

Since I needed a 432 MHz filter for another project, I put one together - construction details below. The filter is shown in Figure 1, and the performance in Figure 2. Loss is about 1 dB, and bandwidth is about 36 MHz, with the common LO frequency of 404 MHz about 15 dB down. A narrower filter would be desirable, but would require wider spacing between the resonators, and there isn't room in the Altoids tin, especially with the rounded corners.

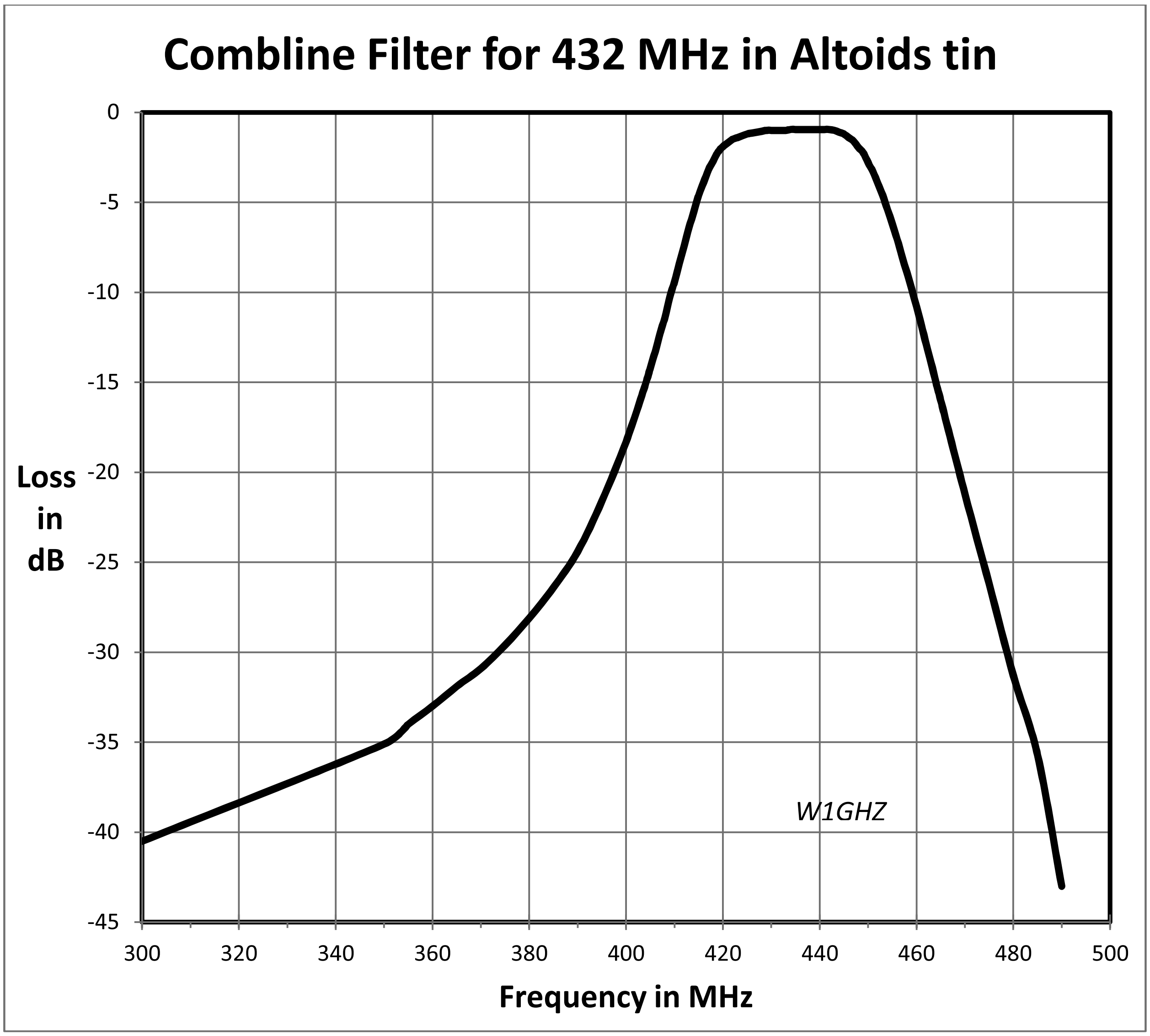

Figure 2 – Performance of 432 MHz Combline Filter

Tuning is a bit tricky, involving pulling one center conductor with a pair of pliers while holding the other two center conductors with other fingers so they make connection to the box. This is repeated for each conductor in turn until the desired performance achieved - then the inner conductors are soldered to the box. Tuning a filter is a series of tradeoffs, and is easier with a swept-frequency setup. The tuning starts around 300 MHz with the inner conductor only pulled out a small amount, perhaps 1/2 inch, but moves up smoothly to 432 MHz or a bit higher – this filter could be tuned to any frequency in this range, perhaps for an LO frequency.

902 MHz Filter

The 432 MHz filter demonstrates that the Altoids filter is feasible - now what about higher frequencies? Rotating the Altoids tin so the resonators fit the short dimension, as shown in Figure 3, makes the length about 57 degrees at 902 MHz. Much less capacitance is required, roughly 1.5 pf, so the inner conductor is nearly all the way out and tuning is much more finicky. The tuning starts about 600 MHz before the inner conductor is pulled out, so it could be tuned to any frequency in between, if needed.

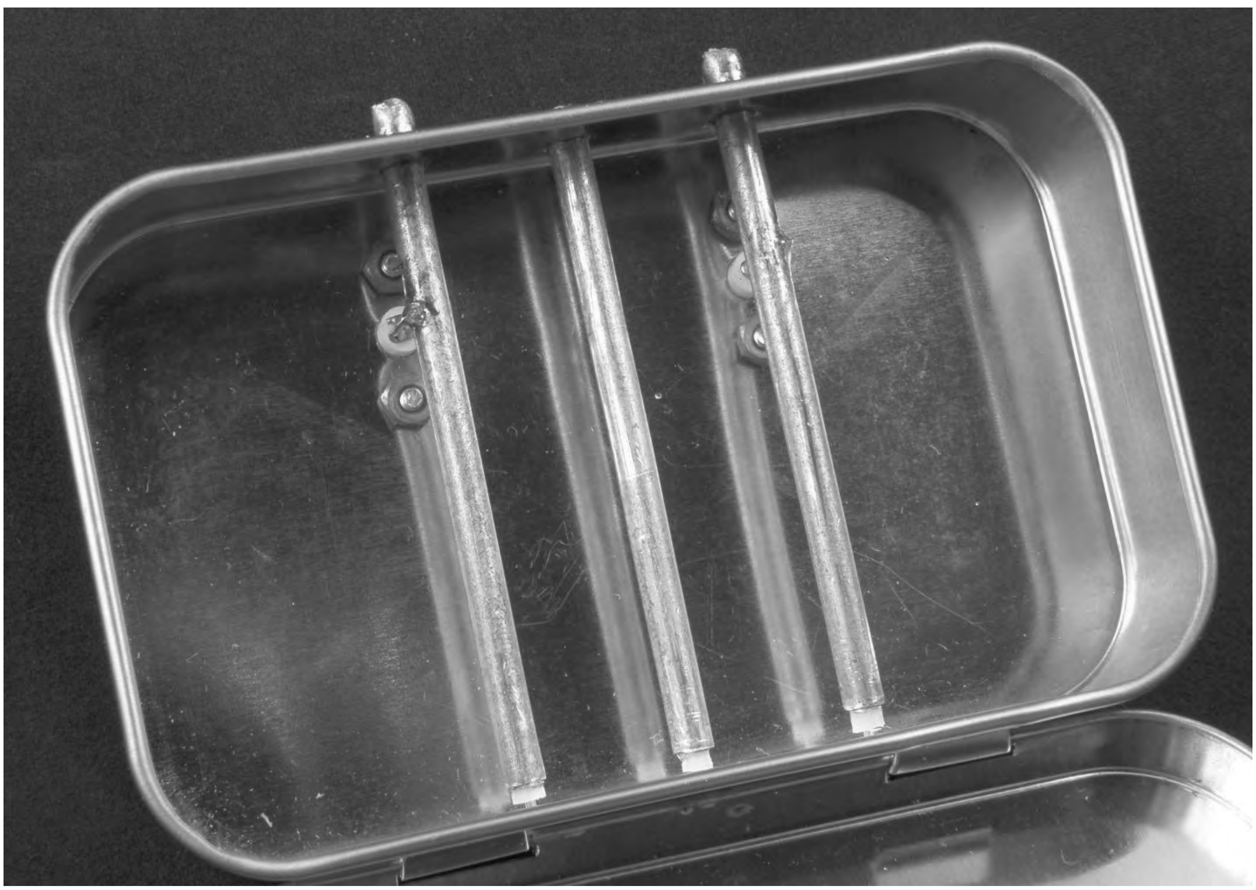

Figure 3 – 902 MHz Combline filter in Altoids tin

Performance is shown in Figure 4, with a loss of about 1 dB and a bandwidth of about 80 MHz. The filter shape isn't as pretty because I chose to improve the VSWR at 902 MHz rather than worry about loss over the whole bandwidth.

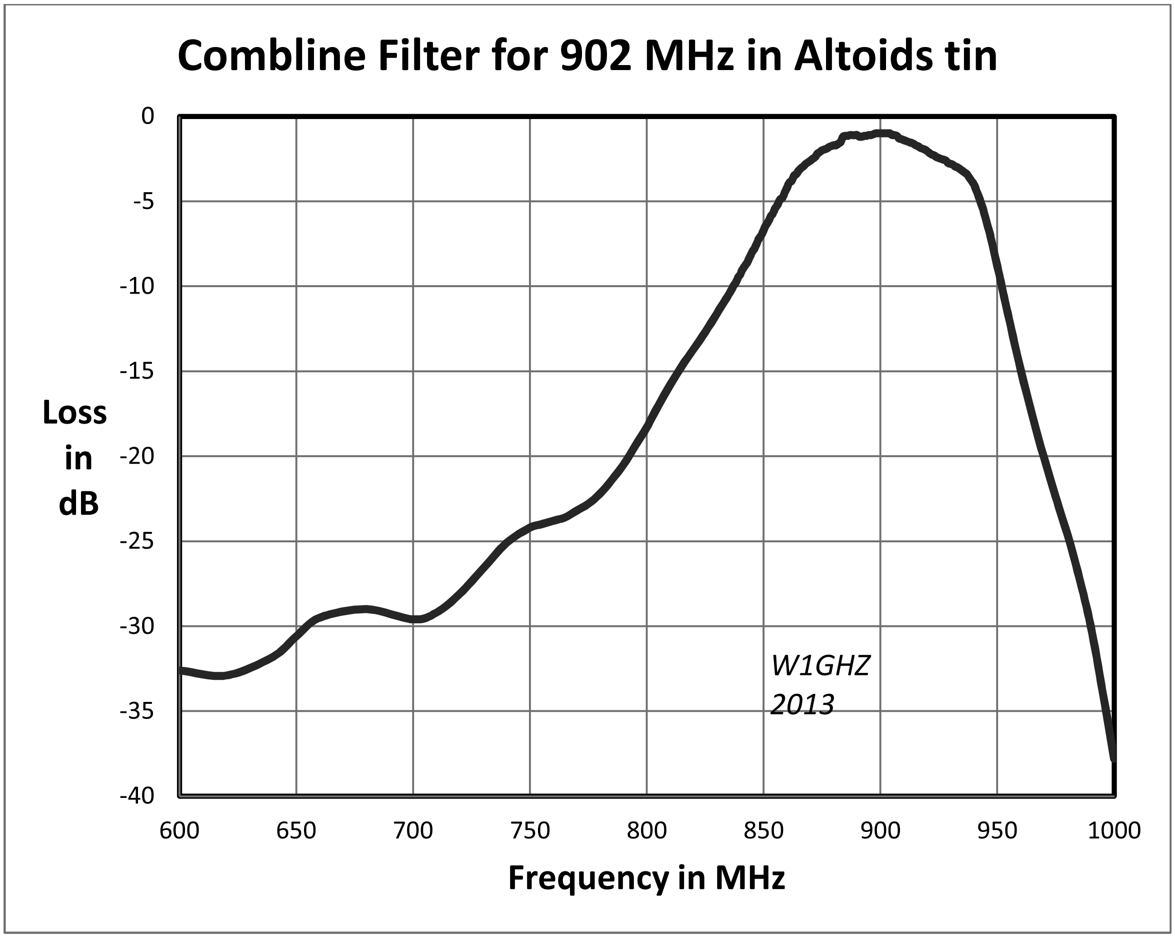

Figure 4 – Performance of 902 MHz Combline Filter

For the higher frequency, there is room in the Altoids tin make the filter sharper by increasing the spacing between resonators or to add an additional resonator. Either would make the tuning more difficult, and increase the loss – tinned steel isn't the highest Q material.

1296 MHz and 1152 MHz Interdigital Filter

The width of the Altoids tin is a quarter-wavelength at 1282 MHz, so resonators for 1296 MHz would be 90 degrees long; unfortunately, this will make a bandstop filter rather than bandpass. Instead, we can flip the center resonator to make an interdigital filter, so that the center resonator grounded at the opposite the grounded end of the adjacent resonators.

I made two interdigital filters with tapped inputs, one for 1296 MHz and one for 1152 MHz for the LO frequency. Both were difficult to tune, especially at 1296 where the resonators are close to ½ wavelength long and only a tiny bit of additional capacitance is possible. The best tuning resulted in a lumpy passband shape and very poor input and output VSWR. The high VSWR resulted in high loss, since most of the power is reflected. The performance curves are included in Figures 5 and 9.

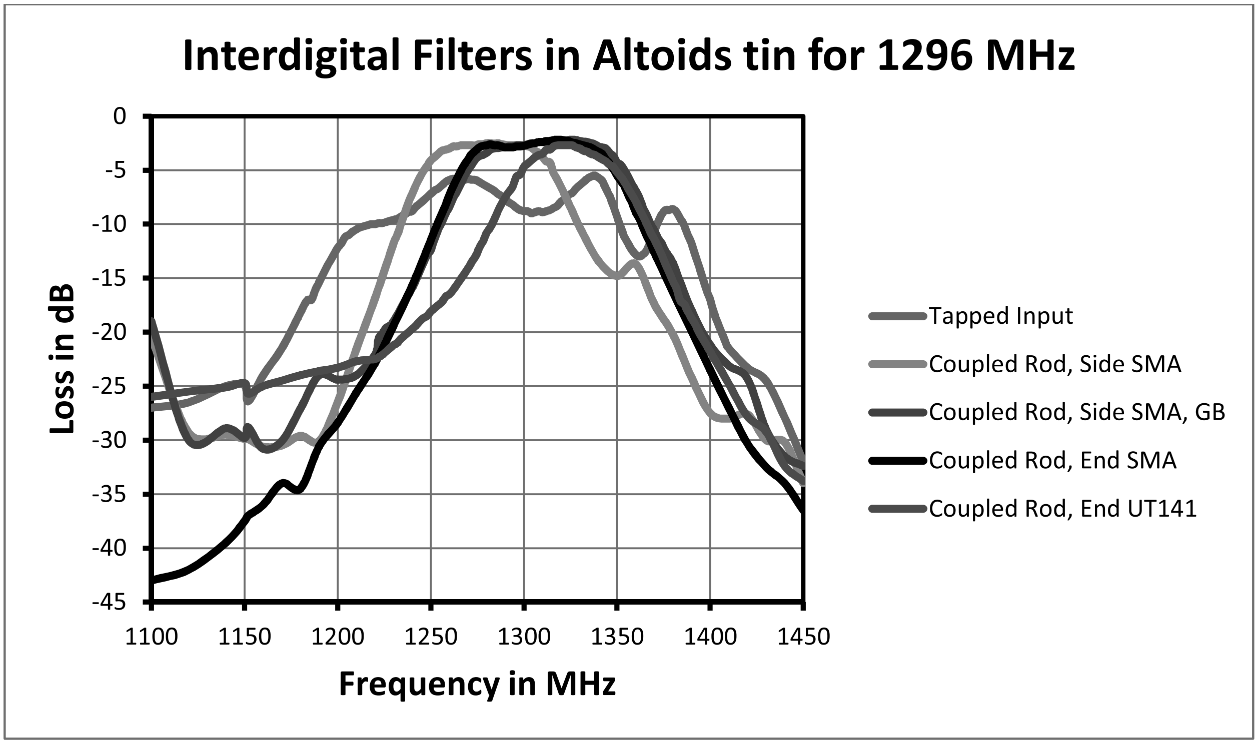

Figure 5 – Performance of 1296 MHz Interdigital Filters

When I made the printed filters for my Cheap and Simple Rover Transverters, I found that side coupled inputs and outputs provided better performance than tapped input and output. There is room in the Altoids tin for additional rods for coupling, and the semi-rigid cable is inexpensive, so I calculated the spacings for side coupling rods and built a couple. The first attempt, in Figure 6, mounted the SMA connectors in the bottom of the box with a wire up to the open end of the coupling rod from the side. Performance of this version, also included in Figures 5, is much better, with good filter shape and improved VSWR. An additional advantage is that very little tuning is needed – the resonators are just about ½ wavelength without capacitance, so only a short stub of center conductor is left to provide mechanical support.

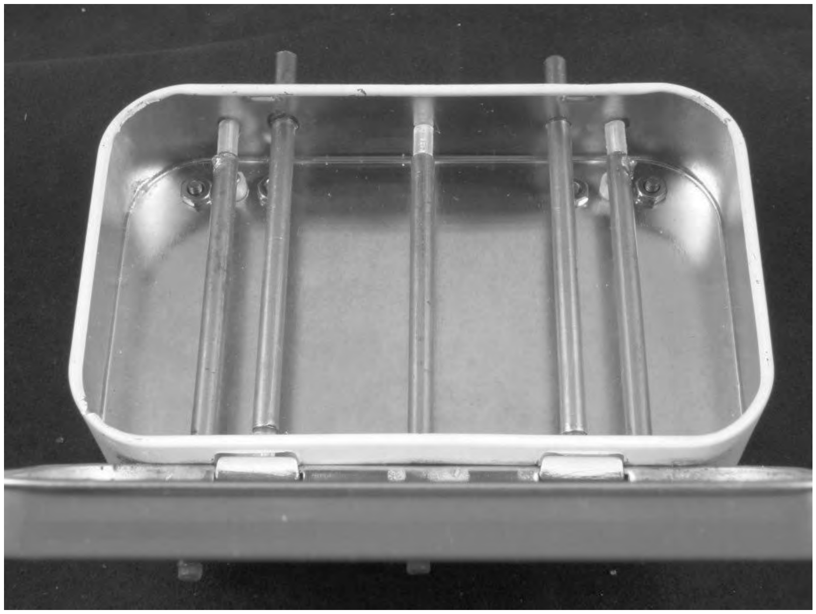

Figure 6 – Interdigital filter with coupled-rod input and side connectors

The 1296 MHz filters in Figure 6 with the side SMA connectors show limited out-of-band rejection in Figure 5, only about 30 dB. I wondered if stray coupling was occurring between the SMA connectors. One solution is to put the SMA connectors in line with the rods, as shown in Figure 7. Figure 5 shows a nice filter shape for this version with much better out-of-band rejection. Rejection of the 1152 MHz LO frequency is better also. This one also requires no tuning – the rods are resonant near 1296 MHz.

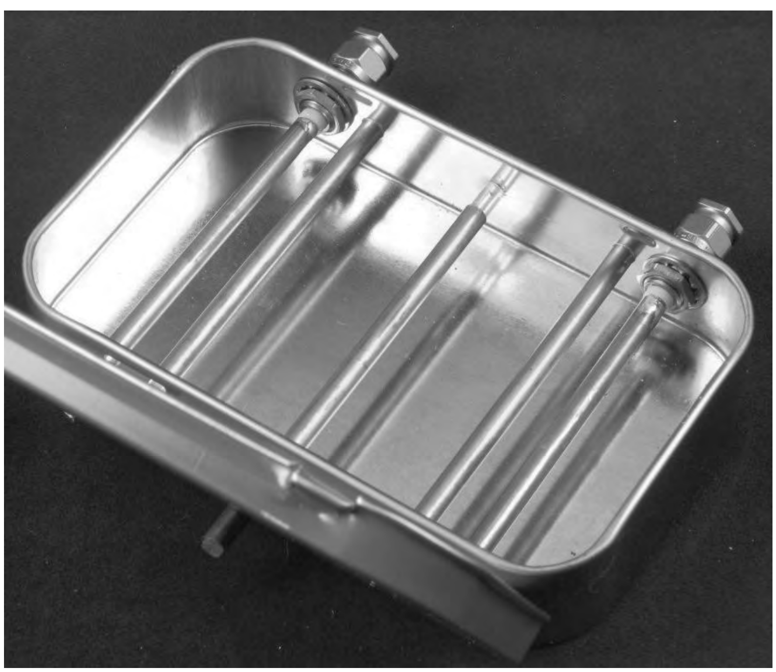

Figure 7 - Interdigital filter with coupled-rod input and end connectors

At the recent 2014 Eastern VHF/UHF Conference, I got a chance to measure the filter in Figure 7 on a modern, calibrated VNA provided by Greg Bonaguide, WA1VUG, of Rohde & Schwarz. The results, shown in Figure 8, are even better than my home measurements, with a clean response curve and loss slightly less than 1 dB.

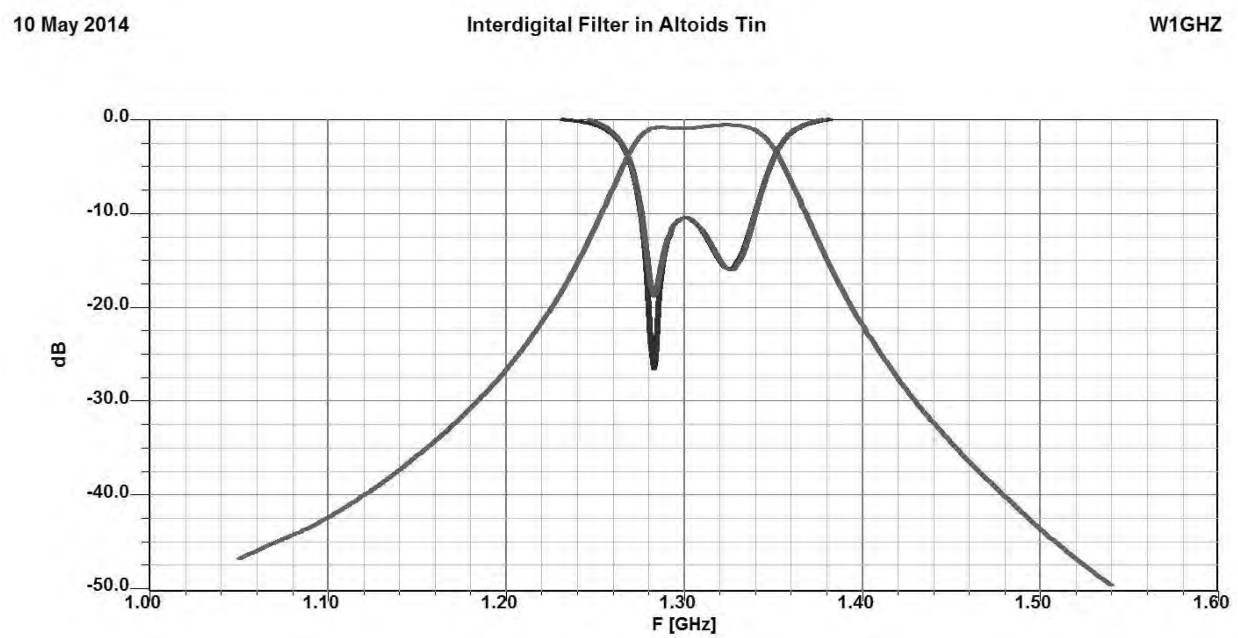

Figure 8 – Performance of filter pictured in Figure 7

I used male SMA connectors for the version in Figure 7 since they were the only ones I had on hand that fit in the space, and I only had two. Male connectors are fine for connecting directly to another module, but most short cables have male connectors, limiting options. Since we are already soldering semi-rigid cable to the box, why not use cable for the input and output, connecting directly to adjacent modules, as shown in Figure 9. With no tuning, this one is centered slightly high in frequency in Figure 5 – I cut the resonators slightly too short so the response is about 2 dB down at 1296 MHz. The center frequency could be moved down by adjusting the center conductor, but I soldered them without testing thoroughly.

Interdigital filters for 1152 MHz are identical to the 1296 MHz filters, except that part of the center conductor is left inside the outer conductor to provide capacitance to lower the resonant frequency. It should be possible to tune these interdigital filters as low as 750 MHz with the center conductor. The curve in Figure 9 labeled "Coupled Rods" is for a filter very similar to the one in Figure 7.

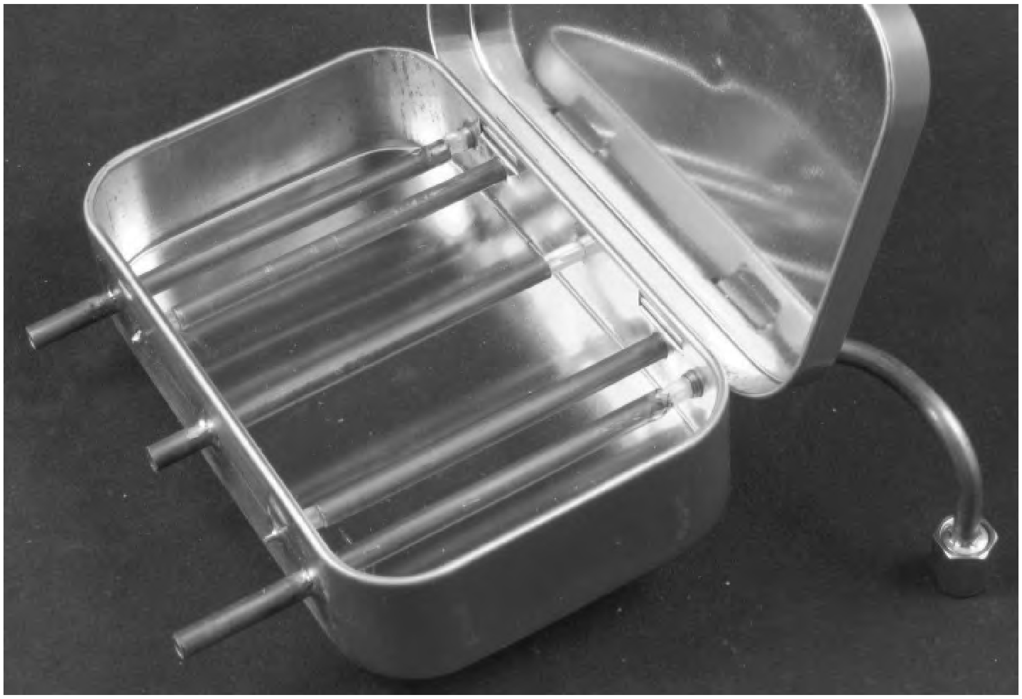

Figure 9 - Interdigital filter with coupled-rod input and semi-rigid cable end connections

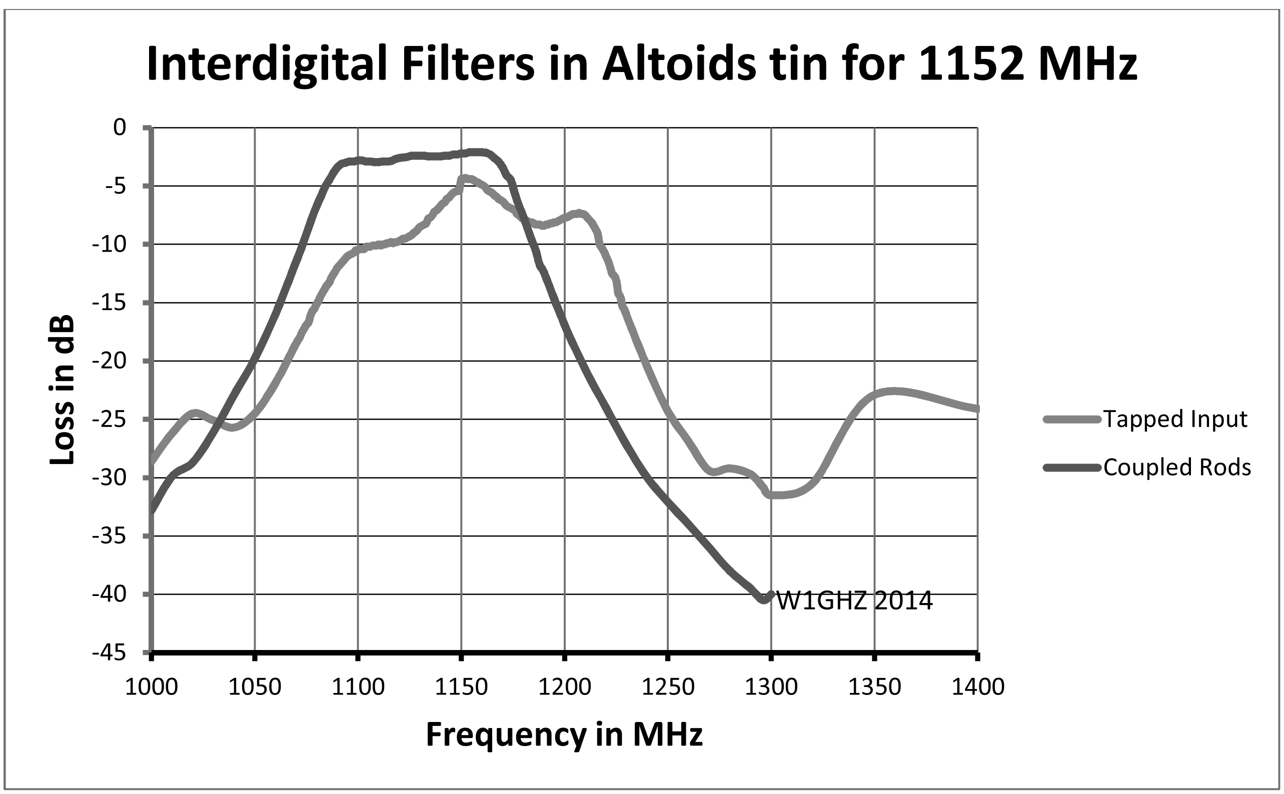

Figure 10 – Performance of Interdigital Filters tuned to 1152 MHz

Filter Construction

The Altoids tin is made of very thin steel, easily soldered with a medium-sized iron, but the paint must be removed first. I use an abrasive wheel (Scotch-Brite Paint and Rust Stripper) in a drill or drill press, which removes paint quickly without tearing up the metal. Then it is a matter of marking and drilling the holes. I mark them with a cheap caliper used as a scribe, prick the hole location with a scriber, then drill a very small hole, #60 or 1 mm at each location. Then I use brad point drill bits which make a clean hole in thin metal. Sets are sold for woodworking (www.woodcraft.com), but only two sizes are needed for these filters: 9/64" for the semi-rigid coax and 5/32" for the SMA connectors.

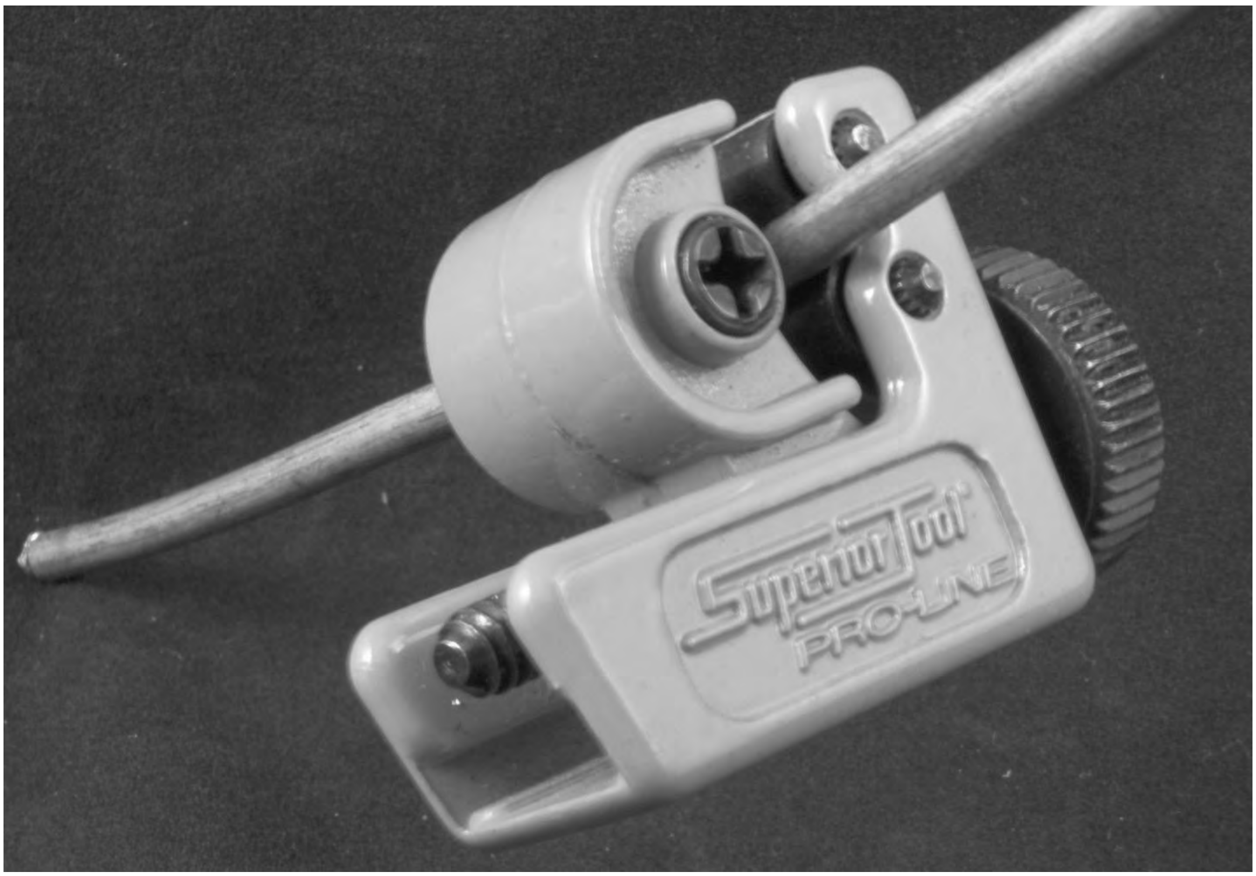

Figure 11 – Preparing semi-rigid coax with miniature tubing cutter

For the semi-rigid coax, the best tool is a miniature tubing cutter. As shown in Figure 11, the tubing cutter is used to nick the outer conductor just enough so it snaps instead of bending. Nick it again about a half-inch away, snap it again, then pull the short section of outer conductor off with pliers. Make a cut all the way around the Teflon at the desired location; the goal is to leave enough to push the exposed Teflon against the wall of the box and control the length of the resonator. Next, pull off the end of the Teflon, leaving a short length of inner conductor exposed. Then clamp the coax in a vise with V-jaws (which also straighten any small bends in the coax) and pull on the inner conductor with pliers (Figure 12) until it starts to move, but leave it in the coax for tuning. Trim the end of the inner conductor slightly to remove any burr.

