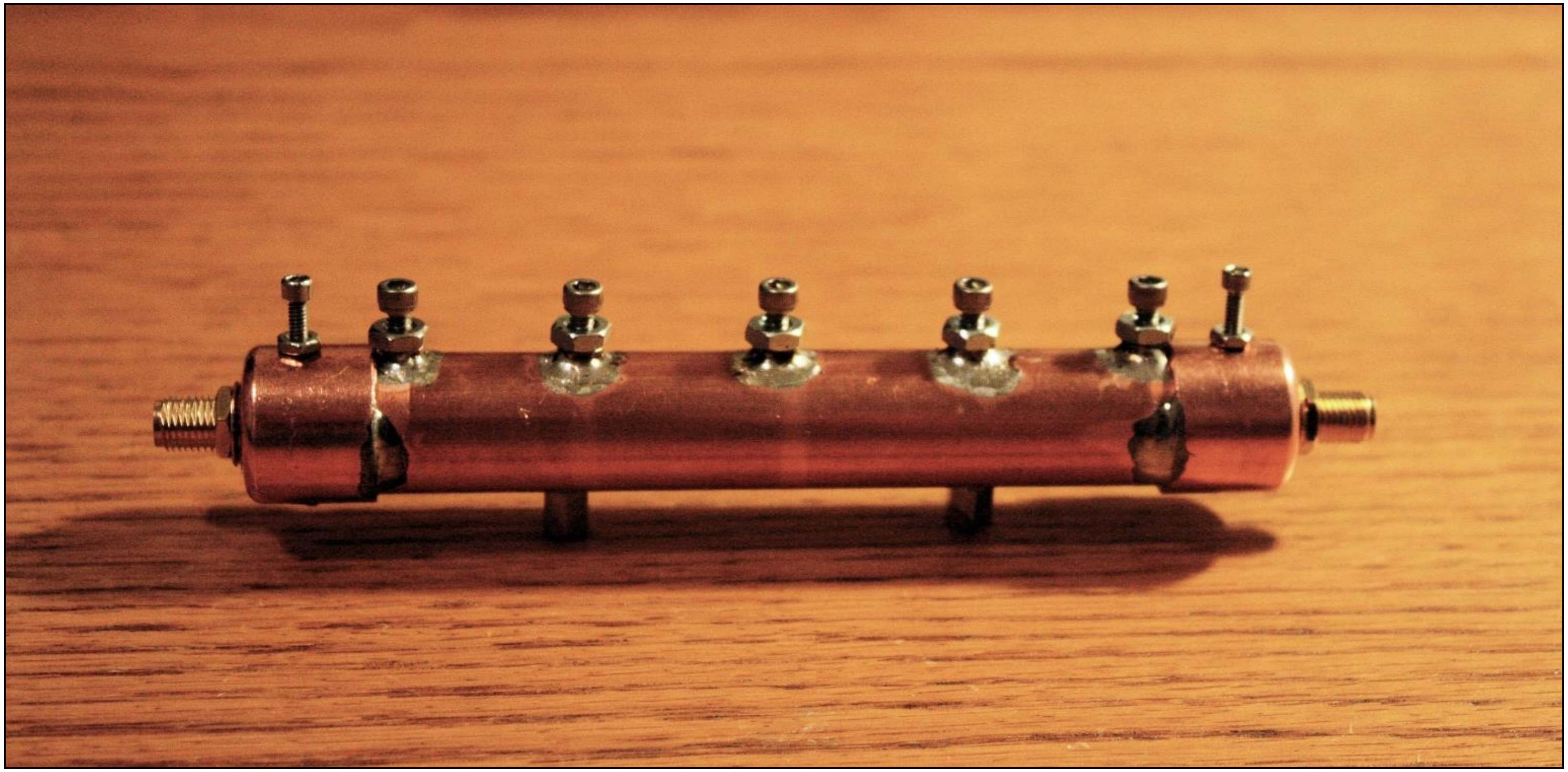
EVANESCENT MODE CIRCULAR WG FILTERS



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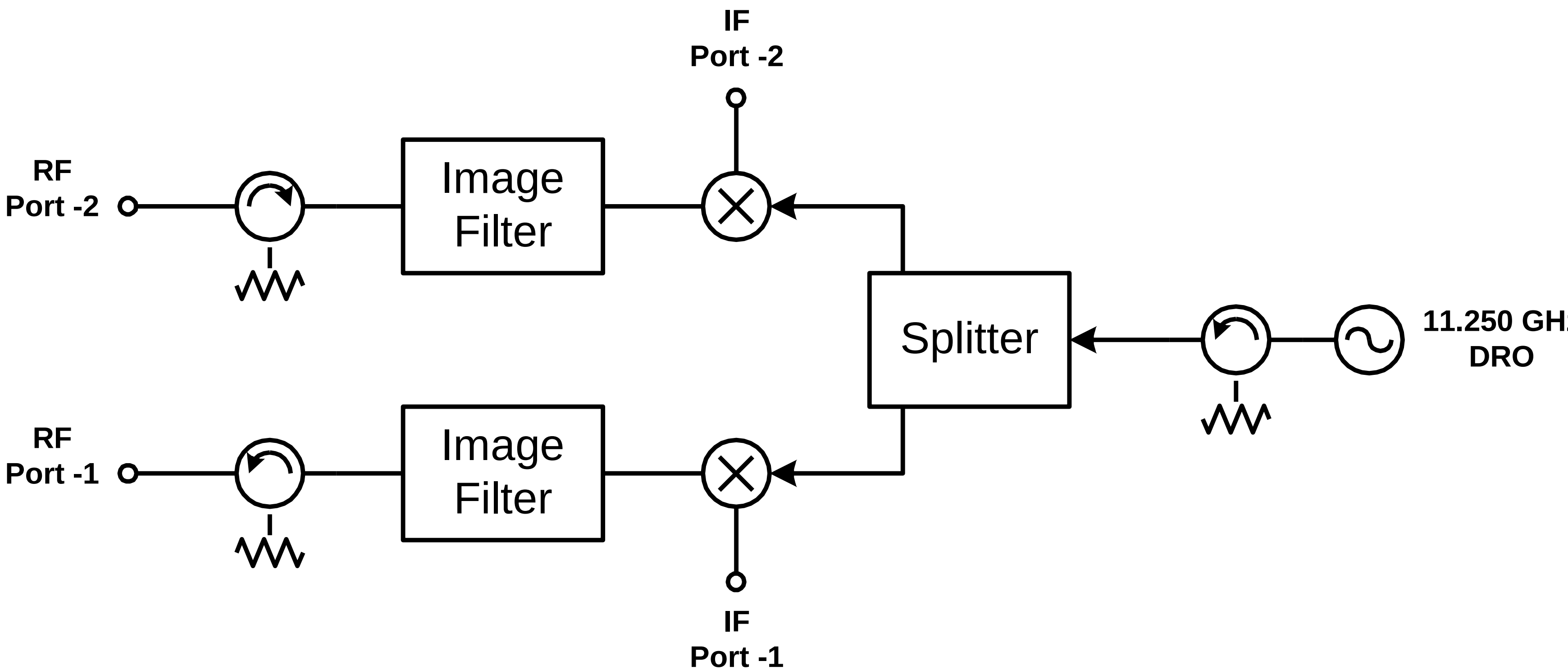
