A Common Design for 6M Through 33CM Beacons

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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.

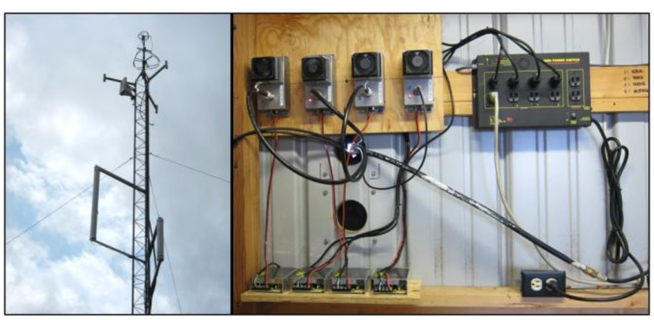


Figure 2 RMG beacon site

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.

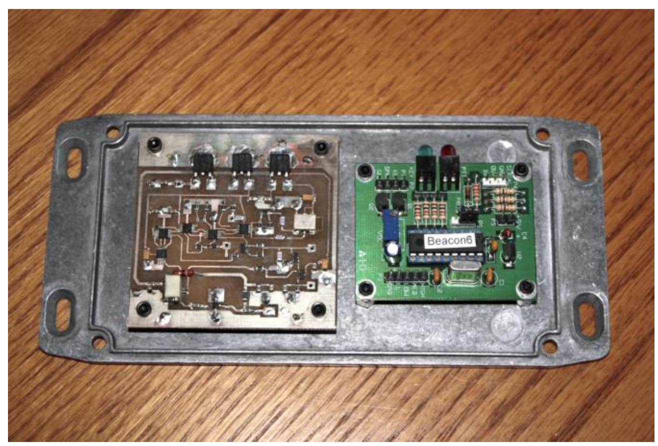


Figure 3 Original 222 MHz Prototype

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.

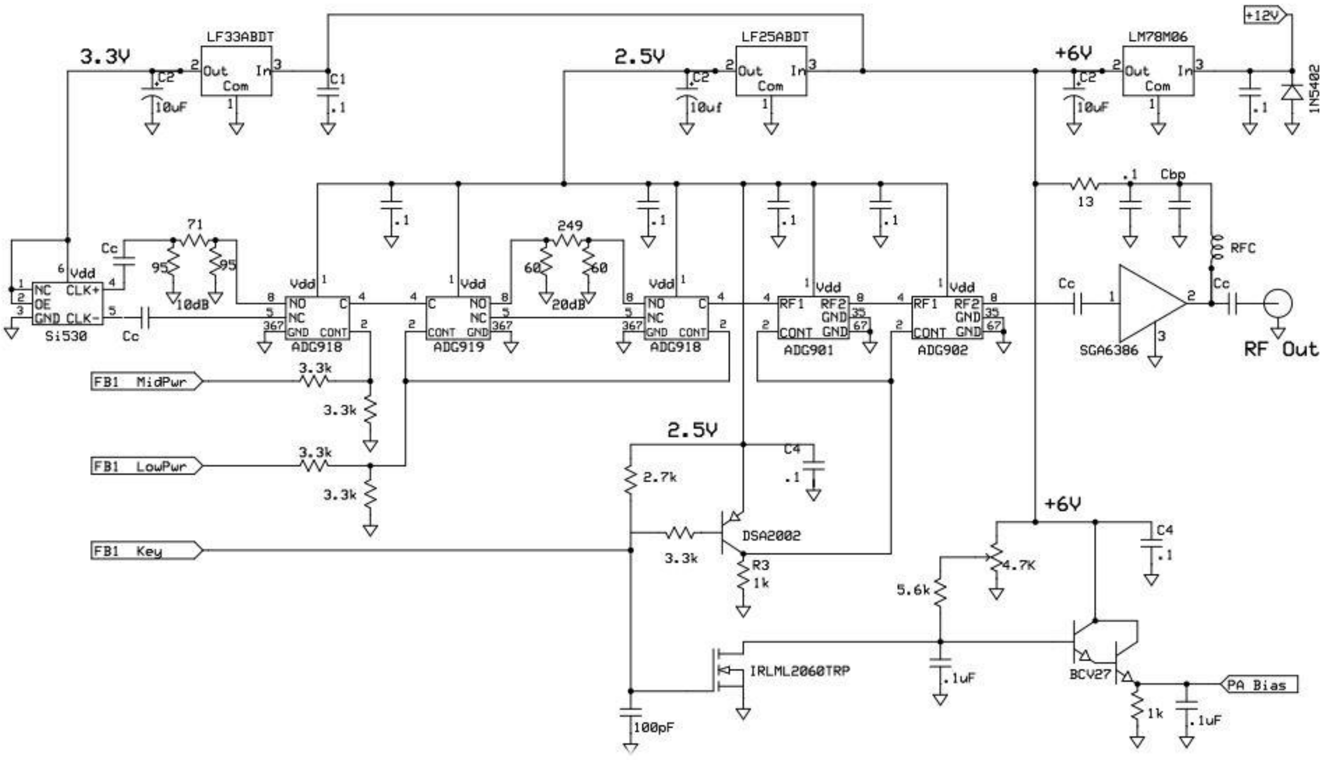


Figure 4 RF board schematic

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.