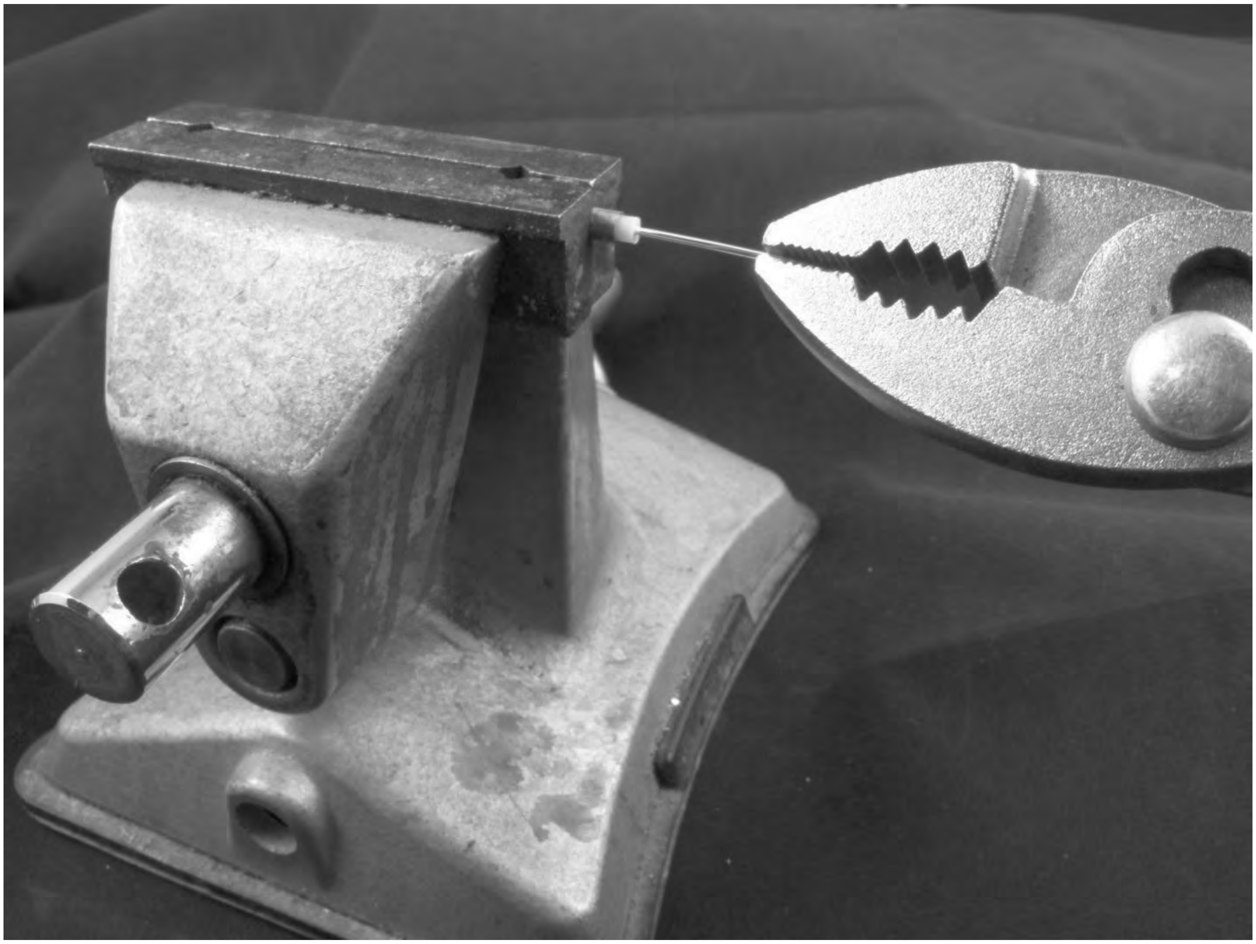

Figure 12 – Pulling out center conductor of semi-rigid coax

Install the SMA connectors in the Altoids box, then add the input and output wires and push them aside. Now it is time to install the resonators. The 0.141" diameter coax is a very tight fit in the 0.140" diameter holes, but the thin metal gives enough so it slides in tightly and stays put.

At the far end, guide the inner conductor through the small hole and adjust for the desired resonator length. When all three resonators are in place, apply a bit of paste flux around them on the outside of the box only, and then solder them in place at the ground end only.

For the comb filters, solder the input and output wires to the resonator tap points with small dab of paste flux. Clean up flux and close the lid, and the filter is ready for tuning.

For the interdigital filters with coupling rods, remove the center conductor completely, then pull the Teflon out enough so that one end of the semi-rigid coax is empty. Inset the empty end toward the connector, apply a small dab of paste flux, and solder the open end to the connector or input cable.

Connect the filter to a detector and a signal generator, preferably a swept-frequency setup. Of course, if you have a network analyzer, that's even better. Tuning is a matter of pulling (or pushing if needed) one center conductor with a pair of pliers; once the center conductor is started, as shown in Figure 12, it becomes easier to move and the vise is no longer necessary. While tuning one resonator, hold the other two center conductors with other fingers so they make connection to the box. Repeat for each conductor in turn until the desired performance achieved - then the inner conductors are soldered to the box. For fine tuning and final compromise, VSWR may be more sensitive than loss.

Dimensions

432 MHz combline filter: resonators are 16.7 mm center to center, input and output taps at 19.5 mm from ground end. Resonator length = 2 mm less than Altoids long dimension.

902 MHz combline filter: resonators are 17 mm center to center, input and output taps at 11 mm from ground end. Resonator length = 2 mm less than Altoids long dimension.

1296 MHz interdigital filter: resonators are 21.2 mm center to center. Coupling rods are 8.8 mm center to center from outside resonators. Center resonator length = 4.3mm less than Altoids short dimension. Outside resonator length = 3.7mm less than Altoids short dimension. Coupling-rod length as needed to reach connector, roughly same as outside resonator.

Summary

These simple filters are easy to build and cost very little, even if you have to buy the Altoids. The 1296 MHz version will work with no tuning required. The filters can help clean up your signal, reduce birdies, and sweeten your breath at the same time.

Acknowledgement

Thanks to Ken, W1RIL, who provided me with a large bag of Altoids tins.

Simple Cheap MMIC Preamps

Who needs a GaAsFET?

Paul Wade W1GHZ ©2014
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I have tried some of the newer MMICs from Minicircuits[1] as moderate power amplifiers[2,3], providing several hundred milliwatts with good gain from VHF through the lower microwave bands. Noise figures (NF) are reasonable for a power amplifier, perhaps 4 dB, so the dynamic range is impressive.

At Microwave Update 2013, WA5VJB was selling LNA kits at a reasonable price – the kit consisted of a MMIC and a PC board. The PCB was marked G4DDK/G8EMY/VJB, two guys who know about LNA design, so I bought one to give it a try. The MMIC is a Minicircuits PGA-103. The datasheet shows NF under 1 dB from 50 MHz up to 2 GHz. I put the kit together and fired it up – the Noise Figure is under 1 dB at 144, 432, and 1296 MHz, all with no tuning. Gain is 22.5 dB at 144 MHz, 20 dB at 432 MHz, and 12 dB at 1296 MHz. Not bad for a $1.99 device!

The circuit, shown in Figure 1, is very simple, with just a blocking capacitor in and out, and an RF choke to supply 5 volts to the MMIC. The reason for the RF choke, unlike the resistor used in older MMICs, is that the current is rather high, about 100 milliamps, so the required resistor would be rather small, less than 10 ohms, which would substantially reduce the gain.

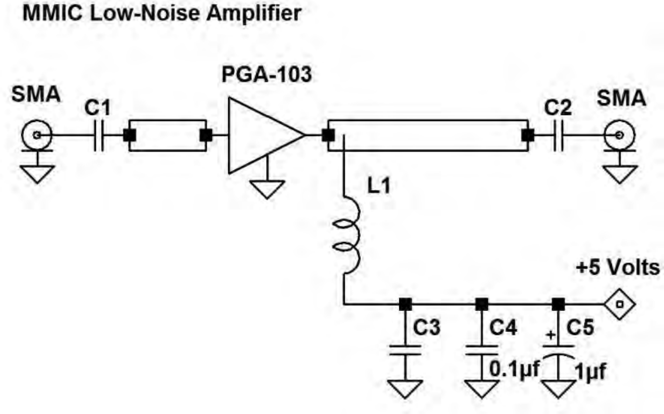

Figure 1- MMIC LNA Schematic Diagram

Frequency	**C1**	**C2**	**C3**	**L1**	Suggested L1	Digikey
144 MHz	1000 pf	1000 pf	1000pf	56 nh	Bournes PM0805-56	M8460CT-ND
432	100	100	100	56	Bournes PM0805-56	M8460CT-ND
1296	18	18	18	27	Bournes PM0805-27	M8456CT-ND
PHA-1	100	100	100	27or56	Bournes PM0805-	M8640CT-ND

The WA5VJB PC board is intended to attach directly to small coax cables. This is probably adequate for VHF, but not for microwave use. I used short lengths of thin semi-rigid coax, shown in Figure 2, but it does not feel robust.

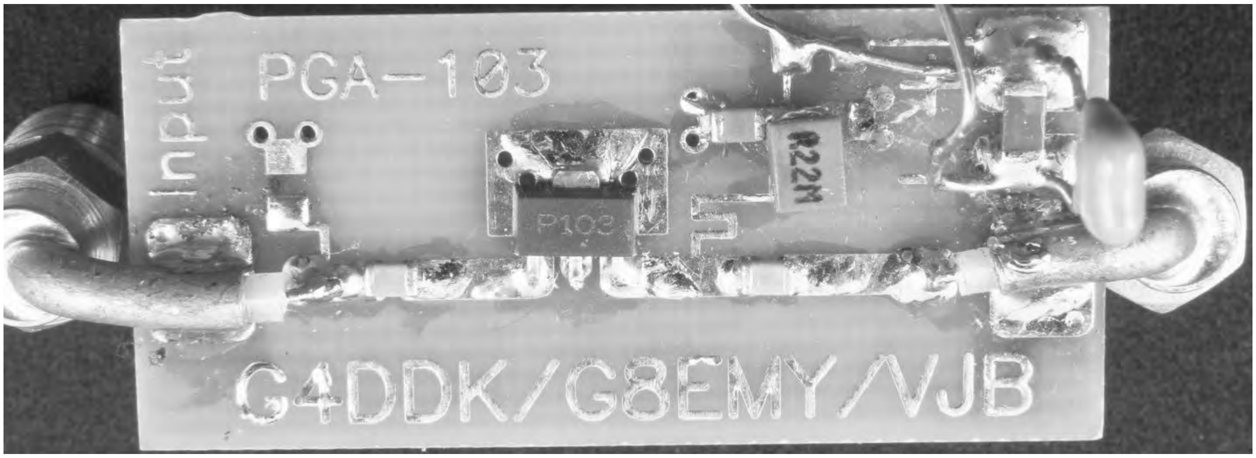

Figure 2 - MMIC Preamp on WA5VJB board

Since the simple circuit is similar to the moderate power amplifiers, I wanted to try some on the same PC boards I use for the power amplifiers. I ordered some PGA-103 MMICs, found some RF chokes in a sample kit from a VHF conference, and put three units together. I chose different component values for each unit: one to favor 144 MHz, one for 432 MHz, and one for 1296 MHz. One of these units is shown in Figure 3.

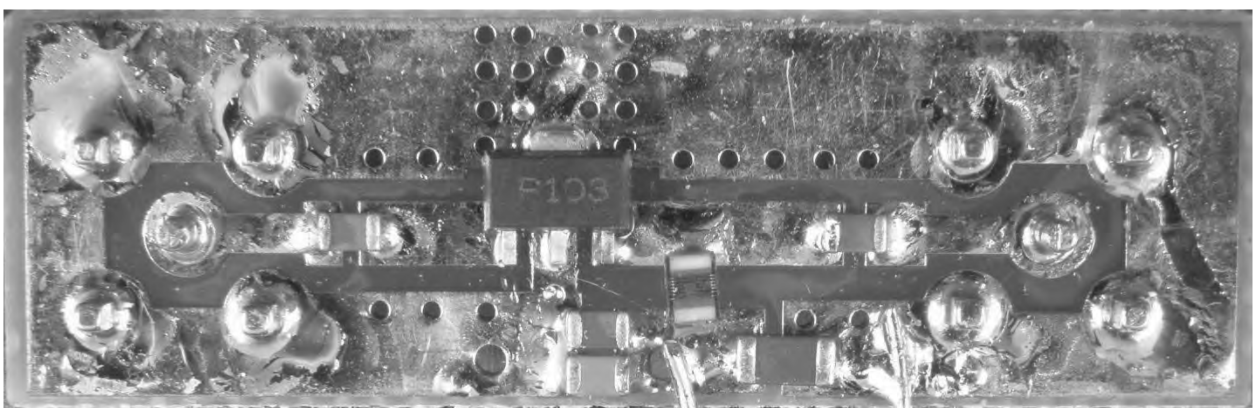

Figure 3 - MMIC preamp on PC board with SMA connectors

The 144 MHz unit had 26 dB of gain at 144, rolling off to 13 dB at 1296 MHz. Indicated Noise Figure was 0.25 dB at 144, 0.6 dB at 432, and 1.95 dB at 1296 MHz.

The 432 MHz unit had 25 dB of gain at 144, 21 dB at 432, rolling off to 13 dB at 1296 MHz. Indicated Noise Figure was 0.35 dB at 144, 0.6 dB at 432, and 1.7 dB at 1296 MHz.

The 1296 MHz unit had 19 dB of gain at 144, 22 dB at 270 MHz, 20 dB at 432, rolling off to 14 dB at 1296 MHz. Indicated Noise Figure was 0.65 dB at 144, 0.6 dB at 432, and 1.65 dB at 1296 MHz. Correcting for the second stage at 1296 gives a calculated device NF of about 0.75 dB. Using the 432 MHz unit as a second stage at 1296 MHz brought the indicated NF down to 0.75 dB.

At the recent 2014 Eastern VHF/UHF Conference, I got a chance to measure two units on modern, calibrated test equipment provided by Greg Bonaguide, WA1VUG, of Rohde & Schwarz. These units have the suggested component values for 144 MHz shown in Figure 1, packaged in an Altoids tin like Figure 6, with the internal voltage regulator shown in Figure 10. The results in Figure 4 confirm that the simple, inexpensive MMIC LNA has excellent performance up to at least the 2.3 GHz band.

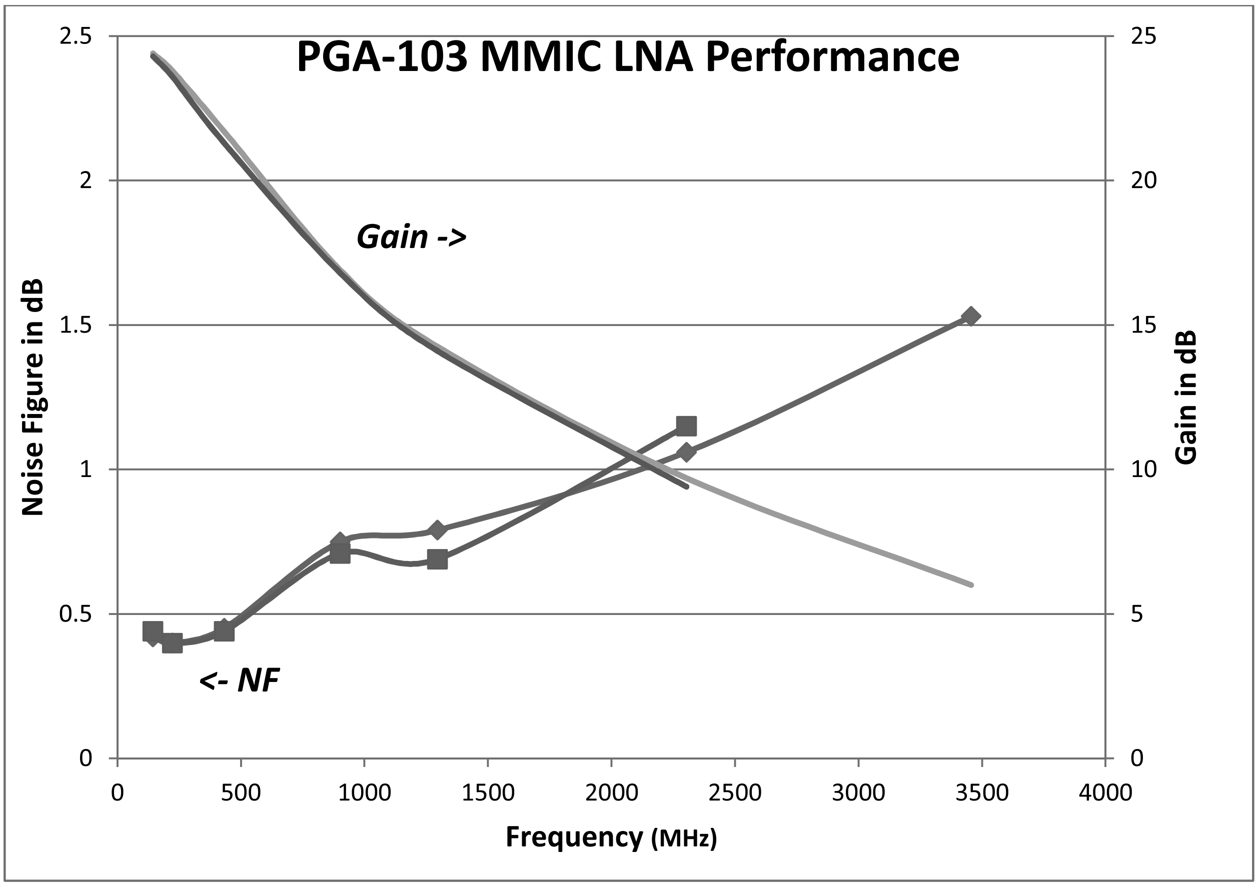

Figure 4 – Measured performance of two MMIC LNAs

Another interesting MMIC is the Minicircuits PHA-1, also priced at $1.99. This device has lower gain, but pretty good noise figure and higher power capability, 200 milliwatts or so. The circuit is the same as Figure 1, and a PC board is shown in Figure 4. I tried a couple of these with the 1296 MHz component values. The gain is nearly flat at 15 dB, falling off slightly to about 13 dB at 1296 MHz. Noise Figure is also flat, about 2 dB at 144, 432, and1296 MHz. This one might be a good choice for a second stage.With appropriate component values, it might make a terrific 6-meter preamp with high dynamic range; most rigs don't need a preamp at six meters, but some of the SDR rigs can use one.

Tuning

A really nice feature of these MMICs is that no tuning is required to get really good performance. The input and output are quite well matched, with Return Loss better than 10 dB over the whole frequency range, so tuning is probably not going to provide a whole lot of improvement.

Providing a low NF with a matched input is quite a contrast to a typical LNA, which might have an input reflection coefficient upward of 0.9 – highly mismatched – when tuned for best NF. We know that a high VSWR increases transmission line loss; does this apply to the LNA as well? A low-VSWR MMIC with a slightly higher NF might reduce cable loss and provide better system performance than a mismatched LNA. EME operators know that putting the LNA right at the antenna eliminates transmission line loss and provides best performance.

Construction

These MMICs are in a small plastic SOT-89 package with three leads – the center lead is ground, and connects to a heatsink paddle on the bottom of the package. As mentioned earlier, these devices draw roughly 100 mA at 5 Volts, so ½ watt is dissipated. Dead-bug construction will not work, heat sinking is required. The PC boards have a number of plated-thru holes under the ground lead and paddle to conduct the heat to the ground plane side of the board. This seems adequate – the MMIC temperature is reasonable, according to one of my ten precision temperature sensors.

The MMIC and SMT components are soldered down with temperature-controlled soldering irons: first a hefty one for the device paddle and the SMA connectors, then a fine tip iron for the leads and other components. Figure 5 shows a unit under assembly in a precision fixture I made to hold the PC boards with SMA connectors attached during assembly.

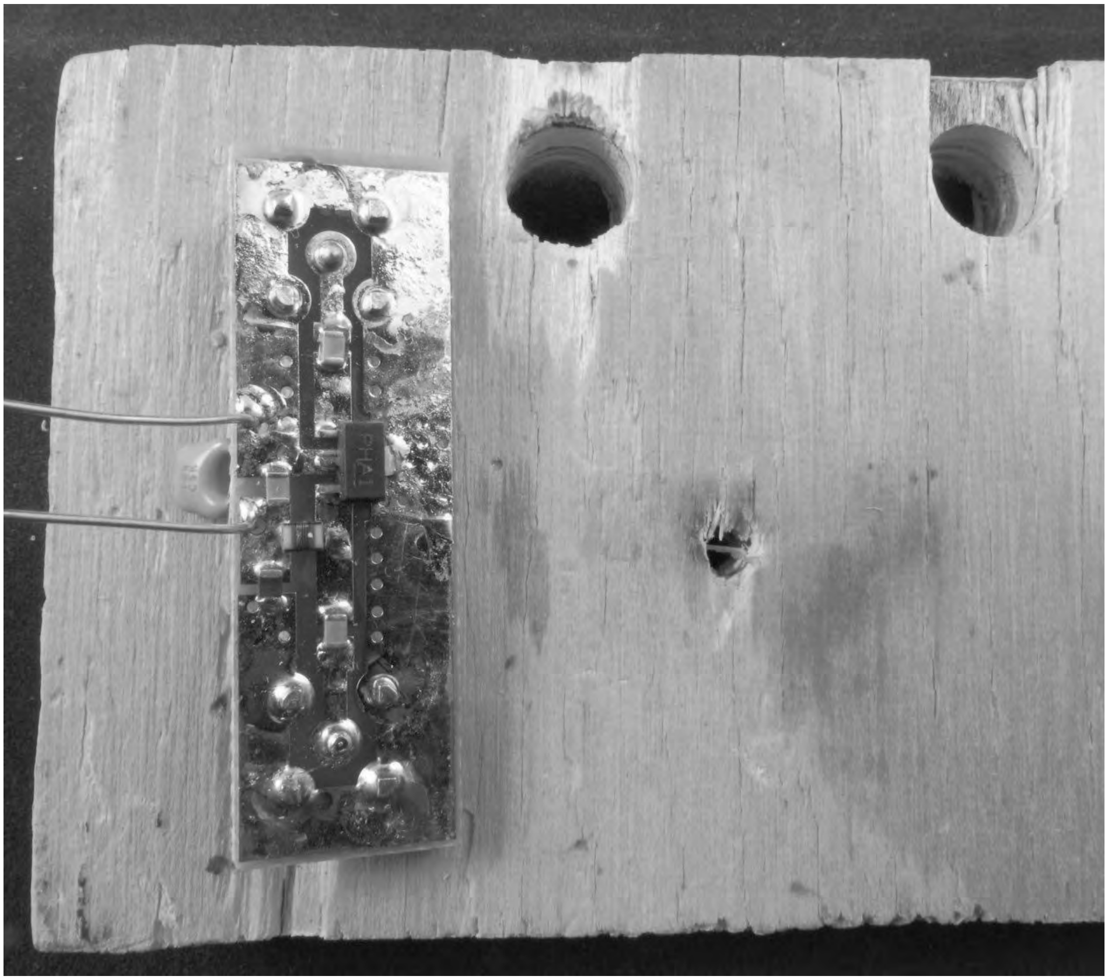

Figure 5 – PC board with PHA-1 MMIC in precision assembly fixture

Packaging

A plain PC board with SMA connectors like Figure 3 works just fine, but doesn't offer much RF shielding or physical protection. For a small, inexpensive metal box, I found a small tin of Altoids mints at the Cabot General Store for $1.19 that is the perfect size. My first attempt at using these had the PC board inside the box and the SMA connector on the outside with the five SMA pins going through the box and board.   The connector is soldered to the box and board. This required accurately drilling ten small holes as well as removing the paint from the Altoids tin.

After putting together a half-dozen or so preamps, I realized that the SMA connector cost was more than everything else combined. Time to look on ebay – I found some Chinese SMA connectors with a long threaded section for about a dollar each. These allow me to assemble and test the board before putting it in the box, and only two ¼ inch holes are required in the tin. Several of these preamps are shown in Figure 6. And the total cost of each preamp is under $10.

Figure 6 - MMIC preamps in small Altoids tin

Power Supply Noise

Since the MMICs operate at 5 volts, the obvious power solution is a three-terminal regulator. I added a 7805 regulator to a couple of the units and was surprised to find that the noise figure increased noticeably, from 0.25 dB to over 0.5 dB on the best unit. Some tests confirmed that the regulator was adding noise, and my oscilloscope showed about 8 millivolts of noise on the 5 volt regulator output.

I did some research and asked for suggestions on the internet microwave reflector. A few responses reminded me that the 7805 data sheet calls for capacitors on input and output – I've been using these things with the recommended capacitors for 40 years and have drawers full of the capacitors. But there were also some useful suggestions, which I appreciate, particularly a noise reduction circuit from Wenzel (http://www.wenzel.com/documents/finesse.html) and suggestions for zener diodes. I breadboarded and tried several different circuits to reduce the noise.

First, I looked at the Wenzel circuit and simulated it in LTSpice[4]. It didn't do diddlysquat to reduce noise. But companies like Wenzel like to run their oscillators at higher voltages, and the circuit works well at 15 volts. A bit of calculation and fiddling with component values yielded the circuit shown in Figure 7, which reduces noise on a 5-volt supply by more than 20 dB.

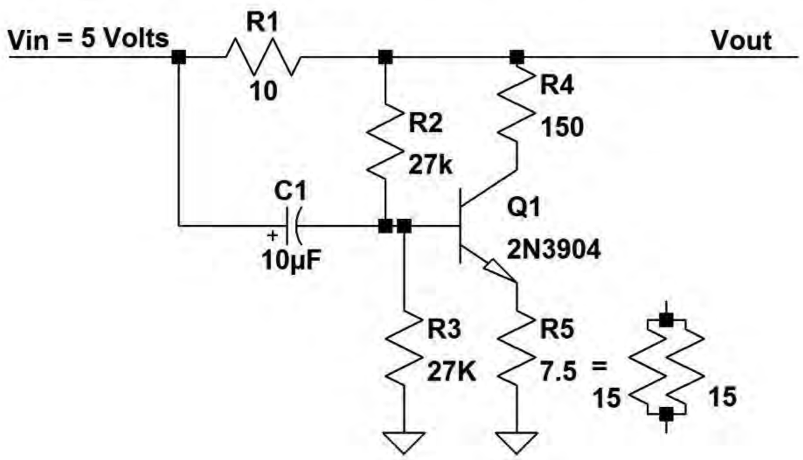

Figure 7 - Wenzel noise reduction circuit modified for 5 Volt operation

Another suggestion was the classic capacitance multiplier, shown in Figure 8.

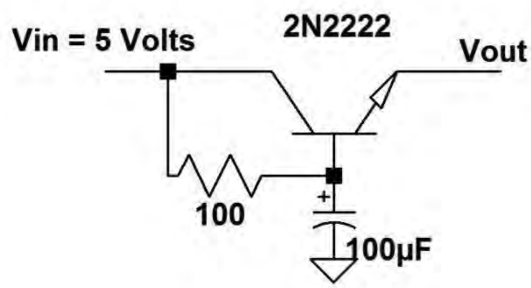

Figure 8 - Capacitance Multiplier for noise reduction

Zener diodes are often used in GaAsFET and HEMT preamps operating at low voltages, but those devices operate at much lower currents. (Zener is a misnomer – true zener diodes operate at 6 to 7 volts, while other voltages are really avalanche diodes, just like RF noise sources. The difference is that noise source diodes have very low capacitance, while power "zener" diodes have enough capacitance to limit noise at VHF and higher frequencies). For a 5 volt zener diode to provide 100 mA from a 12 volt battery (perhaps 11 to 15 volt range), a lot of power would be wasted in the zener and dropping resistor. However, most of my transverters operate on 8 volts from an internal regulator – having a fixed input voltage makes the zener practical, as shown in Figure 9, because we don't have to waste as much current to allow for a wide input voltage range.

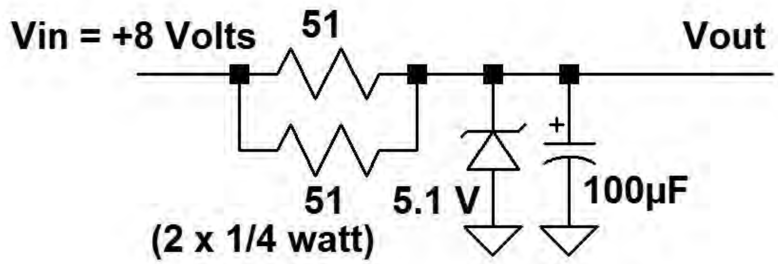

Figure 9 - Zener diode for 100 mA output

Finally, a simple resistor and capacitor following the three-terminal regulator, like Figure 10, may be adequate to reduce low-frequency noise. The RF decoupling capacitors should take care of higher frequencies.

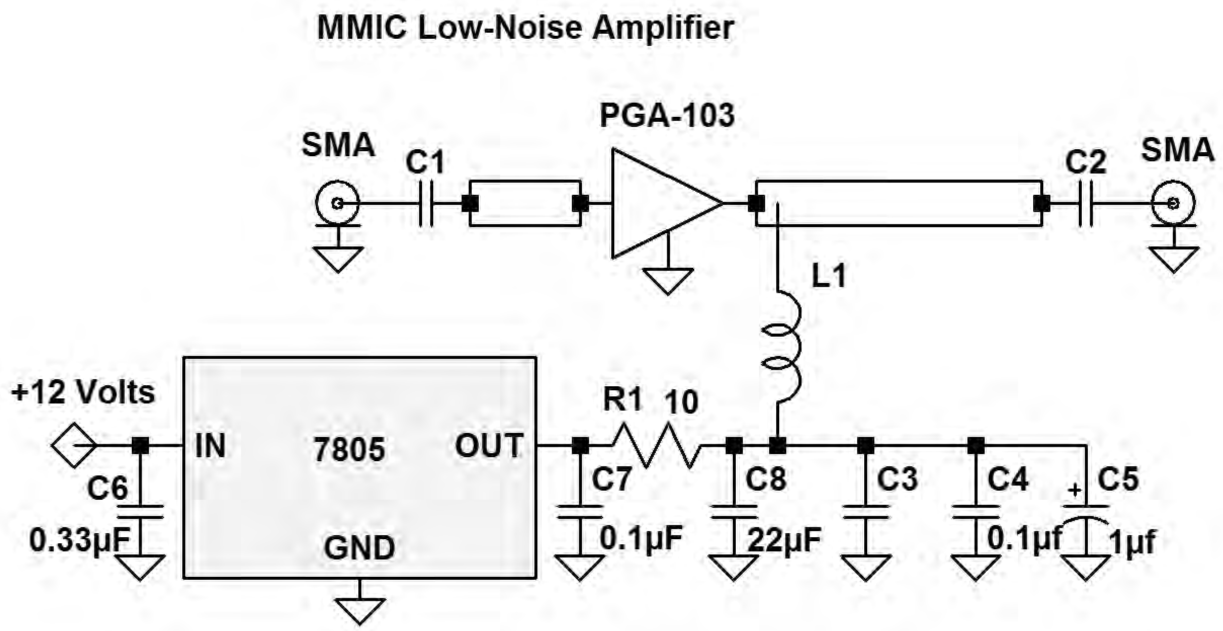

Figure 10 - Complete MMIC preamp schematic with simple R-C noise reduction

I breadboarded all of these noise reduction circuits and tried them on several preamps at both 144 and 432 MHz, testing the NF while powered with a battery for comparison. All of the circuits were successful in reducing the NF to the battery-powered level, so I wasn't able to get any meaningful comparison. However, none of the preamps were as good as the original one with 0.25 dB NF – that one failed during the January VHF contest. I'd like to repeat the experiment with a really good one, but haven't found another yet. For now, the simplest solution, following the 3-terminal regulator with the resistor and capacitor like Figure 10 seems to suffice. The resistor drops the voltage to around 4 volts, but the data sheet hints that NF may be better at lower voltage – I don't see any appreciable difference.

Several complete preamps in small Altoids tins are shown in Figure 6. The regulator and noise reduction circuit is dead-bug wiring. Note that an idiot diode in series with the input voltage is missing from the schematic diagram, but included in each preamp.

Oscillations

After all the power supply experiments, when I tested all the units on the air with the VE2FUT 222 MHz beacon, I found that some of the units showed spurious responses on the FUncube dongle bandscope in Figure 11. Since they seem to have some relation with the beacon keying, my guess is a low frequency oscillation mixing with the beacon signal. The oscillations were still present with the preamp powered by a battery, so they are coming from the MMIC. The beacon signal is still weakly present, but should be ~40 dB out of the noise. These units also had about 10 dB more noise output than the other units. I don't know why this oscillation didn't show up on the noise figure meter, but on-the-air is what counts.