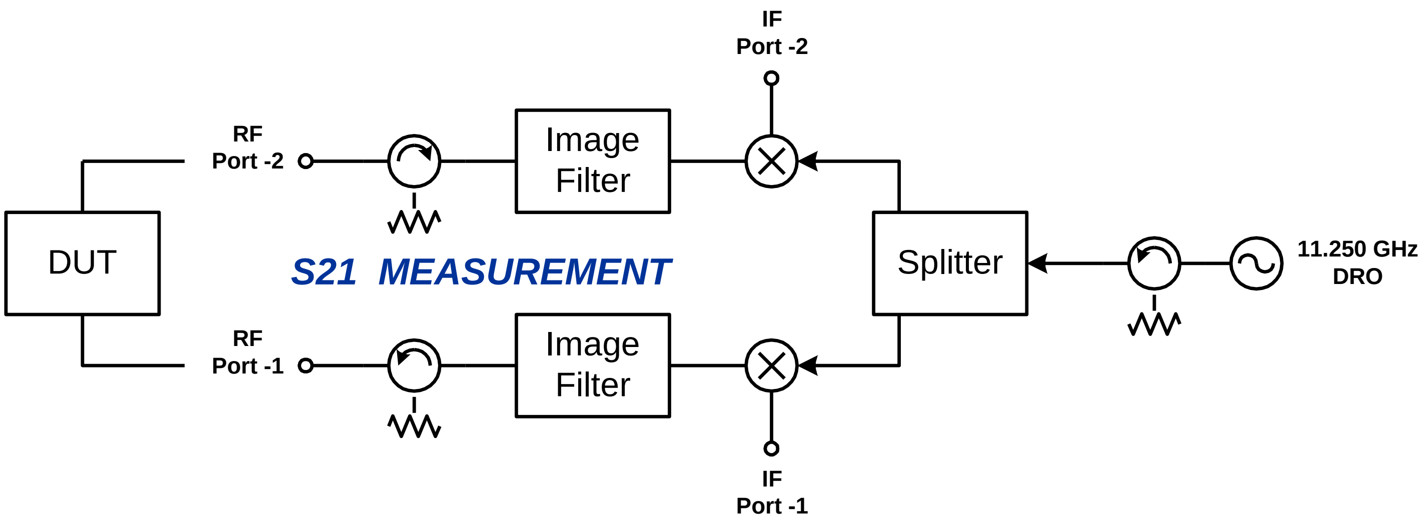
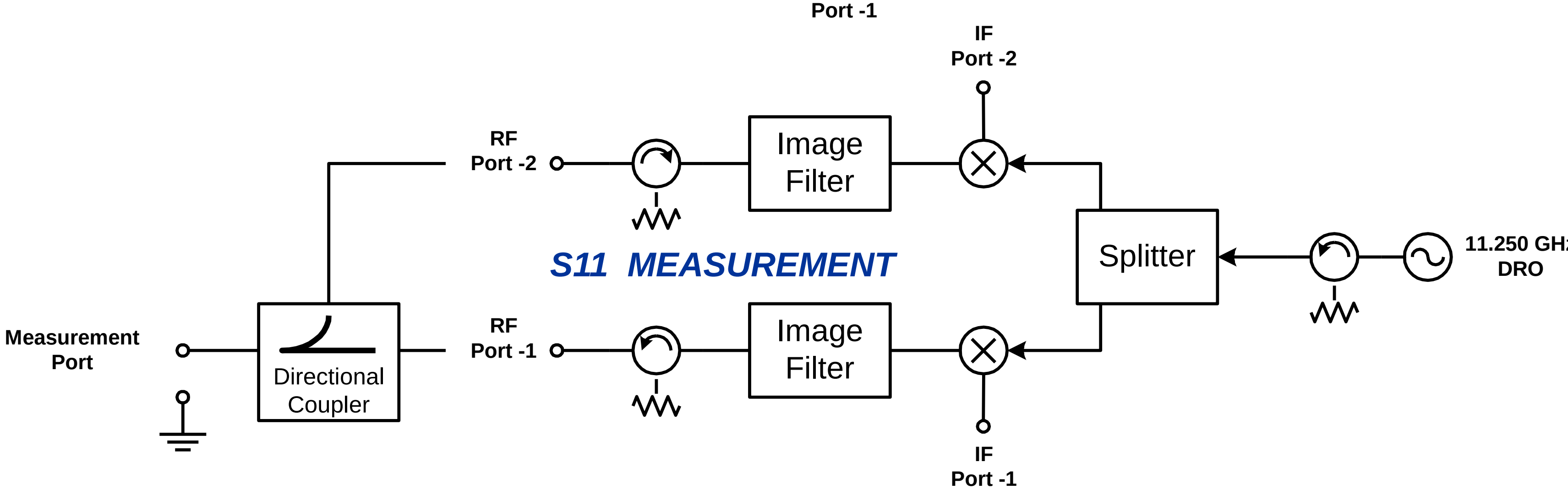
MOTIVATION: NEED IMAGE FILTERS for X-BAND TEST-SET

