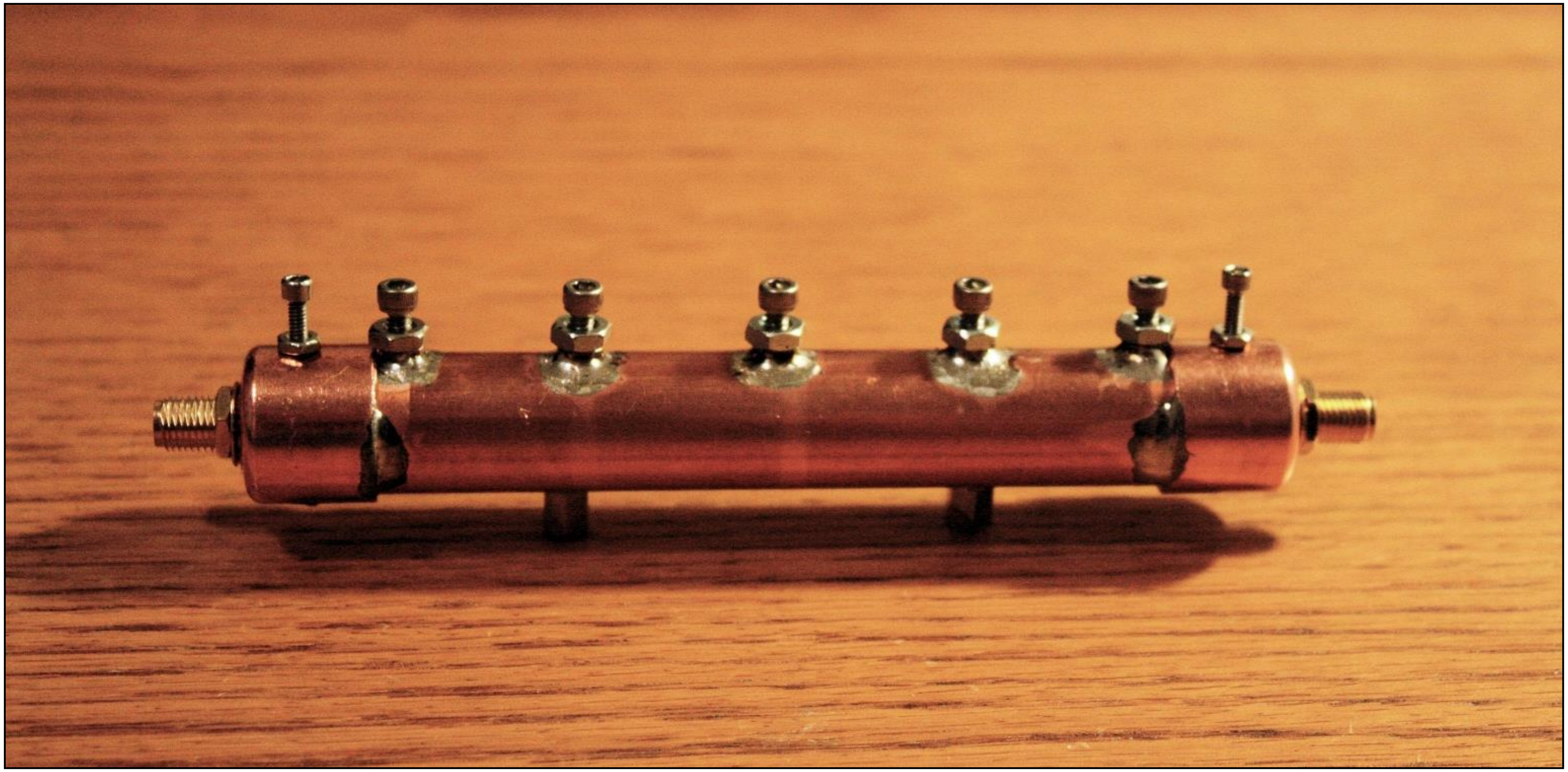
EVANESCENT MODE CIRCULAR WG FILTERS



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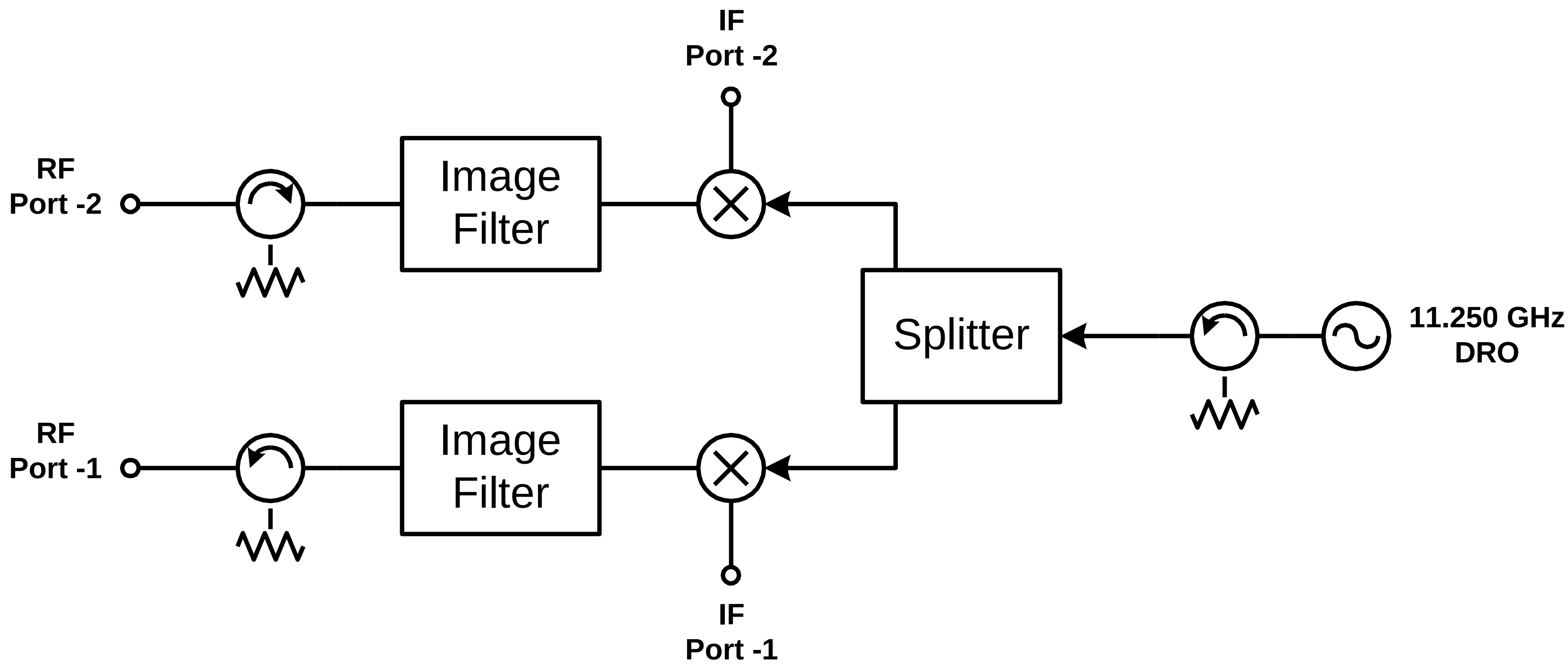