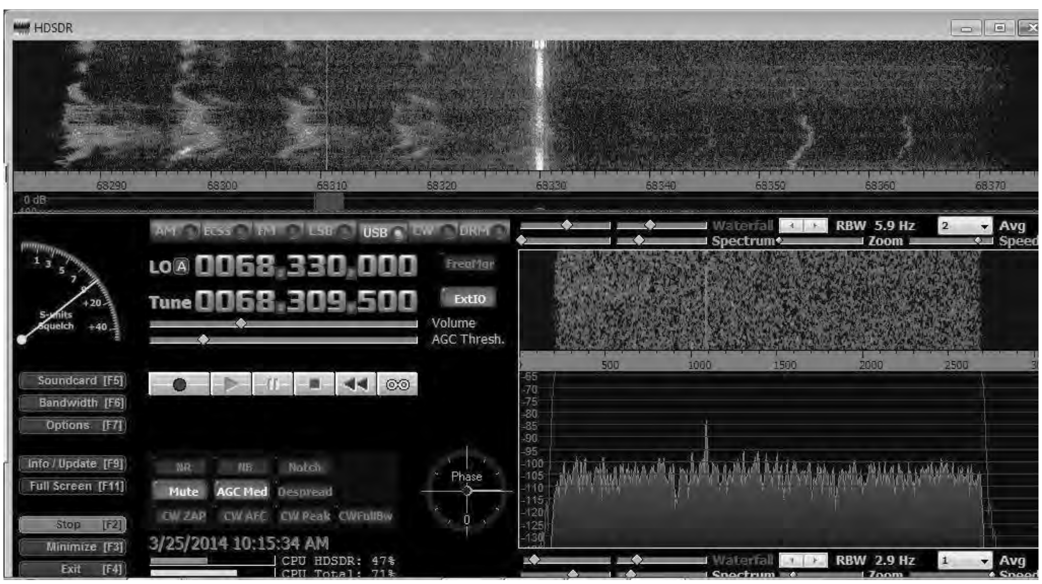

Figure 11 - Oscillating MMIC preamp listening to strong beacon

The oscillating units all had larger values of L1, 220 nh or 270 nh, chosen to be a high impedance at 144 MHz. The stable units have smaller L1, 30 or 51 nh, which appear to be wound with fine wire inside the surface mount inductor package; the winding is almost visible in Figure 3. Changing L1 to 51 nh tamed the oscillation. The inductor I use is Coilcraft 0805HQ-51NXJL from a sample kit – I haven't found anywhere to buy these in small quantities. Some suggested alternatives are listed in Figure 1.

A screenshot after changing L1 is shown in Figure 12. I swung the beam to aim at the K2DLL 222 MHz beacon. The VE2FUT beacon is now off to the side, reducing the signal to about 15 dB out of the noise. This direction is close to most contest activity, so I can see beacons while watching the calling frequency – this is how I realized that my preamp had failed.

Figure 12 - Preamp after changing L1, receiving two beacons

Power supply noise can also increase phase noise in oscillators. Phase noise is insidious – we don't notice its effect on weak signals, and it is hard to measure. So adding some of these noise reduction circuits to oscillators might help, and certainly can't hurt.

Filters

These preamps are really broadband, totally untuned, with high gain – they amplify everything. For instance, the strongest FM broadcast station at my QTH, at 107.9 MHz, is -17 dBm on an FM turnstile antenna. Amplified by 25 dB, this is enough power to make the mixer in a transverter seriously upset. And there are many other FM, TV, and pager transmitters that are also line of sight. Selectivity of the ham antenna and the receiver helps, but a filter for each ham band significantly reduces the birdie count. See the accompanying filter articles for some suggestions.

One advantage of well-matched preamps like these is that the filter response will not be upset and the filter will perform as expected. Many filters are seriously affected by high VSWR or high Q at the input or output – we don't usually measure this, but sometimes don't get the performance we expect from a filter.

Summary

These MMICs make a great LNA which is simple, cheap, and easy to build. Putting one in front of a pretty good transverter makes the band really come alive. Performance is not quite as good as the best HEMT LNAs, but close enough for all terrestrial work and for EME below 432 MHz, frequencies where atmospheric and local noise is the limiting factor. Even for EME on the higher bands, these preamps would make a great second stage.

A real test is watching a beacon signal just above the noise pop right up on the bandscope when the preamp is added, in Figure 12. The signal strength jumps up more than 20 dB, so it sounds impressive. More important is that the bandscope shows several dB improvement in signal-to-noise ratio – that's what counts, and makes a difference for copying weak signals

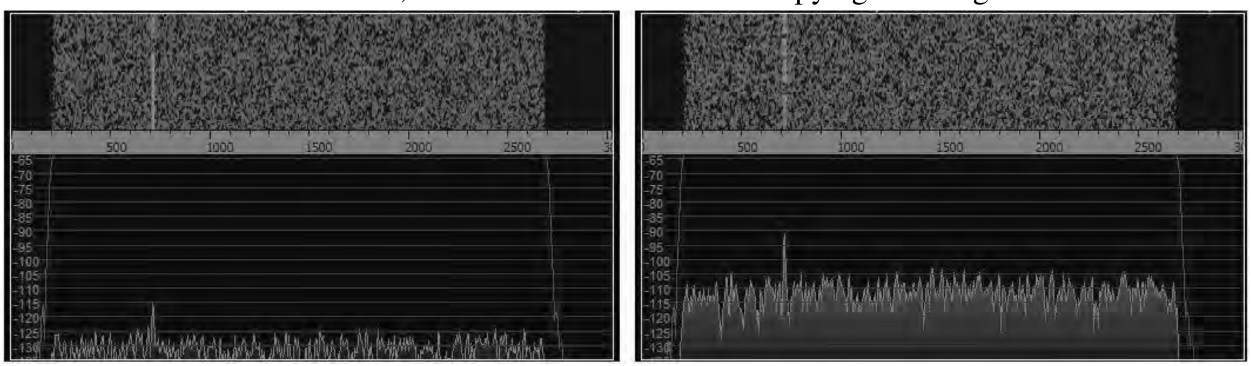

Figure 13 – Bandscope display without preamp on left, with preamp on right

I've made a dozen or so of these preamps, and all work well, with NF under 1 dB. This is a large enough sample size that you can expect similar results with no tuning. Only an hour or so is required for assembly and packaging, and the cost is low, around $10 if you buy everything.
I'd suggest building several so you have ready spares for roving, experiments, or even in case of a failure. When one of mine failed during the January VHF contest, I was able to swap it out in a couple of minutes.

So who needs a GaAsFET? No one, these MMICs are at least as good. Some of the HEMT devices might be better, but it only matters for EME or for bragging rights at NF competitions.

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2. Paul Wade, W1GHZ, "A Modest Power Amplifier for Cheap and Simple Microwave Transverters," *Proceedings of the 46th Conference of the Central States VHF Society*, ARRL, 2012, pp. 121-122.
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4. www.linear.com

Power Line Noise as seen at WA4NJP

By Ray Rector, WA4NJP
Gillsville GA, EM84dg

Purpose of the paper:
To provide real-life field experiences to the local amateur radio community with regard to RFI generated by local power company HV lines.

Additional limitations:
As I live in a rural area in Northeast Georgia, we are not subject to salt water spray or acid rain, we have temperature extremes of –5F to +105F, we have humidity range of <10% (winter) and >70% in month of Aug.

Caution:
At no time should we as Amateur Radio operators try to do anything physical to the power line equipment; don't push, hit or shake the poles; don't pull or shake the guy wires. Just don't touch…. only look and listen…

Over the years, most Amateurs have experienced some type of interference to the normal reception of their station. This interference can be of many types. It can come from nearby lighting, any electrical appliance or even the doorbell circuit. It can be natural or man-made. Today's society has seen a very large influx of new electronic gadgetry. A lot of these gadgets are powered by switching supplies that can generate strong interference. The new TV's, as nice as they look, can be an excellent source of interference. LED lighting, CFL's and other discharge lighting can also cause problems. These sources have to be addressed on a one by one case to try to find and fix the problem source. Any of these can generate noise that can be heard through our receiving systems, and to a big extent, they have a unique sound or noise signature. Almost all of these can be found and repaired by us, assuming that we as the Amateur operator have access to the offending device.

But there is one type of noise that is sometimes hard to find, can be at a very high level and at times seems to come from many directions. And…it is one that we as Amateur Operators cannot do anything about, by ourselves.

This is local power line noise, and it is generated in many places, by many different circumstances.

It is of the utmost importance that we as Amateurs let the professionals do their job, as there is a very large liability when working on or around HV distribution lines. They (local power company) are the only ones that should be involved with the actual hands-on when working around power lines. Any hitting, shaking the pole or guy wire are tasks that should always be done by the trained, skilled and authorized professional that knows and understands the limits and extents of these actions.

It can be said that there is no financial benefit to the local power company for fixing noise problems. There is no measurable amount of energy wasted in generating power line noise. So at best they will cooperate with us if we understand that our small problem takes no priority in their normal workday. We will have to be patient and let them schedule their work, within their normal timeframes, taking into consideration weather, line maintenance, new construction and many other normal activities.

I have found that Mondays/Fridays are not a good days to request help as they are always busy, but Wednesdays and Thursdays are good!

About 4 years ago, I retired and built a new Shack. I only had to move my equipment 150 feet, but it may as well been a mile! For I still had to do new wiring, new operating positions, new cable entry and the relocation of many antennas and new grounding. As I began to establish a new operating position, I found that I had a lot of power line noise, so a call to my local company was made and in short order, I began to get real results. The local contact was cooperative, knowledgeable and also had support from his company.

power company employee listening with ultrasonic receiver to pinpoint noise source.

Since I have stations on 50, 144, 220 and 432, I already have antennas to pinpoint the sources of my earlier noise problems. These noises were within 100 yards, and right in front of my home. With continued effort, the two really bad ones were fixed. The level of interference from them made it impossible for me to pinpoint them with my station antennas, but a second receiver located 100 yards away did the trick.

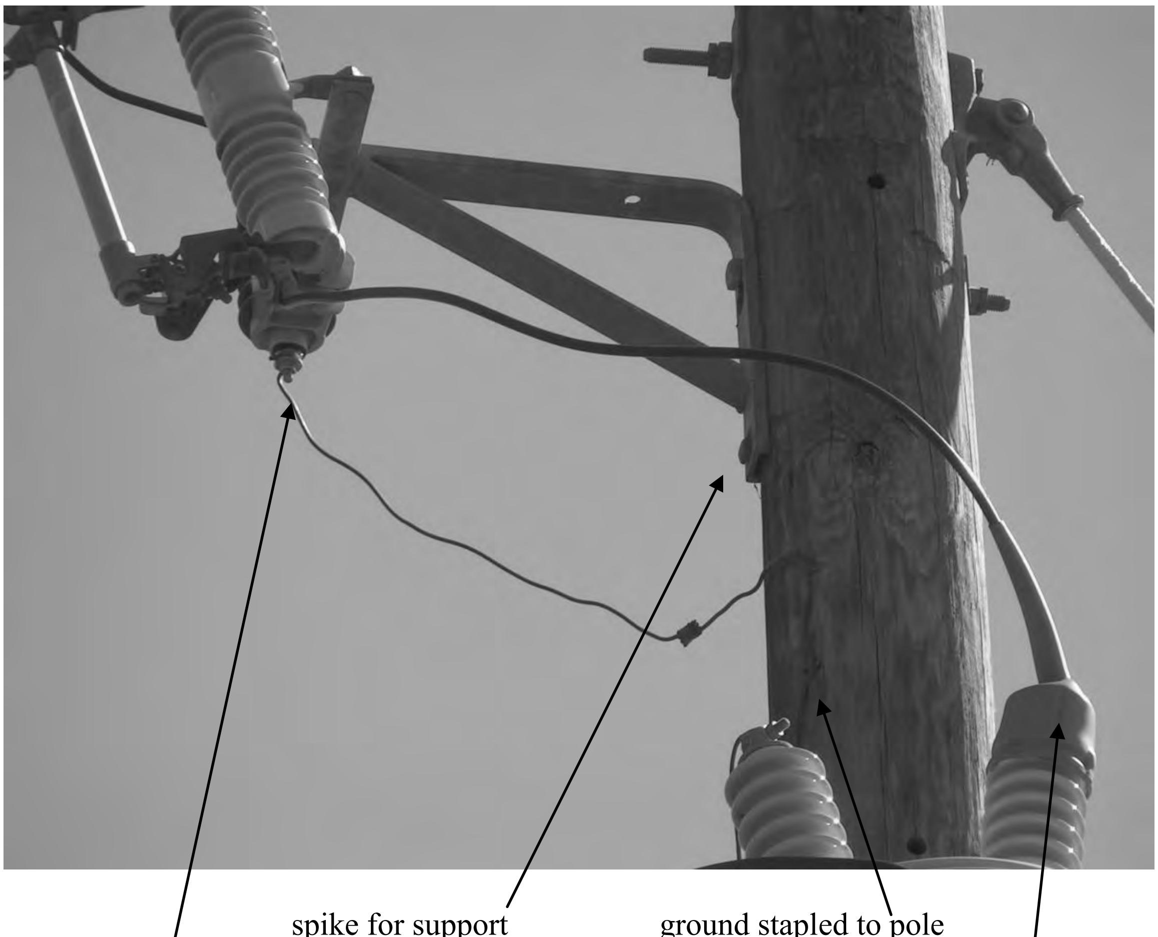
Now to make a rash statement, in 3 years of trouble shooting the electrical noise in my local area, we did not find a single bad insulator!!! We found drops to homes with missing or bad insulation and real evidence of corrosion and arcing; we found loose hardware, more loose hardware, rusted hardware, hardware improperly installed and all of these can cause NOISE.

The biggest offender of all these hardware devices was the lowly STAPLE! As seen by the construction crew, it is a simple device to secure and support the ground wire as it makes its way from the bottom of the lightning arrestor down, bonds to the neutral and then continues down the pole into the ground as part of the grounding circuit for protection. The real problem is that the staple will not stay tight.

First Story…One morning I went to the shack to see how conditions were on 6 meters and found that I had an S9+ noise apparently coming from one of the poles that was just worked on, an email to my local contact brought a 3 man crew to investigate…. The guy in the bucket using an ultrasonic sniffer located the problem quickly: loose hardware on the pole. Well, as this was their second effort on the same pole in 2 weeks, a work order was put in to replace this 35 year old pole. Another week, here comes two trucks, 6 men and a trailer with a new pole…After 3 hours, the weather was good, new pole, new hardware, reused the old transformer and the power was back on…All was quiet from this pole, I did discuss a different location I had spotted and off they went to pursue this noise. A bit later they said they found "some more loose hardware" and all was quiet for the moment from some of the first very strong problem areas. But sometimes this proved not as good as one would think; seems like the noise wanted to run or radiate at great distances from the real problem area. I went so far as to put up a second station on 144 to try to triangulate the problems.

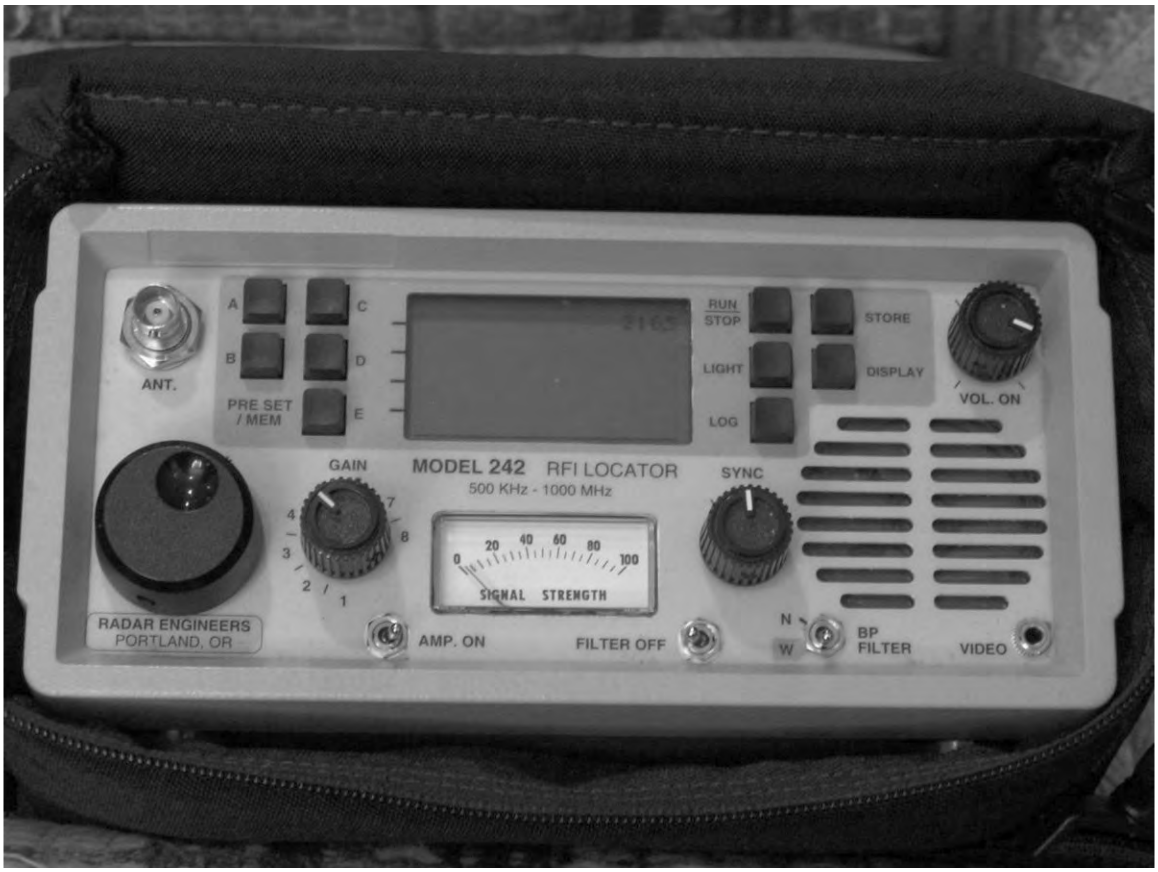
Nice day, nice weather and nice new pole for my QTH!

Second Story… 30 days later from 1st story, same type of noise, same pole, (now new) S9+ noise on 50 MHz, another email, in three days, same crew, up in air with ultrasonic sniffer, again “ found loose hardware”. This time there was a discussion about maybe some changes need to be made in the construction that was normal…the “loose hardware” was noted as the bracket that held the fuse holder and the lightning arrestor…It was mounted to the pole with one bolt through the top with a proper washer and nut on bottom end, where the noise was coming from, was a small spike that was driven in the bottom of this bracket to give it additional support. It had backed out, as the pole sees different weather, back up into the air, removed the spike, drilled through and placed a second bolt to properly secure this bracket…in the next two hours this was done to three poles…….I still am hearing from the “guy” in the bucket that the staples were also noisy, “so I give ‘em a little tap”…



This is a picture of the typical pole hardware installation; you see the ground wire from the bottom of the lighten arrester goes to the pole and attached with several staples as it goes down the pole. Also note the large “spike” nail that is driven into the lower mounting hole of the right angle arrester/fuse holder bracket. Finally, there is the “squirrel guard”, which can also be a noise generator. Not sure why, but there seems to be a constant corona arc from hardware at top of insulator to this plastic insulating device, The same noise is seen when the power line crew slide the long (normally Orange in color) protective insulation on the lines when working on them. This noise stops when they are removed.

In watching these men work, it became apparent that all of them want to find and eliminate noise so they won't have re-calls. They have a lot of equipment to find noise: the ultrasonic receiver, hand-held, with small a parabolic dish used to "listen" to the noise source from ground level; there are other ultrasonic listening devices on long fiberglass poles (sniffer) that the man in the bucket could listen very close to an offending area; they have several RF receivers, from DC to daylight, some with a recording scope.



This is a photo of one of the receivers that is used in the search for local power line noise, complete with 'S" meter and LCD recording scope; it has a broad frequency range, several filters and optional internal preamp; battery powered and with an external antenna input.

They even had a set up that would allow the engineer to monitor a fixed frequency, attach a GPS, hook it to the laptop and drive around the community; on the return, he could get a Google map of the drive and the noisy spots highlighted on map; pretty cool tools for out in the country…..

Third Story… 30 days passed, same noise, same place. So I emailed the EMC and two days later same crew came out…all scratching their heads, some like me, with nothing to scratch!!!

They went up in the air and found the same loose piece of hardware…"the staples". In normal pole installation, this #6 ground wire is run from the bottom of the lightning arrestor back to the pole where it is then attached to the pole with 2-3 staples, then continuing to the neutral where it is bonded and then continues toward the earth being held in place with numerous staples as it progress to the bottom of the pole. The staples that are above the neutral wire are in a HV field, when the staples lose DC contact with the ground wire, and the humidity is low, a small arc appears, this arc is estimated to be only a few thousandths long but at 100 yards is S9 on 50 Mhz…Houston, we now have a problem, this is three times for the same noise…A few phone calls to Corp Headquarters', Eng, Dept…to try to resolve this issue…I guess you could say that some southern engineering was in the making…a sort of waiver was allowed to slightly modify the construction…DON'T USE STAPLES AS THEY JUST WILL NOT STAY TIGHT!! The answer was to reroute the ground wire straight down from the lightning arrestor to the neutral wire, not going to the pole not using staples..

Anything inside of the circle is in this High Voltage field.

ground wire from arrestor **no** staples

additional bolt, **no** spikes **no** squirrel guard

After modifying numerous poles in the local area, most of the power line noise has now been minimized.

Hardware: the cotter pin that holds the clevis on an insulator can get isolated by corrosion and act just like the staple; the wire wraps that secure the HV wire on top of insulators can also become corroded and arc; any wire span that is not tensioned properly will have loose hardware; finally, loose guy wires are also a big problem. And last but not least old wooden poles that cannot keep the attached hardware tight are a real problem.

typical example of slack span

The slack span is normally found on a connection to go directly across the street, some times less than 50 ft. Without proper tension, the hardware does not make good connection and because it is in the High Voltage field, it causes small arcs. Arcs = noise.

As you can see, the new center guy wire has no tension on it, the other end is where the loose hardware is and it is in the HV field near top of pole.

Now you're thinking "what about all these leaky insulators" we keep hearing about?

In almost 4 years of trying to solve my noise problems, "insulators" have not been an issue. They have changed a few in my area, but only because other associated hardware was being changed at the same time.

Photo of 120/240 drop from transformer to my home

In the continued hunt for all the noise we find another noise on wet days, the above picture is of the main drop line from the transformer to the home meter base, we found noise from this line, as the weather had deteriorated the insulation and allowed it to split.

The insulation split allowed moisture ingress and with time, corrosion formed around the inner (aluminum) conductor, resulting in small amounts of intermittent current flow. This noise was also found with the use of ultrasonic listening devices. This was the actual wire that fed my home and had been in service for about 35 years. Now I have a new and slightly larger new service cable, and some of my neighbors have also had new drops installed.

After 3 years and many service calls, I can see a BIG difference. Can't say I have all my noise solved, but….I'm definitely gaining on it!!

I have heard that if it rains it will "wash the insulators clean" but I just don't see that at my QTH. My problems have always been small arcs within hardware. These arcs are extinguished with rain or high humidity or as the hardware moves about with weather.

After dozens of workdays, some with 3 trucks and up to 7 men, the local power company is still cooperative to the needs of the local Amateurs, but I would suggest that before you contact the local power company, you be sure that you have your house in order. Be absolutely sure that the noise is coming from their power lines, turn off the main breaker to the home and operate with a battery connection. Be REAL sure that the noise is not within your home. Put a mobile rig in the car, listen to the offending frequency and ride around to try to find the source. Have an idea of where to start, be able to show the power company how much interference you are having. Make notes of time of day, day of week, weather conditions at that moment and any other information about operating habits.

In my neighborhood, the local power company has now replaced 10 poles, a LOT of hardware, and tightened up loose spans and guy wires. Still, there remains much to be done.

As most of the work that was done in my neighborhood was on older lines that were upgraded to 14.4KV from 7.2KV a few years back without a complete rebuild, some of the problems I have had were from older construction, most of the work was done on single phase lines as we do not have 3 phase in the neighborhood.

To summarize: all my problems were totally hardware related!

The HV field above the neutral is very prone to cause static build up on any piece of hardware that is not properly attached, these include:

1……….staples or spikes above the neutral…
2……… tie wires holding the Hot line to the insulator
3……….any bolt that goes through the wooden pole will loosen with time
4……….loose guy lines
5……….any loose spans, short traverse to close pole.
6……….missing ground wires, copper theft
7……….mounting hardware for transformers, fuse clips or arrestors
8……….old 120/240 drops to homes, bad insulation
9……….loose connections, at transformer, on neutral bonding

Almost impossible to name each item that can be used in the construction of HV electrical service, but any item of hardware that gets isolated, in this field will generate noise. The noise from ONE staple with a just a few thousandths of an inch, used to attach the ground to pole, located half way between the natural and the hot line, will generate a signal that can be heard for a mile, at 100 yards it is S9+. So you can see that it takes a lot of attention to make and keep these lines quiet. New metal poles will help this as they replace older wood poles.

I know that all types of hardware is not shown or even used in my area, but I think you can take away from this is that most noises generated by lines on wooden poles will fall into one or more of the previous topics. With care and patience, your local power company should be able to resolve most of these issues; they are capable and usually willing to help resolve these issues caused by their equipment. I hope this first-hand information will give you as an amateur more insight as to what we need to do with respect to working with the Professionals.

Key Words in above paragraph…PATIENCE…

Remember: they are the experts and we are the ‘amateurs’.

SIMPLE Splice for 7/8" Heliax®

Ott Fiebel, W4WSR

INTRODUCTION

Most UHFers would tell you that their preferred transmission line is hard line – the larger the better. No wonder, as once the rest of the system has been tweaked for best performance the transmission line remains as the weakest link in overall performance. Unfortunately, as with most bigger and better things, such low-loss cable and their connectors are quite costly and often out of reach of the average Ham. Thus compromise continues to be the order of the day.

An irritating situation is finding some reasonably priced odd lengths of large coax at that are too short for our application. Or, conversely, finding a piece that is significantly longer than needed. What do you do then, cut it or accept the additional loss of the surplus? What follows will answer these questions.

THE STORY

While rummaging through a Hamfest not long ago, I came across several vendors offering reasonably priced odd lengths of Andrews 7/8" Heliax®. The source of this material was cell phone sites that were being refurbished. One fellow offered a lot consisting of about six pieces varying from about forty feet to over sixty feet in length. All had at least one type "N" connector attached and the asking price was a paltry sum of less than $100. SOLD!

But now what? I needed a length of about 82 feet in all. It wouldn't bother me to "waste" a few feet at that price if I could splice two pieces together. The choker came when I investigated the cost of a splice connector, which turned out to be more than the total price of the coax I bought! It was now time for some good old Ham ingenuity…

THE FACTS

The first thing I did was to take a hacksaw and cut off a piece in order to determine the construction of this stuff. Unlike its 1/2" size little brother, which has a spiral outer conductor, spiral dielectric and solid center conductor, the 7/8" Heliax® has a corrugated outer conductor, dense foam dielectric and hollow center conductor. Using a good hacksaw produced a relatively clean cut that could be nicely dressed with a file to a very acceptable flush surface. Observation indicated that, as opposed to a spiral pattern, the corrugated outer conductor would negate the need for any particular radial alignment when butting two pieces together. And if both interfaces were cut at the same relative point of the corrugation the resultant juncture would not alter the cable's physical appearance.

To join the center conductors one could use a longitudinally slit piece of tubing which has an initial diameter just slightly larger than the center conductor I.D. This "bullet", when inserted into the center conductors, would provide a good firm connection. This technique was widely used to join air dielectric coax back in the “old” days. When tried, the resultant joint aligned beautifully and had only the slightest gap in the outer conductor which could be easily bridged with solder. Voila! A good – and weatherproof - splice was created…

But suppose it isn’t practical to perform a solder connection, is there another simple way to join these pieces together? There sure is! By using a split cylinder made from a discarded piece of outer conductor that is then slipped over the junction, both pieces are held in perfect alignment. The junction could then be made rigid by clamping the assembly together with a hose clamp. Problem solved!

THE DETAILS

1.) Strip the outer jacket from each piece to be joined a minimum length of 1.5” (approximately 6 convolutions) being careful not to cut the outer conductor.

2.) Using a sharp tubing-cutter, cut through the outer conductor at the center of the fourth groove from the end. Use minimum pressure so as not to deform the coax all-the-while noting that the alignment remains correct.

3.) Using a fine-toothed hacksaw, carefully cut through the coax using the circumferential cut made by the tubing cutter as a guide.

4.) Clamp one of the small pieces just cut off lengthwise in a vise and again using the hacksaw cut an axial slit through the corrugated copper. Carefully remove the copper from the dielectric. De-burr it and put aside. This will be used as the outer-conductor clamp sleeve. Discard the remains.

5.) Using a broad/fine file, dress the cut ends lightly to remove any burrs. De-burr the inner edge of the center conductor I.D. with a de-burring tool or sharp knife. Also ensure that there are no burrs on the outer diameter of the inner conductor.

6.) Roll a small piece of fine-grit emery cloth (grit side out) and use to lightly sand the inside of the inner conductor. Clean the inner conductor with a rag or tissue moistened with WD-40 or similar product.

7.) Using a tubing cutter, cut off about a three-quarter inch length of 5/16” diameter brass tubing.

8.) Clamp the piece of tubing lengthwise in a vise and, using a hacksaw, cut an axial slit. De-burr. This will be used as the center-conductor joiner bullet.

9.) Slide the joiner bullet approximately halfway into the center conductor of one of the sections to be spliced.

10.) Place a 1” stainless hose clamp and the outer-conductor clamp sleeve over the other section.

11.) Carefully align and butt sections together assuring that the joiner bullet seats neatly into both inner conductors.

12.) Position the outer-conductor clamp sleeve such that it is centered over the joint. There should be two corrugations over each side of the junction.

13.) Position the hose clamp over the center of the outer-conductor clamp and, while maintaining axial pressure to the joint, tighten firmly.

NOTE: If a permanent, weatherproof splice is desired, perform the following:

A.) Clean the adjacent outer conductor surfaces of the joint sufficiently for soldering.

B.) Install the bullet, but do not install the clamp sleeve and hose clamp.

C.) Connect the sections and, while maintaining firm axial pressure, quickly tack-solder several points around the joint circumference. AVOID EXCESSIVE HEATING.

D.) Carefully solder the remaining voids. Although this is not a particularly difficult procedure, it may help to cool the joint with a dampened cloth between applications of heat to help prevent dielectric melting.

E.) Wrap exposed copper surfaces with a good quality vinyl tape for extra protection

CONCLUSION

The procedure described provides a means for joining lengths of 7/8" Heliax® for near zero cost, yet it probably introduces less discontinuity than a commercially available splice. The same technique could also be used for any cable having similar physical characteristics.

If the need for a lower loss transmission line is in your future, but your budget won't permit it, this may well be your inexpensive way to a bigger signal.

Fig.1

Shown are: the hose clamp, outer-conductor clamp sleeve, center-conductor joiner bullet and finished interfaces showing a joiner bullet installed.

Fig. 2

Photo shows final assembly of the temporary splice at left and permanent splice at right.

HOW TO HOIST YOUR TOWER AND ANTENNA ARRAY WITHOUT CLIMBING

By Ben Lowe, K4QF
Email: K4QF@ARRL.NET

As we get older and wiser, or perhaps just wiser at a younger age, the prospect of raising a tower and installing an array along with electronics becomes less appealing due to climbing the tower and working at heights. Microwave operators, as they progress higher in frequency, come to the realization that we need to put the station, or at least part of it, at the top of the tower to avoid the feedline loss or the use of expensive, heavy feedline such as waveguide. Even low loss waveguide necessitates the use of pressure systems to keep water from condensing inside the waveguide, and that's another complication in getting the signal from the rig to the antenna**.** In my own case, I run a split system with the signal generating portion of the station inside the shack where the temperature is fairly constant and the microwave portion of the station on the tower to minimize the feedline loss. Since I am like many hams and live in a rural area, I needed some method of doing all of my tower work by myself since help isn't readily available.

Realizing that the tower work, i.e. installing the feedlines, control cables, and tower electronics, is much easier and quicker with both feet on the ground, it became clear that some method for hoisting the entire tower, antennas, feedlines, and electronics would be a valuable capability. What was needed was the illusional "skyhook" so that everything could be installed and checked out with the tower laying on the ground negating the need to stack the tower sections and then climb the tower multiple times and pull everything up to attach to the tower.

This scheme isn't quite as convenient as having the "skyhook," but it's a close second. I wanted to get the tower up at least 70 feet with the antenna mast extending above that, so the final configuration has the top antenna, a 144 MHz yagi, at 78 ft. above the ground. After thinking about how this could be accomplished, several non-conventional concepts were developed. First, if the antenna tower itself, Rohn 25G, was to be 70 ft. long, a hoisting tower should be at least half that long. In this case, the hoisting tower was chosen to be 40 ft. of Rohn 25 tower as these sections could be attached to the antenna tower for hoisting and then removed and stored until the next time the tower was to be lowered. The basic approach for hoisting the tower is shown below in Fig. 1.