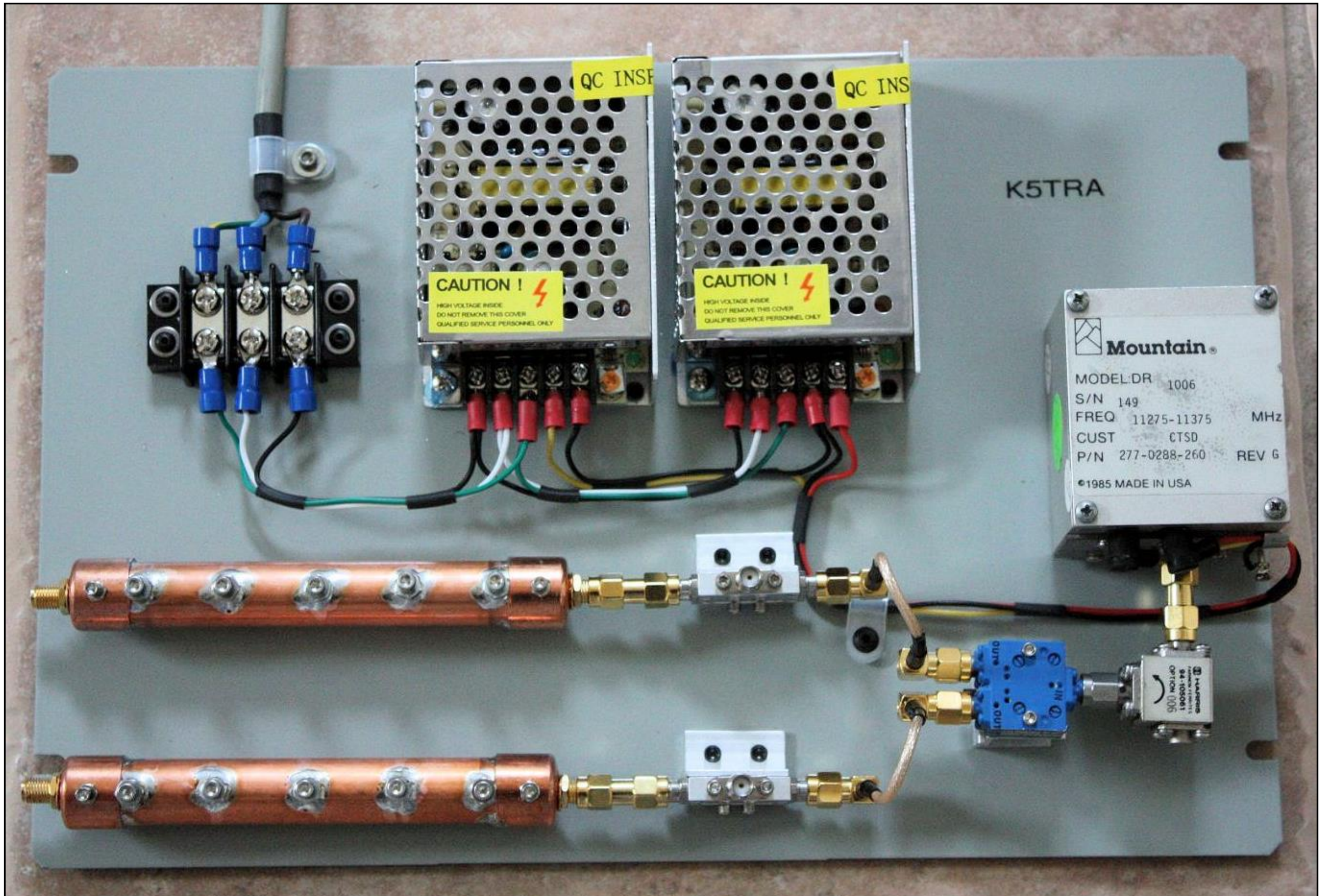


X-BAND TEST-SET CONFIGURATIONS

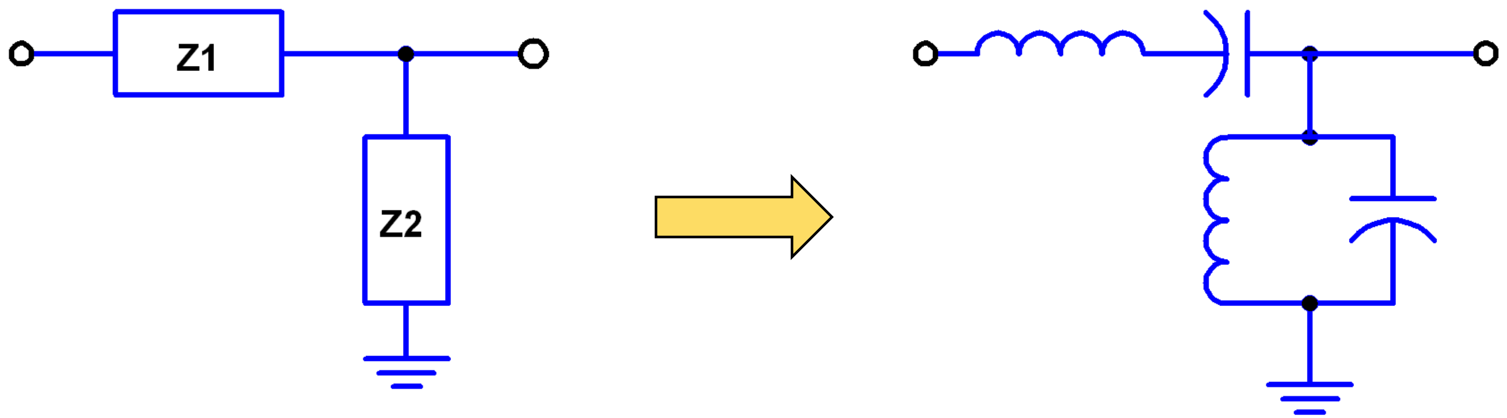




X-BAND TEST-SET

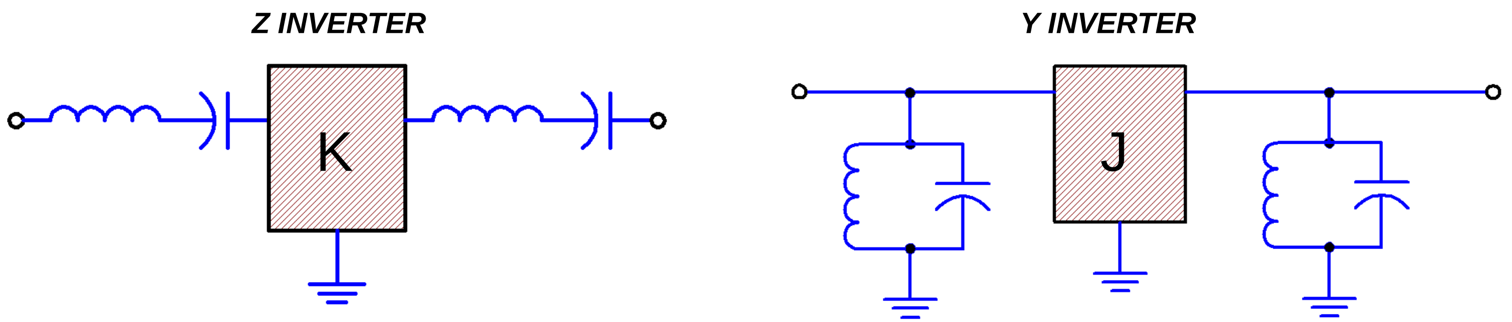


LADDER FILTER BASIC BUILDING BLOCK



- Passband: Z1 ⇨ *short* and Z2 ⇨ *open*
- Stopband: Z1 ⇨ *open* and Z2 ⇨ *short*

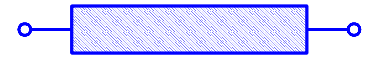
J and K INVERTERS PROVIDE REUSE OF RESONATOR TYPE



- Impedance inverter (K) with a series resonator behaves like a parallel resonator
- Admittance inverter (J) with a parallel resonator behaves like a series resonator
- Impedance/admittance inverter interface between similar resonators provides maximum stopband attenuation
- Most common impedance inverter is transmission line that is an odd multiples of $\lambda/4$

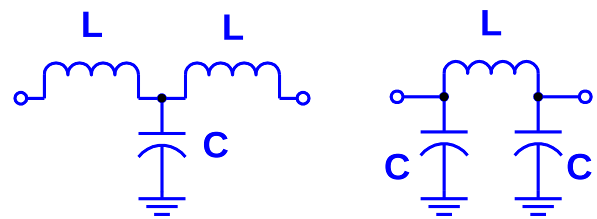
IMPEDANCE/ADMITTANCE INVERTERS

- Impedance (or admitance) inverters can be used to convert parallel resonance to a series resonance characteristic.
- The canonic impedance inverter is the λ/4 line.
- LC forms provide moderate bandwidth Z inversion.
- Capacitive T and π sections are for narrow band applications. Negative C or L is absorbed into resonator (cancels some positive C or L).