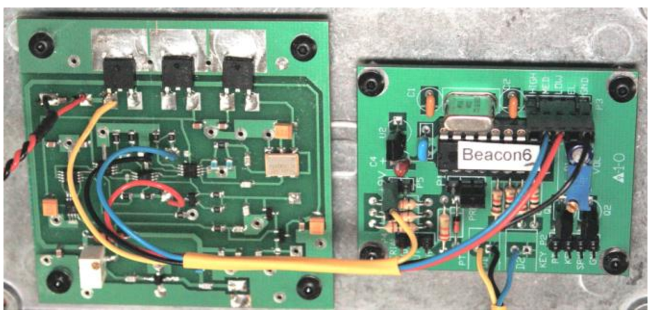


Figure 5 RF and FB-1 board assembly

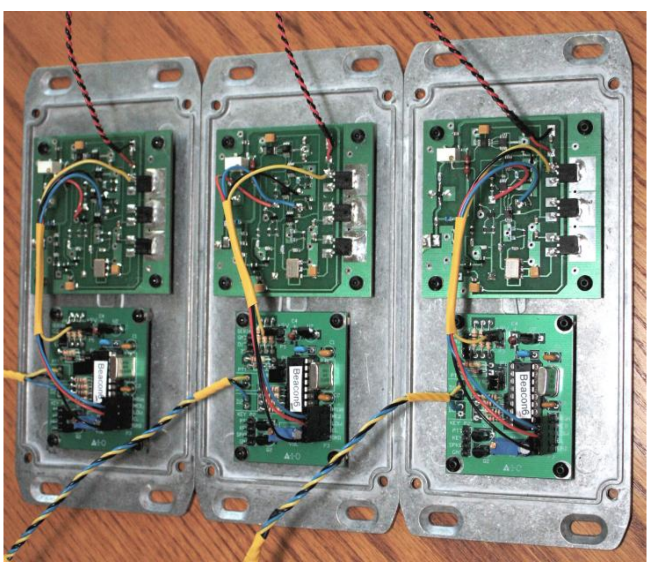


Figure 6 RMG beacons: RF and FB-1 boards

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 5th order LPF with a shunt trap tuned for enhanced 2nd harmonic rejection.

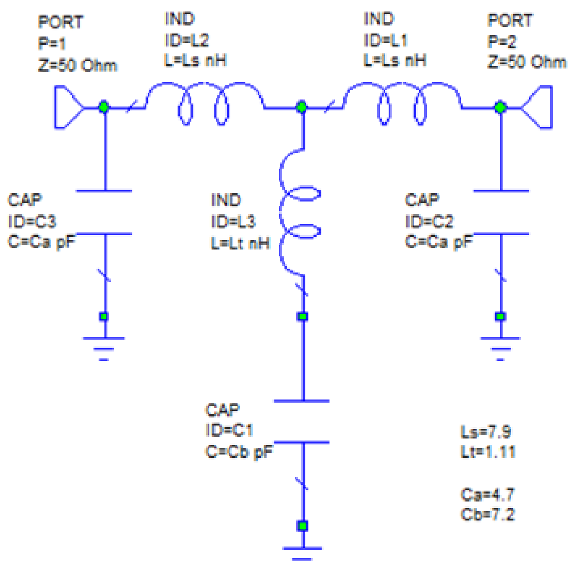
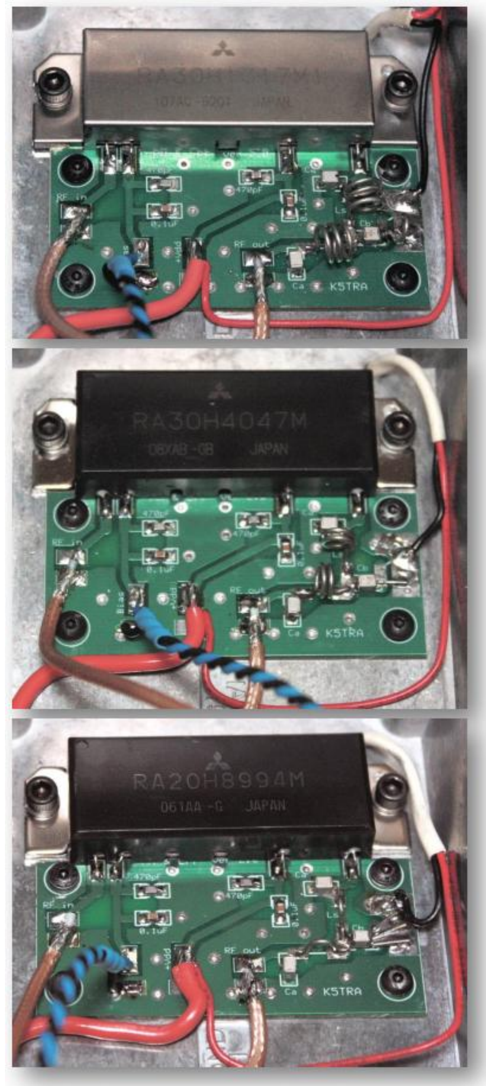