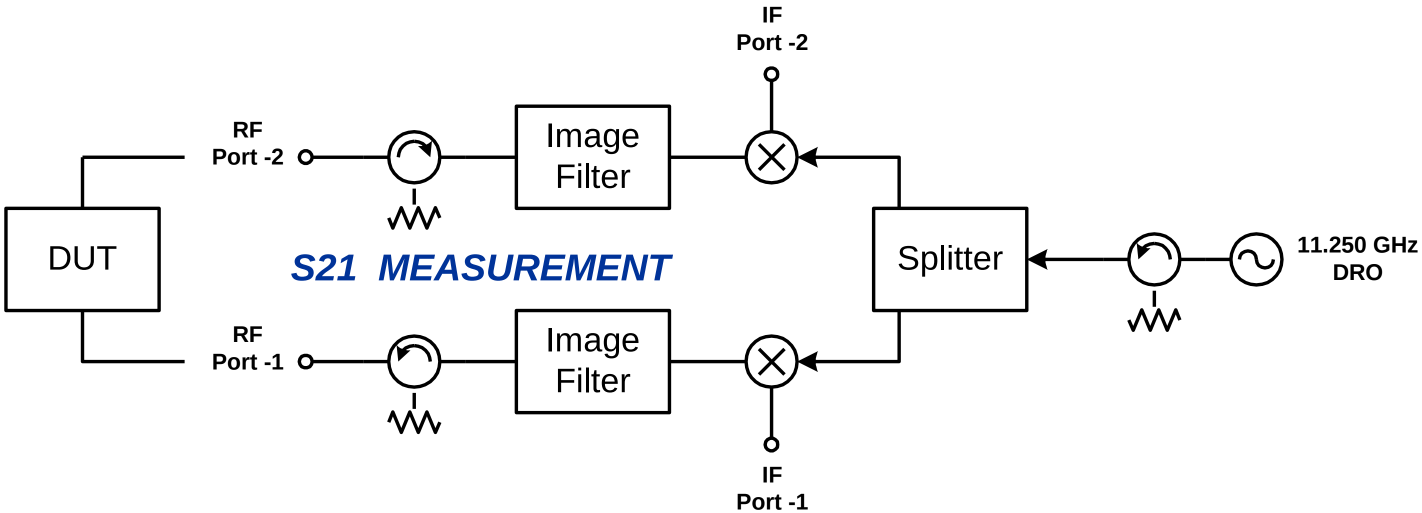
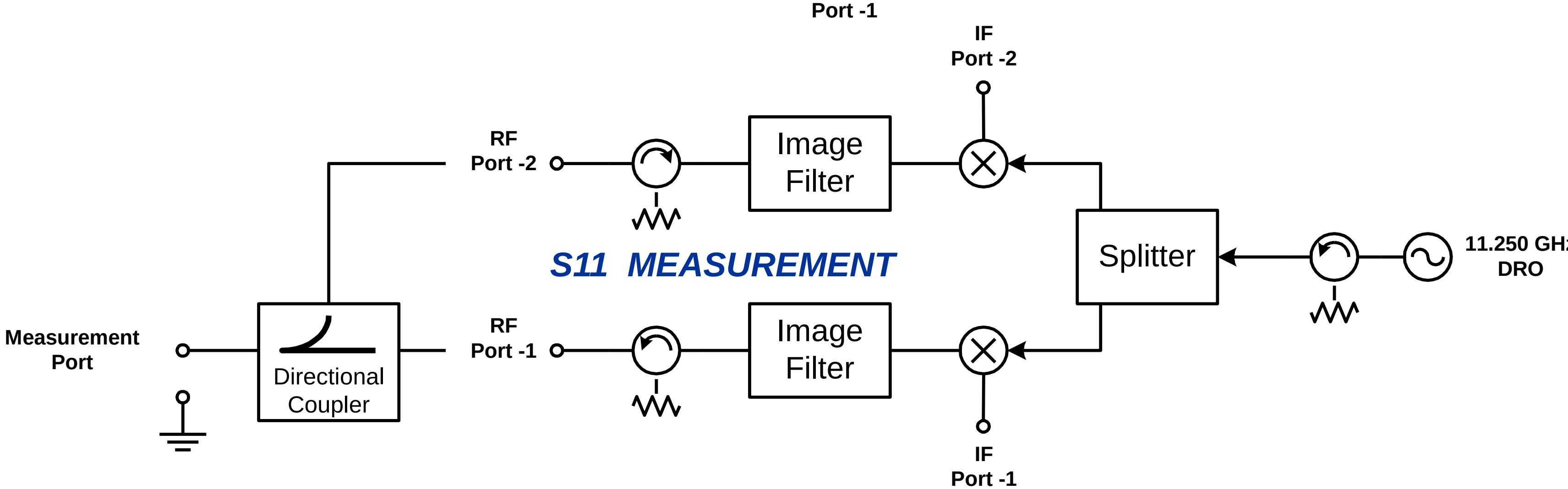
MOTIVATION: NEED IMAGE FILTERS for X-BAND TEST-SET