DISCLAIMER: Tower work is dangerous and should be performed only by people competent in this area. Ben Lowe, K4QF, assumes no responsibility or liability for this method of tower installation, and all work is performed at your own risk.
K4QF, 23-Jul-2012

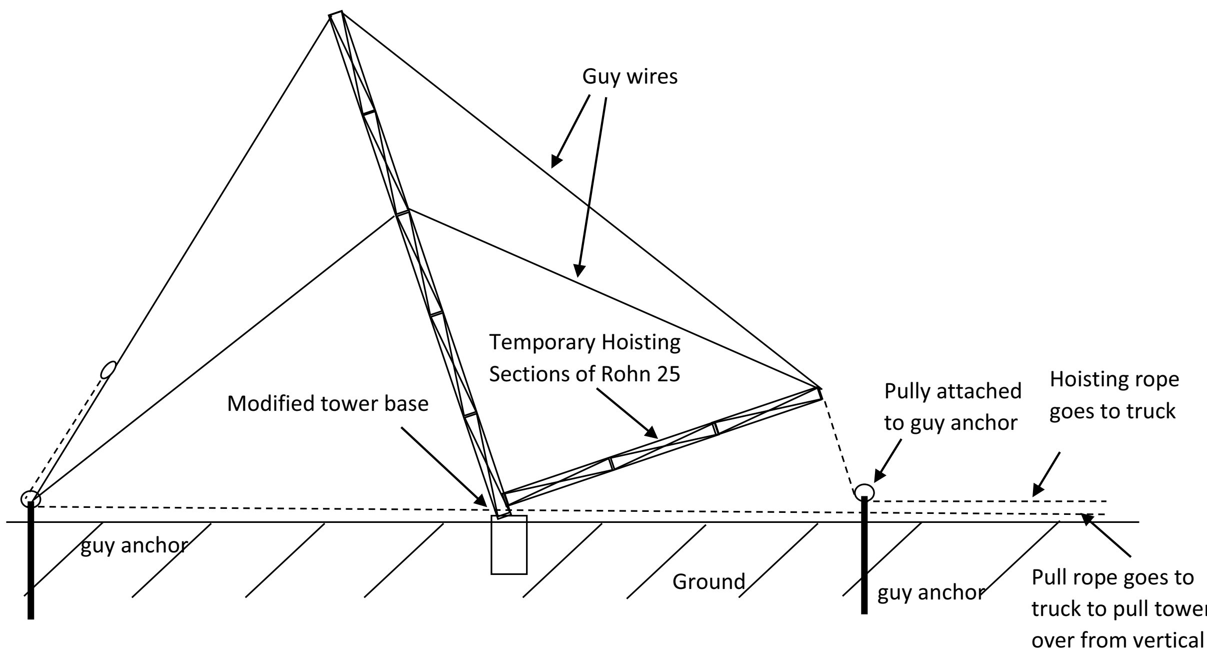


FIGURE 1 - DIAGRAM FOR HOISTING TOWER

Some method for connecting these two towers at a 90 degree angle was required. Second, the antenna tower would have to be guyed at two levels, and there should be four sets of guys spaced every 90 degrees around the tower instead of the usual three sets of guys spaced every 120 degrees. This accomplishes three things. 1) As the tower is raised and lowered, the back set of guys used to pull on the tower, both the front top guy and the bottom front guy, are attached to the hoisting tower. This permits one guy, the top guy for example, to be removed from the guy anchor and attached to the hoisting tower while the lower guy still attached to the guy anchor supports the tower and keeps it from toppling over. When the top guy is firmly attached to the hoisting tower, then the bottom guys is removed from the guy anchor and attached to the hoisting tower. 2) While raising or lowering the antenna tower, the tower itself is supported at two levels helping to keep the tower from buckling. This may not have been an issue, but it's better to have additional support than not quite enough. 3) Having guys on each side of the antenna tower as it is raised and lowered provides stability for the tower keeping it from rotating during the hoisting process. The antenna tower and the guys extending to each side form a plane which is maintained from the fully vertical position to the fully horizontal position.

The first task is to pour a tower base foundation that provides the necessary hardware for a tilt over tower. I used a Rohn tilt over base plate, but in retrospect, a better method would be to use a regular Rohn 25G base plate. The tabs on the tilt over base plate are certainly the weakest point for this method of tower erection, but because of the force vectors on this tower, the tabs don't get all the stress as a singular tower; i.e. the hoisting tower places more downward force on the tabs as the antenna tower approaches the more horizontal position. A better method would be to modify a regular base plate by clamping a steel bar with U-bolts across the lower side of the base plate on the same side where the two legs of the antenna tower attach to the base plate. My foundation has six, threaded rods imbedded in the concrete for the foundation that permit some tweaking of the base to insure a vertical tower after the concrete hardens. This also gets the base plate 1 ½ inches above the concrete to let it dry to help prevent rusting in the future. If a base plate is modified with the steel bar on the bottom side, 2 of the threaded rods would have to be eye-bolts imbedded in the concrete that allow the steel bar on the bottom of the base plate to pass through them. It would be best to use stainless steel eyebolts, again to inhibit rusting. If the steel bar attached to the base plate was another threaded rod, it would be a simple matter to install some washers and nuts to this rod as it passed through the eye-bolts to hold it in place. I used a 2 ft. x 2 ft. concrete foundation that is in a 4 ft. deep hole, but it would be best to consult the Rohn tower information for foundation requirements. The hole required ½ yard of concrete, or in my case, 20 of the 80 lb. bags of Quickcrete, the mixture that needs only water and mixing to derive the concrete.

Since the soil in my area is very stable, I installed four of the Screw-In guy anchors at a distance of 41 feet from the tower base. This is closer to the tower base than Rohn specifies, but Rohn does not account for using four sets of guys instead of three sets at 120 degrees. The distance of 41 feet was chosen because this allows the end of the hoisting tower to lay 40 feet from the base of the antenna tower for convenient transfer of the guys from the guy anchor to the hoisting tower. The screw-in guy anchors used were the 5/8 in. diameter, 4 foot long anchors with 6 inch diameter augers to catch as much soil as possible. Using a digging bar to twist and screw in these anchors required about 20 minutes of turning for each anchor to get the anchor eye even with the ground.

For the initial tower raising, I poured the foundation with the tower base and threaded rods in place and let it set up for about a week. Then, I attached 20 ft. of Rohn 25 laying horizontally to the base with a rope attached to the top of this 20 ft. I hand walked up this 20 ft. Then, I attached 20 ft. of hoisting tower with the hoisting rope tied to the top and running through a pulley attached to the guy anchor and hand walked the initial 20 ft. of tower back to the horizontal position. At that point, I attached another 20 ft. of tower for a total of 40 ft. of tower section, and the first level of guys at 40 ft., four of them with three of the guys tied to the appropriate guy anchors. The length of the guys was calculated making sure to leave some excess, and these guys were attached using guy grips that were not twisted all the way to the end so that they could later be positioned as needed. At the guy anchors on the side for the hoisting tower and on the side opposite that, I used anchor shackles to attach pulleys to the guy anchors. I then used my hoisting rope attached to the tie down just under the front truck bumper to pull up this 40 ft. of tower with the 20 ft. of hoisting section. The 40 ft. of tower had a rope attached to the backside guy so I could pull it back down. Once I had the 40 ft. of tower vertical and the hoisting tower horizontal, I then attached another 20 ft. of hoisting tower for a total of 40 ft. of hoisting tower. I pulled the tower back down using another longer pull rope on the back side of the tower with the help of the pickup truck. This rope and the rope used for hoisting the tower are tied to the tie downs just under the front bumper of the pickup so that all tower hoisting is performed with the truck in reverse so that I can observed the progress out the front window of the pickup. The tower, of course, is laying over in the opposite direction from the pickup so that if for some reason it got away it would fall away from the pickup and not over on the truck. At that point, I added another 30 ft. of tower for a total of 70 ft. and attached the four top guys at the 68 ft. level. With both the top guys and the guy at the 40 ft. level attached to the hoisting tower, I then pulled up the entire 70 ft. of tower with the truck just as a test run. At this point, everything was going so smoothly, I started to gain confidence I could pull up the 70 ft. of tower with the rotor and antennas mounted to the top of the tower. I used twist guys on the guys at convenient levels to attach the pull ropes and hoisting rope to the guys.

When pulling the tower up and down, one point to keep in mind is that you are dealing with significant weights. Now that my tower is fully loaded with antenna, rotor, and feed lines, I cannot pull the tower over by hand when I start to lay it over. I have to use the pickup truck with the longer rope to the back side pulley and attached to the guy to get the hoisting tower off the ground, but this point is critical. When pulling the tower over, the top of the hoisting tower is lifted only about 10 feet off the ground until the "tipping point" is reached. Make sure at this point to have the hoisting rope tied off to the other tie down under the bumper of the pickup. I know about how much of the hoisting rope goes through the pulley before the tipping point is reached, so just as a precaution, I put a slip knot in the hoisting rope through the pulley as a safety to catch the tower in case someway the hoisting rope came free from the pickup. At the tipping point, the tower is balanced and could go either way, so at this point the tower can be directed by hand; i.e. pulling on either rope. However, pulling about 3 ft. of rope one way or the other shifts the weight so that any more than this puts too much weight on the rope to hold by hand. Never pull these ropes by hand without the ends of the rope tied to the pickup as a precaution. On a couple of occasions when the grass was wet, I have raised and lowered the tower using my RAV-4 with front wheel drive which is considerably lighter and smaller than the pickup truck as backing a pickup with rear wheel drive on wet grass doesn't provide a great deal of traction.

One word of caution is in order. DO NOT STAND UNDER THE TOWER OR NEAR TO THE LINE WHERE THE TOWER COULD FALL ON YOU OR ANYONE ELSE WHEN HOISTING. One of the safety features of using this method is that I can do my tower raising while in my truck or near the front of the truck to tie off the hoisting ropes as necessary. I do normally have a spotter who stands well to the side of the tower and watches as the tower is raised and lowered just as a precaution. The spotter should stay well clear of the tower as it is raised and lowered. Once the tower is near the ground, I lower it onto a step ladder which keeps the antennas off the ground.

Once the hoisting tower is carried from storage and assembled, about a 2 hour process, the time necessary to lay the 70 foot tower down or raise it to the vertical position is approximately 10 minutes. In other words, go very slowly and be very deliberate. Figures 2 and 3 show how the base plate for the hoisting tower is attached to the main tower.

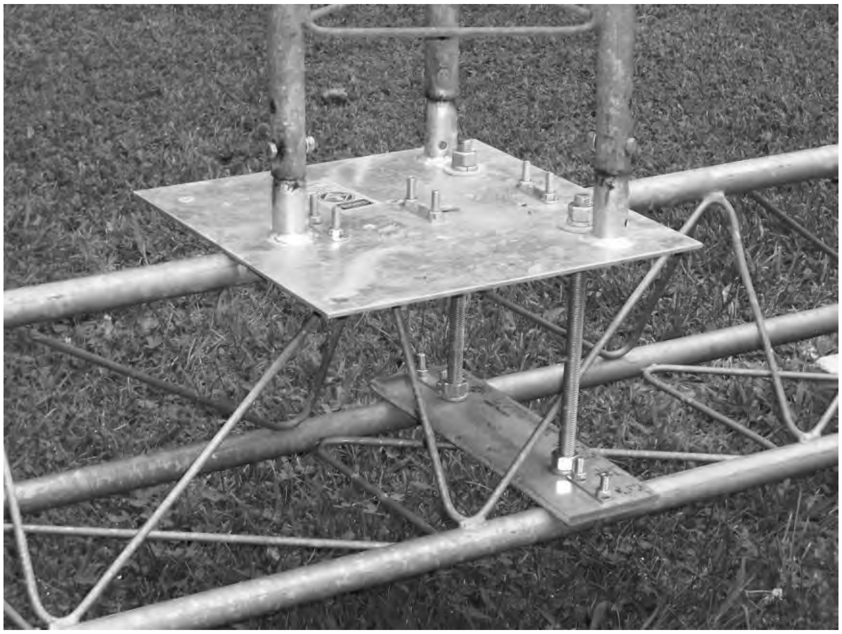


FIGURE 2 - INTERFACE TO ATTACH HOISTING MAST TO TOWER, VIEW 1

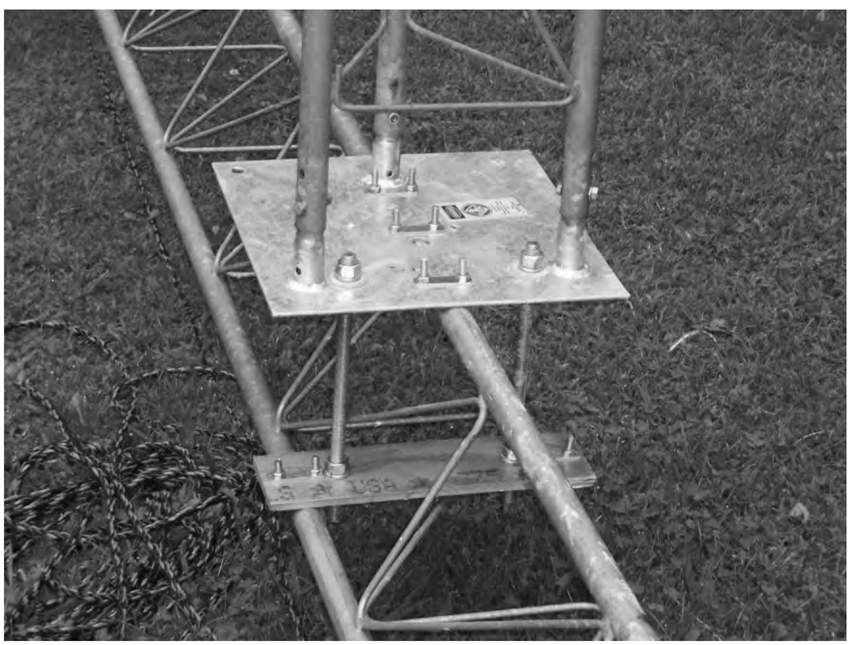


FIGURE 3 - INTERFACE TO ATTACH HOISTING MAST TO TOWER, VIEW 2

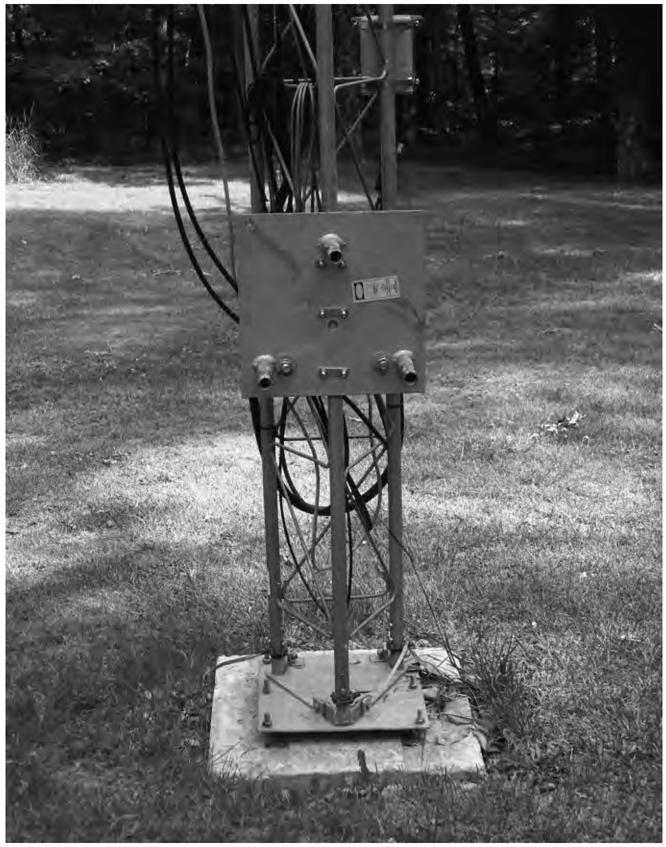


FIGURE 4 - HOISTING MAST INTERFACE LEFT ON TOWER

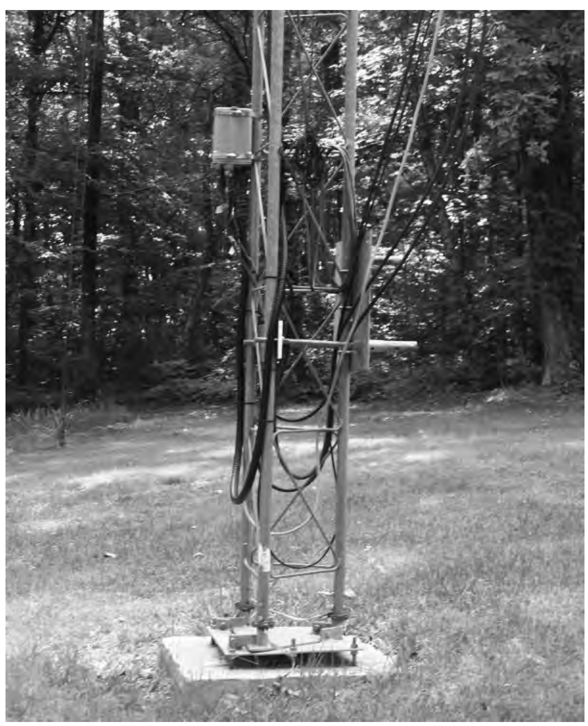


FIGURE 5 - SIDE VIEW OF HOISTING MAST INTERFACE

Figures 4 and 5 above show a front and side view of the base plate used to attach the hoisting tower to the main tower.

Once the tower and successfully up, antennas were installed for four bands; 144 MHz, 432 MHz, and a dual band antenna for 1296 and 2304 MHz between the 144 MHz yagi and the 432 MHz yagi.

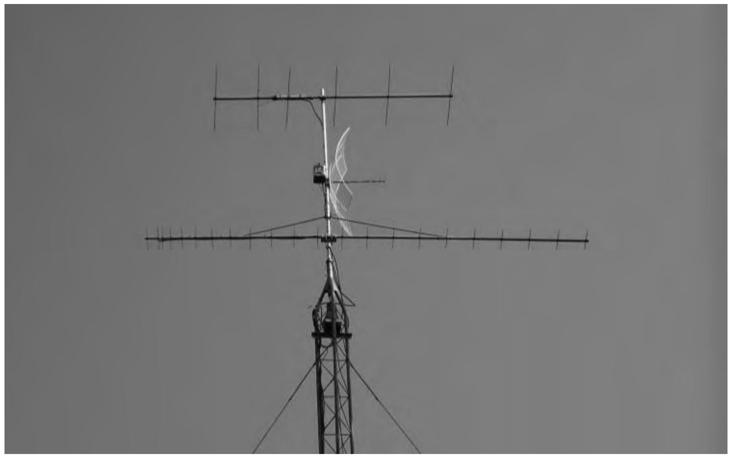


FIGURE 6 - 144/ 432 MHz YAGIS, DUALBAND 1296/2304 MHZ DISH

Figure 7 shows the hoisting tower attached to the main tower. Since the ground where the main tower is placed has a slight slope, the hoisting tower is attached to the main tower about 3 feet about the ground, and the other end of the hoisting tower lays on the ground, keeping the hoisting tower level and not placing any strain of the base place attached to the main tower.

FIGURE 7 - HOISTING MAST ATTACHED TO TOWER

Fig. 8 shows the twist guys attached to the guy wire to provide a method to attach the chain on the hoisting tower to the guy wire, and Fig. 9 shows the chain around the hoisting tower used to attach the hoisting tower to the twist ties around the guy wire.

FIGURE 8 - TWIST TIES USED TO ATTACH GUYS TO HOISTING MAST

FIGURE 9 - CHAIN USED TO ATTACH HOISTING MAST TO TOWER GUYS

Figure 10 shows one of the pulleys attached to a guy anchor with a shackle.

FIGURE 10 - PULLEY ATTACHED TO GUY ANCHOR USED FOR HOISTING TOWER

Figure 11 shows the hoisting tower attached to the main tower with the other end laying on the ground.

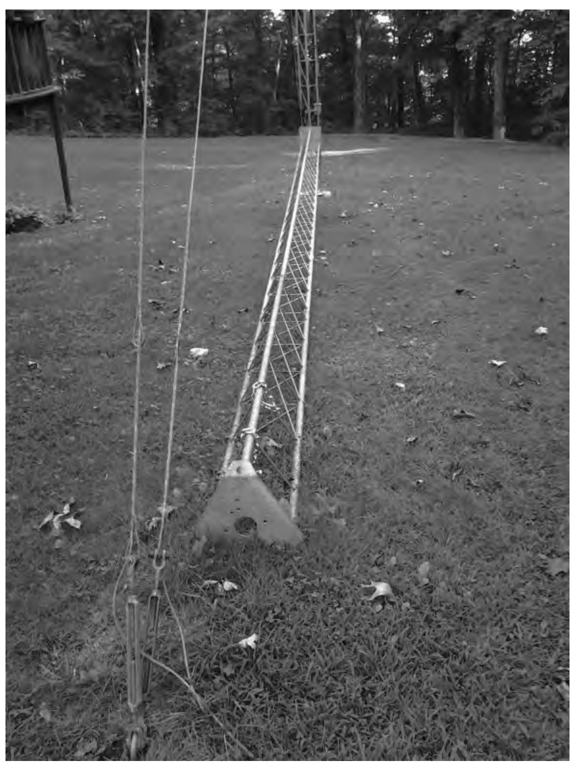


FIGURE 11 - 40 FT. HOISTING MAST LAYING ON GROUND

As always, tower installation is a dangerous business, and every caution should be taken to insure safety to those installing the tower. This approach permits the tower to be raised and lowered without requiring the installer to be on the tower or near the tower base should it collapse. The antennas and tower are expendable, the installer are not**.**

DISCLAIMER: Tower work is dangerous and should be performed only by people competent in this area. Ben Lowe, K4QF, assumes no responsibility or liability for this method of tower installation, and all work is performed at your own risk.
K4QF, 23-Jul-2012

Chambers Award Recipients

1971 Mel Wilson, W2BOC, for his dedicated observation and brilliant reporting of VHF propagation phenomena.

1972 Ed Tilton, W1HDQ, for his many years of research and reporting as Editor of *QST*'s "The World Above 50 Mc."

1973 Tommy Thomas, W2UK/KH6UK, for his numerous VHF exploits, particularly on the Hawaii to West Coast duct with W6NLZ. In addition, he, in company with W4HHK, showed the value of meteor scatter for working long distances on 2 meters.

1974 Dick Knadle, K2RIW, for his design of amplifiers and parabolic dishes.

1975 John Fox, W0LER, for his studies of OSCAR telemetry.

1976 Joe Reisert, W1JR, for his many technical contributions to VHF and UHF and his oft demonstrated helpfulness to his fellow amateurs.

1977 Bob Sutherland, W6PO, for his dedicated efforts in bringing EME technical information to amateurs worldwide through distribution of the famous Eimac *EME Notes.*

1978 Wayne Overbeck, N6NB, for his technical accomplishments and contest activities.

1980 Jan King, W3GEY, for his work in amateur satellites.

1981 Louis Ancioux, WB6NMT, for his promotion and technical contributions to 220 MHz in our continuing efforts to retain this valuable allocation.

1982 Al Katz, K2UYH, for his many technical accomplishments.

1984 Ron Dunbar, W0PN, for his technical contributions to the Amateur Satellite program in writing software and serving as a command station.

1985 Don Hilliard, W0PW (ex W0EYE), for his technical contribution to VHF/UHF including the W0EYE Yagi.

1986 Paul Wilson, W4HHK, for his continuing technical contributions to UHF, especially in EME on 13 cm.

1987 Leroy May, W5HN (ex W5AJG), for his over 50 years of contributions to VHF and UHF including many articles in amateur magazines beginning the 1930s.

1988 Al Ward, WB5LUA, for his many outstanding technical contributions in the field of VHF, UHF and microwave equipment.

1989 Kent Britain, WA5VJB, for his promotion of the microwave bands, including his numerous articles on simple, easy-to-build equipment.

1991 Jim Vogler, WA7CJO, for his many outstanding technical contributions, including participation in the first 10-GHz EME contact.

1992 Chip Angle, N6CA, for his many VHF-UHF accomplishments in advancing the state-of-the-art in practical amplifier and apparatus designs and his contributions to transpacific microwave communications on 3, 5 and 10 GHz.

1993 Dr. Paul Shuch, N6TX, for his many years of outstanding technical contributions to the Society and radio amateur interests in VHF and above.

1994 Jim Davey, WA8NLC, and Rick Campbell, KK7B, for their development of "no-tune" transverters for the microwave bands.

1995 Zack Lau, KH6CP, for his many contributions of technical designs from DC to microwave, and his generous assistance to all seeking technical advice.

1996 Tom Clark, W3IWI, for his many contributions to the amateur satellite program.

1997 Paul Wade, N1BWT, for his numerous microwave construction articles.

1998 Greg McIntire, AA5C, for his outstanding technical articles in QST and the CSVHFS Proceedings and his helping others achive 10 GHz EME capability.

1999 Les "Lucky" Whitaker, W7CNK, for his many firsts. In 1970 he worked WB6NMT, to become one end of the first 220 MHz EME QSO. In 1987 he worked KD5RO to become one end of the first 3.4 GHz EME QSO. A few weeks later he worked WA5TNY to become one end of the first 5.7 GHz EME QSO. And in 1988 he was one end of the second 10 GHz EME QSO.

2000 Barry Malowanchuk, VE4MA, For his work on dish feed design, low noise amps, and EME activty.

2001 Will Jensby, W6EOM, for his record breaking millimeter work and helping hundreds more get on the microwave bands.

2002 Mike Staal, K6MYC, for his many years of superior antenna design, development, and production benefitting VHF'ers and above.

2003 David Robinson, WW2R, for hundreds of articles published about VHF/UHF/SHF technology and active operation on the bands. Dave holds one end of the US continental 24 GHz distance record.

2004 Gerald Youngblood, AC5OG, for his ground-breaking work with Software Defined Radios which are advancing the art of VHF and above.

2005 Gary R Lauterbach, AD6FP, for his pioneering 47 GHz EME work.

2006 Jeffrey Leer, KGØVL, for his Auroral research and operations. Through his studies, expeditions, and presentations many operators have increased knowledge and enjoyment during Auroral openings.

2007 Bob McGwier, N4HY, for his work with AMSAT flight hardware and Development work with Software Defined Radios.

2008 Barry Malowanchuk, VE4MA, and Al Ward, W5LUA, for their work in the first 24 GHz and 47 GHz EME QSO's. This year's award departs a bit from the tradition of the Chambers Award; in fact, John Fox, the original custodian of these awards, was consulted to make sure we were still within the original charter. John felt that this was an excellent idea. Often there are teams who's work are difficult to separate, the Wright Brothers, Mutt and Jeff, Laurel and Hardy, Abbot and Costello, along with so many others. In like manner, we add Barry and Al to the list of notable duos!

2009 Presented to Ronald J Stefanskie, W9ZIH. The Chambers Award to, W9ZIH, recognizes and honors his lifetime of achievement on the bands above 50 MHz. Ron has consistently been a trailblazer on the higher bands; a list of record-distance contacts on the amateur microwave bands shows that he anchored one end of many record contacts. His dedication to amateur radio microwave operation has resulted in a greater understanding of microwave propagation.

2010 No award presented.

2011 Presented to Joe Taylor, K1JT, for his development of the WSJT suite of software programs which have been benefitial in completing contacts via meteor scatter and moonbounce on 50 MHz and above.

2012 To Jim Kennedy, KH6/K6MIO for his notable contributions to the science of VHF propagation through his studies and analysis of hither-to unexplained very long distance Six Meter propagation of both the Sporadic E and F2 varieties.

2013 Presented to Zack Lau, W1VT, for his continuing VHF+ work.

Wilson Award Recipients

1982 Bill Tynan, W3XO, for his continuous service and dedication towards promoting VHF and UHF amateur radio activity.

1983 Ed Fitch, W0OHU, for 16 years of devoted service to the Society.

1984 Ray Nichols, W5HFV, for his many years of service to the Society as its historian.

1985 Al Ward, WB5LUA, for his many years as Prize Chairman and his numerous fine technical talks at various CSVHF conferences.

1986 Mark Thorson, WB0TEM, for his continued and valuable service to the Society, particularly in maintaining the VHF antenna range.

1987 Jimmy Treybig, W6JKV, for his many DXpeditions to sometimes difficult spots to give us all new countries on 6 meters.

1988 Lionel Edwards, VE7BQH, for his many hours spent conducting the 2-Meter EME Net on 20 meters. In so doing, he has helped many new EMEers get started and many old-time moonbouncers increase their stations worked totals.

1989 Joe Muscanere, WA5HNK, for his many years of service to the Society, including serving as its Treasurer for ten years.

1991 Kent Britain, WA5VJB, for his numerous contributions to the Society, especially in maintaining the microwave antenna range.

1992 Bob Taylor, WB5LBT, for his many years of service to the Society as a member of the Board of Directors, as President for 1982, and Treasurer for 1990-91 and as Chairman of the 1982 Conference.

1993 Rod Blocksome, K0DAS, for his many years of service to the Society, twice serving as President, and as editor of the director's newsletter.

1994 Gerald Handley, WA5DBY, for his dedicated and continuing service as Chairman of the Society's Board of Directors.

1995 Charlie Chennault, WA5YOU, for his continuing service to the Society as Treasurer, and his efforts to ensure compliance with government regulations.

1996 Bill Olson, W3HQT, the founder of Down East Microwave, for making quality equipment and parts readily available to all.

1997 Dave Meier, N4MW, for his many years of service to the Society, serving as President for 1994 and many years as Assistant Treasurer.

1998 Larry Hazelwood, W5NZS, for his many years of service to the Society as Secretary.

1999 Gary Gerber, KB0HH, for his many years of working on the prize committee.

2000 Steve Kostro, N2CEI, For his work in helping so many hams come on the air with low cost equipment.

2001 Joel Harrison, W5ZN, Past CSVHFS President, active VHF/UHF/Microwave operator, ARRL VP, for his support of our VHF bands.

2002 Bruce Richardson, W9FZ, for energy and effort to the society as Treasurer, Board Member, Conference Host, and Newsletter Editor.

2003 Sam Whitley, K5SW, for years of service to the society as President, Vice-President, and Treasurer many times in the early years of the society.

2004 Emil Pocock, W3EP, for his work supporting the VHF Community with his many QST Columns from 1992 through 2002..

2005 Emily Ward, for sustained service to the society supporting and sponsoring conference family programs.

2006 John Fox, WØLER, for his sustained service to the society over a forty year span. John played key roles at the time of the society's birth. Later, during the 1970's, John served as President, Treasurer, and conference host. Today, John again serves on the conference host team as mentor and Family Program specialist.

2007 Tommy Henderson, WD5AGO, for his work organizing CSVHFS Conferences and conducting the Noise Figure Measurements.

2008 William Caldwell, N0LNO, for his many contributions to CSVHFS. His service has been in many capacities and over many years. He has served as Vice President, Acting President and Chairman of the Board of Directors. One notable year, Bill stepped up and hosted the conference at the last minute when the President was called away to go fishing for Aluminum in the South Pacific.

2009 Presented to John Kalenowsky, K9JK. John is commended for his service to the Society serving as conference Vice President. Further, John's on going organizing and administering of the VHF Spring Sprints events.

2010 Presented to John Germanous, WB9PNU, for all his work.

2011 Presented to Joe Lynch, N6CL, for his years of service to the VHF community through his editorship of The CQ VHF column and CQ-VHF

2012 Presented to Jay Liebmann, K5JL, for his continuous service and dedication promoting VHF and UHF Amateur Radio activity.

2013 Presented to Maty Weinberg, KB1EIB, for years of service to the Society through her work on the Conference Proceedings published by ARRL.

Previous Conference Locations and Society Officers

Year	Site	Officers
1965	Sioux Falls, SD	None, Informal Get-together
1966	Sand Springs, OK	None, Informal Get-together
1967	Western Hills Lodge near Tulsa, OK	Larry Nichols, W5UGO, Chairman Sam Whitley, W5WAX, Committee Chair Don Hilliard, WØEYE, Committee Chair Dennis Main, WØYMG, Committee Chair Jay Liebman, W5ORH, Committee Chair
1968	Lake of the Ozarks	Larry Nichols W5UGO, Chairman Joe Hall, K9SGD, Conference Host Glenn Smith, WØDQY, Conference Host Don Hilliard, WØEYE, Program Chair

A decision was made to incorporate, and a Board of Directors and Officers were selected.

Year	Site	Officers
1969	Boulder, CO	Don Hilliard, WØEYE, President Louis Breyfogle, WØMOX, Vice-President Bill McCaa, KØRZJ, Treasurer Ted Mathewson, W4FJ, Secretary
1970	Western Hills Lodge near Tulsa, OK	Sam Whitley, W5WAX, President Jay Liebman, W5ORH, Vice President Allen Burson, K5WXZ, Treasurer Ted Mathewson, W4FJ, Secretary

Upon suggestion of Bill Smith, KØCER, the Chambers Award was established.

Year	Site	Officers
1971	Sioux Falls, SD	John Fox, WØLER, President Ted Mathewson, W4FJ, Vice-President Dick Hart, KØMQS, Treasurer Tom Schrum, K7NII, Secretary
1972	Overland Park, KS	Larry Nichols, W5UGO, President Dick Hart, KØMQS, Vice-President Sam Whitley, W5WAX, Treasurer Ted Mathewson, W4FJ, Secretary
1973	Minneapolis, MN	John Fox, WØLER, President Ron Dunbar, WØMJS, Vice-President Bill Smith, KØCER, Treasurer Ted Mathewson, W4FJ, Secretary
1974	Boulder, CO	Dick Hart, KØMQS, President Carl Scheideler, W2AZL, Vice President Charlie Calhoun, K5BXG, Treasurer Ted Mathewson, W4FJ, Secretary

1975	Western Hills Lodge near Tulsa, OK	Charlie Calhoun, K5BXG, President Sam Whitley, W5WAX, Vice-President John Fox, WØLER, Treasurer Ted Mathewson, W4FJ, Secretary
1976	Houston, TX	Richard Allen, W5SXD, President Orville Burg, K5VWW, Vice-President Ron Dunbar, WØMJS, Treasurer Ted Mathewson, W4FJ, Secretary
1977	Kansas City, MO	Orville Burg, K5VWW, President Joe Muscanere, WA5HNK, Vice-President Ed Fitch, WØOHU, Treasurer Ted Mathewson, W4FJ, Secretary
1978	Rochester, MN	Ed Fitch, WØOHU, President John Fox, WØLER, Vice-President Terry Van Benschoten, WØVB, Treasurer Ted Mathewson, W4FJ, Secretary
1979	Dallas, TX	Al Ward, WB5LUA, President Charlie Calhoun, WØRRY, Vice-President Joe Muscanere, WA5HNK, Treasurer Ted Mathewson, W4FJ, Secretary
1980	Colorado Springs, CO	Ray Uberecken, AAØL, President Keith Ericson, KØKE, Vice-President Joe Muscanere, WA5HNK, Treasurer Ted Mathewson, W4FJ, Secretary
1981	Sioux Falls, SD	Ed Gray, WØSD, President Chuck Hoover, KØVXM, Vice-President Joe Muscanere, WA5HNK, Treasurer Ted Mathewson, W4FJ, Secretary
1982	Baton Rouge, LA	Bob Taylor, WB5LBT, President Charles McGough, K5BMG, Vice-President Joe Muscanere, WA5HNK, Treasurer Ted Mathewson, W4FJ, Secretary

Dedicated to the memory of Mel Wilson, W2BOC; the Wilson Award was established.

1983	Overland Park, KS	Tom Bishop, KØTLM, President Jim McKim, WØCY, Vice-President Joe Muscanere, WA5HNK, Treasurer Ted Mathewson, W4FJ, Secretary

Dedicated to the memory of Carl Scheideler, W2AZL.