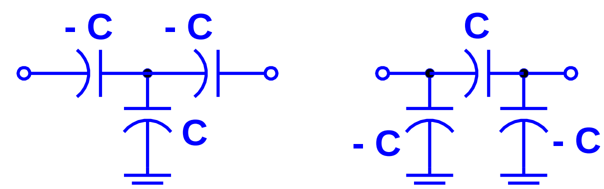


Transmission Line
J (or K) Inverter

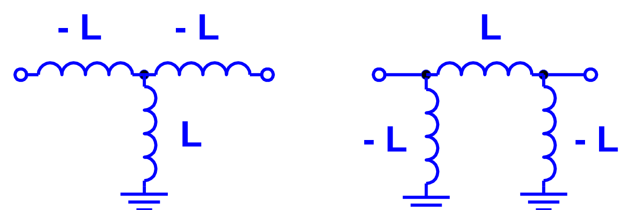
$$Z_0, \quad \theta = \frac{\lambda}{4}$$



$$Z_0 = \sqrt{\frac{L}{C}}, \quad \omega_0 = \frac{1}{\sqrt{LC}}$$



$$Z_0 = \frac{1}{\omega_0 C}$$



$$Z_0 = \omega_0 L$$

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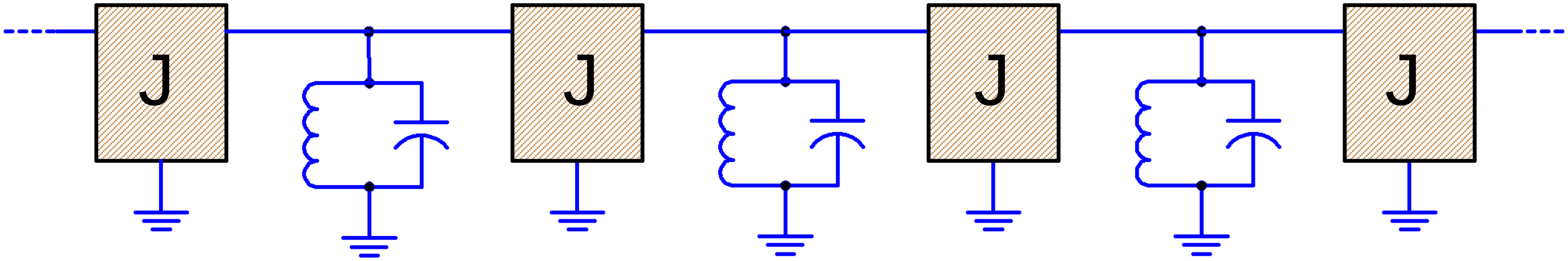
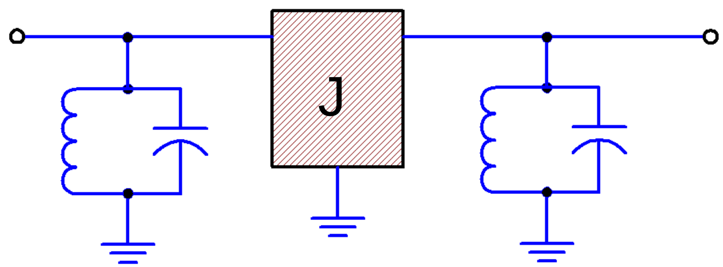
BANDPASS FILTER STRUCTURE WITH J INVERTERS

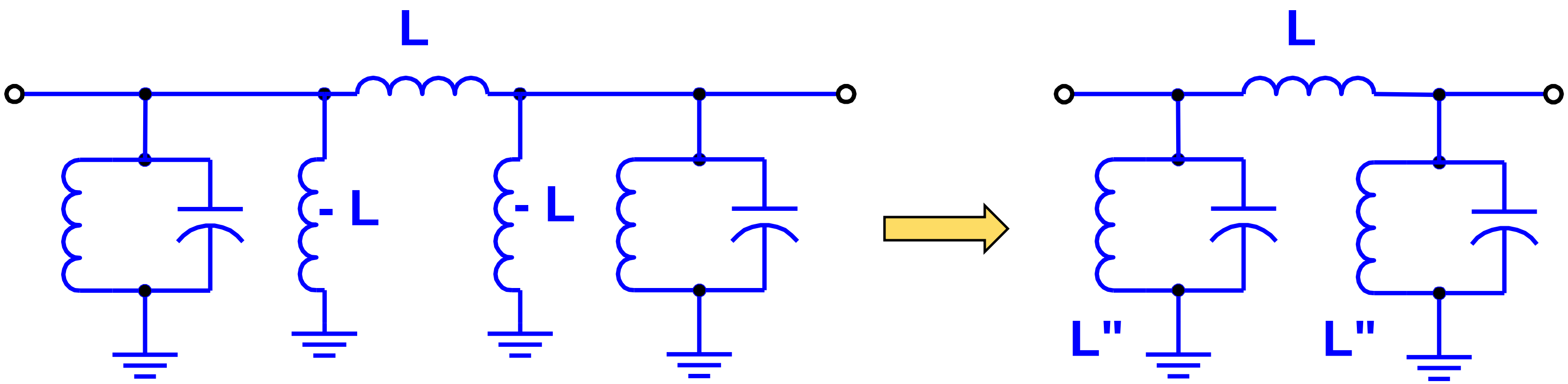


- Filters are formed as cascade of parallel resonators and inverters
- How do we realize a structure like this in WG?

BANDPASS FILTER WITH INDUCTIVE J INVERTERS

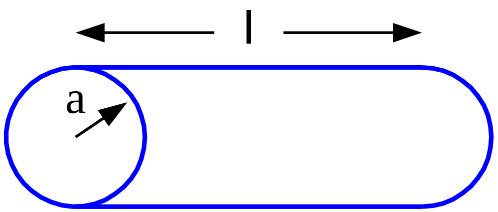
Y INVERTER



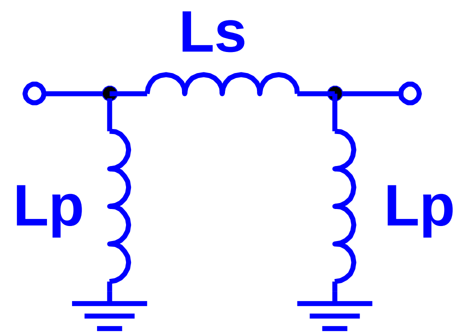


- Negative inductors of inverter cancel some of the resonator inductance
- Inverter admittance/impedance sets coupling between resonators. In this case, coupling is set by $(\omega L)^{-1}$