X-BAND TEST-SET CONFIGURATIONS





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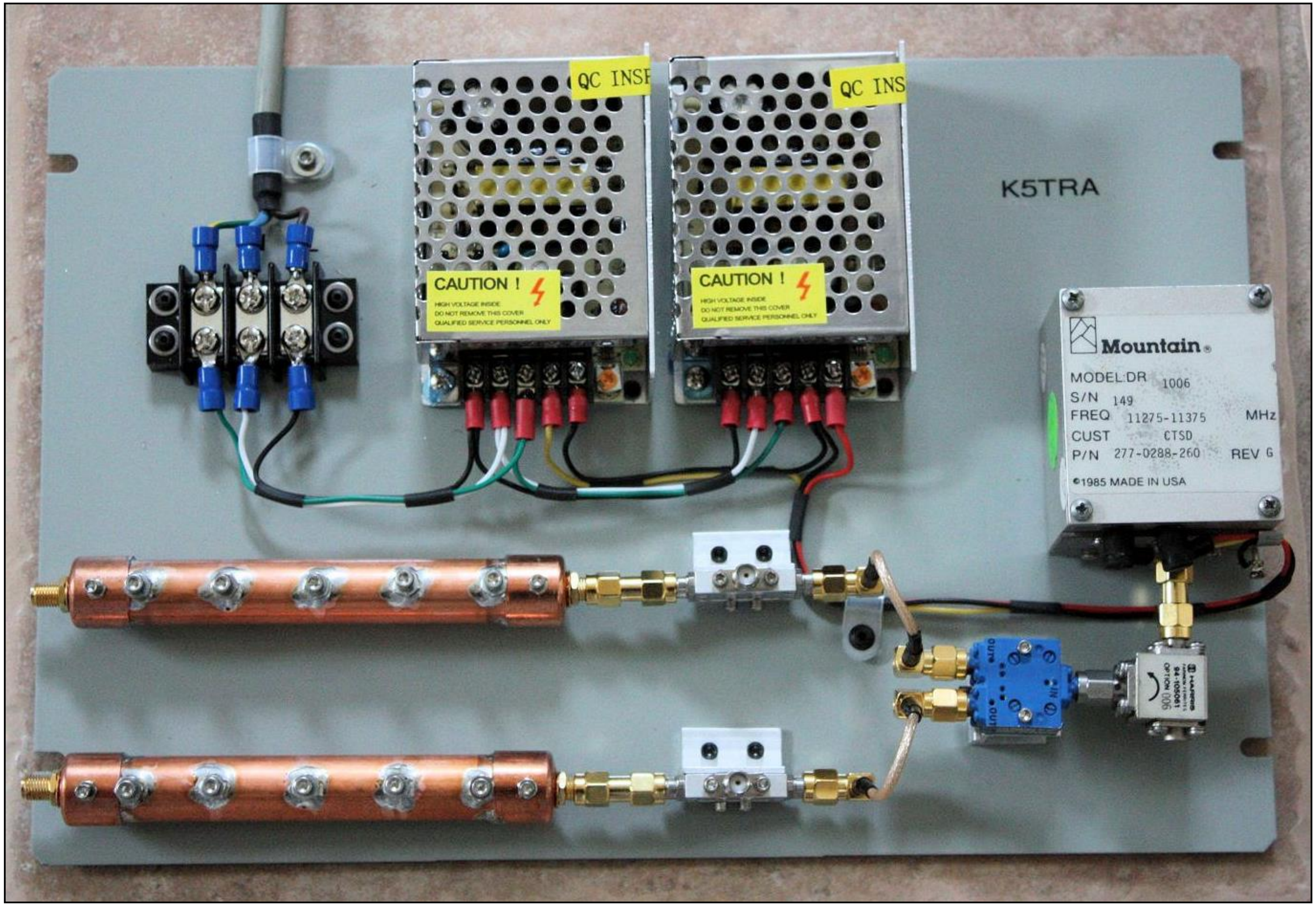
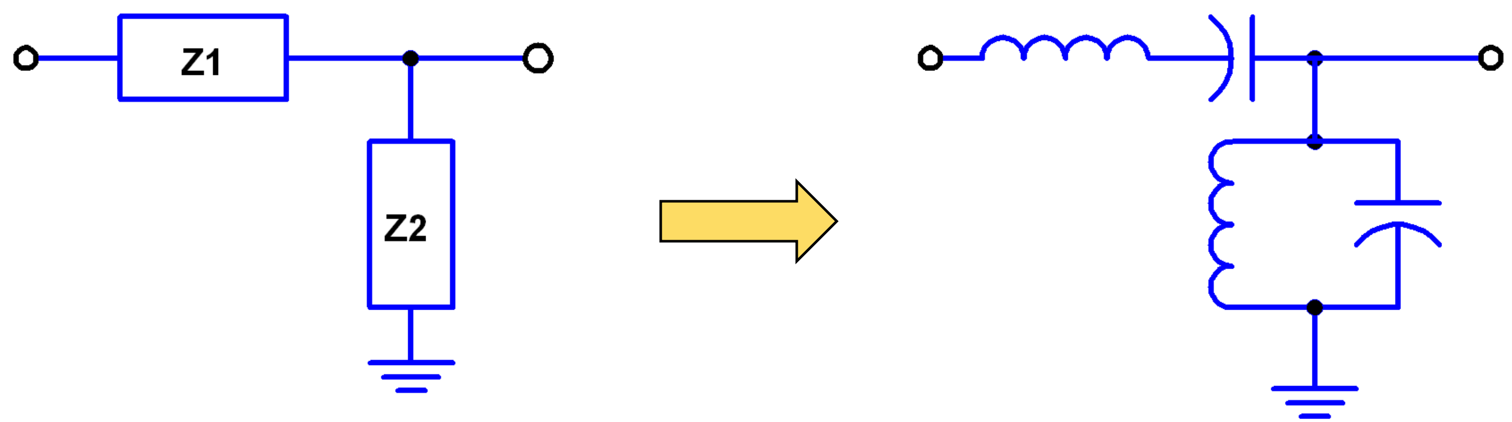
X-BAND TEST-SET

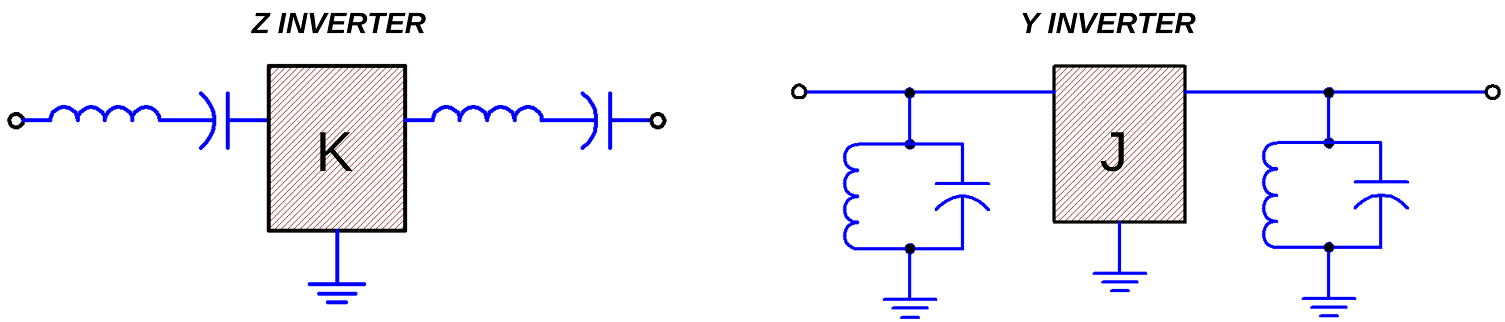


LADDER FILTER BASIC BUILDING BLOCK



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

J and K INVERTERS PROVIDE REUSE OF RESONATOR TYPE

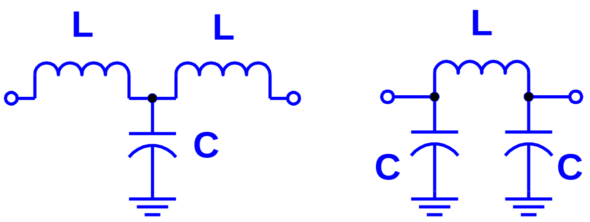


- Impedance inverter (K) with a series resonator behaves like a parallel resonator
- Admittance inverter (J) with a parallel resonator behaves like a series resonator
- Impedance/admittance inverter interface between similar resonators provides maximum stopband attenuation
- Most common impedance inverter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

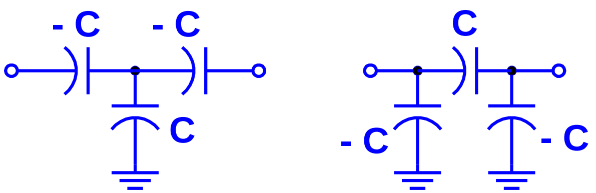
IMPEDANCE/ADMITTANCE INVERTERS

- 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).