Figure 7 LPF schematic

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.



144 MHz PA and LPF

432 MHz PA and LPF

902 MHz PA and LPF

Figure 8 RMG beacons: PA board and LPF

References

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

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

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

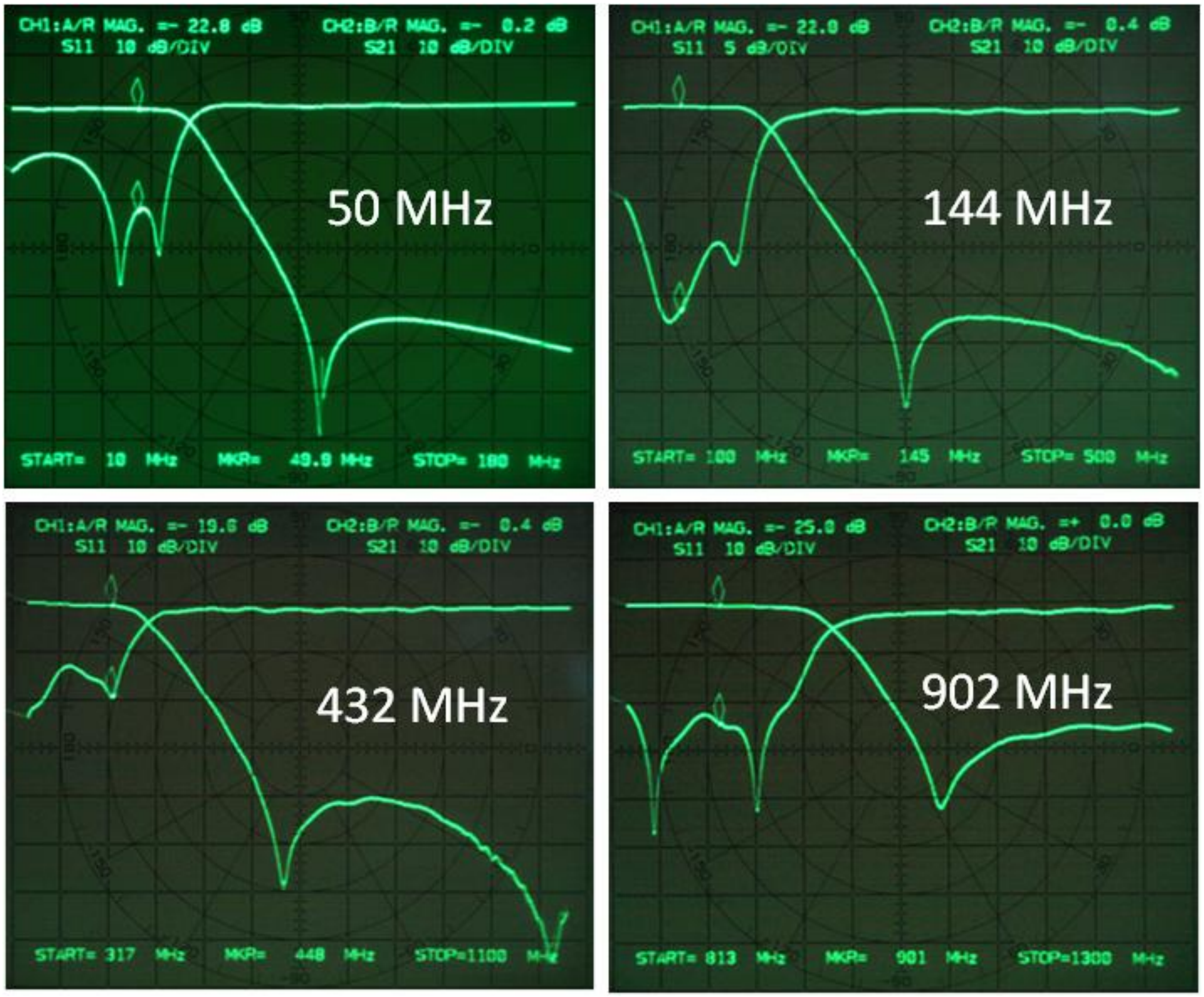


Figure 9 Measured LPF performance from four bands