EVANESCENT WG MODEL



COPPER PIPE
CIRCULAR WG



$$a = inside\ radius\ in\ mm$$

$$l = length\ of\ WG\ section$$

$$F_c = 1.8412 \times \frac{300}{2\pi\, a}$$

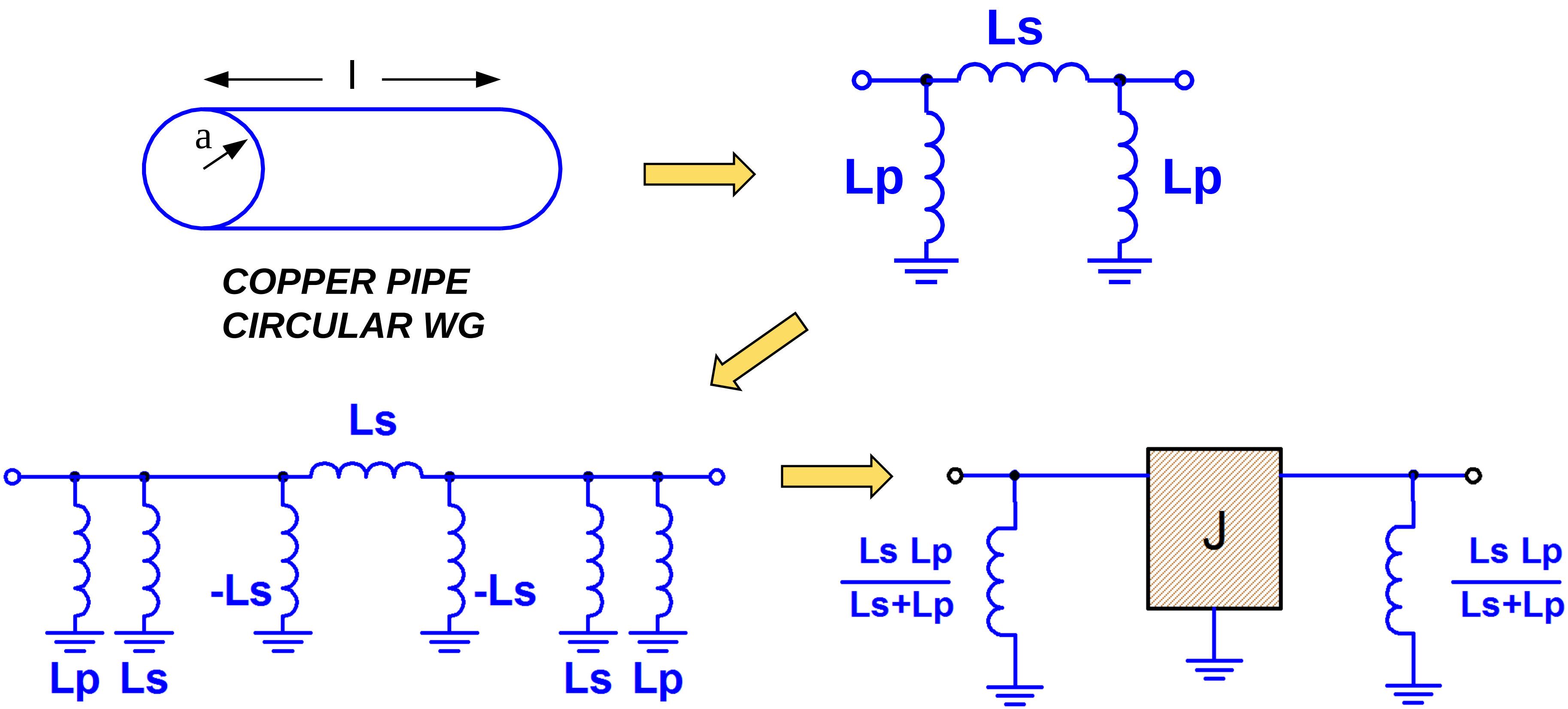
$$Ls = \frac{X_0 \sinh(\gamma l)}{2\pi\ freq} \qquad Lp = \frac{X_0 \coth\left(\frac{\gamma l}{2}\right)}{2\pi\ freq}$$

$$\gamma = \frac{2\pi}{\lambda_0}\sqrt{\left[\left(\frac{F_c}{F_0}\right)^2 - 1\right]} \qquad X_0 = \frac{377}{\sqrt{\left[\left(\frac{F_c}{F_0}\right)^2 - 1\right]}}$$

$$X_0 \sim 599\ \Omega$$

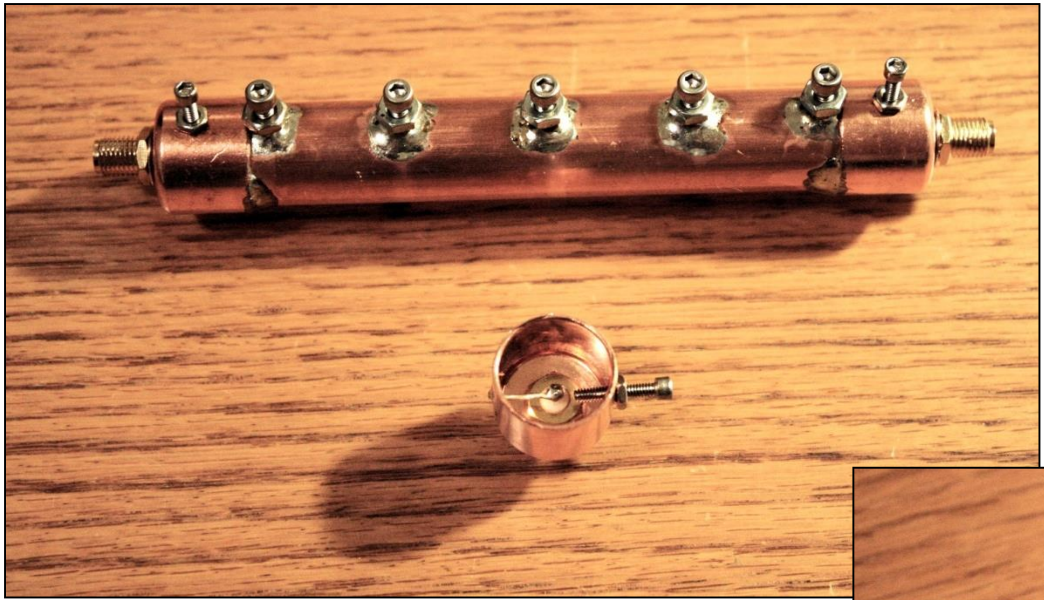
- Operation *BELOW* TE_{11} cutoff frequency
- Propagation falls off quickly
- Behavior is reactive (inductive)