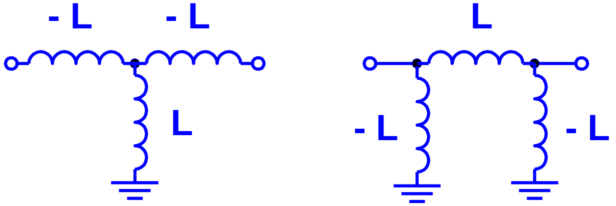
$$Z_0, \quad \theta = \frac{\lambda}{4}$$



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

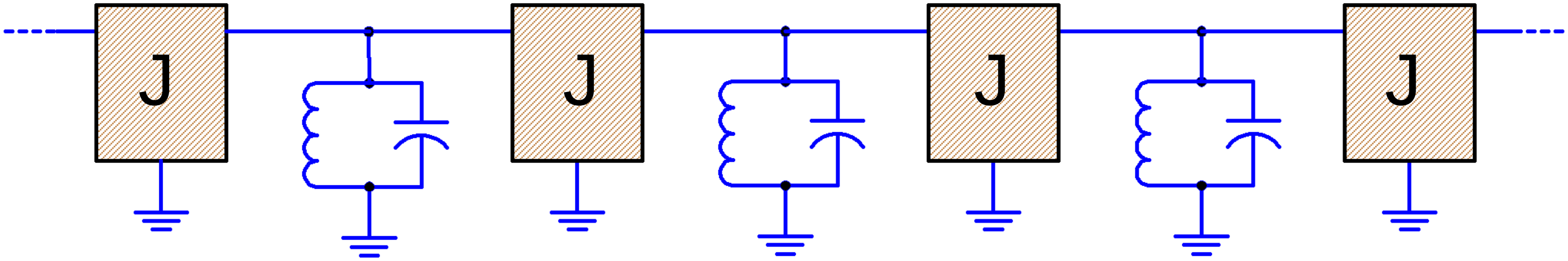


$$Z_0 = \frac{1}{\omega_0 C}$$



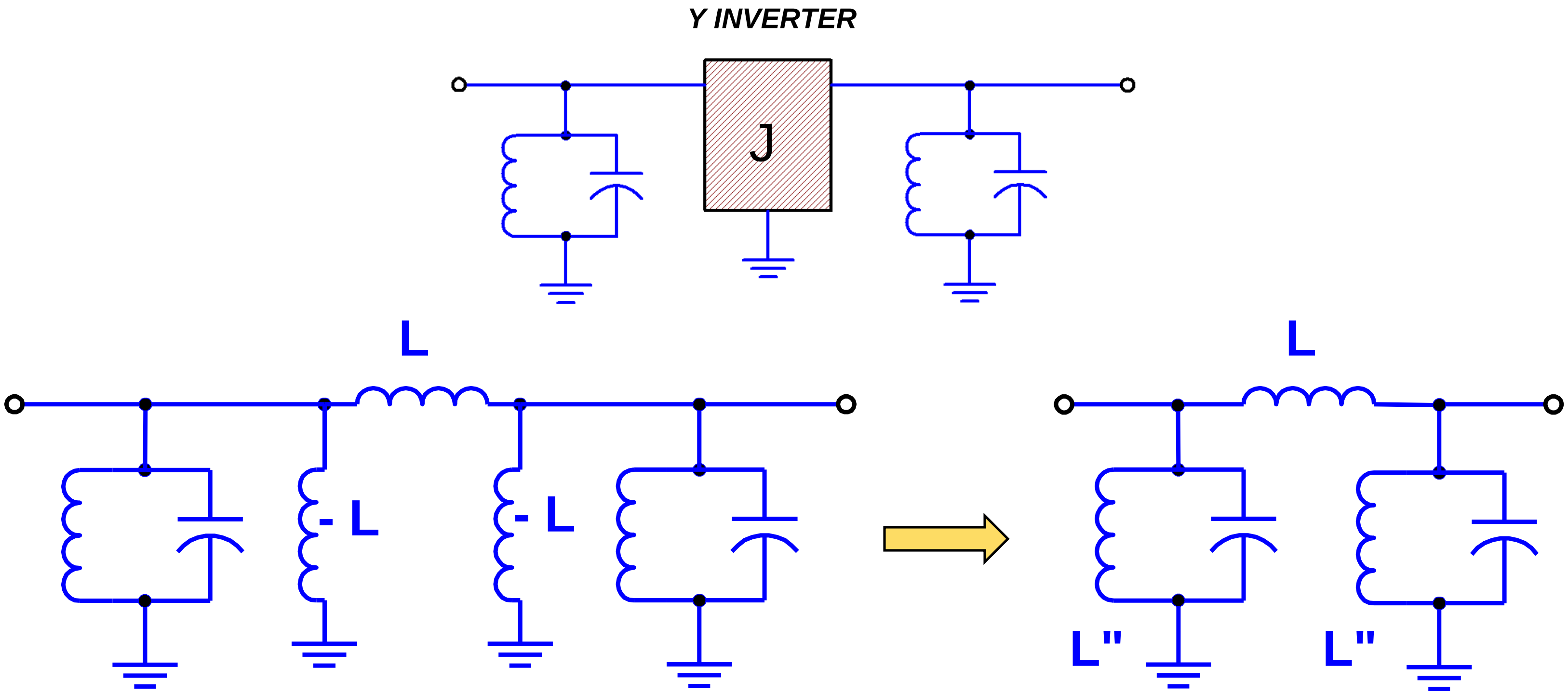
$$Z_0 = \omega_0 L$$

BANDPASS FILTER STRUCTURE WITH J INVERTERS



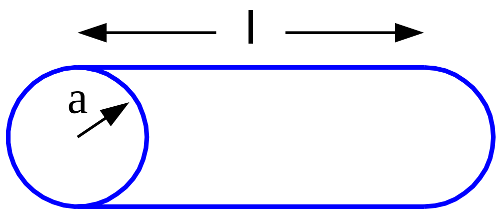
- Filters are formed as cascade of parallel resonators and inverters
- How do we realize a structure like this in WG?