1984	Cedar Rapids, IA	Rod Blocksome, KØDAS, President Barry Buelow, WAØRJT, Vice-President Joe Muscanere, WA5HNK, Treasurer Ted Mathewson, W4FJ, Secretary

The first published Proceedings were issued this year.

1985	Tulsa, OK	Charlie Calhoun, WØRRY, President Connie Marshall, K5CM, Vice-President Joe Muscanere, WA5HNK, Treasurer Ed Fitch, WØOHU, Secretary
1986	St Louis, MO	Bob Sluder, NØIS, President Al Ward, WB5LUA, Vice-President Joe Muscanere, WA5HNK, Treasurer Ed Fitch, WØOHU, Secretary
1987	Dallas, TX	Al Ward, WB5LUA, President Wes Atchison, WA5TKU, Vice-President Joe Muscanere, WA5HNK, Treasurer Ed Fitch, WØOHU, Secretary
1988	Lincoln, NE	Roger Cox, WBØDGF, President Kermit Carlson, W9XA, Vice President Joe Muscanere, WA5HNK, Treasurer Ed Fitch, WØOHU, Secretary
1989	Rolling Meadows, IL	Charles Clark, AF8Z, President Kermit Carlson, W9XA, Vice President Joe Muscanere, WA5HNK, Treasurer Ed Fitch, WØOHU, Secretary
1990	Wichita, KS	Jon Jones, NOØY, President Jon Lock, KFØM, Vice-President Bob Taylor, WB5LBT, Treasurer Larry C. Hazelwood, W5NZS, Secretary
1991	Cedar Rapids, IA	Rod Blocksome, KØDAS, President Ron Neyens, NØCIH, Vice-President Bob Taylor, WB5LBT, Treasurer Larry C. Hazelwood, W5NZS, Secretary
1992	Kerrville, TX	Bill Tynan, W3XO, President Derwin King, W5LUU, Vice-President Charlie Chennault, WA5YOU, Treasurer Dave Meier, N4MW, Assistant Treasurer Larry C. Hazelwood, W5NZS, Secretary Bob Sluder, NØIS, Assistant Secretary

1993	Oklahoma City, OK	Joe Lynch, N6CL, President Tommy Henderson, WD5AGO, Vice-Pres. Charlie Chennault, WA5YOU, Treasurer Dave Meier, N4MW, Assistant Treasurer Larry C. Hazelwood, W5NZS, Secretary Bob Sluder, NØIS, Assistant Secretary

Dedicated to the memory of Joel Paladino, N6AMG, who contributed so very much to the advancement of our interests in the wonderful world of VHF and above.

1994	Memphis, TN	Dave Meier, N4MW, President Joel Harrison,, WB5IGF, Vice-President Charlie Chennault, WA5YOU, Treasurer Dave Meier, N4MW, Assistant Treasurer Larry C. Hazelwood, W5NZS, Secretary Bob Sluder, NØIS, Assistant Secretary
1995	Colorado Springs, CO	Lauren Libby, KXØO,President Hal Bergeson, WØMXY, Vice-President Charlie Chennault, WA5YOU, Treasurer Dave Meier, N4MW, Assistant Treasurer Larry C. Hazelwood, W5NZS, Secretary Bob Sluder, NØIS, Assistant Secretary
1996	Bloomington, MN	Paul Husby, WØUC, President Jon Lieberg, KØFQA, Vice-President Charlie Chennault, WA5YOU, Treasurer Dave Meier, N4MW, Assistant Treasurer Larry C. Hazelwood, W5NZS, Secretary Bob Sluder, NØIS, Assistant Secretary
1997	Hot Springs, AR	Joel Harrison, W5ZN, President Al Ward, WB5LUA, Vice-President Charlie Chennault, WA5YOU, Treasurer Dave Meier, N4MW, Assistant Treasurer Larry C. Hazelwood, W5NZS, Secretary Bob Sluder, NØIS, Assistant Secretary
1998	Kansas City, MO	Denise Hagedorn, AJØE, President Al Ward, WB5LUA, Vice-President Dave Meier, N4MW, Treasurer Charlie Chennault, WA5YOU, Ass't Treas. Larry C. Hazelwood, W5NZS, Secretary Bob Sluder, NØIS, Assistant Secretary
1999	Cedar Rapids, IA	Rod Blocksome, KØDAS, President Bill Caldwell, NØLNO, Vice-President Dave Meier, N4MW, Treasurer Charlie Chennault, WA5YOU, Ass't Treas. Larry C. Hazelwood, W5NZS, Secretary Bob Sluder, NØIS, Assistant Secretary

2000	Winnipeg, Manitoba, Canada	Barry Malowanchuk, VE4MA, President Jim Roik, VE4AQ, Vice-President Bruce Richardson, W9FZ, Treasurer Lauren Libby, WØLD, Assistant Treasurer Larry C. Hazelwood, W5NZS, Secretary Tom Bishop, KØTLM, Assistant Secretary
2001	Fort Worth, TX	Lilburn Smith, W5KQJ, President Kent Britain, WA5VJB, Vice-President Bruce Richardson, W9FZ, Treasurer Lauren Libby, WØLD, Assistant Treasurer Larry C. Hazelwood, W5NZS, Secretary Tom Bishop, KØTLM, Assistant Secretary
2002	Milwaukee, WI	Ken Boston, W9GA, President Marc Holdwick, N8KWX, Vice-President Bruce Richardson, W9FZ, Treasurer Lauren Libby, WØLD, Assistant Treasurer Larry C. Hazelwood, W5NZS, Secretary Tom Bishop, KØTLM, Assistant Secretary
2003	Tulsa, OK	Charlie Calhoun, K5TTT, President Tommy Henderson, WD5AGO, Vice-Pres. Bruce Richardson, W9FZ, Treasurer Lauren Libby, WØLD, Assistant Treasurer Larry C. Hazelwood, W5NZS, Secretary Tom Bishop, KØTLM, Assistant Secretary
2004	Mississauga, Ont.	Peter Shilton, VE3AX, President Bob Morton, VE3BFM, Vice-Pres. Bruce Richardson, W9FZ, Treasurer Lauren Libby, WØLD, Assistant Treasurer Larry C. Hazelwood, W5NZS, Secretary Tom Bishop, KØTLM, Assistant Secretary
2005	Colorado Springs, CO	Lauren Libby, WØLD, President Ken Anderson, W5ETT, V-P Ops Joe Lynch, N6CL V-P, Programing Doug Wilson, WA0VSL, V-P Tech Ops Bruce Richardson, W9FZ, Treasurer Lauren Libby, WØLD, Assistant Treasurer Larry C. Hazelwood, W5NZS, Secretary Tom Bishop, KØTLM, Assistant Secretary

Dedicated to the memory of Ted Mathewson, W4FJ, a founding member of CSVHF. Ted was instrumental in the early growth of the society. The society would not be here today if not for his efforts during the formative years.

2006	Bloomington, MN	Bruce Richardson, W9FZ, President Jon Platt, W0SQ, Vice President Bruce Richardson, W9FZ, Treasurer Lauren Libby, WØLD, Assistant Treasurer Larry C. Hazelwood, W5NZS, Secretary Tom Bishop, KØTLM, Assistant Sec
2007	San Antonio, TX	Paul Goble, ND2X,, President Thomas Visel, NX1M,, Vice President Larry C. Hazelwood, W5NZS, Secretary Bruce Richardson, W9FZ, Treasurer
2008	Witchita, KS	Mel Graves ,WR0I, President David Powers, KA0KCI, Vice President Larry C. Hazelwood, W5NZS, Secretary Bruce Richardson, W9FZ, Treasurer
2009	Elk Grove Village, IL Chicago Area	Kermit Carlson, W9XA, President John Kalenowsky, K9JK, Vice President Larry C. Hazelwood, W5NZS, Secretary Bruce Richardson, W9FZ, Treasurer
2010	St Louis, MO	Ron Ochu, KO0Z, President John Germanos, WB9PNU, Vice President Larry C. Hazelwood, W5NZS, Secretary Bruce Richardson, W9FZ, Treasurer
2011	Irving, TX DFW Area	Charles Clark, AF8Z, President Kent Britain, WA5VJB, Vice President Larry C. Hazelwood, W5NZS, Secretary Bruce Richardson, W9FZ, Treasurer
2012	Ceder Rapids, IA	Bill caldwell, N0LNO, President Steve Ssawyers, NA0IA, Vice President Al Groff, N0VM, Registration Elizabeth Caldwell, N0UTP, Family Program Elizabeth Blocksome „ Jane Groff „ Rod Blocksome, K0DAS, Technical Program Barry Buelow, W0IY, Proceedings Fred Spinner, W0FMS, Noise Figure Kent Britain, WA5VJB, Antenna Range Mark Thorson, WB0TEM „ Mark Kovalan, K8XK „ Bryan McCOY, KA0YSQ, Audio/Visual Larry C. Hazelwood, W5NZS, Secretary Bruce Richardson, W9FZ, Trassurer

2013	Elk Grove Village, IL Chicago Area	Kermit Carlson, W9XA, President John Kalenowsky, K9JK, Vice President Larry C. Hazelwood, W5NZS, Secretary Bruce Richardson, W9FZ, Treasurer Dom Baker, WA2VOI Antenna Range Kent Britain, WA5VJB „ Marc Thorson, WB0TEM „ Steve Sherman, N9LHD „ Greg Braun, N9CHA , Registration Dave Carlson, AA9D „ Steve Spasojevich AG9D Mike Metroka, WB8BZK, Rover Dish Displays Ron Steinberg, K9IKZ, Photography & Video Jerry Hymen, KA9VMD „ John Kalenowsky, K9JK, Technical Program Kermit Carlson, W9XA, Prizes Sandra Estevez, K4SME, Proceedings John Kalenowsky, K9JK, ” Steve Kostro, N2CEI „ Kent O’Dell, KA2KQM „ Ken Boston, W9GA, Promotion Al Ward, W5LUA, Noise Figure Measurement Tony Emaneule, WA8RJF „

CSVHFS "STATES ABOVE" 2013

Where have all the sunspots gone?

There is a popular song left over from the folk music era of the 60's that laments the question "Where have all the flowers gone?" Only in our case, the question is more like "where have all the sunspots gone?" And, along with the sunspots go VHF radio QSOs …

Most observers of solar cycles agree that we should now be enjoying a "peak" of VHF propagation and great conditions….But, recorded sunspots are averageing far less than previous cycles….leading some to speculation of another "minimum".

Apparently, Bob Mathews, K8TQK doesn't pay much attention to what can't be done as he has turned in another outstanding collection to achieve the 1st place plaque for the "States Above" program. Bob worked 165 states/provinces to continue his dominance of this event plus prove you may not need active solar cycles to make VHF contacts…

He is again followed by Bill Davis, KØAWU and Gary Mohrlant, WØGHZ who turned in 109 and 93 states/provinces respectively… Bill and Gary have also consistently scored high in States Above, often trading places for the 2nd and 3rd plaques.

Thanks to everyone who participates in the program…Good fun had by all !

73s

Jim Hermanek KØKFC

CALL	QTH	50	144	222	432	902	1296	2304	3456	5760	10	24	TOTAL
WA5TKU	TX	24	1		2								27
K0AWU	MN	53	33	9	6	2	3				3		109
K09A	IL	52	17	4	5	2	2						82
K8TQK	OH	55	32	21	21	15	14	2	2	1	2		165
K9JK/R	IL	34	19	13	13		2						81
N4MM	VA	47	9										56
W0GHZ	MN	49	19	5	6	5	5	1	1		2		93
W9FZ/r	MN												ua

CSVHFS Reverse VUCC (VUCC/r) Award Honor Roll

As of: May 27, 2014 Program Administrator: Arliss Thompson, W7XU

	50 MHz (100)	
1	W9FZ	100
2		
3		

	144 MHz (100)	
1	K9KNW	100
2		
3		

	222 MHz (50)	
1	W9FZ	110
2		
3		

	432 MHz (50)	
1	K9JK	50
2	W9FZ	70
3		
4		
5		

	902 MHz (25)	
1	NØDQS	30
2	W9FZ	95
3	K9JK	45
4		
5		

	1296 MHz (25)	
1	NØDQS	30
2	ND2X	25
3	K9JK	45
4	W9FZ	90
5		

	2304 MHz (10)	
1	NØDQS	30
2	WØZQ	17
3	ND2X	10
4	KAØKCI	15
5	KCØIYT	10
6	N5AC	13
7	W9FZ	10

	3456 MHz (5)	
1	NØDQS	25
2	WØZQ	16
3	KCØIYT	6
4	N5AC	13
5		
6		
7		

	5760 MHz (5)	
1	NØDQS	25
2	WØZQ	16
3	KCØIYT	6
4	N5AC	13
5		
6		
7		

	10 GHz (5)	
1	W9FZ	10
2	NØDQS	25
3	WØZQ	41
4	KCØIYT	7
5	KAØKCI	6
6	N5AC	9
7	VE3SMA	5

	24 GHz (5)	
1	NØDQS	10
2	WØZQ	12
3	N5AC	5
4		
5		
6		
7		

	47 GHz (5)	
1		
2		
3		
4		
5		
6		
7		

	Light (5)	
1		
2		
3		
4		
5		

	Satellite (100)	
1	N7SFI	200
2	N5AFV	109
3	ND9M	340
4	KD4ZGW	100
5		

For information on the Reverse VUCC Award Program, please visit the Central States VHF Society Web Site at www.csvhfs.org or contact:

Arliss Thompson, W7XU
CSVHFS VUCC/r Award
45720 268th St.
Parker, SD 57053
w7xu@w7xu.com

2013 144 MHz Spring Sprint Results (April 8)

SINGLE-OP

CALLSIGN	DX SCORE	Qs	Ms	SCORE	Grid Square(s)
K8TQK	21550	57	36	2052	EM89je
K3TUF	10753	41	20	820	FN10we
W9GA	7474	36	16	576	EN53ve
W9JN	7000	25	11	275	EN54dn
WZ1V	6674	30	12	360	FN31rh
N9DG	5739	27	11	297	EN53bj
W9KXI	5731	26	16	416	FN12ne
KA3HED	5273	28	11	308	FM29co
KA2KQM	5233	17	14	238	EM74tm
W2BVH	4981	36	10	360	FN20up
N9LB	4065	21	8	168	EN52hv
W1QK	4049	26	9	234	FN31gk
K8GDT	4000	17	11	187	EN91bf
KE0CO	3213	27	9	243	CN87tl
N7EPD	3281	28	9	252	CN87rl
WB0YWW	3012	9	8	72	EN22uk
KA2LIM	2912	13	9	117	FN12nf
K0SIX	2904	13	8	104	EN35dj
N2SLN/3	2808	16	8	128	FN21go
AA4DD	2788	13	11	143	EM86un
N3UM	2508	13	7	91	FM18qx
N4BRF	2363	12	6	72	EL96vk
N8WNA	2323	15	6	90	EN82jm
KO9A	2306	24	8	192	EN52xc
KJ1K	2127	8	4	32	FN32km
KI7JA	2089	18	6	108	CN85rl
VE7JH	2016	10	4	40	CN88du
WV9E	1882	14	7	98	EN43jv
VE3JVG	1865	9	6	54	FN03cp
KJ4QLP	1836	14	8	112	EM97qi
N2ZBH	1782	18	7	126	FN30au
WB9WOZ	1779	16	5	80	EN61as
N9NDP	1661	12	6	72	EN62bn
K7YDL	1580	15	4	60	CN85mj
K0JJ	1456	14	5	70	CN85ns
W3HMS	1414	8	3	24	FN10mf
N9TZL	1406	8	7	56	EM78mm
AB2YI	1244	7	5	35	FN03nf
KB2KOL	1040	6	4	24	FN02oq
W2SJ	1033	13	4	52	FM29jr
KD8FHY	970	9	4	36	EN91bc
KA1R	872	5	2	10	FN42ne
KB1JEY	685	11	4	44	FN20je
K7BWH	557	13	3	39	CN87xn
N2CSP	462	10	2	20	FN20sn
KF4YLM	451	7	4	28	EM97ve
W5VY	424	3	3	9	EM34us
N6ZE	289	5	3	15	DM04ne
WA2NXK	260	6	2	12	FN20tl
NJ7A	171	7	2	14	DN30xp
N2DCH	76	1	1	1	FN22ac

ROVER

CALLSIGN	DX SCORE	Qs	Ms	SCORE	Grid Square(s)
VA3ELE/R	8155	38	20	760	EN93xs, FN03as
K9JK/R	4216	53	23	1219	EN51xx, EN52xa,xb, EN61ax, EN62aa
WB8BZK/R	3879	44	14	616	EN52xc, EN62ad
WW7D/R	2637	37	10	370	CN86xx, CN87xa,xd, CN96aw, CN97ad
N2DCH/R	112	2	2	4	FN12xd, FN22ad

ROOKIE

CALLSIGN	DX SCORE	Qs	Ms	SCORE	Grid Square(s)
KD8RAP	266	4	3	12	EM79uf
KB3ZTT	118	2	1	2	FN10jc
K7TFT	90	2	2	4	DN40br

2013 222 MHz Spring Sprint Results (April 16)

SINGLE-OP

CALLSIGN	DX SCORE	Qs	Ms	SCORE	Grid Square(s)
K1WHS	11008	34	14	476	FN43mj
K8TQK	7887	18	16	288	EM89je
K3TUF	6497	25	12	300	FN10we
N9LB	6218	20	14	280	EN52hy
K8GDT	5869	19	12	228	EN91bl
KU2A	5143	20	10	200	FN42cs
N9DG	5062	17	14	238	EN53bj
W9GA	4968	18	13	234	EN53ve
K8MM	3828	16	11	176	EN83fa
WB2SIH	3557	20	10	200	FN31dd
W9KXI	3289	14	10	140	FN12ne
N8WNA	2849	12	8	96	EN82jm
AF1T (Paper	2827	15	7	105	FN43cd
W2BVH	2669	19	7	133	FN20up
K3MD	2152	8	7	56	FN10mw
W1QK	2123	13	7	91	FN31gh
WA3SRU	1979	11	7	77	FN20ie
K7ND	1693	15	6	90	CN87qf
N2DCH	1556	8	7	56	FN22ac
KO9A	1453	11	7	77	EN52xc
N7EPD	1398	18	6	108	CN87rf
K0SIX	1255	4	4	16	EM35dj
W2SJ	1093	10	4	40	FM29jr
N6ZE	1024	13	5	65	DM04ne
N2SLN	986	5	5	25	FN22qj
AA4DD	944	5	5	25	EM86un
K7AWB	797	4	2	8	DN17es
WV9E	744	5	5	25	EN43jv
KI7JA	641	3	1	3	CN85d
N2CSP	607	7	4	28	FN20sn
KE0CO	247	5	3	15	CN87tl

ROVER

CALLSIGN	DX SCORE	Qs	Ms	SCORE	Grid Square(s)
KA2LIM/R	4208	19	16	304	FN11mx, FN12nf
K1DS/R	4027	23	13	299	FM29hx, FN20ie
WW7D/R	2024	34	9	306	CN86xx, CN87xa, CN96aw, CN97ad
WB8BZK/R	1965	20	12	240	EN51xx, EN52xc, EN61ax, EN62aa
K9JK/R	60	2	2	4	EM65ox, EM66ro

ROOKIE

CALLSIGN	DX SCORE	Qs	Ms	SCORE	Grid Square(s)
KD4YDD	33	1	1	1	EM84ab

2013 432 MHz Spring Sprint Results (April 24)

SINGLE-OP

CALLSIGN	DX SCORE	Qs	Ms	SCORE	Grid Square(s)
K3TUF	10324	37	16	592	FN10we
K8TQK	6014	14	13	182	EM89je
WZ1V	5585	32	10	320	FN31rh
W9GA	4941	18	14	252	EN53ve
W9KXI	3358	12	8	96	FN12na
WB2SIH	3202	18	9	162	FN31dd
K8GDT	2732	10	9	90	EN91bl
WA2ONK	2253	17	6	102	FN20pf
WO1S	2057	22	7	154	DM13cm
W2BVH	1922	14	6	84	FN20up
AF1T (Paper	1918	12	5	60	FN43cd
N9DG	1906	7	5	35	EN53bj
KA3HED	1807	10	6	60	FM29co
W2SJ	1740	13	5	65	FM29jr
N7EPD	1725	22	7	154	CN87rf
W9SZ	1706	7	6	42	EN50ue
N6ZE	1664	27	4	108	DM04qb
KO9A	1437	10	8	80	EN52xc
KU2A	1342	12	5	60	FN42cs
KS2AM	1292	8	4	32	FN20xi
KE0CO	1260	19	6	114	CN87tl
N2SLN	930	5	4	20	FN23ll
K1KC	863	7	6	42	EM73xs
N3UM	575	4	4	16	FM18qa
KI7JA	569	6	2	12	CN85rl
K7ND	454	10	4	40	CN87qi
KE7SW	359	9	4	36	CN87td
AA4DD	340	2	2	4	EM86un
K7YDL	323	5	2	10	CN85mj
KE6GFI	234	4	3	12	DM03ww
K6DHP	107	3	3	9	DM03xr
AJ4UQ	9	1	1	1	FM02al

ROVER

CALLSIGN	DX SCORE	Qs	Ms	SCORE	Grid Square(s)
K1DS/R	4630	34	13	442	FM29hx, FN20ie
WW7D/R	2208	37	6	222	CN86xx, CN87xa,xd CN96aw, CN97ad
WE7X/R	734	18	6	108	CN87xl, CN97al
N5BF/R	254	4	3	12	DM04mt,ql,qn,sh

2013 Microwave (902 MHz & Up) Spring Sprint Results (May 4)

SINGLE-OP

CALLSIGN	DX SCORE	Qs	Ms	SCORE	Grid Square(s)
K8TQK	**3044**	12	11	132	EM89je
KB8VAO	**984**	7	6	42	EN91kt
K8GDT	**940**	5	5	25	EN91bf
K7ND	**866**	15	8	120	CN87qf
W9SZ	**844**	15	11	165	EN52sa
N9LB	**835**	6	6	36	EN52hv
K1DS	**610**	8	6	48	FN20ie
K3TUF	**610**	8	6	48	FN10we
W3HMS	**589**	5	4	20	FN10mf
VE3NYZ	**448**	6	5	30	FN03ib
WA3SRU	**389**	5	4	20	FN20le
N6ZE	**272**	4	3	12	DM04qb
KE7SW	**209**	8	5	40	CN87td
KO9A	**201**	11	6	66	EN52xc
N5BF	**75**	3	2	6	DM04vf
AA4DD	**65**	4	3	12	EM86un

ROVER

CALLSIGN	DX SCORE	Qs	Ms	SCORE	Grid Square(s)
W9SNR/R	**2434**	28	18	532	EN52xc, EN62cc
VE3SMA/R	**1167**	14	7	98	EN93sg, FN03df
K9JK/R	**334**	17	9	153	EN51xx, EN52xa,xc EN61ax, EN62ad
WB8BZK/R	**285**	13	7	91	EN52xc, EN62ad

ANTENNA RANGE RESULTS

Elk Grove Village, IL

July 26, 2013

Kent, Marc and others forwent the antenna gain measurements in favor of ark construction.

NOISE FIGURE RESULTS

Elk Grove Village, IL

July 26, 2013

Band	Call	Design	Device	Noise Figure dB	Gain dB
50 MHz	**KF8QL**	DEMI	FPD 750	0.86	12.8
	W3XO	ARR P50VDG		1.13	25.9
	WA3ZKR	Homebrew	SP5122Z 2 Stage	4.19	25.3
144 MHz	**KA0RYT**	Homebrew	MGF1402	0.22	26.2
	WA5VJB	Homebrew	MGF2116	0.24	22.7
	N4PZ	AGO	ATF-10135	0.32	15.7
	VE3ADQ	Homebrew	PGA 103	0.56	24.6
	NI0W	ARR SP144VDG	MGF1302	0.57	22.5
	N4PZ	Homebrew	ATF-10135	0.58	14.6
	WD9EXD	Landwehr		0.75	19.8
	WA3ZKR	Homebrew	SP5122Z 2 Stage	0.93	40.3
	WD9EXD	Landwehr		2.6	9.2
222 MHz	**WA3ZKR**	Homebrew	SP5122Z 2 stage	0.83	42.0
	VE3ADQ	Homebrew	XVTR	2.6	35.6
432 MHz	**K6DV**	JL Labs	Cavity 1302	0.54	18.1
	VE3ADQ		PGA 103	0.59	21.7
	WA3ZKR	Homebrew	SP5122Z 2 Stage	0.73	40.3
	WD9EXD	Landwehr		1.35	17.4
	WD9EXD	Landwehr		1.35	17.0
	WD9EXD	Landwehr		1.41	16.7
902/903 MHz	**WA3ZKR**	Homebrew	SP5122Z 2 stage	0.62	33.7
1296 MHz	**K6DV**	W7CNK	ATF-35076	0.24	34.9
	N4PZ	AGO		0.32	35.0
	N4PZ	KA0RYT	ATF-54143	0.54	17.1
	WA3ZKR	Homebrew	SP5122Z 2 stage	0.67	28.3
2304 MHz	**WA5VJB**	Commercial	Isolator front end	0.42	59.0
	K3PU	LUA	DEMI	0.43	18.0
	N4PZ	Homebrew		0.68	12.0
	N4PZ	Homebrew		1.1	10.1
	WA3ZKR	Homebrew	SP5122Z 2 stage	1.69	13.9
3456 MHz					
	WA3ZKR	Homebrew	SP5122Z 2 stage	2.16	11.3
10368 MHz	**KA9VGG**	RF AMPs		9.41	26.8
	K0CQ	Harris		10.57	28.6

Band	Call	Design	Device	Noise Figure dB	Gain dB
24192 MHz	**K9PW**	Homebrew	XVTR	3.05	25.3
	K0CQ	MTI LNA		3.18	17.5
	KB0PE	CTT	SN 96028	4.93	10.4
	KB0PE	CTT	SN 96033	4.96	12.0
	KB0PE	CTT	SN 96029	5.09	12.0
	KB0PE	CTT	SN 96023	5.12	12.4
77184 MHz	**W5LUA**	Homebrew XVTR	Using WA1MBA LNAs	4.0	58.0

Testing by: W5LUA and WA8RJF
Equipment supplied by W5LUA, WA8RJF & K9PW
N4000a Noise Source supplied by Agilent
8973A used up through 2304 MHz - 8971 used at 3456 & Above
Measurement Accuracy +/- 0.2 dB at 10 GHz and below
Compiled by WA8RJF

50MHz Beacons

Beacons in IARU Region 1 will soon move up the band to new frequencies

50000	GB3BUX	Nr Buxton	IO93BF	25	HTurnstiles	Omni	A1	24	TNonOp
50000	HK4RCA	Antioquia	FJ26FD	5	Halo	Omni	A1	?	0313
50001	BV2YA	Taipei	PL05SA	10	GP	Omni	A1	24	0513
	BV2B								
50001	VE1UW	Pictou NS	FN85QN				A1	?	0513
50001.0	VE1SMU	Nr Halifax NS	FN84	25	3-el Yagi	East	A1	24	NonOp
50001.4	IW3FZQ	Monselice PD	JN55VF	8	5/8 GP	Omni	A1	24	0513
50002	Z21SIX		KH52ND	30	5/8 Vert	Omni	A1	24	0513
50002	VO2FUN	Labrador	FO62	3	H.Dip@6m	N-S	A1	24	0912
50003	PP0TA	Trinidade Island		10	5/8 Vert	Omni	A1	OP?	0911
50003.25	W9DR		EM75	95		Omni	A1	IRREG	0911
50004	A47RB	Oman	LL93FO						0513
50004.0	I0JX	Rome	JN61HV	10	5/8 Vert	Omni	F1	24	0613
50004.5	AH2G	Mt Barrigada Guam	QK23	50	Horiz Loop	Omni	A1	24	0413
50005	9M4SIX	Penang Island	OJ05DJ	50	5/8 GP	Omni	A1	24	0413
50005	YV5KG	Caracas					A1	?	0213
50006	A71A	Doha	LL55SH	70	6-el	330	A1	?	0412
50006	IQ8KK		JM89DH					IRREG	0513
50007	LU8DZE	La Plata	GF05				A1		0613
50007	VA2ZFN	Mt Kanasuta QC	FN08HE	4	Halo	Omni	A1	24	0613
50007	HG1BVB	Horman	JN87FI	20	X-Dip	Omni	F1	24	0613
50007	ZD7VC	St Helena	IH74	45	M2 Loop@20'		A1	24?	0413+
50007.8	DU1EV	Metro-Manila	PK04MP	10	1/2 GP	Omni	A1	24	0613
50007.3	ZS2X	Nr Rocklands	KF26PD	20	Noriz. Yagi		F1	24	0212
50008.0	K0GUV	Park Rapids MN	EN26	8			A1	PT	0613
50008	IQ8KK	Cosenza	JM89DH	3	Horiz.	Omni	A1		0612
50008	I5MXX	Pieve A Nievole	JN53JU	10	5/8 Vert	Omni	A1	24	0513
50008	VE8SIX	Inuvik NT	CP38DI				A1	IRREG	0812
50008	HI8W	Ft Resolue	FK48	5	Halo	Omni	A1	24	0613
50008	XE2HWB	La Paz BCS	DL44WR	8	1/2 Dio		A1	24	0613
50008.6	J88ARC	St Vincent	FK93				A1	24	0213
50008.8	EA6CA		JM19NL						0712
50009	VE3WCC	Nr Ottawa	FN15WC	1	KU4AB Horiz	Omni	A1	24	0613
50010	LU7FTF	Castelar SF	FF88XK	5	Dipole		A1	24	0513
50010	SV9SIX	Iraklio	KM25NH	30	Vert. Dip.	Omni	F1	?	0513
50010	JA2IGY	Mie	PM84JK	10	5/8 GP	Omni	A1	24	0613
50010	PY5VC		GG46					?	0413
50010.5	K8MMM	Novelty OH	EN97	90	H.Dip@50'	N-S	A1	24	0613
50011.9	OX3SIX	Tasiilaq	HP15EO	100	Dipole				0613
50012	OH1SIX	Ikaalinen	KP11QU		XoverX Dip	Omni	A1	24	0613
50013	CU3URA	Terceira I.	HM68QM	5	GP	Omni	A1	24?	0613
50013	LZ1JH	Stara Zagora	KN22TK	1	GP	Omni	A1	OP?	0412
50013.5	6V7SIX	Ngaparou	IK14LK	45	2xHO Loop	300/	A1	24	0313
						020			
50014	OK0SIX							INT	
50014	KH9/WA2YUN	Wake I	RK39HH	40	2xHor Loop		A1	24	0413
								?	0413
50014.7	9Y4AT	Trindad/Tobago	FK90				A1	OP?	0612
50015	SV5SIX	Rhodes	KM46CK	3	Dipole			24	0613
50015.6	LU9EHF	Lincoln BA	FF95MM	15	Hentena		A1	24	0613
50015.7	XE2K	Mexicali	DM22FP	20	1/2 Vt@33m	Omni	A1	24	0613

50015.7	HI8AX		FK48						1112
50016	GB3BAA	Nr Tring	IO91PS	10	Vert Dip	Omni	A1	24	0513
50017	OH0SIX	Stalsby	JP90XI	3	Horiz Dip	N-S	A1	24	0413
50017	JA6YBR	Miyazaki	PM51RT	50/10/ 1/0.1	T'stile	Omni	A1	24	0413
50018	VE4ARM	Austin MB	EN09MW	50	3-el Yagi	NE	A1	24	0613
50018	PR8ZIX	Imperatriz MA	GI64GL	45	halo	Omni	A1	24	0613
50018	EA1FBU		IN52QG						0512
50018	XE1RCS	Cerro Gordo	EK09OS	50	AR-6	Omni	A1	24	0513
50019	CE1BB	Arica	FH41				A1		0512
50019	IZ1EPM	27km NE Turin	JN35WD	12	5/8 Vert	Omni	A1	24	0513
50019.3	IK5ZUL	Follonica GR	JN52JW					24	0613
50020	IW8RSB	Simeri ChrichiCZ	JM88HW	10	5/8 Vert	Omni	A1	24	0512
50020	ED2YAH	Nr Zaragoza	IN91SR	10	Horiz	Omni	A1	24	0613
50020	VE8WD	Yellowknife NT	DP22	20	Ringo	Omni	A1	24?	0613
50020.5	ER1SIX	Nr Kishinev	KN47JG	1	GP		A1	24	0613
50021	CX1CCC	Montevideo	GF15VD	5	GP	Omni	A1	24?	0613
50021	YV5JF						A1	??	0113
50002.8	V51VHF		JG87GN				A1	NonOP	1211
50021.2	9Q1D		JI75PQ					24?	0513
50021.3	CN8IG		IM79HM				A1		0213++
50021.8	LX0SIX	Bourscheid	JN39AV	5	Big wheel		A1	24	0613
50022	S55ZRS	Nr Dobovec	JN76MC	8	1/4 GP	Omni	A1	24	0613
50022	HG8BVB	Gerla	KN06OQ	5	GP	Omni		24	0512
50022.5	PY9MM								1012
50023.5	UN1SIX		MN83KE					?	0612
50023	SR5FHX	Warszawa	KO02KH	3	5/8 GP	Omni	A1	24	0513
50023.5	C5YK								0413
50023.8	VE9BEA	Frederickton NB	FN65					24?	0612
50023.5	ZP5AA	Asuncion	GG14	2.5	Dipole	Omni	A1	QRT?	1211
50024.0	ZL2WHO	Waipuna Ridge	RF70OM	800	2xdipole	N-S	A1	24	0413
50024	9H1SIX								0613
50024.4	YS1YS	Volcano of San Salvador	EK53IR	40	V dublZepp	Omni	A1	24	0413
50024.9	VE4SPT	Gillam MB	EO15	60	Delta Loop	000	A1	24	0613
50025	EA1HBX		IN62BL	0.25	Solar		A1	?	0613
50025	9H1SIX	Attard, Malta	JM75FV	7	5/8 GP	Omni	F1	24	0112
50025	IQ4FA	Ferrara	JN54TU	1/5	Ringo	Omni	A1	08-20	0412
50025	SK2TT		JP94QL				A1	?	0712
50025	YV4AB	Valencia	FK60AD	15	AR6@1210m	Omni	A1	24	0613
50025.4	OH2SIX	Lohja	KP20DH	80	1/2Vert@4m	Omni	A1	24	0513
50026	SR9FHA	Krakow Choragwica	KN09AS	5	5/8 GP	Omni	F1A	24	0513
50026	VA7CV		CN79				A1		0512
50027	JE7YNQ	Fukushima	QM07	50	2 T'stiles	Omni	A1	24	0513
50027	XE2D	Tijuana	DM12KM				A1	?	0113
50027.7	SR3FHB		JO91CQ						0513
50028	PY1WS		GG87LE	10	Vertical	Omni	A1	OP?	1111
50028	5T5SIX		IK28AC	50					Planned
50028.5	ZS6WAB		KG46RB						0513
50029.2	CE3AA	Santiago	FF46QN	50	halo@12m	Omni	A1	24	1112
50029.3	9A0BHH		JN85JO					24	0613
50030	VY1DX	Whitehorse YU	CP20	20	Halo@20'	Omni	A1	24?	0513
50030	IS0GQX						A1	?	0512
50030	XE1FAS		EK09VB				A1	?	0712
50031	HG7BVA	Gyomro	JN97QK	5	Vert Dip	Omni		24	0613
50031.5	CS5BCP	Serra D'Aires	IM59QM					24	0613
50032V	JR0YEE	Niigata	PM97	2	Loop		A1	24	0413