EVANESCENT WG SECTIONS PROVIDE J INVERTER and RESONATOR L

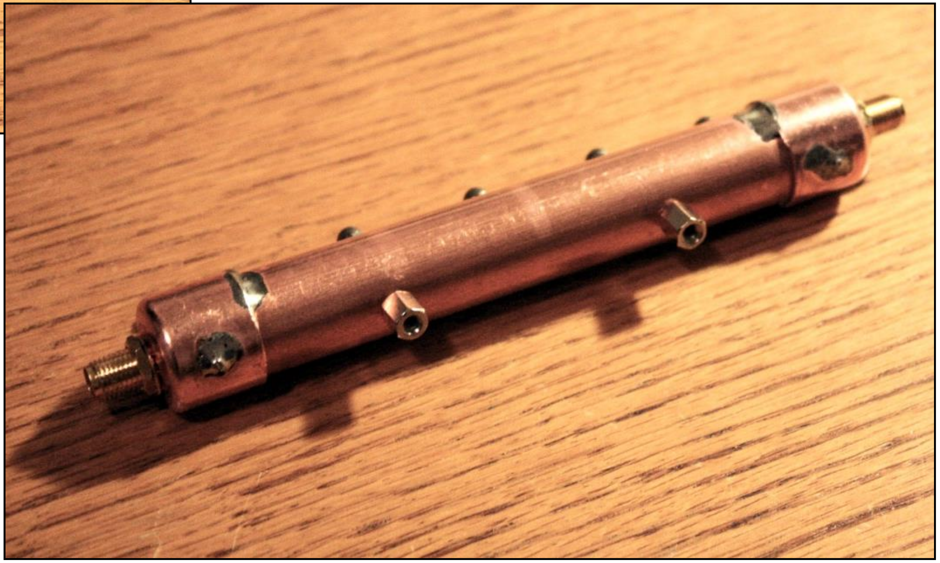


- *RESONATOR C CAN BE ADDED WITH TUNING SCREWS*
- *SCREW SPACING SETS Ls (SETS COUPLING)*

EVANESCENT WG FILTER CONSTRUCTION

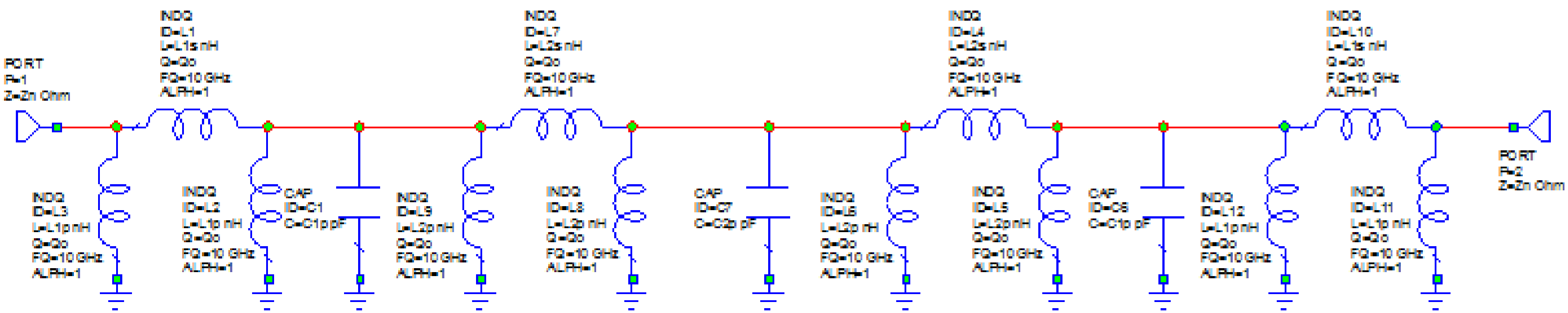


- Operation *BELOW* cutoff frequency
- 0.5” Cu pipe for X-band (actual ID = 0.565”)



- 4-40 tuning screws
- Tapped holes and soldered brass nuts
- Stainless locking nuts
- Coupling loop with 2-56 tuning
- 0.25” 4-40 stand-off mounting

EVANESCENT WG FILTER ANALYSIS 6th ORDER EXAMPLE



l1=6.899
b: 0.1367
XLs1=X0*sinh(b*l1)
XLs1: 410.7
Ls1=XLs1/6.28/Fo
Ls1: 6.307

XLp1=X0*cosh(b*l1*0.50)/sinh(b*l1*0.50)
XLp1: 857.9
Lp1=XLp1/6.28/Fo
Lp1: 13.18

L1s=Ls1
L1p=Lp1
C1p=0.09485

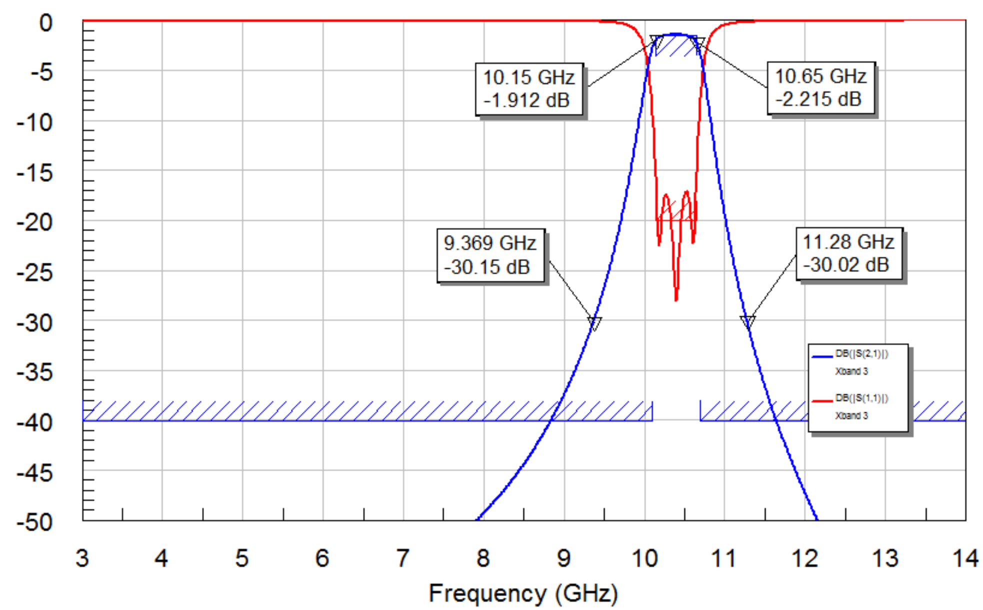
x1=l1/25.4
x1: 0.2716

l2=22.27
b: 0.1367
XLs2=X0*sinh(b*l2)
XLs2: 3951
Ls2=XLs2/6.28/Fo
Ls2: 60.67

XLp2=X0*cosh(b*l2*0.50)/sinh(b*l2*0.50)
XLp2: 414.7
Lp2=XLp2/6.28/Fo
Lp2: 6.369

L2s=Ls2
L2p=Lp2
C2p=0.08137

x2=l2/25.4
x2: 0.8769



INDUCTOR Qo FOUND EMPERICALLY TO BE APPROXIMATELY 200

K5TRA

DESIGN TABLES N= 2, 3, & 4

N=4

%BW	BW(MHz)	l1(mil)	l2(mil)	l3(mil)	C1(pF)	C2(pF)	Loss(dB)	RetLoss(dB)	F30L(GHz)	F30H(GHz)
5	500	194	841	966	0.06865	0.05075	2.66	21.25	9.66	11.07
3	300	219	938	1070	0.06491	0.05064	3.17	25.46	9.87	10.90
2	200	259	1051	1180	0.06077	0.05058	4.41	25.12	10.04	10.75
1	100	298	1173	1314	0.05797	0.05055	6.08	30.26	10.17	10.63
0.5	50	308	1215	1369	0.05743	0.05054	6.64	40.98	10.20	10.60