BANDPASS FILTER WITH INDUCTIVE J INVERTERS

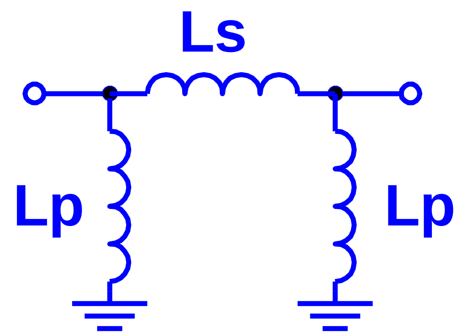


- Negative inductors of inverter cancel some of the resonator inductive susceptance.
- Inverter admittance/impedance sets coupling between resonators. In this case, coupling is set by $(\omega L)^{-1}$

EVANESCENT WG MODEL



COPPER PIPE
CIRCULAR WG



$a = inside\ radius\ in\ mm$

$l = length\ of\ WG\ section$

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

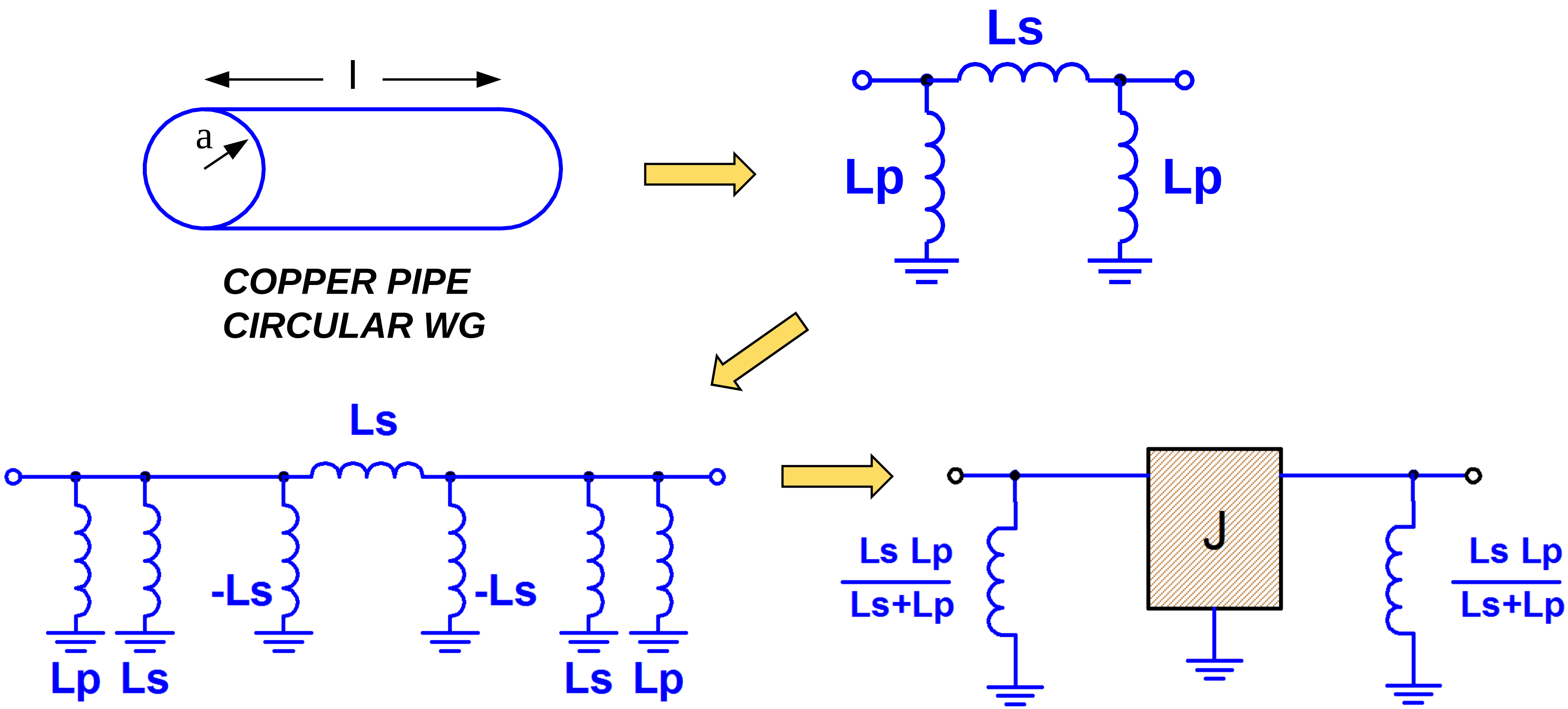
$$Ls = \frac{X_0 \sinh(\gamma l)}{2\pi\ freq} \qquad Lp = \frac{X_0 \coth\left(\frac{\gamma l}{2}\right)}{2\pi\ freq}$$

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

$$Xo \sim 599\ \Omega$$

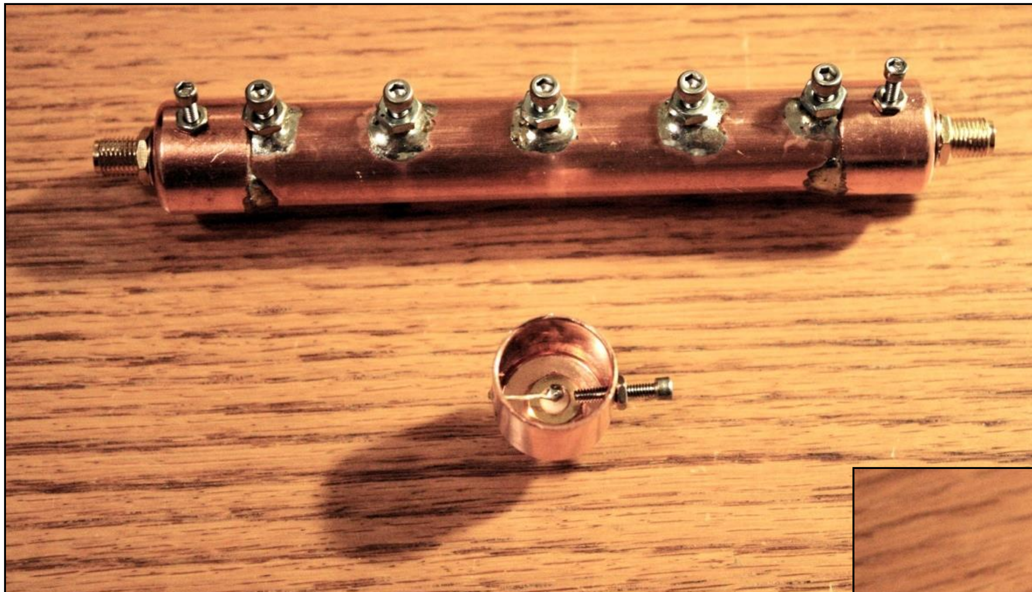
- Operation *BELOW* TE_{11} cutoff frequency
- Propagation falls off quickly
- Behavior is reactive (inductive)