50032.9	ZD8VHF	Ascension I.	II22TB	50	Dipole			24	0413
50033	VE7FG	Prince George BC	CO83	50	R.Ranger	Omni	A1	24	0613
50033	VE2RCS	Lachute QC	FN25				A1		0613
50034	VA5MG	Nr LittleBearLake	DO74PH	15	5-el Yagi	040	A1	24	0513
50033	OH5SHF	Kouvola	KP30HV	20	2-el 2dBd	200	F1	24	0513
50034	D4C	Monteverde	HM76MV	40	Vertical	Omni	A1	NonOp?	0512
50034.2	CS3BSM	Santo de Sierra	IM12OR	40	Horizontal		A1	24	0613
50035	SV8GKE		KM08HQ						0412
50035	OY6BEC	Faroe Is.	IP62OA				F1	24	0613
50035	VO1SEP		GN37AE					IRREG	0513
50035	US0SU		KN28JW					?	0413
50036	VE4VHF	Headingly MB	EN19	35	Vertical	Omni	A1	24	0613
50036	OA4B	Lima	FH17	13	Vertical	Omni	A1	24	0613
50036V	CS5BALG	Sitio dos Cavalos	IM67AH	40			A1	24	0613
50036.5	SR8FHL	Lublin	KO11HF	4	1/2 Dipole	Omni	A1	24	0513
50036.6	IK1JLL		JN33TT					?	0512
50037	JR6YAG	Okinawa	PL36				A1	24	0513
50037.5	ES0SIX	Hiiuma Island	KO18CW	15	Horiz Dip.	E/W	A1	24	0912
50038	LU5EGY	Buenos Aires	GF05QI	50	5/8 Vert	Omni	A1	24	0613
50038	VY0YHK	Gjoa Haven	EP28BP	15	Horiz Dip		A1	24	0513
50038.5	FR1GZ	Reunion							0512
50039	VO1ZA	St Johns NFD	GN37	10	1/4 Vert	Omni	F1	OP?	0712
50039	FY7THF	Kouru	GJ35	10	Vertical	Omni		24	0513
50039	CE1B	Antofagasta	FG46TL	40	halo@6m	Omni	A1	24	0213
50040	C6AFP	Abaco	FL16	30	Loop	Omni	A1	24	TNonOp
50040	ZL3SIX	Christchurch	RE66	65	H		A1	24	0613
50040	SV1SIX	Nr Athens	KM17UX	25	Vert Dip	Omni	F1	24	0513
50040	VA2YKT	Rapide Blanc QC	FN37LS	1	halo loop	Omni	A1	24	0513
50041	ON0SIX	Waterloo	JO20EP	5	Hor. X-Dips	Omni	A1	24	1012
50041.1	CP6B	Santa Cruz da la Sierra	FH82	40	Halo Loop	Omni	A1	24	0513
50042	YF1OO	Bogor	OI33JK					QRT?	0711
50042.5	GB3MCB	St Austell	IO70OJ	40	Dipole	E/W	F1	24	0613
50043	VE6ARC	Grand Prairie AB	DO05	25		Omni	A1	24	0613
50044	ZS6TWB	Pietersburg	KG46RC	75	5-el Yagi	N-S	A1	24	0413
50044	YY4DNN		FK30KE				A1	?	1112
50044	XE3N	Playa del Carmen	EL60TU				A1	?	1011
50045	OX3VHF	Qaqortoq	GP60QQ	20	GP 20m asl	Omni	F1	24	0812
50045	YU1AVQ		KN04FU					?	0511
50045	SR2FHM	Gdansk	JO94II	7	Dipole	Omni	A1A	24	0513
50045	LZ2CM	Montana	KN13ME	0.5	GP1550masl	Omni	A1	24	0611
50045	NH6P	Keaau HI	BK29MN				A1	24	0412
50045.6	JW5SIX	Hopen Island	KQ26MM	10	Dipole		A1	24	0513
50045.7	SV9GPV	Rethymno Crete	KM25EH	5	M2Loop@40'	Omni	A1	24	0613
50046	LU2MCA	Godoy Cruz	FF57OB				A1	24	0413
50046.5	VK8RAS	Alice Springs	PG66	15	X-Dipoles	Omni		TNonOp	0911
50046.5	SP2DNI								0512
50047	JW7SIX	Kappe Linne	JQ68TB	10	3-el Yagi	South	A1	24	0513
50047	ZF1EJ	Cayman Is	EK99IG				A1	24	0413
50047V	IZ8DXB	Naples	JN70EO					24	0511
50047.2	YU0ZNI	SSE Beograd	KN03WH	1	GP	Omni	F1	24	0513
50048	VP8VHF								0413
50048.2	SQ2LYF	Sharograd Gdansk	JO93GX				A1	?	0512
50048.8	VY0SNO	Iqaluit NU	FP53RR	30	Comp 201-70	Omni	A1	24	0613
50048.5	TR0A	Libreville	JJ40	15	5-el	North	F1	?	1112
50048.7	JW9SIX	Bear Island	JQ94LM	15	GP	Omni	A1	24	0613
50049	CE8B	Nr Punta Arenas	FD46NX	50	halo@10m	Omni	A1	24	0413

50049	E51WL	North Cook Is	BI00XX	30	5/8 Vert	Omni			0413
50049	LZ1SJ		KN32DR						0513
50049.4	LZ2CC	Slatina Okr Loveshki	KN22GS	5	GP	Omni		24	0613
50049.6	LZ0SJB	Sliven	KN32DR	2	GP	Omni		24	0413
50050	ZS6JON	Krugersdorp	KG33VV	20	3-el Yagi	N	A1		0513
50050	YV5JF								0513
50050	GB3RAL	Nr Didcot	IO91IN				A1/JT65BH24		0612ZZ
50050	XE2OR	Nava Coahuila	DL98OK	20	5-el@27m		A1	?	0612
50050	SV2JAO		KN10DN					24	0513
50050.6	E51USA	Rarotonga	BG08CT	20	halo@36'	Omni	A1	19-07h	0113
50050.6	VE1CZ	New Glasgow NS	FN85HQ					?	0313
50051	LA7SIX	Bardu	JP99EC	30	4-el Yagi	190o	A1	24	0613
50052.5	IT9AKC								0513
50053	V44KAI	St Kitts/Nevis	FK87QH	2	5/8 Vert	Omni	A1	24	0613
50054	OZ6VHF	Ribe	JO57EI	25	X-Dipole	Omni	A1	24	0613
50054	IZ8EDJ								0512
50055	LZ0MON								0812
50055	PY1ON			5			A1	?	0512
50055.1	PV8BR								0313
50055	N9JXY	Auburn IN	EN71LI	1	Squalo	Omni	A1	24	NonOp
50055	LU5FF	San Justin SF	FF99RF	20	5/8 GP	Omni	F1	24	0313
50055	ZL2MHF	Nr Wellington	RE78NS	10	V 1/2 Dip	Omni	F1	24	NonOp
50056	VA7SIX	Coquitlam BC	CN89	10	Ringo	Omni	A1	24	0513
50057	IT9X	Messina	JM78LB	10	HorizLoop	Omni	A1	24	0812
			JT65B/BPSK						
50057	VK7RAE	Don Hill	QE38DU	20	X-Dipoles	Omni	A1	24	0413
50057	TF1SIX	Fludir	HP94SC	8	1/2 Dipole		A1	24	0513
50057.2	IQ4AD	Serione Parma	JN54DT	8	GP	Omni	A1	24?	0613
50057.5	VK4RGG	Nerang	QG62QA	6	Turnstile	Omni	A1	24	0303
50058	HB9SIX	Nr St Gall	JN47QF	8	MixPolarize	SW	A1	24	0413
50058	OE3XLB	Maiersdorf	JN87AT	10	5-el Yagi			24	0513
50058	IW0DTK	Minturno LT	JN61TG					?	0513
50059.0	LU4HH	Cordoba	FF78CI	1	5/8 Vert	Omni	A1	24	0413
50059	CE6B	Valdivia	FF30		Dipole/halo		A1	24?	0413
50059	W6ORM						A1		0612
50059.5	VE3UBL	Ajax ON	FN03	10	Turnstile	Omni	A1	24	0613
50059.7	W4CBX	Bristol TN	EM86				A1	24	0413
50059.91	K4TQR	Birmingham AL	EM63OM	4	Dipole	NW/SE	A1	24	0613
50060	HK6FRC	Quindio	FJ37MC				A1	24?	0313
50060	SK6QW	Nr Mariestad	JO68WR	8	Vert.Dip.	Omni	A1	24	0513
50060.0	KD4NMI	Knightdale NC	FM05RT	100	Vert.Dip.	Omni	A1	24	0613
50060	N7JW		DM37FC				A1	?	0613
50060	K7FL	Battle Ground WA	CN85SS	1.5	Inv Vee	Omni	A1	24	0513
50060	K5AB	Georgetown TX	EM10DP	20	Horiz Loop		A1	24	0613
50060.0	GB3RMK	Nr Inverness	IO77UO	40	Dipole	N/S	F1	24	0613
50060	EA4UW	Toledo	IN80EC					IRREG	0612
50060.0	WB5LLI	Kenner LA	EM40	20	GP@20f	Omni	A1	24	0513
50060.0	WB0RMO	Fairbury NE	EN10	25	Squalo		A1	24	0613
50060	YO5LD		KN34CK					?	0512
50060.5	W8EH	Middletown OH	EM79TM	20	GP	Omni	A1	24	0113
50060.6	LU4SH			1					0513
50060.75	EA4Q	Cuenca	IN80WC	5	GP		A1		0513
50061	LU4TC		FG75IT				A1	?	0113
50061	K9MU	Altoona WI	EN44HT	25	Loop@40'	Omni	A1	24	0313
50061	WG2Z	Andover Twp NJ	FN21OA	100	Halo pair	Omni	A1	24	0413
50061	W3HH	Nr Ocala FL	EL89	3	1/4 Vert	Omni	A1	24	0613

50061	KD4AOZ	Watkinsville GA	EM83				A1	24	0613
50061	N7JW	Panguitch UT	DM37	10			A1	24	0812
50061	LA7SIX	Malselv	JP99EC	100	4-el Yagi	190	A1	24	0312
50061.7	KH6HME	Hilo HI	BK29KQ	70	7-el Yagi	USA	A1	24	0413
					Summer: Stack halos	Omni			
50062	W9DR	NC	EM75	95			A1	IRREG	0711
50062.0	LZ0SIX		KN22XS						0712
50062	W7KNT	Nr Hall MT	DN36HO				A1	24	0613
50062.0	W3PIE	Uniontown PA	FM09DW				A1	?	0513
50062.5	GB3NGI		IO65VB	30	1/4 Vert	Omni		24	0613
50062.6	W9RAS	Cassopolis MI	EN71	1	Squalo@80'		A1	?	0513
50062.8	KB6BKN	Novato CA	CM88				A1	24	0512
50063	LU2ERC	Ensenada BA	GF15AD				A1	?	0212
50063	N4JQQ	Memphis TN	EM55				A1		0513
50063	W7RV	Scottsdale AZ	DM43BL				A1		0613
50063	LY0SIX	Vilnius	KO24PS	7	Slope Dip.	320	A1	24	0413
50063	WR7NV		DM26IF				A1	24	0513
50063.4	KL7KY	Wasilla AK	BP51	75	Loop@65'	Omni	A1	24	0513
50063.3	W9JN	Carson WI	EN54DM	20	Halo@20'	Omni	A1	24	0613
50063.5	N0SAP	Nixa MO	EM37IB	8	J-Pole	Omni	A1	24	0613
50063.5	AH6EZ/W9	Saint Charles IL	EN51SW				A1		0613
50063.5	K1MS	Westford	FN42	10	3-el Vert	070	A1	24	0613
50064	GB3LER	Shetland	IP90JD	30	dipole	0/180	A1	24	0613
50064	KP3FT	Ponce PR	FK68				A1	24	0613
50064V	K3TYE		DM42PE				A1		0213
50064.0	W3APL	Laurel MD	FM19NE	7	Sqalo		A1	24	0613
50064.2	KH6HI	Ewa HI	BL01	50	Turnstile	Omni	A1	24	0413
50064.9	LU3DXG		FF81				A1		0512
50065	GB3IOJ	Jersey					A1	24	0613
50065	ED4YAK		IN80FK					OP?	0612
50064	EA4TD	Pruebas	IN80FJ				A1	?	0612
50065.0	KA0CDN	Aurora CO	DM79OS	50	Halo	Omni	A1	24	0513
50065	K8TB	Holland MI	EN62WU	5	Squalo	Omni	A1	24	0613
50065	W4CLM	Cartersville GA	EM74				A1	?	0513
50065.5	W0MTK	Fruita CO	DM59	4	4 Vees	Omni	A1	24	0513
50065.7	VK6RPH	Walliston WA	OF88AA	20	U Dipole	Omni	A1	24	0413
50065.9	W5GPM	Bartlesville OK	EM26				A1	24	0613
50066	WA1OJB	Bowdoin ME	FN54AA	30	V.Dip@85'	Omni	A1	24	0513
50066	OE3XAC	Kaiserkogel	JN78SB	10	1/4 GP@750m	Omni	A1	24	0613
50066	K6WKX	Santa cruz CA	CM86XX	4	Halo	Omni	A1	24	0912
50066	K3TYE	Tucson AZ	DM42PE				A1	?	0613
50066.2	W5SIX	Horse MountainNM	DM54WA	0.5	7-el Yagi	060	A1	24	0613
50067	WZ8D	Loveland OH	EM89BI	100	Loop@75'		A1	24	0613
50067	OH9SIX	Pirttikoski	KP36OI	35	2 X-dip	Omni	A1	24	0613
50067	W4FWS	Orlando FL	EL98GK				A1		0613
50067	W4PLB	Orlando FL	EL98JP				A1	24	0513
50067	ED4YAS								0513
50067.5	N8PUM	Champion MI	EN66AL	50	PAR Horiz	Omni	A1	24	0613
50067.7	K0EC	Vail Mountain CO	DM69	45	1/2V+1/2H	E-W	A1	24	0613
50067.7	XE2O	Monterey	EL05				A1		0613
50068	K5KDX	Van Buren AR	EM25SM	10	M2 Loop		A1		0513
50068	HG8BVD		KN86HT	10	Vertical	Omni	A1		0513
50068	N4LR	Fairburn GA	EM73QN				A1	?	0113
50068.5	K2ZD	West Orange NJ	FN20US	20	5/8	Omni	A1	24	0513
50068.9	K6FV	Woodside CA	CM87UL	100	varies	NE	A1	24***	0613
50069	W8GTX	StClairShores MI	EN82	1	1/4 Vert	Omni	A1	24	TNonOp
50069	WA3TTS	Pittsburgh PA	EN90XL	1	3x batwing	Omni	A1	24	0613

50069	W7WKR	Stehekin WA	CN98PI				A1		0113	
50069	FM1AZC	Martinique I.	FK94NL	10	Turnstile	Omni	A1	24	0513	
50069.4	W4TTU		DN54LM				A1	?	0613	
50069.5	YO5PBG	Baia Mare	KN17SP	3	Vert Dip	Omni	A1	24	0613	
	YO4C		KN44HE	0.2					0513	
50069	YO4KCA		KN44HE						0613	0513
50069.9	W4HHK	Collierville TN	EM55DB				A1	?	0513	
50070	SK3SIX	Ostersund	JP73HC	7	X-Dip	Omni	A1	24	0513	
50070	ZS6AYE	20km Nelspruit		15	1/2 dipole	N-S	A1	OP?	0313	
50070	EA4EUB		IN80EJ					QRT?	0512	
50070	EA3GXZ		JN01OF				A1	OP?	0612	
50070	WA7LNW	SouthWest UT	DM37				A1	24?	0512	
50070	WA7X	Fairview UT	DM49HO	1	J-Pole	Omni	A1	24	0513	
50070	K0HTF	Central Iowa	EN31MM				A1	24?	0512	
50070.5	KD0MND		EN42HB	5	M2 loop@60'	Omni	A1	24	0513	
50071	W5HN	Allen TX	EM13SJ	0.5			A1	24	0513	
50071	ZS6SJV		KG54ML				multi		0513	
50071	LU6EE		GF02KQ				A1	24	0413	
50071	SJ2W		KP04HM	5		S	A1	IRREG SUMMER	0712	
50071	W3DOG	Ocean City MD	FM28EI	45	Stack Halos	Omni	A1	24	0613	
50072	EA8SIX	Canary Is.	IL28GC						0613	
50072	KC5HUG	W Canyon Lake TX	EL09uw	20W, 2W, 200mW,	Par	Omni	angle at 30' 1080' asl			
50072	W9DR	Punta Gorda FL	EL86UX	95	Yagi	N	A1	IRREG	0413	
50072	PY2XW	Campinas SP	GG67LF				A1	24?	0313	
50072.4	W6NIF	Fresno CA	DM06				A1	IRREG	0612	
50072.5	N7DGI	Casper WY	DN62TT	7	OA-50loop@6m		A1	IRREG 15-0200	0513	
50072.9	N4VBV	Sumter SC	EM93TW	5	Dipole	N-S	A1	24	0513	
50073	K0KP	Duluth MN	EN36WT	100	Delta Loop	Omni	A1	24	0613	
50073	EA3SIX	Madrid	JN11BK						0513	
50073	N7TR		DM09				A1		0513	
50073	N7SCQ	Dixon CA	CM98CK				A1	24	0513	
50073	VO1FU	Goulds NL	GN37OL			Vary	A1	IRREG	0513	
50073	PP2SIX	Anapolis-Go	GH53MP				A1	?	0412	
50073.6	P43JB	Oranjestad Aruba	FK42				A1	IRREG	1212	
50073.5	VE3DDW	Hillsburgh ON	EN93				A1	24?	0613	
50074	W5RP	San Angelo TX	DM91				A1	24?	0512	
50074	W0FY		EM48RP				A1		0613	
50074	KD4HLG	Oxford GA	EM73XQ				A1	?	0513	
50074.5	SV3BSF	Petra	KM08UA		2-el DK7ZB	320	A1	24	0613	
50074.5	ED7YAD	Malaga	IM76QO	15	Horiz Loop	Omni	A1	24	0613	
50075	VR2SIX	Hong Kong	OL72					OP?	0512	
50075	JY6ZZ		KM71WX					24	0613	
50075	W7PFR	Mineral WA		12			A1	24	0513	
50075	KA7BGR	Central Point OR	CN82	40	2x2el	SW/NE	A1	24	0613	
50075	NL7XM	Easton PA	FN20IP	3	Dipole	N-S	A1	24	0613	
50075	K7IHZ		DM33				A1		0113	
50075.5	LW2ETU	Avellaneda BA	GF05TI	1	GP	Omni	A1	?	0213	
50076	WR9L	Bourbonnais IL	EN61BD	10	Turnstile	Omni	A1	24	0513	
50076	W4IT	Sassafras Mtn SC	EM85OB	1	H Squalo	Omni	A1	24?	0513	
50076	YV5LIX	Caracas		5			A1		0513	
50076.1	CS5BLA	Aldeia de Chaos	IM57PX	2.5	Horiz Dip	Omni	A1	24	0613	
50076.8	K7AZ	Nr Lompoc CA	CM94SO	10/1/0.1	M2Loop		A1	24	0613	
50077	OA4TT	Canete	FH16TW	50	6-el Yagi	Vary	A1	IRREG	0413	
50077	VE3WE		FN03				A1	?	0812	
50077	EA7URC	Cordoba	IM78IE				A1	?	0712	

50077.6	N0LL	Smith Center KS	EM09OW	60	2 halos	Omni	A1	24	0613
50077.9	XE2S	Sonara	DL49				A1	24	0613
50078	N2GHR	Nr Centereach NY	FN30LU	8	5/8 GP	Omni	A1	24	0513
50078	NM7D	Saint George UT	DM37	15	Halo @ 30'	Omni	A1	24	0513
50078.5	K0DU	CO	DM58PK				A1	24?	0613
50079	W2MPK	Nr Syracuse NY					A1	OP?	0112
50079	JX7SIX	Jan Mayen I	IQ50RX	10	Dipole	150/330	A1	24	0513
50079	W4CHA	Tampa FL	EL88				A1	24	0113
50079	YU6MM		KN07					?	0912
50079.0	W3CCX	Philadelphia PA	FM29JW	4	halo@500'	Omni	A1	24	0513
50078.7	W2UTH	Holley NY	FN12FS	1.5	Dipole		A1	24?	0613
50079.45	W8IF	Nr Selma OH	EM89CR	100	H-Loop@25'		A1	24	0513
50079.5	WA4FC	Carson VA	FM17FE	2	M2Loop@25'	Omni	A1	24?	0513
50079.5	RB1SIX								0513
50079.6V	TI2NA	Irazu Volcano	EJ89	30	Vertical	Omni	A1	TNonOp	0213
50079.6	UU6SIX		KN85DJ						0613
50080	XE1H	Guadalajara	DL80HQ	25	GP	Omni	A1	OP?	0313
50080	K6FRC	Tracy CA	CM97HP	10	Horiz Loop	Omni	A1	24	0613
50080	ED1YBR		IN52PF	8-10	Dipole		A1		0613
50080	W5SXD	TX					A1	IRREG	0512
50080	WA0OQA	Scott City KS	DM98MG				A1		0613
50080	F6IKY	Viuz la Chiesaz	JN26OP	3	GP			?	0613
50080	ZS1SIX	Cape Town	JN96FB	10	Dipole		F2A	IRREG	1112
50080.1	FK8SIX	Noumea	RG37FR	15	GP	Omni	F1	24	0413
50080.4	4X4SIX	Jerusalem	KM71NU	5	Dip@500m	NW/SW	A1	24	0613
50081.5	PP1CZ	Vitoria ES	GG99UQ	5	1/2 Vert	Omni	A1	?	0113
50082	PP6AJM		HI19LD				A1	?	0412
50082.5	LU4FW	Rosario SF	FF97QA	15	5/8 Vert	Omni	A1	24	0712
50082.7	CX1AA	Montevideo	GF15LC	3	Inv Vee	Omni	A1	?	0613
50083}	DF0ANN	Moritzberg Hill	JN59PL	2	Hor Loop	Omni	A1	24	0513
50083}	DB0DUB	Kaarst	JO31HF	2	Horiz	Omni	A1	?	0613
50083	DB0HGW	Greifswald	JO64QC	3	Mag. Loop				0513
50086	LU7YS	S.Martin de los Andes,Patagonia	FE49IU	5	1/4 @8m	Omni	A1	24	0413
50096VV	S9SIX							IRREG	1012
50210	VK0RMI	Macqarie Island	QD95					2013	Plan
50281	VK4RHT	Atherton	QH22RR	10	Vertical	Omni		24	0513
50282.1	VK4RTL	Townsville	QH30JP	3	Turnstile	Omni	A1	24	0613
50288	VK2RHV	Mt Sugarloaf NSW	QF57SC	25	Turnstile	Omni	F1	24	0413
50289	VK2RSY	Nr Sydney NSW	QF56MH	25	Turnstile	Omni	A1	24	0313
50291	KK4XO	Coral Springs FL	EL96UF	20	EF706Yagi	Vary	PSK/A1	24?	1011
50292.8	OE9ICI						JT65		0513
50293.7	VK3RMV	Mount Dundas	QF02WH	15	1/4 GP	Omni	A1	24	0113
50295	9H1AA	Malta					ROS	5min	0112
50295.1	VK3RMH	Wattle Glen VIC	QF22OH	10	2xH Loops	Omni	A1	24	NonOp
50297.9	VK7RST	Mt Nelson Hobart	QE37PB	15	Dipole	E-W	F1	24	0113
50300	VK0RTM	Mawson Base	MC12KJ	16	2xH.Loops		A1	24	0213
50304	VK6RSX	Nr Dampier WA	OG89II	50	Horiz dip.	Omni	A1	24	0613
50306	VK6RBU	Bunbury WA	OF76WR	20	3-elYagi	W-E	A1	24	0213
50310	VK8VF	Darwin NT	PH57	100	DeltaLoop	Omni	A1	24	0513
50315	VK5RBV	Barossa Valley	PF95MK	12	Hor. halo	Omni	A1	24	0613
50315.0	FX4SIX	Neuville	JN06CQ	5	5-el Yagi	090	A1	24	NonOp
50320	F6BHU	Nevers	JN17NA	5	3-el Yagi	315	A1	24	0313
50320	VK5VF	Mt Lofty	PF95IA	8	HorizXDips	Omni	A1	24	0413
50321	ZS5SIX	Pietermaritzburg	KG50	7	Halo	Omni	F1	24	0312
50405	SR8FHS	Drohobyczce	KN11EV	3	GP	Omni	A1	24	0512
50413	EA8RCP								0413

50414	OK0SIX								QSY hr
50416	GB3BAA								QSY hr
50422	S55ZRS								QSY hr
50426	IQ4FA								QSY hr
50447	JW7SIX								QSY hr
50448	FX4VHF								QSY hr
50451	LA7SIX								QSY hr
50457	IW0DAQ	Genzano di Roma	JN61HQ	2	GP	Omni	A1	24	0613
50462	SR5FHW	Warszawa	KO02KH	3	5/8GP	Omni	A1		Planned
50471	OZ7IGY	Toelloese	JO55WM	25	Big Wheel		PI4/A1	24	0613
50475	OK0NCC		JO79EW						0613
50479	JX7SIX								
50480	JH8ZND	Chitose	QN02UW	10	5/8 GP	Omni	A1	24	0613
50490	JG1ZGW	Tokyo	PM95VP	10	7el Yagi	South	A1	24	0513
50499.5	5B4CY	Zygi	KM64PT	20	1/4 GP	Omni	F1	24	0912
50506	OK0EMW								0213
52343	VK4ABP	Longreach	QG26	10	1/4 Vert.	Omni	A1	OP	1212
52425	VK3RBH	Nr Broken Hill	QF07SX						Planned
52438	VK3FGN	Mildura	QF15CT	3	J-Pole	Omni	A1	OP?	NonOp
52490	ZL2SIX	Blenheim	RE68			Omni	F1	OP?	NonOp

ZZ GB3RAL JT65B even mins, A1a odd mins
*** K6FV schedule 1515-0030 approx at 055 degrees, 1030-1515approx at 275 degrees
* May break for QSOs
+ W8GTX operates 1030-2300UTC Oct-Ap, 1030-0200UTC Ap-Sep
= Frequency sharing beacons INT= Intermittent TEMP= Temporary PT= part-time
EX=experimental V= Varies

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VHF/UHF BEACONS by WZ1V

144.170	KH6HME	BK29go	HI	Mauna Loa	60W to pair of 7 el yagis east.
144.273	VE3DDW	EN93vu	ON	Hillsburg	.
144.275	N0EC	DN70lf	CO		50W to pair Big Wheels.
144.275	N5EAD	EM10	TX	Austin	10W to 6el yagi pointed east.
144.275	N9SS	EN50es	IL	Peoria	50mw to 2M Big Wheel @ 30' (820'ASL)
144.275	VA7SIX	CN89	BC	Coquitlam	50W to squalo @ 600'.
144.275	W1RJA	FN41cu	CT	Killingly	20 watts to loop antenna.
144.275	W6TOD	DM15dx	CA	Ridgecrest	30 watts pair loops 2400' asl.
144.276	W2RTB	FN12ar	NY	Victor	3W+Eggbeater @450' asl de K2ERG, heard Feb 2008
144.277	KA0EWQ	EN15	MN	Johnson	10W+3el yagi aimed SE.
144.277	W0PW	EM26	MO	Neosho	35W to Big Wheel @ 50'.
144.277	W4CRZ	EM93tw	SC	Sumter	5W to KB6KQ loop @ 20'.
144.277	W4PLB	EL98gk	FL	Orlando	28W to horizontal loop
144.278	K7XC	DM09nm	NV	Fallon	10W to horiz loop @ 20'
144.278	N2GHR	FN30lu	NY	Long Island	20W to 5 el. pointed 210 deg, 300' asl.
144.278	N8PUM	EN66dl	MI	Ishpeming	10W to PAR omni.
144.279	N0UO	EM07sa	KS	Kiowa	10W 1810' AGL.
144.279	N3FTI	FN20aj	PA	Reading	4W discone.
144.280	N4MW	FM17kn	VA	New Kent	5W to four M2 HO loops @ 90', freq GPS-locked
144.280	VE2FUT	FN35rc	QC		15W+Turnstile 2000' ASL.
144.280	VE3ZAP	EN94vc	ON	Shelburne	
144.280	VE4VHF	EN19gu	MB	Winnepeg	15W to vertical.
144.280	W0ETT	DM79ch	CO	Como	30W to bigwheel 9500' asl.
144.280	W4HHK	EM55db	TN	Memphis	2W+Sqloop at 30' http://www.qrz.com/w4hhk
144.280	W5HN	EM13sj	TX	Desert	1.5W to halo @ 180'
144.281	N4PPG	EM76xg	TN	Knoxville	3.5W to antenna @ 20'
144.281	VE4ARM	EN09mw	MB	Austin	30W to 5el yagi @ 53' to SE
144.282	WI8Z	EN84ca	MI	Standish	5W to colinear antenna @ 30'
144.283	KJ6KO	CM88ws	CA	Bald Mtn	40W stacked HO loops 1700'ASL
144.283	VE3LPL	EN92kx	ON	London	5W to halo @ 22'
144.283	W3CCX	FM29jw	PA	Philadelphia	4W to single loop @ 435'
144.283	WR9L	EN61bd	IL	Bradley	10W to turnstile @ 45'.
144.284	N8LGL	EM89lc	OH	Lake White	10W to omni.
144.284	VE1CBC	FN63	NS	Yarmouth	heard 4/22/08
144.285	WA1ZMS	FM07fm	VA	Bedford	7 KW ERP at 4200' asl aimed 60 deg.
144.285	WA4IOB	EM73	GA	Snellville	2W squalo
144.285	WB2LHP	EN74gq	MI	Traverse Cit	1W to vertical.
144.286	N0UD	DN87sh	ND		30W to stacked big wheels.
144.286	VE6EMU	DO33ng	AB		40W to pair HO loops @ 160'
144.286	WD4GSM	EM86qv	VA	Wise	4200' asl.
144.287	W0VD	EM27			
144.288	N0YK	DM98mg	KS	Friend	30W to a pair of M2 Ho loops @100'
144.288	N3ZRX	FN20dn	PA	Downington	
144.288	VE1UW	FN85qn	NS	Stellarton	10W 3el Yagi SW, new 7/17/12
144.289	KA6LSL/7	DM22tp	AZ	Yuma	20W to 6 el yagi pointed WNW
144.289	W9WZJ	EM69tr	IN	Avon	10W to pair of M2 loops @ 27'
144.290	K2DLL	FN23xc	NY	Providence	20W + 2 Big Wheels 1620'ASL
144.290	K7PO	DM32	AZ	Gila Bend	15W to vertical @ 900'.
144.290	W9WXN	EM68wg	IN	Corydon	5W FSK to vertical at 673' asl.
144.290	WA9HCZ	EN43ju	WI	La Crosse	6 watts pair wheels 1170' asl.
144.290	WB7VVD	DM32	AZ		0.5W to vert. 800' Elevation
144.291	K7UV	DN31xm	UT	Brigham City	20W to phased M2 Horiz Loops.
144.291	N7BHC	FM15pa	NC	Oriental	50W to 16 el pointed at 70 deg.