N=3

%BW	BW(MHz)	l1(mil)	l2(mil)	C1(pF)	C2(pF)	Loss(dB)	RetLoss(dB)	F30L(GHz)	F30H(GHz)
5	500	216	866	0.06500	0.05079	2.10	15.69	9.36	11.30
3	300	240	961	0.06259	0.05066	2.31	20.38	9.63	11.09
2	200	280	1072	0.05913	0.05059	3.13	20.51	9.87	10.89
1	100	320	1196	0.05680	0.05055	4.22	23.45	10.05	10.74
0.5	50	361	1310	0.05513	0.05054	5.80	25.83	10.16	10.63

N=2

%BW	BW(MHz)	l1(mil)	l2(mil)	C1(pF)	Loss(dB)	RetLoss(dB)	F30L(GHz)	F30H(GHz)
5	500	214	753	0.06576	1.22	13.26	7.33	12.26
3	300	253	880	0.06136	1.43	15.70	8.53	11.77
2	200	272	947	0.05974	1.54	18.72	8.90	11.56
1	100	319	1079	0.05686	2.10	21.34	9.44	11.21
0.5	50	352	1176	0.05545	2.69	23.01	9.69	11.02

DESIGN TABLES N= 5, & 6

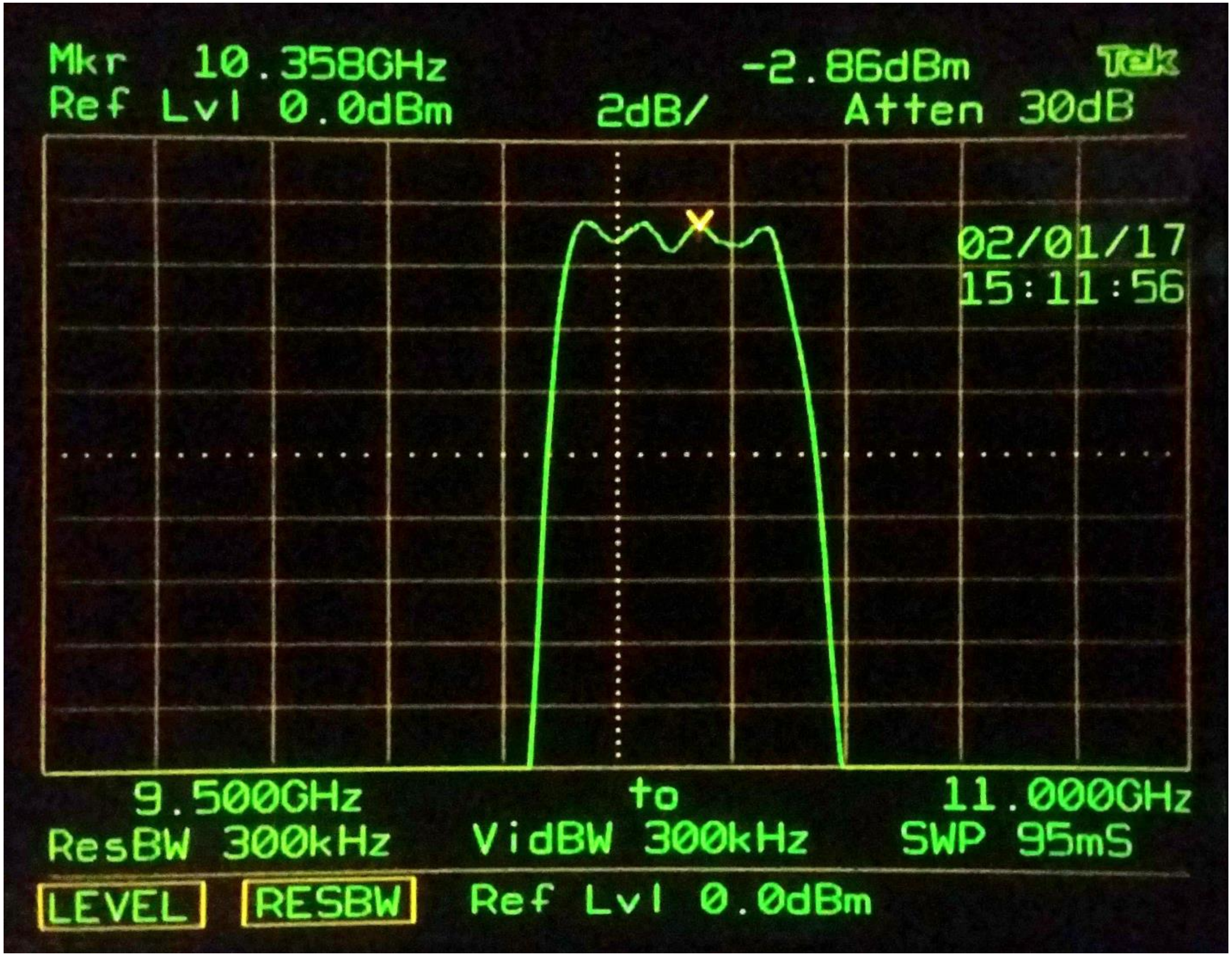
N=6

%BW	BW(MHz)	l1(mil)	l2(mil)	l3(mil)	l4(mil)	C1(pF)	C2(pF)	C3(pF)	Loss(dB)	RetLoss(dB)	F30L(GHz)	F30H(GHz)
5	500	218	887	1020	1038	0.06517	0.05069	0.05062	6.32	20.21	9.98	10.81
3	300	221	950	1116	1142	0.06470	0.05062	0.05057	6.72	29.45	10.10	10.70
2	200	223	983	1172	1204	0.06441	0.05060	0.05060	6.89	39.20	10.15	10.65
1	100	235	1035	1245	1285	0.06302	0.05058	0.05054	7.68	48.89	10.20	10.59
0.5	50	279	1162	1385	1436	0.05919	0.05055	0.05053	11.83	48.44	10.28	10.51

N=5

%BW	BW(MHz)	l1(mil)	l2(mil)	l3(mil)	C1(pF)	C2(pF)	C3(pF)	Loss(dB)	RetLoss(dB)	F30L(GHz)	F30H(GHz)
5	500	171	793	961	0.07322	,05081	0.05088	3.10	27.41	9.77	10.99
3	300	218	940	1098	0.06514	0.05063	0.05058	4.63	28.00	10.10	10.77
2	200	256	1050	1209	0.06103	0.05058	0.05055	6.43	29.20	10.14	10.66
1	100	279	1151	1344	0.05922	0.05055	0.05054	8.64	30.03	10.23	10.57
0.5	50	300	1225	1452	0.05788	0.05054	0.05053	11.13	31.48	10.28	10.52