EVANESCENT WG SECTIONS PROVIDE J INVERTER and RESONATOR L



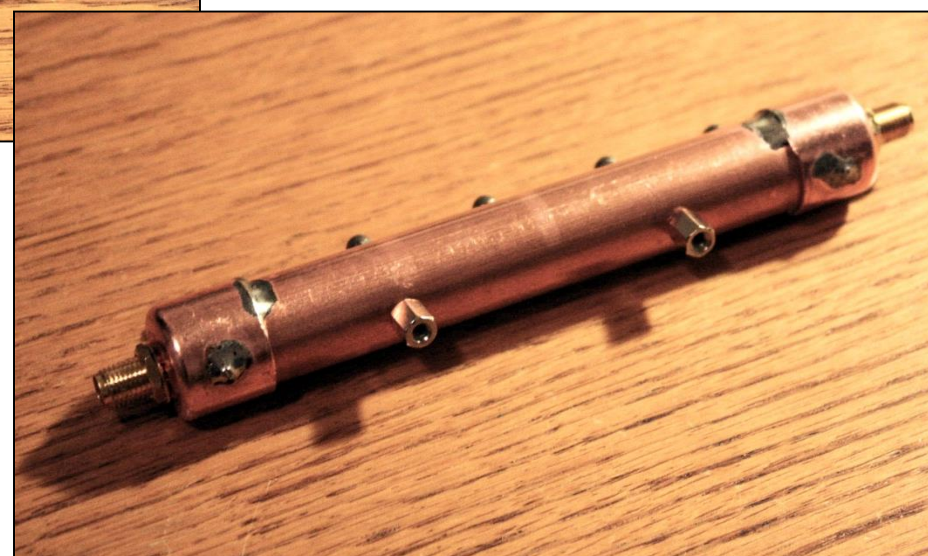
- ***RESONATOR C CAN BE ADDED WITH TUNING SCREWS***
- ***SCREW SPACING SETS Ls (SETS COUPLING)***

EVANESCENT WG FILTER CONSTRUCTION

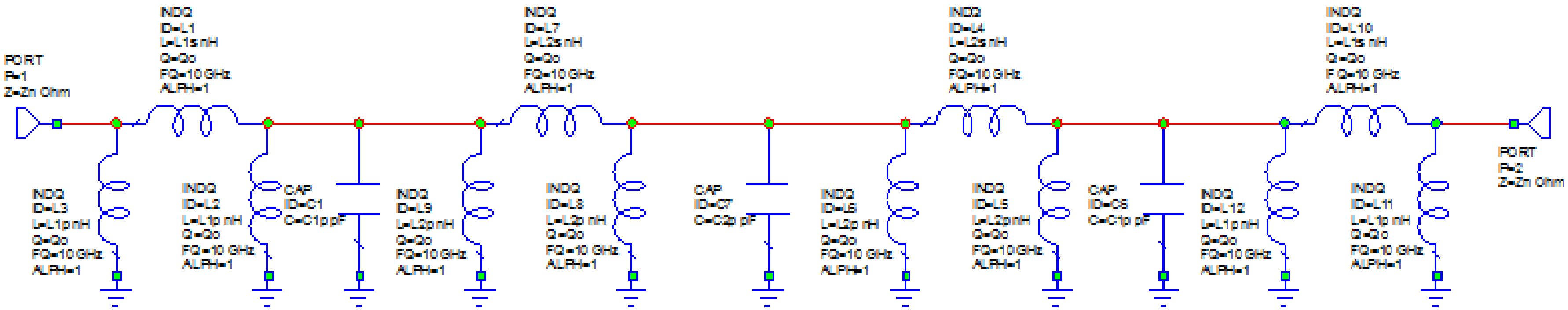


- Operation *BELOW* cutoff frequency
- 0.5” Cu pipe for X-band (actual ID = 0.565”)

- 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

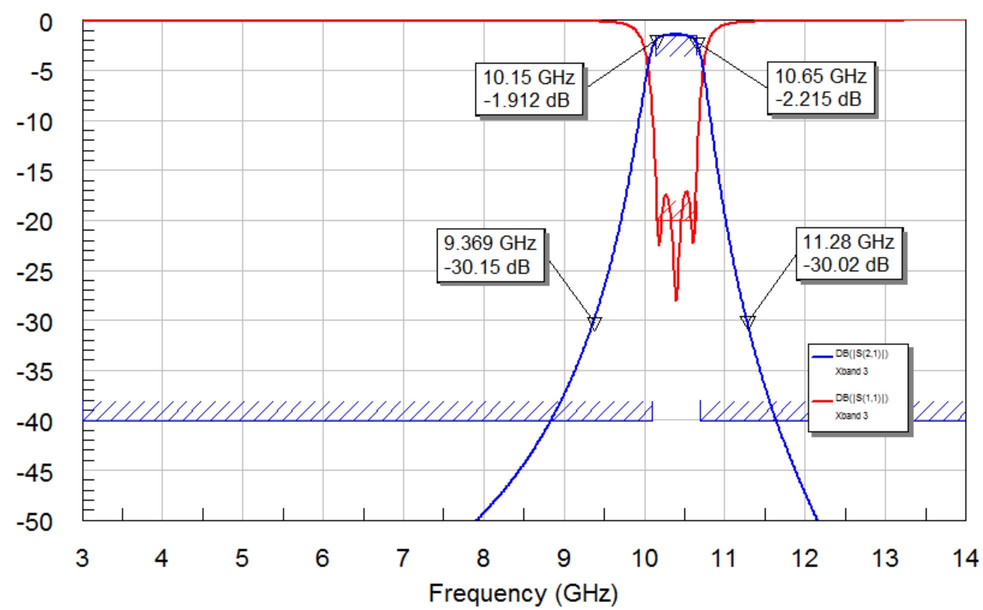
x1=l1/25.4
x1: 0.2716

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

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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	219	886	1004	0.06527	0.05108	4.00	13.05	9.77	10.96
3	300	254	1005	1127	0.06147	0.05099	4.76	16.15	9.98	10.78
2	200	277	1082	1213	0.05970	0.05097	5.46	18.56	10.08	10.70
1	100	314	1202	1349	0.05745	0.05094	7.23	21.86	10.19	10.59
0.5	50	324	1247	1402	0.05694	0.05094	7.82	25.54	10.22	10.57

N=3

%BW	BW(MHz)	l1(mil)	l2(mil)	C1(pF)	C2(pF)	Loss(dB)	RetLoss(dB)	F30L(GHz)	F30H(GHz)
5	500	167	757	0.07403	0.05146	1.23	22.14	8.88	11.63
3	300	186	837	0.07036	0.05123	1.44	24.90	9.23	11.39
2	200	230	956	0.06393	0.05106	2.06	28.54	9.62	11.10
1	100	244	1008	0.06248	0.05102	2.25	36.20	9.74	11.00
0.5	50	269	1081	0.06027	0.05098	2.77	40.26	9.88	10.88