144.292	VE8BY	FP53rs	NU	Iqaluit	23W to 8 bay dipole array
144.292	WA4HFN	EM55ab	TN	Memphis	10 watts m2 loop 35'
144.294	N6NB	DM05sb	CA	Tehachapi	60 Watts to yagi pointed NW.
144.295	K5RMG	EM00xh	TX	Austin	10W, 1W, 100mW, Par Omniangle at 45' 1240' asl
144.295	K5RMG	EM00xh	TX	Bee Cave	20W bigwheel 1290' asl.
144.295	N0LL	EM09ow	KS	Smith	12W to stacked PAR omnis @ 35'
144.295	VE1SMU G	FN74os	NS	Lake George	10W yagi pointed WSW
144.295	W1JHR	FN42em	MA	Harvard	1.5W to indoor HO Loop.
144.296	KA7BGR	CN82nk	OR	Medford	8w to full wave loop @ 30'.
144.296	W1XR	FN64fo	ME	Jonesport	25 to 5 el yagi pointed north.
144.296	W3APL	FM19ne	MD	Laurel	10W+loop @ 60'
144.296	W4CBX	EM86wk	TN	Holston Mt.	
144.297	VE3WCC	FN15vf	ON	Almonte	3W to stacked KU4AB horiz. omni's.
144.297	W2UTH	FN12hv	NY	Bloomfield	1W to Big Wheel @ 30'.
144.298	K6WKX	CM86xx	CA	Santa Cruz	20w to a halo, 180' asl.
144.298	K7KMT	DN64ve	WY		25w to a loop.
144.298	WD9BGA	EN53ba	WI		
144.299	WA7X	DM49ho	UT		100W to cycloid dipole
144.300	K4MHZ	FM25df	NC	Hatteras	100W to 12 el pointed 65 deg to Europe
144.300	K4IDC	EM76ma	TN	Crossville	700mw to omni loop
144.300	KD4NMI	FM05rt	NC	Knightdale	10W vertical omni @ 575'.
144.300	W0BLK	DN84	SD	Rapid City	35 watts big wheel at 50'.
144.300	WA3TTS	EN90xn	PA	Pittsburgh	10W to pair PAR loops at 44' 1200'asl.
144.305	K3MEC	FM09tf	VA	Gore	1.5W to pair of sq loops at 2200'asl.
144.400	VO1ZA	GN37js	NF	Carbonear	250W 11 el yagi to Europe.
222.015	K5BYS	EM13mn	TX	Dallas	100mw to halo 1500'.
222.017	KJ6KO	CM88ws	CA	Bald Mtn	25W to pair of loops 1700' asl.
222.050	W0PW	EM26	MO	Neosho	10W to turnstile at 1150' asl.
222.050	W2UTH	FN12hv	NY	Bloomfield	5W to PAR Omni-Angle @ 30'.
222.051	K2DLL	FN23xc	NY	Providence	25W to Big Wheel 1620'ASL
222.051	W8VO	EN82ln	MI	Sterling Hts	QRV 6-11am and 6pm-midnight.
222.052	N6XQ	DM12jr	CA	San Diego	1W to 6 el yagi pointed north.
222.052	XE2ERD	DM10			6 el yagi pointed north.
222.053	KOHTF	EN31do	IA	Des Moines	Gnd plane
222.055	VE3TFU	EN93vd	ON	Waterford	2W to 3 el. @ 50' pointed SW.
222.055	W0ETT	DM79ch	CO	Como	30W to wheel 9500' asl.
222.055	W6TOD	DM15dx	CA	Ridgecrest	20 watts pair Bigwheels 2400' asl
222.056	W4PLB	EL98gk	FL	Orlando	10W to horizontal loop.
222.056	WA4IOB	EM73	GA	Snellville	2W.
222.057	W2RTB	FN12ar	NY	Victor	3W+eggbeater @450' asl de K2ERG
222.057	WD4GSM	EM86qv	VA	Wise	300mW to turnstile at 4200' asl
222.060	AA5C	EM13se	TX	DFW	8W to dipole @ 45'
222.060	K5RMG	EM00xh	TX	Bee Cave	20W bigwheel 1290' asl.
222.060	K5TRA	EM00xh	TX	Austin	10W, 1W, 100mW, Big Wheel at 45' 1240' asl
222.060	N4MW	FM17kn	VA	New Kent	15W to Sqloop @ 90', freq. is GPS-locked.
222.062	W0ZQ	EN34it	MN	Bloomington	10W to Big Wheel @ 60'.
222.063	VE3WCC	FN15vf	ON	Almonte	3W to stacked KU4AB horiz. omni's.
222.064	W3CCX	FM29jw	PA	Philadelphia	4W to single loop @ 435'
222.070	K4IDC	EM76ma	TN	Crossville	3.5w to omni loop
222.072	K3DEL	FM28fn	DE	Sussex cty.	2W yagi beaming NE
222.075	WD5AGO	EM26be	OK	Tulsa	3W to big wheel @ 30'
432.078	KH6HME	BK29go	HI	Mauna Loa	30W to pair of 22 el Quagis east
432.155	N4QH	EM84im	GA	Toccoa	2W to loop cw + fm 1020 Hz tone
432.180	N0UO	EM07sa	KS	Kiowa	3W 1810' AGL
432.280	KJ6KO	CM88ws	CA	Bald Mtn	50W to 4 loops @ 1700' asl.
432.280	N4PZ	EN52gb	IL	Mt Morris	50W to pair Big Wheels @ 70'.
432.288	W3CCX	FM29jw	PA	Philadelphia	5W to Big Wheel @ 435'

432.294	N6NB	DM05	CA	Tehachapi	5W to yagi pointed 315 deg.
432.297	K3DEL	FM28fn	DE	Sussex cty.	5W to yagi @ 135'.
432.299	N9SS	EN50es	IL	Peoria	50mw to 2M Big Wheel @ 30' (820'ASL)
432.300	K4IDC	EM76ma	TN	Crossville	12w to omni loop
432.300	K5YG	EM50oj	MS	Ocean Spring	8W HO loop or yagi toward EL98.
432.300	K6ER	CM87sv	CA	Sausalito	2W horizontal 1125' amsl.
432.300	N4MW	FM17kn	VA	New Kent	50W to Sqloop @ 90', freq. is GPS-locked.
432.300	VE1UW	FN85qn	NS	Stellarton	10W 5el Yagi SW, new 7/17/12
432.300	VE4ARM	EN09mw	MB	Austin	35W to 5el yagi @ 53' to SE
432.300	W2UHI	EN63vb	MI	Grand Haven	10W omni
432.300	W2UTH	FN12hv	NY	Bloomfield	5W to PAR Omni-Angle @ 30'.
432.303	KW2T	FN13			0.25W FSK
432.305	WA4PGI	FM07bw	VA	Covington	5W+crossed dipoles,+/-5KHz
432.306	W2RTB	FN12ar	NY	Victor	3W+Eggbeater @450' asl de K2ERG
432.307	W4PLB	EL98gk	FL	Orlando	10W to horizontal loop.
432.309	WA4ZTK	EM85ar			0.9W+yagi to northeast
432.311	N8PUM	EN57vi	MI	Greeley	3W to turnstile on Mt. Horace.
432.311	W3APL	FM19ne	MD	Laurel	7W+turnstile @ 60' QSL N4GYN
432.313	K7RAT	CN85ss	WA	Battleground	200mW to horiz loop @ 30'.
432.320	K1IIG	FN31lm	CT	Prospect	4W ERP, single wheel at 950' amsl.
432.323	WA3TTS	EN90xn	PA	Pittsburgh	10W to 4 loops at 49' 1205' asl.
432.324	N0EDV	EN45fa	WI	Bloomer	4W to Holoop at 30'.
432.325	K5BYS	EM13mn	TX	Dallas	100mw to halo @ 1500'.
432.328	VE2FUT	FN35rc	QC	Montreal	10W + 2x12 yagis south/west
432.345	K5RMG	EM00xh	TX	Bee Cave	20W bigwheel 1290' asl.
432.345	K5RMG	EM00xh	TX	Austin	10W, 1W, 100mW, Big Wheel at 45' 1240' asl
432.347	WD4GSM	EM86qv	VA	Wise	5W, 4200' asl.
432.350	KOHTF	EN31do	IA	Des Moines	J-pole
432.352	WA4IOB	EM73	GA	Snellville	1.5W to 4 dipole omni array
432.358	VE3WCC	FN15vf	ON	Almonte	3W to stacked KU4AB horiz. omni's.
432.360	W0ETT	DM79ch	CO	Como	30W to wheel 9500' asl.
432.360	W6WE	CM95ra	CA	Nipomo	30W to pair of KB6KQ loops @ 25'.
432.365	VE3TFU	EN93vd	ON	Waterford	2W to 7 el. @ 45' pointed SW.
432.370	WW2DX	FN22wb	NY		30W to pair hor loops @ 100', 1800'asl.
432.372	K4UHF	EM85cg	NC	Cherokee	1W to Eggbeater
432.375	W1UHE	FN41jp	RI	Tiverton	2W to Bigwheel.
432.380	W5HN	EM13kf	TX	DFW	0.5W to square loop @ 280'
432.399	WA7X	DM49ho	UT		750W ERP vertical yagi pointed N.
902.310	K4UHF	EM85cg	NC	Cherokee	4W to Alford slot
902.325	K5BYS	EM13mn	TX	Dallas	100mw to omni @ 1500'
902.330	K5RMG	EM00xh	TX	Austin	15W, 1.5W, 150mW, Helical Collinear at 45' 1240' asl
902.380	W5HN	EM13kf	TX	DFW	6W to Alford slot @ 280'
902.400	W4PLB	EL98gk	FL	Orlando	10W to Egg Beater.
902.550	N2NEP	FN13da	NY	Henrietta	10W + Big Wheel
902.989	KA8EDE	EM89ap	OH	Xenia	5W to dipole @ 90', 985' asl.
903.050	W3APL	FM19ne	MD	Laurel	slot at 60' - TEMP. DOWN.
903.055	WA1ZMS	FM07fm	VA		100W to Turnstile 4200ft AMSL
903.060	K1TR	FN42iv	NH	Derry	15W bigwheel @ 100'
903.065	K8EB	EN73cb	MI	Marne	omni
903.073	W3CCX	FM29jw	PA	Philadelphia	5W to Littlewheel @ 435'
903.073	WD4GSM	EM86qv	VA	Wise	5W to Horizonal Loop 4200' asl.
903.075	K3XF	DM70km	CO	Fort Collins	10W to wheel @ 8300' amsl.
903.082	K3DEL	FM28fn	DE	Sussex cty.	8W looper beaming NE
903.085	K3SIW	EN52xb	IL	Schaumburg	30W to corner refl aimed East
903.098	K5RMG	EM00xh	TX	Bee Cave	
903.280	N4MW	FM17kn	VA	New Kent	50W to yagi @ 30 deg, freq. is GPS-locked.

903.297	KJ6KO	CM88ws	CA	Bald Mtn.	50W to 8 el/ yagis N-S 1700' asl.
903.310	VE2CLO	FN35	QC	Montreal	10W + corner refl. 10dB SW
903.364	VE3WCC	FN25ek	ON	Ottawa	3W to KU4AB horiz. omni @ 300'.
903.400	W0BA	DN70km	CO	Ft Collins	200mW to horiz. omni.
903.714	NU7Z	CN87	WA	Seattle	Standard gain ant.
1296.000	W4PLB	EL98gk	FL	Orlando	10W to Egg Beater.
1296.054	W3APL	FM19ne	MD	Laurel	8W to slot @ 120'
1296.055	N7LQ	DM09cf	NV		1.5W to 14 el looper pointed north
1296.059	K3SIW	EN52xb	IL	Schaumburg	20W to 15 el looper aimed East
1296.062	WD4GSM	EM86qv	VA	Wise	5 Watts to Alford slot 4200' asl.
1296.075	W7HR	CN87qn	WA	Bremerton	2W to 24 el aimed at Mt. Rainier.
1296.079	W8KSE	EM79ur	OH	Dayton	2W to Big Wheel 800' AGL.
1296.133	K5PJR	EM37ka	MO	Sparta	4W to Alford slot omni.
1296.200	WA4PGI	FM07	VA		5 Watts to Alford slot
1296.223	K3LNZ	FM09gg	MD	Backbone Mtn	5W to 4 Little Wheels
1296.230	W0ETT	DM79ch	CO	Como	30W to pair of wheels 9500' asl.
1296.247	N0YK	DM98mg	KS	Friend	3W to pcb Big Wheel @ 25'
1296.247	W3CCX	FM29jw	PA	Philadelphia	5W to Alford slot @ 435'
1296.250	KH6HME	BK29go	HI	Mauna Loa	15W to 4x25 el yagis east
1296.251	W3HMS	FM19qv	PA	Red Lion	1.5W to Alford slot hor. @ 1130' asl
1296.257	W2UTH	FN12hv	NY	Bloomfield	2W to halo @ 30'.
1296.269	W3KWH	EN90wk	PA	Pittsburgh	1W to an Alford slot.
1296.270	KD5RO	FN13	NY		
1296.272	KJ6KO	CM88ws	CA	Bald Mtn	10W 25el pointed 145 deg 1750'MSL
1296.274	N4PZ	EN52gb	IL	Mt Morris	5W to NW-SW yagis @ 40'.
1296.280	N4MW	FM17kn	VA	New Kent	6W to yagi @ 30 deg, freq. is GPS-locked.
1296.286	W1RJA	FN31th	CT	Old Saybrook	7W to K1WHS bi-dir LPY @ 155' NE-SW.
1296.299	N9SS	EN50es	IL	Peoria	50mw to 2M Big Wheel @ 30' (820'ASL)
1296.300	K2DLL	FN23xc	NY	Providence	40W ERP stacked W6OAL MiniWheels
1296.300	K6QPV	DM12mq	CA	Mt SanMiguel	16W to horiz. yagi aimed NW
1296.300	WD5AGO	EM26ad	OK	Tulsa	2 Watts to 6dB slot omni.
1296.305	VE2FTR	FN35gs	QC	Montreal	2W to dual quad at 35'.
1296.306	WW8M	EN72xf	MI		1W to LPY @ 105' pointed at Chicago
1296.308	K2YAZ	EN74av	MI		1W 5 el @60' aimed at Chicago
1296.310	K4UHF	EM85cg	NC	Cherokee	1W to Alford slot
1296.310	VE2CLO	FN35	QC	Montreal	15W + double dimond 10 dB SW, still QRV?
1296.325	K5BYS	EM13mn	TX	Dallas	100mw omni @ 1500'.
1296.317	K8EB	EN73cb	MI	Marne	omni
1296.325	VE3TFU	EN93vd	ON	Waterford	5W to 23 el. @ 40' pointed SW.
1296.327	VE2FUT	FN35rc	QC	Montreal	4W to Big Wheel omni.
1296.329	N6XQ	DM12jr	CA	San Diego	18W to 4 loopers @ 330 deg.
1296.331	W8VO	EN82	MI		
1296.340	W6PQL	CM97am	CA		30W to yagi pointed 140 deg.
1296.360	K5DYY	EL07wu	TX	Alice	2W to Tri-Delta loop @ 100'
1296.380	W5HN	EM13kf	TX	DFW	2W to Alford slot @ 280'
1296.400	WA6UFQ	EM00xh	TX	Austin	15W, 1.5W, 150mW, Helical Collinear at 45' 1240' asl
1296.763	NU7Z	CN87us	WA	Seattle	700 mw to pair of miniwheels
2304.015	VE2CLO	FN35	QC	Montreal	0.6W + double dimond 10dB SW
2304.015	K3SIW	EN52xb	IL	Schaumburg	10W to 7dB horn aimed SE
2304.040	K5RMG	EM00xh	TX	Bee Cave	
2304.041	W3CCX	FM29jw	PA	Philadelphia	1W to 8 slot @ 435'
2304.050	N7LQ	DM09cf	NV		0.5W to 21 el looper pointed north
2304.050	W4PLB	EL98gk	FL	Orlando	12W to Alford slot.
2304.064	K5BYS	EM13mn	TX	Dallas	180mw to omni @ 1500'
2304.150	NQ2O	FN13ch	NY		10W Pair of Loopers to SSE @ 75'.
2304.171	K3UO	FM09rc	WV	North Mt	10W to waveguide 24 slot ant @70' 2600' asl

2304.280	N4MW	FM17kn	VA	New Kent	4W to yagi @ 30 deg, freq. is GPS-locked
2304.297	K3MEC	FM09tf	VA	Winchester	1W to 4x3el yagis NE-SE-SW-NW at 2200'asl.
2304.300	WW8M	EN72xf	MI		1W to LPY @ 105' pointed at Cleveland
2304.303	W6IFE	DM14kf	CA	Heaps Peak	8W to 12 slot omni.
2304.310	K4UHF	EM85cg	NC	Cherokee	1W to Alford slot
2304.325	K2YAZ	EN74av	MI		1W to slot @60'
2304.325	K8EB	EN73cb	MI	Marne	omni
2304.330	AB5SS	EL29ko	TX	Houston	1W to W6OAL 4 bay nanowheel 9dBd
2305.001	AA5C	EM13se	TX	DFW	1W to Alford slot @ 48'
2401.000	W3HMS	FM19qv	PA	Red Lion	1.1W to Lindenblad RHCP 1130' asl
2427.000	K8OCL	EN82bn	MI	Genoa Twnshp	100mW spreadspectrum vertical omni
3456.015	K3SIW	EN52xb	IL	Schaumburg	5W to 7dB horn aimed SE
3456.075	W4PLB	EL98gk	FL	Orlando	6W to Alford slot.
3456.150	NQ2O	FN13ch	NY		5W Pair of Loopers to SSE @ 75'.
3456.145	K3UO	FM09rc	WV	North Mt	5W to waveguide 24 slot ant @70' 2600' asl
3456.200	WA1VVH	FN42eq	MA	Pepperell	4W to 16 slot waveguide @ 145'
3456.203	W3CCX	FM29jw	PA	Philadelphia	5W to 16 slot @ 435'
3456.295	WW8M	EN72xf	MI		350mW to LPY @ 105' pointed at Chicago
3456.325	W5HN	EM13kf	TX	DFW	20mW to Alford slot @ 280'
5759.945	K3SIW	EN52xb	IL	Schaumburg	5W to 7dB horn aimed SE
5760.000	K6QPV	DM12mq	CA	Mt SanMiguel	2.5W to a WA6CGR 10 dB omni slot.
5760.074	WA4PGI	FM07bw	VA		5 Watts ERP
5760.120	W4PLB	EL98gk	FL	Orlando	11W to WG slot.
5760.165	K3UO	FM09rc	WV	North Mt	5W to waveguide 24 slot ant @70' 2600' asl
5760.196	W3CCX	FM29jw	PA	Philadelphia	5W to 32 slot @ 435'
5760.201	W3HMS	FM19qv	PA	Red Lion	210mW to 8 slot hor. @ 1130' asl
5760.325	K8EB	EN73cb	MI	Marne	omni
5760.325	W5HN	EM13kf	TX	DFW	25mW to 6 slot WG @ 280'
10367.906	W2UHI	EN63vb	MI	Grand Haven	
10367.987	WA4PRR	FM18qq	MD	Sunderland	20mW omni 12 slot waveguide up 15 M
10367.990	KF6KVG	CM97ae	CA	Los Gatos	200mw to 12 dB horn pointed 330 deg.
10368.000	KI4NPV	EL98hr	FL	Longwood	3W to horns pointed SE/NW
10368.015	W4PLB	EL98gk	FL	Orlando	3W to WG slot.
10368.024	K0RZ	DM79gv	CO	Starr Peak	50mw to 9dBi cardioid pointed E @ 10,550' asl
10368.042	W3CCX	FM29jw	PA	Philadelphia	0.5W to 32 slot @ 435'
10368.045	K3SIW	EN52xb	IL	Schaumburg	1W to 2' dish aimed West
10368.072	W3HMS	FN10ni	PA	Harrisburg	on Blue Mountain
10368.118	W6HCC	DN70lr	CO	Wellington	
10368.130	W4FWS	FM14ux	NC	Cedar Island	7W to waveguide slot ant
10368.160	KA3EJJ	FM19of	MD	EllicottCity	0.5W
10368.180	K3UO	FM09rc	WV	North Mt	4W to waveguide 36 slot ant @70' 2600' asl
10368.200	K5RMG	EM00xh	TX	Bee Cave	1W 18 dB/180 deg sector horn east.
10368.200	WA1VVH	FN42eq	MA	Pepperell	750mW omni 10 slot waveguide 340'.
10368.215	NO5K	EM10ch	TX	Austin	2W, 8 slot WR-90 at 40' 900'asl
10368.216	W7CQ	CN83jx	OR	Eugene	250mW to 14" dish beamed north.
10368.250	K7RJ	DN31it	UT	Park Valley	750mW to omni slot (15W EIRP).
10368.265	K1JCL	FN31us	CT	Coventry	200mW omni 16 slot horiz @ 190'
10368.265	K1FFK	FN32jp	MA	Adams	120mw to 2x8 slot antenna 3500' asl
10368.270	N2YYU	FN32ce	NY	Blue Hill	100mw to 2x8 slot antenna 700' asl
10368.280	N4MW	FM17kn	VA	New Kent	1.5W+waveguide slot @95', freq. is GPS-locked.
10368.297	WW8M	EN72xf	MI		sporadic, 1W to dish @ 70'
10368.300	KA1RMF	FN42kl	MA	Stoneham	1W to small horn pointed NW.
10368.300	N6CA	DM03ts	CA	Palos Verdes	1.6W to 16 dBi omni.
10368.300	WA8RJF	EN91em	OH	Cleveland	slot antenna.
10368.310	N6CA	DM04ms	CA	Mt. Frazier	1.5W to 16 dBi omni 8000' asl.
10368.315	N8PUM	EN57vi	MI	Greeley	200mW to 32 slot omni on Mt. Horace.
10368.320	N1JEZ	FN34om	VT	Mt Mansfield	800 mW to 16 slot WG omni 3780 asl, GPS locked.

10368.325	K2YAZ	EN74av	MI		180 mW to 10 dB horn @60' pointed Chicago
10368.325	K3AWS	EN91um	PA	Atlantic	1.5W to 24 slot Alford slot 1713' asl.
10368.325	VE3ZV	EN92vw	ON	Waterford	200mW to 17 dBi horn SW email ve3tfu@hotmail
10368.325	W5HN	EM13kf	TX	DFW	25mW to 8 slot WG @ 280'
10368.325	W6ASL	CM88wj	CA	Mt. Vaca	1W to 10 dB Omni.
10368.330	AF6HP	DM13fr	CA	Santiago Pk.	500mw to 11 dB omni.
10368.350	KH6HME	BK29go	HI	Mauna Loa	2W to 4' dish east
10368.360	K0RZ	DM79jx	CO	Boulder	500mW 23dBi S and 50mw 21dBi North
10368.360	K6QPV	DM12mq	CA	Mt SanMiguel	500mw to 12 dB omni.
10368.380	NT5NT	EM12px	TX	Dallas	1W 200 degree horn W 246' agl
10368.750	KA8EDE	EM89ap	OH	Xenia	50 mW 16 slot waveguide at 89’
10368.900	WA3PTV	FM19bs	PA	Mercersburg	New.
10368.900	WB9PNU	EM48ss	MO	St. Louis	2W to 2x16 slotted waveguide @ 100'
10369.192	AD6FP	CM97bl	CA	Fremont	50mw omni.
24092.053	K0RZ	DM79gv	CO	Starr Peak	100mw to 17dBi horn pointed NE @ 10,550' asl
24191.975	KF6KVG	CM97ae	CA	Los Gatos	200mw to 14 dB horn 330 deg.
24192.010	AD6FP	CM97bl	CA	Mt. Allison	50mw to 12 dB omni.
24192.035	W4PLB	EL98gk	FL	Orlando	150 mW to WG slot.
24192.050	K6QPV	DM12mq	CA	Mt SanMiguel	200mw to 12 dBi horn 320 deg.
24192.100	W5HN	EM13kf	TX	DFW	1mW to 18 dB horn east @ 280'
24192.210	N0KGM	DN40co	UT	Cottonwood H	8mW to 17dB horn pointed west @ 35'.
24192.250	K2YAZ	EN74av	MI		100 mW to 16 slot @60'
24192.380	N4FRE	EM13qd	TX	DFW	1.1W to 18 dB horn south @ 30'
24192.400	AA5C	EM13kf	TX	DFW	50mW to 12 slot WR-42 ant @ 48'.
24192.500	K0RZ	DM79jx	CO	Boulder	100mW 23dBi N
47087.990	KF6KVG	CM97ae	CA	Los Gatos	5dbm to 14dB Horn at 330 deg.
79920.	KF6KVG	CM97ae	CA	Los Gatos	0dbm to 14dB Horn at 330 deg.

TNX to all the contributors to this list. Please forward updates to WZ1V

2013 Central States VHF Society Member Roster

CALL	NAME	ADDRESS	CITY	STATE	ZIP	DAY PHONE	NIGHT PHONE	EMAIL	BANDS	GRID	Life Mem
AAØKW	Joe Spinks	3165 29th Ave	Marion	IA	52302	319-295-2645	319-377-1070	radioman02@aol.com	B	EN42fb	X
AA7XT	William H. Hein	479 S 16 1/2 Rd	Glade Park	CO	81523-8545	970-628-5120	970-628-5120	bill@innovantennas.com	ABDE	DM59pa	X
AA9IL	Mike Kana	33339 N. Rule Ct	Grayslake	IL	60030	847-207-2040	847-207-2040	aa9il@sbcglobal.net	AB9EHIJ	EN62ai	
AA9MY	Bob Davis	118 Cape Ann Court	Pekin	IL	61554	309-263-8620		aa9my@arrl.net	ABCDE	EN50	X
AB9QC	Randall Taylor	1139 Roland Ln	Green Bay	WI	54303					EN64	
AB9SQ	Nicholas Lauerman	1300 S White Oak Dr #828	Waukegan	IL	60085	847-936-0135	708-670-8839	ab9sq@arrl.net	ABCDE	EN62	X
ACØOQ	Jon Gorski	P.O. Box 266	Vinton	IA	52349	519-472-5102				EN32xd	
AC5TM	Thomas Miller	1413 Prentiss Ave	New Orleans	LA	70122-2052	504-251-7515		ac5tm@arrl.net	ABD	EM40	X
AC9DN	Roy Crosier	800 E Arthur Apt E3	Warsaw	IN	46580-3070	574-269-2566	574-269-2566	valvetimer@gmail.com	AB	EN71	
AD6P	Dr. Cleyon Yowell	PO Box 273	Haven	KS	67543	620-663-8873	316-663-8873	ad6p@cox.net	BD	EM18ab	X
AF4JF	Herbert Ullmann	30 Newberry Dr	St Peters	MO	63376-3108	636-922-1070	636-922-1070	af4jf@ullmann.us	ABDEI	EM48qs	
AF8Z	Chuck Clark	8763 FM 2478	Celina	TX	75009	469-667-3877	469-667-3877	af8z@earthlink.net	ABCDEH	EM13	X
AIØZ	Mark Denker	401 W Franklin St	Morristown	MN	55052	507-685-2522	507-685-2522	mdenker@bevcomm.net	ABCD	EN34gf	X
GØKSC	Justin Johnson	20 Sanders Rd	Canvey Island		SS8 9NY			justin@g0ksc.co.uk	AB		
G4DDK	Sam Jewell	Blenheim Cottage	Falkenham	Ipswich	IP10 0QU	44 1394 448495		sam@g4ddk.com	ABDEFGIJK	JO02pa	X
KØCQ	Gerald N Johnson	3271 340th St	Ellsworth	IA	50075	515-836-2118	515-836-2118	geraldj@weather.net	ABCDI	EN32fh	
KØDAS	Rod Blocksome	690 Eastview Drive	Robins	IA	52328-9768	319-393-8022	319-393-8022	rkblocks@plutonium.net	ABCD9EF	EN42eb	X
KØGOB	Roger Volk	4773 Oakbrier Dr	St Louis	MO	63128	314-487-4050	314-487-4050	k0gob@arrl.net	ABCDE	EM48tm	
KØGRM	Dennis "Doc" Murphy	111 W Arikara Ave	Bismarck	ND	58501-2604	701-258-6747	701-258-6747		AB	DN96ot	X
KØGU	Jay Kesterson	6200 NE Frontage Rd.	Wellington	CO	80549	970-568-7813	970-568-7813	k0gu@verinet.com	ABCD	DN70mq	X
KØHAC	Holly Nelson	5621 36th Ave S	Minneapolis	MN	55418	612-719-6351	612-619-4071	holly@chris.org	ABCDEI	EN34	X
KØKFC	Jim Hermanek	1213 207th St	St Croix Falls	WI	54024	715-483-2684	715-483-2684	jhermanek@centurytel.net	ABCDEI	EN35	
KØMHC	Jim Froemke	2561 Co Rd 5 NE	Alexandria	MN	56308	952-836-8378	952-836-8378	rvrover@hotmail.com	ABCD9EFGHI	EN26ha	
KØRZ	William D. McCaa Jr.	181 S 80th St	Boulder	CO	80303	303-499-1936	303-499-1936	k0rz@comcast.net	ABCD9EFGHIJ	DM79jx	
KØSHF	Lenny Klosinski	4925 42nd Ave S.	Minneapolis	MN	55417	952-448-4412	612-724-8271	SixtCylHum@aol.com	ABCD9EFGI	EN34jv	X
KØSIX	Vince Pavkovich	23260 189th St	Big Lake	MN	55309	763-263-6387	763-263-6387	k0six@arrl.net	ABCD	EN35dj	
KØSM	Andrew Flowers	53 Park Ridge Dr	Pittsford	NY	14534			aflowers@frontier.net	ABI	FN13ed	X
KØTLM	Tom Bishop	4936 N Kansas Ave	Kansas City	MO	64119-3442	816-459-2233	816-452-6953	tbishop@birch.net	ABCD9EF	EM29re	
KØUO	Steve Walz	17353 SE US281	Kiowa	KS	67070-8819	620-825-4643	620-825-4643	stevew@rsicorp.com	ABD9E	EM07	X
KØVM	Al Groff	5710 Michael Drive NE	Cedar Rapids	IA	52411	319-393-8134	319-393-8134	k0vm@arrl.net	A	EN42db	X
KØYVI	Arnold Krusemark	1825 Glengarry	Carrollton	TX	75006		972-245-4463	arnoldk1@juno.cpom		EM12	X
K1OYB	Martin J Feeney	99 Running Hill Rd	Scarborough	ME	04074-8934	207-775-8374	207-839-5072		ABCD9E	FN43tp	
K2DRH	Robert J Striegl	10915 Fuller Rd	Albany	IL	61230	309-887-4182	309-887-4182	k2drh@arrl.net	ABCD9EFG	EN41vr	
K3CB	Owen Wormser	25911 Goose Neck Rd	Royal Oak	MD	21662	202-362-8294	202-362-8255	owormser@c3iusa.com	ABCD9EFGHIJKL	FM18vr	X
K3IO	Dr. Thomas Clark	6388 Guilford Road	Clarksville	MD	21029	301-854-3113	301-854-3113	k3io@verizon.net	ABDFI	FM19me	X
K4LVV	Itice Goldthorpe	2420-207 Roswell Ave	Charlotte	NC	28209-1677				ABD	EM95	X
K5AND	Dick Hanson	16400 Hamilton Pool Rd	Austin	TX	78738	512-940-9978	512-263-4121	dick@dkhanson.com	ABDE	EM10bh	X
K5DYY	Don R Galloway	193 County Rd 116	Alice	TX	78332	361-664-4132	361-664-4132	k5dyy@att.net	ABCD9EFI	EL07ws	X
K5GJ	Greg Jurrens	5520 Great Divide Dr	Austin	TX	78738	512-963-4713		greg@flex-radio.com	BCD9EFGHI	EM10ag	X
K5GTX	Greg Evans	815 Wind Elm Dr	Allen	TX	75002	214-505-6738		k5gtx@live.com	ABD	EM13qb	X
K5LLL	Ron Marosko	P.O. Box 370	McDade	TX	78650	512-332-1640	512-253-6082	k5lll@arrl.net	ABCD9EFGI	EM10kf	X
K5PJR	Tony Bickel	3351 Hwy 125 N	Sparta	MO	65753	417-459-3622	417-459-3622	k5pjr@centurytel.net	ABEH	EM37ka	X