EVANESCENT WG FILTER INSERTION LOSS, 2 dB/DIV



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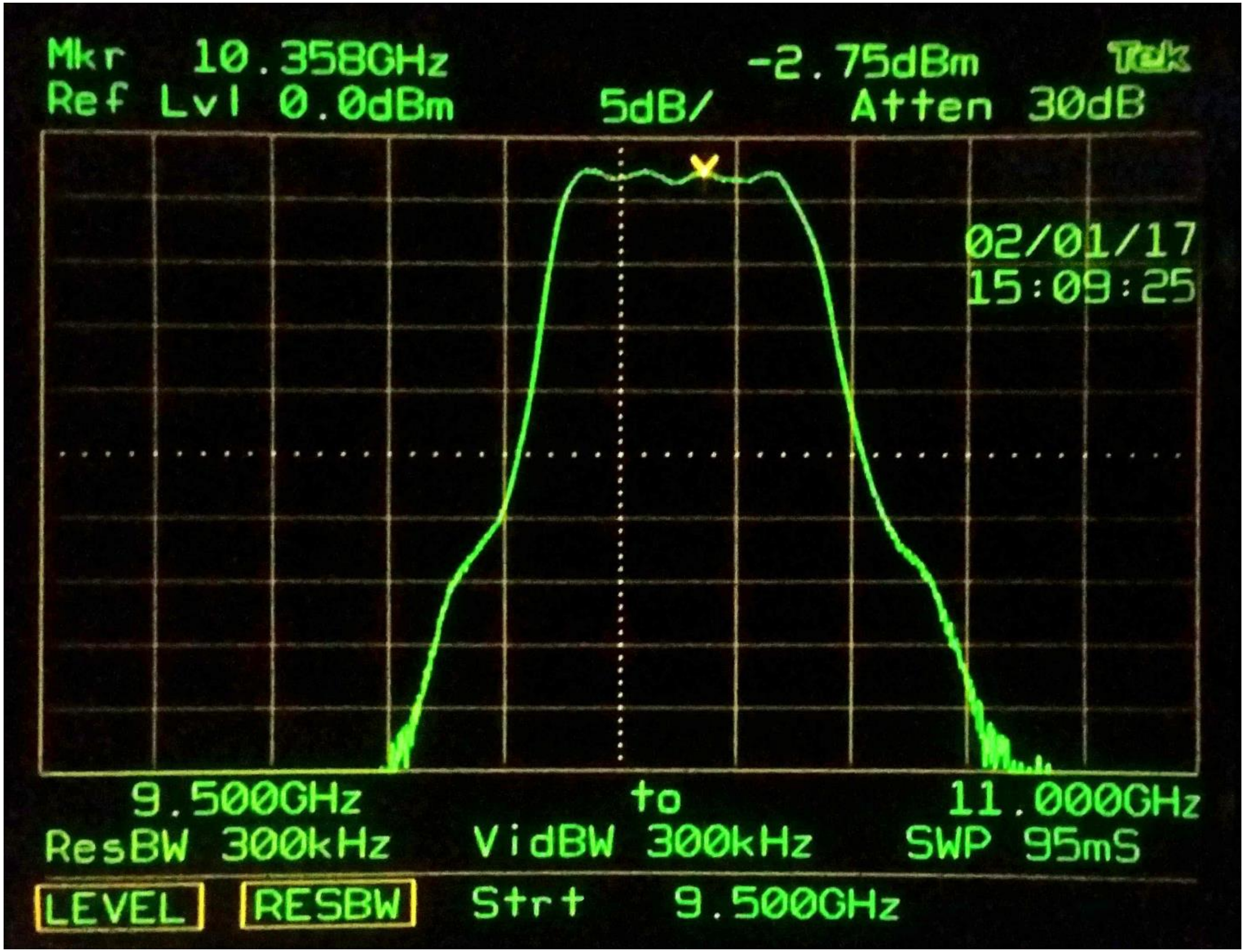
EVANESCENT WG FILTER INSERTION LOSS, 5 dB/DIV



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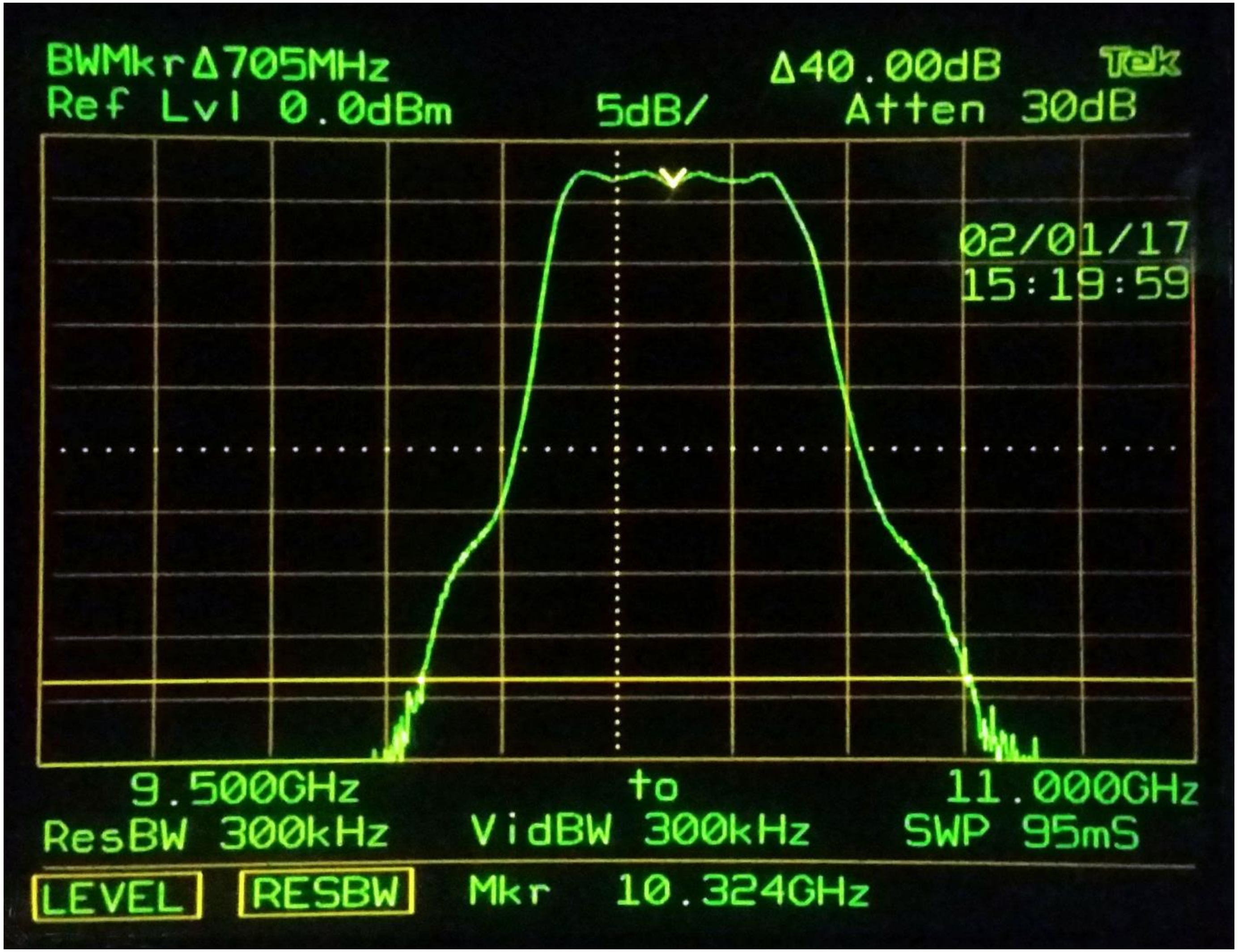
EVANESCENT WG FILTER -40 dB BW = 705 MHz



EVANESCENT WG FILTER USED IN K5TRA X_BAND TEST SET