N=2

%BW	BW(MHz)	l1(mil)	l2(mil)	C1(pF)	Loss(dB)	RetLoss(dB)	F30L(GHz)	F30H(GHz)
5	500	184	672	0.07105	0.85	16.00	5.08	12.68
3	300	230	823	0.06401	1.16	17.70	8.06	11.98
2	200	267	930	0.06050	1.49	18.86	8.83	11.59
1	100	283	989	0.05927	1.59	24.73	9.11	11.43
0.5	50	304	1052	0.05797	1.86	28.11	9.35	11.27

DESIGN TABLES N= 5, & 6

N=6

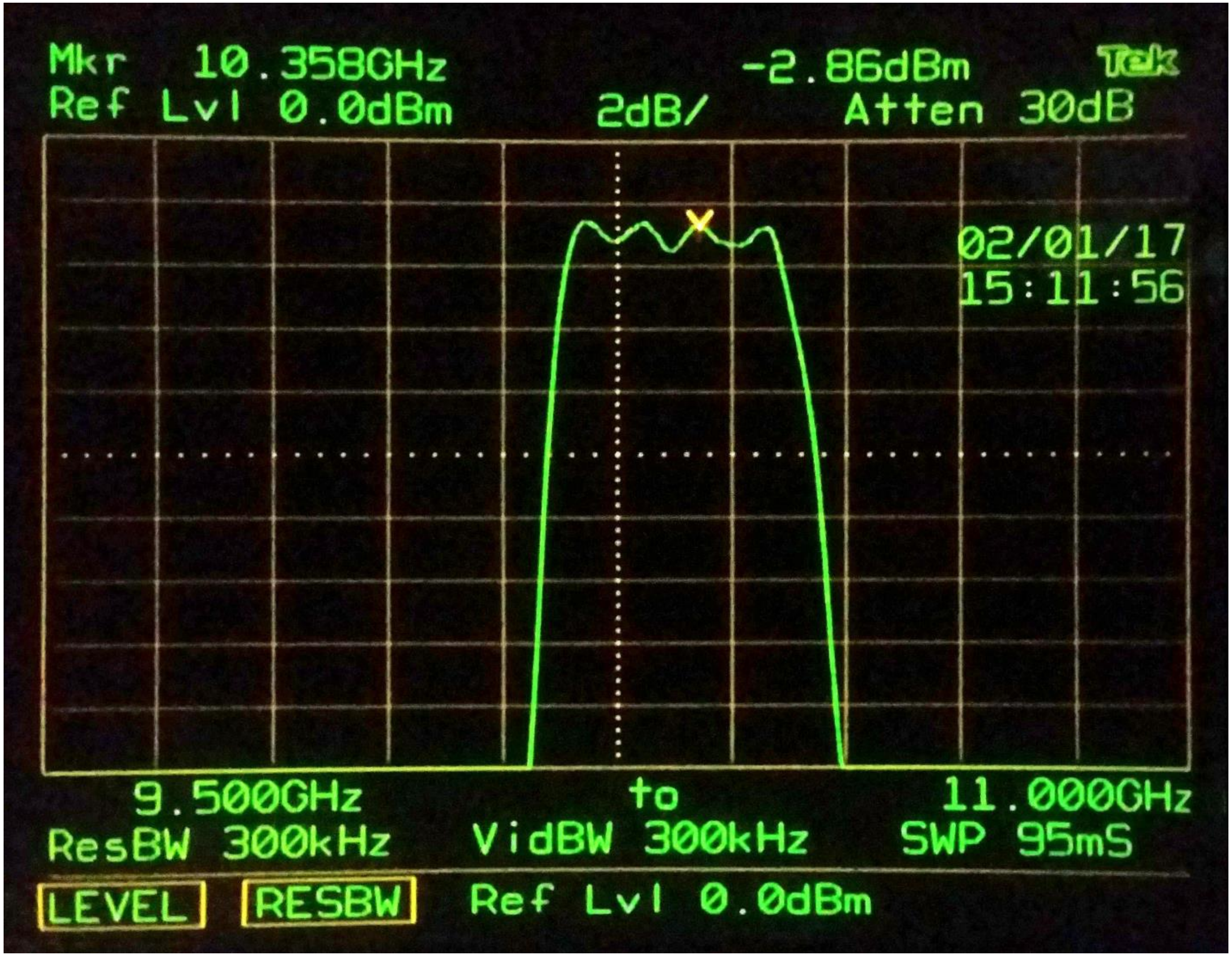
%BW	BW(MHz)	l1(mil)	l2(mil)	l3(mil)	l4(mil)	C1(pF)	C2(pF)	C3(pF)	Loss(dB)	RetLoss(dB)	F30L(GHz)	F30H(GHz)
5	500	179	822	990	1010	0.07166	0.05115	0.05103	5.26	17.61	9.93	10.83
3	300	220	953	1121	1142	0.06515	0.05102	0.05097	7.21	20.12	10.10	10.68
2	200	252	1049	1221	1245	0.06167	0.05097	0.05095	9.35	21.48	10.19	10.60
1	100	303	1193	1381	1415	0.05804	0.05094	0.05093	14.11	24.63	10.29	10.51
0.5	50	323	1254	1446	1472	0.05696	0.05094	0.05093	15.35	25.43	10.31	10.13