CALL	NAME	ADDRESS	CITY	STATE	ZIP	DAY PHONE	NIGHT PHONE	EMAIL	BANDS	GRID	Life Mem
K5QE	Marshall P Williams	314 Lighthouse Dr N	Hemphill	TX	75948	409-787-3830	409-787-3830	k5qe@k5qe.com	ABCD9EFG	EM31cj	X
K5TTT	Charles E. Calhoun	16101 E. 98th St. N.	Owasso	OK	74055	918-481-3714	918-272-9872	k5ttt@tulsa.com	ABD	EM26ch	
K5VH	Tom Haddon	1005 Hidden Hills Drive	Dripping Springs	TX	78620	512-787-6204	512-894-4374	k5vh@arrl.net	ABCD9EFGI	EM00xe	X
K6DV	Gene Powers	PO Box 253	Brighton	IA	52540	319-694-4300	319-694-4300	k6dv@aol.com	ABCDEI	EN41	
K6MIO/KH6	Jim Kennedy	PO Box 1939	Hilo	HI	96721-1939	808-937-5387	808-964-3140	jimkennedy@hawaii.rr.com	ABDE	BK29ks	
K6QXY	Robert Magnani	1500 Los Alamos Rd	Santa Rosa	CA	95409-3308	707-538-3801	707-538-3801	k6qxy@aol.com	ABCDE	CM88ql	X
K6UM	Steve Lund	15385 NE Kincaid Rd	Newberg	OR	97132-6926	503-627-1927	503-538-2469	stlund@umich.edu	A	CN85mh	
K7BV	Dennis Motschenbacher	290 West Rd	Turkey	NC	28393	860-917-7637	860-917-7637	k7bv@aol.com	A	FM04xv	X
K8EB	Erwin Beemer	953 Garfield	Marne	MI	49435	616-791-6873	616-677-1897	mrdxcc@sbcglobal.net	ABCD9EFGHIJ	EN73cb	X
K8TB	Tom Bosscher	3148 Rosewood	Hudsonville	MI	49426	616-648-0058	616-648-0058	tom@bosscher.org	ABD	EN72bv	
K8TQK	Bob Mathews	73 Landrum Rd	Bainbridge	OH	45613	740-634-3773	740-634-3773	k8tqk@horizonview.net	ABCD9EFGHI	EM89je	
K8XK	Mark Kovalan	5706 Sanden Rd NE	Cedar Rapids	IA	52411	319-295-3851	319-395-0837	makovala@rockwellcollins.com		EN42	X
K9AKS	Curt Roseman	2120 12th St.	Moline	IL	61265	309-764-6122	309-764-6122	croseman@usc.edu	ABCDE	EN41	X
K9GY	Eric Hall	3355 193Rd St	Lansing	IL	60438	708-280-1210	708-280-1210	k9gy@sbcglobal.net	ABCD	EN61fn	
K9JCZ	Gary Gilbertson	1354 S Park Ave	Fond du Lac	WI	54935			k9jcz1@charter.net	ABCDE	EN53ss	X
K9JK	John Kalenowsky	58 N. Oak Street	Palatine	IL	60067-5238	847-776-0828	847-776-0828	hamk9jk@ameritech.net	ABCD9EFGI	EN52xc	X
K9KM	Howard Huntington	25350 N Marilyn Ln	Hawthorn Woods	IL	60047	847-668-3808	847-438-3452	k9km@arrl.net	AB	EN52xe	X
K9KNW	Joe Goggin	294 Brandy Ln	Naples	FL	34114	239-642-0720	239-642-0720	fortgoggin@aol.com	ABCDE	EL96ec	X
K9LQZ	Lowell K De Poy	Box 28 Milltown Rd	Hardinsburg	IN	47125		812-472-3749	ldepoy@blueriver.net	ABD	EM68ul	X
K9MQG	Bruce Roe	5719 E Skinner Rd	Stillman Valley	IL	61084	815-234-8039	815-234-8039	bcroe@juno.com		EN52jd	
K9OQN	Arnis Jakobsons	282 Monterery	Elmhurst	IL	60126				ABCDE	EN61	
K9PW	Pete Walter	1931 Prairie Sq #211	Schaumburg	IL	60173-4130	847-576-3756	847-980-2540	k9pw@arrl.net	ABCD9EFGHIJ	EN52	X
KAØKCI	David Powers	7802 East Morris St	Wichita	KS	67207	316-652-1484	316-652-1484	ka0kci@arrl.net	ABCD9EFGHI	EM17	X
KAØY	Kenneth Kucera	2986 160th St	Riverside	IA	52327	319-648-5037	319-648-5037	ken@ka0y.com	ABCDEF	EN41fk	X
KAØYSQ	Bryan McCoy	10200 Hawks Haven Rd.	Cedar Rapids	IA	52411	319-295-5575	319-393-7505	bcmccoy2@juno.com	ABCD9EF	EN42	
KA2KQM	Kent O'Dell	2752 Monument Rd	Jasper	GA	30143	678-362-8667	706-692-8995	kotoka2kqm@windstream.net	ABDE	EM74tm	X
KA8JJN	Allan Koch	10667 Tallpine Ln	Allendale	MI	49401	616-895-2477	616-895-2477	ka8jjn@arrl.net	BCD	EN72	X
KA9CFD	Jay Hainline	4305 N. 1550th Rd.	Colchester	IL	62326	309-652-3698	309-652-3698	ka9cfd@yahoo.com	ABCD	EN40om	
KA9VPG	Georgette Serocki	35144 Sheridan Dr	Ingleside	IL	60041					EN52	
KBØG	Bdale Garbee	4390 Darr Cir.	Black Forest	CO	80908	719-494-1874	719-495-0091	bdale@gag.com	ABCD9EFGHI	DM79pa	X
KBØHH	Gary Gerber	511 S. Lincoln	Anthony	KS	67003	620-845-0599	620-845-0599	kb0hh@sbcglobal.net	ABCD9EF	EM06vu	X
KBØOLI	Pat Barott	5433 137th	Lino Lakes	MN	55014	651-491-5432	763-784-0698	kb0oli@msn.com		EN35	X
KBØPE	Dave S. Calvert								ABCD9EGHI	EM48ts	X
KBØYWM	Dexter Schnebly	137 N Chelmsford	Wichita	KS	67230	316-733-6340	316-733-6340	dxschnebly@hotmail.com		EM17	X
KB5MY	Dan Hammill	P.O. Box 2110	Ramona	CA	92065-0936	760-519-9553	760-789-3784	kb5my@yahoo.com	ABCD9E	DM13nc	X
KB9KCJ	Lesa Bergeron	35956 E CR 800 N	Mason City	IL	62664	217-691-7811		ko2r@speednet.com	ABCDE	EN50	X
KCØAKJ	Jay Nabholz	3186 Brandon Diagonal Blvd	Brandon	IA	52210			kc0akj@arrl.net	AB	EN42	
KCØZHF	Rodney Waln	402 Williams St	Cheyenne	WY	82007			kc0zhf@yahoo.com	BD	DN71oc	X
KC5DPT	Tad Beverage	PO Box 1756	Stillwater	OK	74076	405-612-0837	405-743-0702	kc5dpt@arrl.net	ABCDE		
KC9BQA	Todd Sprinkmann	N1347 Lynn Rd	Adell	WI	53001	262-305-0640	262-305-0640	sprinkies@excel.net	ABCD9EF	EN63ao	X
KC9SDO	Doug Abrahamson	16943 Comly Rd	Pecatonica	IL	61063		815-974-0329	kc9sdo@gmail.com	ABD	EN52	
KDØEAG	David Witten	3715 Wakefield Dr	Columbia	MO	65203-4465	573-492-2180	573-449-2180	wittend@wwrinc.com	BCD9F	EM38tv	X
KDØJHW	Bill Thomas	175 Sugar Creek Ln	North Liberty	IA	52317	319-594-5299		kd0jhw@gmail.com		EN41	
KDØL	Don Kirchner	1812 Timber Hills Dr	Coralville	IA	52241	319-335-1958	319-338-7300	donald-kirchner@uiowa.edu		EN41	

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KDØORB	Steven Arey	207 Norma St SW	Cedar Rapids	IA	52404	319-573-7733	319-396-3226	manilia_xpress@yahoo.com	BD	EN41dw	X
KD4WOV	Tom Tishken	36417 Bristol Circle	Grand Island	FL	32735-9630			kd4wov@earthlink.net			X
KD9SG	Harold Mathis	2701 Tower Ln	Troy	IL	62294	618-667-9727	618-667-9727	kd9sg@arrl.net	ABCD	EM58bs	
KFØQ	Matt Burt	292 Valley Oaks Drive	Winona	MN	55987-6008	507-474-5311	507-459-9444	kf0q@hbci.com	ABCD9EFGI	EN44ea	X
KF5IPC	Wanda Chennault	4745 Attala Rd 3231	West	MS	39192	318-387-2701	318-343-6005	ckc@iamerica.com	ABCDEI	EM42am	X
KGØVL	Jeffrey Leer	11801 East Bennington	Fairbank	IA	50629	319-822-3196	319-822-3196	kg0vl@aol.com	AB	EN32wo	
KG1X	Scot Gronewald	16412 CR E-45	Olin	IA	52320	319-480-1939	319484-2994	kg1x@netins.net		EN41	
KL7IZW	Steve Plock	3668 CR 770	Princeton	TX	75407	972-658-8077	972-736-1717	wohnfeld@aol.com		EM13sc	X
KMØT	Mike King	1176 5th Ave Circle NE	Sioux Center	IA	51250	712-722-0228	712-722-3787	scsueepe@mtcnet.net	ABCD9EFGHIJ	EN13vc	X
KM5PO	Jim McMasters	2805 Shady Lane S	Arlington	TX	76001	817-846-1395	817-563-2720	jim_mcmasters@tandybrands.com	ABCD9EFGHI	EM12ko	X
KOØZ	Ron Ochu	115 S. Sixth St	Girard	IL	62640	217-481-5821	217-481-5821	ronochu.sky@gmail.com	ABDE	EM59	
KZØQ	Stephen Moraco	310 Scrub Oak Way	Monument	CO	80132-8554	719-590-5714	719-488-0453	kz0q@amsat.org		DM79ob	X
NØAKC	Charles Betz	5305 Olson Dr.	Eau Claire	WI	54703	715-828-0361	715-834-7961	cmbetz@charter.net	ABCD9EFGI	EN44gu	
NØEIS	Charles Wehking	10451 Sappington Ln	Saint Louis	MO	63128-1656	314-843-8296		n0eis@juno.com	AB	EM48tm	X
NØGZ	Ken Kaplan	1965 S. 9th Ln	West Des Moines	IA	50265	515-287-2280	515-287-2280	kbkaplan@mchsi.com	ABCDE	EN31	X
NØHZ	S. Earl Jarosh	1432 Quebec Ave N.	Golden Valley	MN	55427	612-868-1313	612-868-1313	earl@jarosh.org	ABCDE	EN34	X
NØIS	Bob Sluder	7511 Local Hillsboro Rd	Cedar Hill	MO	63016	636-285-7605	636-285-7605	bcsluder@msn.com	ABCDE	EM48qi	
NØKM	David Newmyer	10482 N. Rd. 4 W.	Center	CO	81125		719-754-2400	n0km@arrl.net	ABD	DM67vr	X
NØKP	Dave Kleindl	P.O. Box 403	Shakopee	MN	55379	612-720-0009	612-720-0009	n0kp@arrl.net	ABCE9EFGHIJ	EN34	X
NØLD	Randy Wing	13038 SW 186th St	Rose Hill	KS	67133	316-371-2293	316-776-9292	n0ld@arrl.net	ABD	EM17kn	
NØLL	Larry Lambert	405 Shelton Drive	Smith Center	KS	66967	913-282-6147	913-282-3701	n0ll@ruraltel.net	ABCDE	EM09	X
NØLNO	Bill Caldwell	4505 Regal Ave NE	Cedar Rapids	IA	52402-2143	319-432-8007	319-378-8636	wcceec@imonmail.com	ABD	EN42	X
NØMMA	Guy West	272 40TH ST NE	Cedar Rapids	IA	52402			guyjwest@yahoo.com		EN41	
NØOBG	James Conley	33 Meadowbrook Country Club	Ballwin	MO	63011	636-230-3907	636-230-3907	jim@commo.com	BDE	EM48ro	X
NØPB	Phillip Baldwin	18297 Monroe Rd 174	Holliday	MO	65258			n0pb@windstream.net	ABCDE	EM39wo	X
NØRES	John Eberenz	70 Anchor Dr	Blue Springs	MO	64015					EM29	
NØTTW	Christopher Salinas	345 Purdy St	Jesup	IA	50648	319-610-2793	319-827-3313	n0ttw@yahoo.com	ABCDE	EN32xl	X
NØUK	Chris Cox	5620 36th Ave South	Minneapolis	MN	55417	612-619-4070	612-727-1971	chrisc@chris.org	ABCD9EI	EN34jv	X
NØXKS	Bob Oldham	P.O. Box 315	Liberty	MO	64069			ibebob@planetkc.com	ABD	EM29	X
NØXP	Alan Feldmeier	2835 Gainsboro Ct	Normandy	MO	63121-4717	314-427-2580	314-427-2580	ajfeldmeier@gmail.com	BD	EM48uq	X
N1LF	Les Rayburn	121 Mayfair Park	Maylene	AL	35114	205-255-4867		les@highnoonfilm.com	ABCD9EF	EM63nf	X
N1ND	Dan Henderson	9 Strawberry Rd Apt 14	Ellington	CT	06029			n1nd@arrl.org		FN31	
N2AM	Kevin Kramer	P.O. Box 893	Durant	IA	52747	563-260-2645	563-505-7783	n2am@arrl.net		EN41	
N2CEI	Steve Kostro	19519 78th Terr	Live Oak	FL	32060	386-364-5529	386-364-5529	n2cei@downeastmicrowave.com	ABCD9EFGHI	EM80kh	
N4HY	Robert Mcgwier	64 Brooktree Road	East Windsor	NJ	08520-2438	609-731-5289	609-731-5289	rwmcgwier@gmail.com	ABCD9EFGHIJ	FN20	X
N4PZ	Steve R. Gross	602 W First St.	Mt. Morris	IL	61054	815-734-4255	815-734-4255	n4pz@live.com	BDEI	EN52gb	
N4SC	Roman Downer	2110 Shawnee Dr SE	Grand Rapids	MI	49506	616-913-7889	616-452-3244	n4sc@arrl.net	ABCD	EN72	X
N5AC	Stephen Hicks	9001 Full Moon Cove	Round Rock	TX	78729	512-535-4713	469-576-4713	n5ac@n5ac.com	ABCD9EFGIJ	EM10dm	X
N5BA	Brian Derx	13618 W. Cypress Forest Dr.	Houston	TX	77070	713-402-5662	281-894-5942	n5ba@comcast.net	ABCD	EL29fx	X
N5GUI	James Whitfield	2432 Mayfield	Wichita	KS	67210			n5gui@cox.net		EM17	X
N5JM	John Meyer	112 Sherwood Forest Dr	New Orleans	LA	70119-3717	504-482-3493	504-482-3493	jmeyer112@sbcglobal.net	ABD	EL49wx	X
N6BXE	Chuck Scroggins	384 West K St.	Brawley	CA	92227	760-344-4137	760-344-0176	clscroggins@iid.com	BD	DM22	
N6CA	Chip Angle	25309 Andreo Ave	Lomita	CA	90717-1715	310-539-5395	310-539-5395	N6CA@ham-radio.com	ABCD9EFGHIJ	DM03ut	X
N6CL	Joseph L. Lynch	5851 E 21st Pl	Tulsa	OK	74115	918-835-9794	918-835-9794	n6cl@sbcglobal.net	ABDE	EM26	X

CALL	NAME	ADDRESS	CITY	STATE	ZIP	DAY PHONE	NIGHT PHONE	EMAIL	BANDS	GRID	Life Mem
N6HV	Denney Pistole	1052 Maplewood Way	Port Hueneme	CA	93041	805-312-4007	805-487-2142	trnet@adelphia.net	ABDI	DM04	X
N6PEQ	Dan Dankert	13672 Fairmont Way	Tustin	CA	92780-1811	714-544-9846	714-544-9846	n6peq@comcast.net	ABCDE	DM13cr	X
N6TQS	Doug Faunt	6405 Regent St	Oakland	CA	94618			n6tqs@arrl.net	ABD	CM87uu	X
N6TX	Dr. H. Paul Shuch	121 Florence Drive	Cogan Station	PA	17728	570-494-2299	570-494-2299	n6tx@arrl.net		FN11lh	X
N8KWX	Marc Holdwick	2607 N. Stuart	Arlington Hts	IL	60004	847-255-0422	847-255-0422	n8kwx@arrl.net	ABCD9I	EN62ac	X
N9CHA	Greg Braun	PO Box 345	Osceola	WI	54020	630-319-6374	630-319-6374	greg@n9cha.com	ABCD	EN35	X
N9DG	Duane Grotophorst	S 7333 Freedom Rd	North Freedom	WI	53951	608-288-5133	608-544-2041	n9dg@yahoo.com	ABCD	EN53bj	X
N9GH	Gary Hansen	183 N Canyon Dr	Bolingbrook	IL	60490	630-759-4955	630-759-4955	n9gh@sbcglobal.net	ABCD9EF	EN51wq	X
N9IFG	Joe Serocki	35144 Sheridan Dr	Ingleside	IL	60041					EN52	
N9LHD	Steven R. Sherman	2134 Sprucewood	Des Plaines	IL	60018-2640	847-827-4595	847-827-4595	n9lhd@yahoo.com	ABD	EN62ba	X
N9SV	Dave Moninger	3663 Hickory Ridge NE	Georgetown	IN	47122	812-366-3912	812-366-3912	davemoninger@gmail.com	ABDE	EM68	
N9WU	Richard Sell	N99 W15833 Bayberry Circle	Germantown	WI	53022	262-257-5778	262-250-0931	n9wu@att.net	ABCD9E	EN53we	X
NAØIA	Steven Sawyers	1822 Somerset Drive	Marion	IA	52302	319-295-5983	319-377-2877	steve@sawyers.org	ABCD9E	EN42fb	X
NBØM	Ed Marciniak	5608 6th St NE	Fridley	MN	55432	612-275-2168	612-246-4940	elmarciniak@mnits.net	BDEI	EN35	
ND2X	Paul S Goble	6116 Rue Des Amis	San Antonio	TX	78238	210-884-9105	210-884-9105	goblefam@swbell.net	ABCDE	EL09	X
NE8I	Lloyd J. Ellsworth	P.O. Box 675	Glen Arbor	MI	49636-0675	248-225-3874	248-225-3874	ne8i@arrl.net	ACD9EFGHIJK	EN82	X
NE8S	Dr GW Ko	550 N Fountain	Wichita	KS	67208-3852	316-573-8118		dr.ko@fcc.ms	ABCD9EFI	EM17iq	X
NG9K	Sheryl Benner	2300 79th Ave W. Lot #125	Rock Island	IL	61201	309-756-5565	443-474-4066	k9fyv@juno.com	BD	EN41	
NJØC	John Conner	1352 Lindenwood Grove	Colorado Springs	CO	80907	719-597-5407	719-597-5407	nj0c@amsat.org	ABCDE	DM78	X
NL7CO	Donald M. Ross	4523 NE Bell	Lawton	OK	73507-7357	580-595-2289	580-595-2289	n12614@aol.com	AB	EM04	X
NM5BB	Bill Boedeker	247 Manhattan Loop	Los Alamos	NM	87544	505-662-4220	505-662-4220	boedeker@cybermesa.com	ABCDIJ	DM65uv	X
NN5DX	Ron Marosko, Jr.	304 S. Mesquite	Ft. Stockton	TX	79735-4234	432-336-5600	432-336-5600	ron@rjr-services.com	ABCD9EF	DM80nv	X
nocall5	James Genz	4890 Woodhaven Dr	West Bend	WI	53095	262-305-1340	262-644-9569	jrgenz@frontier.com			
NT9E	David Whaley	1517 W Reiche Ln	McHenry	IL	60051			nt9e@arrl.net		EN52vi	
NY7C	David Palmrose	4125 SW 192nd Ave	Aloha	OR	97007			dcpalmrose@aol.com	A	CN85	X
VE2XX	Stu Truba	2217 Dynastie	St Lazare	QU	J7T 2C9	514-923-5078	450-424-8700	8877@videotron.ca	ABCD9EFG	FN25wk	
VE3ADQ	Peter Szilagyi	66 Palace Dr	Sault Ste Marie	ON	P6B 5H5	705-256-6667	705-256-6667	szcsaba@shaw.ca	ABD9E	EN76	
VE3AX/7	Peter Shilton	3360 Almond Gardens Rd. W.	Grand Forks	BC	V0H 1H4	250-443-4480	250-442-2663	ve3ax@telus.net	ABCDI		X
VE3WY	Bob Morton	Box 1471	Everett	ON	L0M 1J0	705-435-2819	705-435-0689	bobm@mapleleafcom.com	ABCD9	FN04ae	
VE4DDZ	Dan Zelich	173 Camirant Crescent	Winnipeg	MB	R3X 1T1	204-771-0583	204-257-2532	zelich@mymts.net		EN19lt	
VE4MA	Barry Malowanchuk	54 Boisselle Bay	Winnipeg	MB	R3X 1M4	204-254-4178	204-254-4178	ve4ma@shaw.ca	BCD9EFGHIJK	EN19lu	
VE5UF	Doug Freestone	Site 715 Box 32 RR7	Saskatoon	SK	S7K 1N2	306-227-9683	306-668-4935	dougf@sasktel.net	AB	DO61ov	
VE6AFO	Ken Oelke	729 Harvest Hills Dr. NE	Calgary	AB	T3K 4R3	403-226-5840	402-226-5840	ve6afo@rac.ca	ABD	DO21xb	X
WØBCG	David DeSpain	5113 Yampa Tr	Ft Worth	TX	76137-4706	214-991-7687	817-605-0761	ddespain@firstva.com	BD	EM12iu	
WØDJM	Dave Michalski	P.O. Box 172	Clear Lake	MN	55319	320-761-3676	320-743-4905	halski@peoplepc.com	ABCD	EN25xk	
WØDQY	Glenn Smith	2 Wood Eagles Ct	St. Charles	MO	63303-5063	636-947-4157	314-623-4157	w0dqy@att.net	ABCDE	EM48rs	
WØFIP	James Irvine	1460 25th St	Marion	IA	52302			w0fip@msn.com		EN42	
WØFMS	Fred M. Spinner	5672 Sutton Rd	Coggon	IA	52218-9716	319-295-0246	319-435-2120	fred@spinner.org	ABCD9EFI	EN42eg	
WØGHZ	Gary A Mohrlant	2303 E. Montana Ave.	Maplewood	MN	55119	651-777-1369	651-777-1369	w0ghz@arrl.net	ABCD9EFGHIJ	EN34lx	
WØGN	John Ely	Box 32	Anamosa	IA	52205-0032		319-462-2149	radio@mediacombb.net	AB	EN42	X
WØIM	David Huff	5320 Kacena Ave	Marion	IA	52302	319-832-1480				EN42	
WØIY	Barry J Buelow	4109 Cedar Heights Dr	Center Point	IA	52213		319-849-3849	w0iy@rf.org		EN42	
WØJT	John Toscano	5220 132nd. Street, West	Apple Valley	MN	55124-8714	952-484-8365	952-484-8365	tosca005@tc.umn.edu	ABCD9EFGI	EN34js	X
WØLCP	Floyd "Bud" Patten	4657 Echo Lane	Stacy	MN	55079-9293	651-462-4307	651-462-4307	bud.patten@frontier.net	ABDEI	EN35lj	

CALL	NAME	ADDRESS	CITY	STATE	ZIP	DAY PHONE	NIGHT PHONE	EMAIL	BANDS	GRID	Life Mem
WØLD	Lauren Libby	6166 Del Paz Dr	Colorado Springs	CO	80918	719-331-7051	719-331-7051	llibby@twr.org	ABD9E	DM78	X
WØPEC	Nels E Knutzen	2046 Highland Parkway	St Paul	MN	55116-1309	612-273-3921	651-699-1515	nknutze1@yahoo.com	AB	EN34	X
WØPHD	Wally Lamb	803 2nd St. N	Warren	MN	56762-1257	218-745-4626	218-745-4626	w0phd@wiktel.com	ABDEI	EN18oe	X
WØPPF	George Carsner	411 Terrace Rd.	Iowa City	IA	52245-5026	319-338-1601	319-338-1601	w0ppf@mchsi.com	BD	EN41	
WØRSJ	William T Murphy	338 Paxinosa Road West	Easton	PA	18040	610 659-5056	610-252-3956	wtmurphy@worldnet.att.net	ABCD9EFGH	FN20jq	X
WØTLE	Richard Philstrom	15449 220th Street N	Scandia	MN	55073	763-514-3915	651-433-5064	rphilstrom@frontiernet.net	ABCDE	EN35og	X
WØUC	Paul Husby	1700 S. Ridgewood Lane	Roseville	MN	55113-5624	651-747-6240	651-642-1559	husby@alum.mit.edu	ABCD9EFGHI	EN35	X
WØUHF	Dan Carlisle	326 S Logan St	Roland	IA	50236	515-294-4550	515-231-7701	carlisle@iastate.edu	ABCD9E	EN32	
WØZQ	Jon Platt	9512 Riverview Ave. S.	Bloomington	MN	55425	952-888-9531	952-888-9531	w0zq@aol.com	ABCD9EFGHI	EN34it	
W1BAH	Doug Bergeron	35956 E CR 800 N	Mason City	IL	62664	217-691-8711	217-691-8711	ko2r@speednet.com	ABCD9EF	EN50	X
W2GPS	Richard Hambly	363 Hawick Court	Severna Park	MD	21146-1409	410-987-7835	410-987-7835	w2gps@amsat.org			X
W2RS	Ray Soifer	190 W Continental Rd 220-186	Green Valley	AZ	85622	201-444-3111	201-444-3111	w2rs@arrl.net	BD	DM41lu	X
W3EP	Emil Pocock	625 Exeter Rd.	Lebanon	CT	06249	860-642-7271	860-642-7271	w3ep@arrl.net	ABDE	FN31vp	
W3OTC	Robert J Carpenter	415 Russell Ave #205	Gaithersburg	MD	20877	301-216-5670	301-216-5670	rcarpen@comcast.net	AB	FM19jd	X
W3XO	William "Bill" Tynan	1054 Indian Creek Loop	Kerrville	TX	78028	830-377-1054	830-896-0336	billandmattie@windstream.net	ABCD9EFG	EM00kd	X
W4MO	Stewart E Haag	113 La Palma Ct	Venice	FL	34292	502-266-5910	502-266-5910	w4mo@verizon.net	B	EL87tc	X
W4VHF	Ted Goldthorpe	2222-306 Selwyn Avenue	Charlotte	NC	28207	704-333-6872	704-333-6872	tgoldthorpe@bellsouth.net	ABD	EM95	X
W4WDH	John L. Kirkman	5570 Hillview Dr. SW	Oxford	GA	30054	770-757-1102	770-786-3188	w4wdh@bellsouth.net	ABCD	EM83	X
W4WUQ	J. Dalton McCrary	2111 Brookwood Lane	Murfreesboro	TN	37129	615-736-2865	615-890-5914	w4wuq@arrl.net		EM65su	X
W4ZRZ	Jimmy Long	8850 Pine Mtn Rd	Springville	AL	35146	205-937-0560	205-467-0295	w4zrz@aol.com	ABCD9EFGHIJ	EM63st	
W5AK	Dick Beerman	16122 Barklea Rd	Cypress	TX	77429	281-256-3486	713-478-2251	rbeersr@sbcglobal.net	AB	EL29dx	X
W5BL	Doug Loughmiller	PO Box 537	Clarksville	TX	75426	214-455-7071	214-455-7071	w5bl@sbcglobal.net	ABCD	EM23	X
W5DBY	Gerald Handley	6509 Forest Park Dr	Arlington	TX	76001	817-465-7927	817-465-7927	w5dby@att.net	ABCD9EFGHI	EM12	X
W5IU	Keith D Pugh	Box 121576	Fort Worth	TX	76121-1576	817-504-0399	817-292-5633	w5iu@swbell.net	ABDEF	EM12hp	X
W5LUA	Al Ward	2306 Forest Grove Estates Rd	Allen	TX	75002	972-542-3165	972-542-3165	w5lua@sbcglobal.net	ABCD9EFGHIJKL	EM13qc	X
W5NI	Bill Hulse	10904 NE Blackwell Rd	Lees Summit	MO	64086	816-246-7280		w5ni@arrl.net	ABD	EM28uw	
W5NZS	Larry C. Hazelwood	PO Box 54437	Oklahoma City	OK	73154	405-848-6400	405-850-3229	w5nzs@aol.com	ABCDEFI	EM15	X
W5SXD	Richard Allen	13523 Knottinghill	Sugarland	TX	77478	281-798-6521	281-798-6521	rca@rcallen.com	ABCD9E	EM02xs	X
W5VY	Howard "Pat" Patterson	110 Dooley Rd	North Little Rock	AR	72116-9208	501-570-2256	501-812-9090	ppattrsn@swbell.net		EM34us	
W5ZN	Joel M Harrison	528 Miller Rd	Judsonia	AR	72081	501-729-5227	501-729-5227	w5zn@arrl.org	ABCD9EFGHIJ	EM45dh	X
W6NTC	Mrs John T "Maureen" Cha	1752 Highland Park Dr	Paso Robles	CA	93446	805-238-4308					X
W7HR	Randy Stegemeyer	P.O. Box 1590	Port Orchard	WA	98366		360-871-1111	retired@easystreet.net		CN87rn	X
W7XU	Arliss Thompson	45720 268th. St	Parker	SD	57053	605-366-7791	605-297-5325	w7xu@iw.net	ABIJ	EN13lm	X
W8MM	Mike Valentine	1861 Dexter Ave	Cincinnati	OH	45206-1459	513-984-8900	513-751-7531	w8mm@arrl.net	ABD	EM79sd	X
W8PAT	John Fredenstine	47055 W Hamilton	Oberlin	OH	44074-9431			w8pat@eriewave.com			X
W9FF	Roger Schneider	3648 Bucher Rd	Astoria	IL	61501	309-329-9946	309-329-9946	w9ffradio@astoriail.net	ABD	EN40tf	
W9FZ	Bruce Richardson	7623 Teal Bay	Woodbury	MN	55125	651-491-1077	651-686-8017	w9fz@w9fz.com	ABCD9EFI	EN43	X
W9GA	Kenneth L Boston	W211 N10435 Parkland Circle	Colgate	WI	53017	262-352-0658	262-293-9428	kboston@lsr.com	ABCD9E	EN53we	X
W9IIX	Douglas Johnson	4421 W 87th St	Hometown	IL	60456	708-337-8172	708-337-8172	w9iix1@yahoo.com	ABCD9EF	EN61dr	X
W9JN	John E. Feltz	3378 Woods Rd	Junction City	WI	54443-9440	715-457-2506	715-457-2506	jfw9jn@tds.com	ABCD	EN54dn	X
W9NTP	Don C. Miller	8339 S. 850 W.	Waldron	IN	46182	317-512-9732	765-525-6452	wyman@tds.net	ABCD9EF	EM79	
W9RM	Keith Morehouse	14N082 French Rd	Hampshire	IL	60140	847-683-7373	847-683-7373	w9rm@calmesapartners.com	ABCD	EN52rb	
W9SNR	Jim Mitzlaff	1727 N. Chestnut Ave.	Arlington Heights	IL	60004	847-632-3138	847-506-0805	w9snr@arrl.net	ABCD9EFGHIJ	EN62ac	
W9SZ	Zack Widup	1003 E Washington St	Urbana	IL	61801-4415	217-384-2288	217-367-5750	w9sz.zack@gmail.com	ABCD9EFGHI	EN50	

CALL	NAME	ADDRESS	CITY	STATE	ZIP	DAY PHONE	NIGHT PHONE	EMAIL	BANDS	GRID	Life Mem
W9UD	Jim Roseman	2131 11th Street	Moline	IL	61265-4747	309-762-3234	309-762-3234	rs3bk@att.net	ABCD9E	EN41sl	
W9XA	Kermit Carlson	1150 McKee Road	Batavia	IL	60510	630-840-2252	630-879-0982	kermit@fnal.gov	ABCD9EFI	EN51uu	X
WAØARM	Bill Glynn	5144 SW Auburn Rd	Topeka	KS	66610	785-575-8370	785-478-4694	bill.glynn@westarenergy.com	ABD	EM28cx	
WAØD	Randy Berger	5541 Yellow Birch Dr	Ft Worth	TX	76244	817-421-2339	817-421-2339	rberger@rberger.com	ABCD9E	EM12	X
WAØVPJ	John Pope	18140 23rd Ave. N	Plymouth	MN	55447	763-505-6025	763-476-2813	wa0vpj@yahoo.com	ABCDE	EN35fa	
WAØVUS	Larry Kemper	2701 170th St	Muscatine	IA	52761	563-607-4131		wa0vus@hughes.net	AB	EN41	X
WAØZZG	Dave Maley	4495 Snow Goose Ct	Marion	IA	52302	319-310-5963	319-377-8488	wa0zzg@arrl.net	ABCD	EN42cb	
WA2VOI	Donn Burke Baker	3128 Silver Lake Rd. NE	Minneapolis	MN	55418-2426	612-781-1359	612-781-1359	wa2voi@arrl.net	ABCD9EFGHIJ	EN35ja	X
WA5JCI	Spencer Petri	710 ACR 335	Palestine	TX	75803	903-277-3128	903-277-3128	wa5jci@flash.net	ABD	EM21jv	X
WA5TKU	Wes Atchison	9618 Indian Trail Rd	Sanger	TX	76266	940-367-8845	940-482-3914	wa5tku@centurylink.net	ABCDEFGHI	EM13ii	
WA5VJB	Kent Britain	1626 Vineyard	Grand Prairie	TX	75052-1405	972-849-0235	972-660-2810	wa5vjb@flash.net	ABCD9EFHI	EM12lq	X
WA5YOU	Charles K. Chennault	4745 Attala Rd. 3231	West	MS	39090	662-290-8582	662-290-8582	wa5you@bellsouth.net	ABCDE	EM53ee	X
WA8RJF	Tony Emanuele	7156 Kory Ct	Concord	OH	44077-2221	440-354-4636	440-357-13564	wa8rjf@arrl.net	ABCD9EFGHI	EN91iq	X
WA9ENA	Dale G Svetanoff	14356 170th Ave.	Monticello	IA	52310-8012	319-480-1674	319-462-5984	svetanoff@earthlink.net	ABCD9	EN42	
WA9KRT	Don Smith	3157 S. Angela Dr.	N. Judson	IN	46366	524-772-3812	524-772-3812	wa9krt@hotmail.com	ABD	EN61pg	
WA9O	Jerry Seefeld	3811A S Kansas Ave	Milwaukee	WI	53207	262-224-4064	262-224-4064	jerryseefeld@sbcglobal.net	ABD9EFGHI	EN62bx	X
WBØJQQ	Randy Gibson	P.O. Box 462	Chillicothe	MO	64601	660-247-0982	660-772-3367	lgibson@greenhills.net	ABCD9EF	EM39cu	
WBØLJK	Dan Rhoades	3140 4th St	Marion	IA	52302	319-360-5632	219-377-1672	dan.rhoades@mchsi.com		EN42	
WBØTEM	Marc Thorson	331 Dakota Street	Akron	IA	51001	712-568-2901	712-568-2901	wb0tem@weaksignal.net	ABC9DEFGHI	EN12rt	X
WBØYFL	Joe Culwell	Box 82	Troy Mills	IA	52344	319-295-0510	319-350-8767	csvhf99@gmail.com	B	EN42	
WBØYRQ	Al Schemmer	1100 10th Street	Howarder	IA	51023			al@acsnet.com		EN12	X
WB2BYP	John Stevens	PO Box 832	Macedon	NY	14502		585-415-4973	wb2byp@arrl.net	ABCD9EFGHIJK	FN13ib	X
WB5AFY	Dan L Osborne	4611 Sand Road	Vernon	TX	76384		972-839-6992	wb5afy@wb5afy.net	ABCDEFG	EM04id	X
WB7DRU	David Donaldson	908 W Crystal Lake RD	Burnsville	MN	55306	612-618-2210	952-892-0534	wb7dru@usfamily.net	ABD	EN34ir	X
WB8BZK	Mike Metroka	730 Oakview Dr	Algonquin	IL	60102-2008	630-399-4192	847-658-7934	vhfrover@aol.com	ABCD9E	EN52ud	X
WB8ZBT	Robert Morrison	118 Carrington Ave	Brighton	TN	38011			robertnmorrison@hotmail.com		EM55dl	X
WB9PNU	John Germanos	11860 Denny Rd	Sunset Hills	MO	63126	314-843-3031	314-843-3031	wb9pnu@charter.net	ABDEI	EM48tn	X
WDØBWQ	David Brandon	301 S Hackett Rd	Waterloo	IA	50701-1661	319-234-4849	319-234-4849	brandondavide@mchsi.com		EN32	
WDØFCH	Earle Young	2210 Rule Ave	Maryland Hts	MO	63043	314-434-7105	314-434-7105	eryoung0@swbell.net	ABD	EM48sp	
WD9IVD	Dallas Dalton	8001 Donna Ln	Edwardsville	IL	62025-6238	618-692-6860	618-692-6860	wd9ivd@arrl.net	ABCD	EM58bv	
WNØDRC	Tom Zuber	4201 Dalewood Ave SE	Cedar Rapids	IA	52403	319-398-5700	319-362-3602	tom@zuberssound.com		EN41	
WQØP	Greg Cerny	209 Broadway	Belvue	KS	66407-9325	785-213-7072	785-456-9679	lykethat@gmail.com	ABCD9EF	EM19vf	
WRØI	Melvin B. Graves	705 E. 117th N.	Sedgwick	KS	67135	316-945-5535	316-772-0293	wr0i@sgdrugfree.com	ABCD9EFGHI	EM17	X