N=5

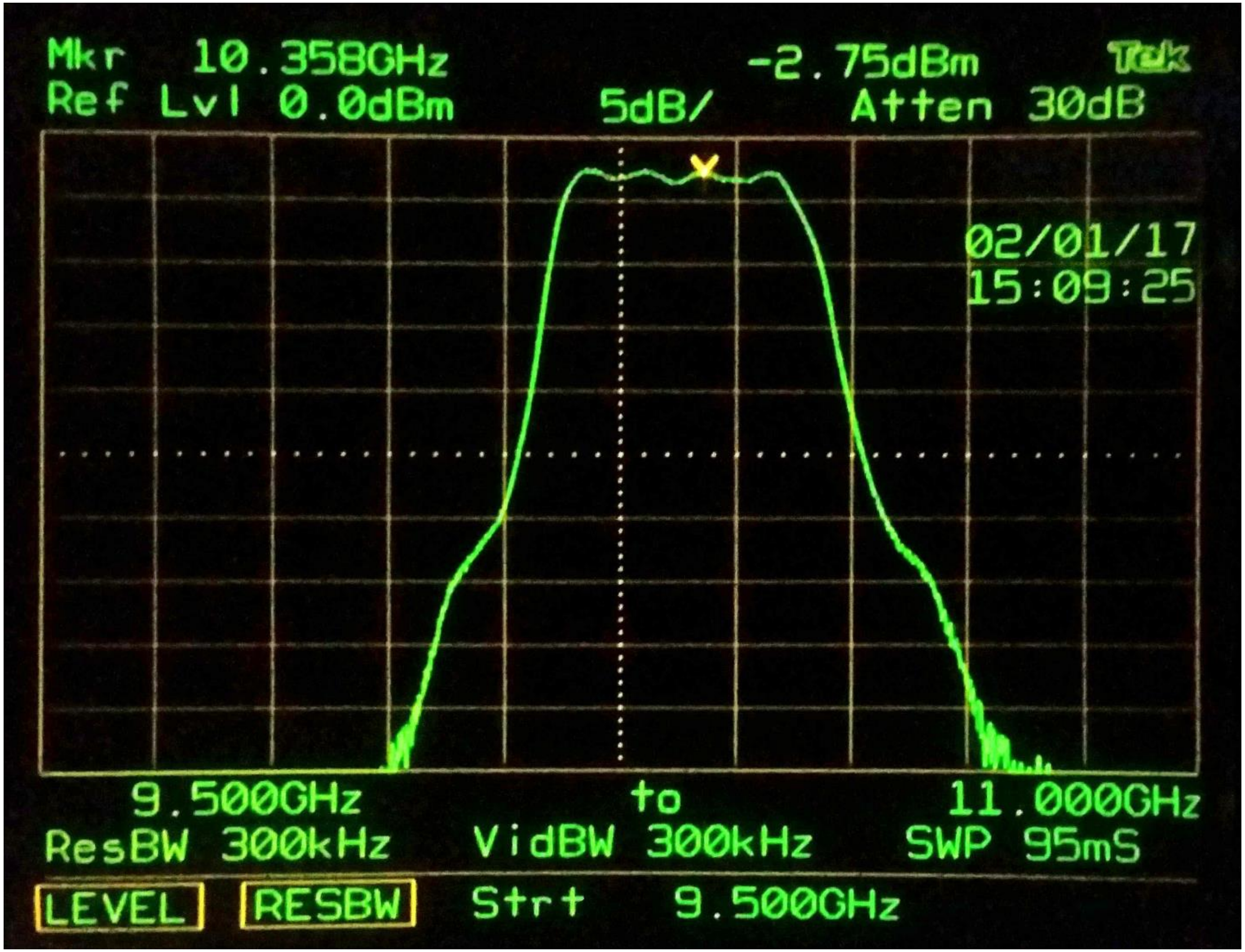
%BW	BW(MHz)	l1(mil)	l2(mil)	l3(mil)	C1(pF)	C2(pF)	C3(pF)	Loss(dB)	RetLoss(dB)	F30L(GHz)	F30H(GHz)
5	500	174	804	972	0.07291	0.05118	0.05105	3.54	16.40	9.79	10.94
3	300	211	932	1097	0.06632	0.05103	0.05098	4.83	20.10	10.01	10.76
2	200	243	1029	1196	0.06256	0.05098	0.05095	6.23	21.88	10.12	10.66
1	100	292	1170	1349	0.05868	0.05095	0.05094	9.39	24.11	10.24	10.55
0.5	50	315	1237	1431	0.05738	0.05094	0.05093	11.10	25.15	10.28	10.52

EVANESCENT WG FILTER

INSERTION LOSS, 2 dB/DIV



EVANESCENT WG FILTER INSERTION LOSS, 5 dB/DIV



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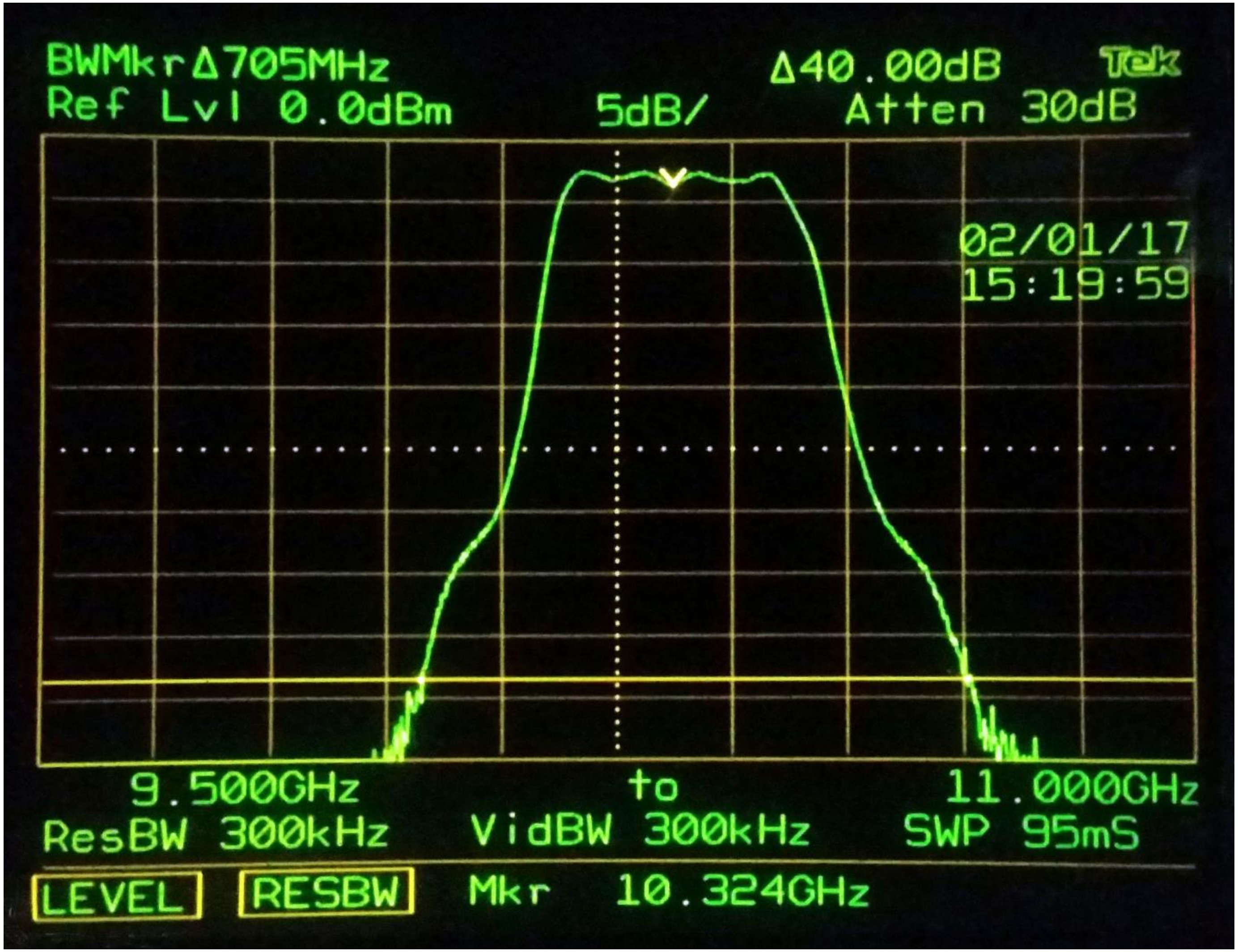
EVANESCENT WG FILTER -40 dB BW = 705 MHz



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EVANESCENT WG FILTER USED IN K5TRA X_BAND TEST SET