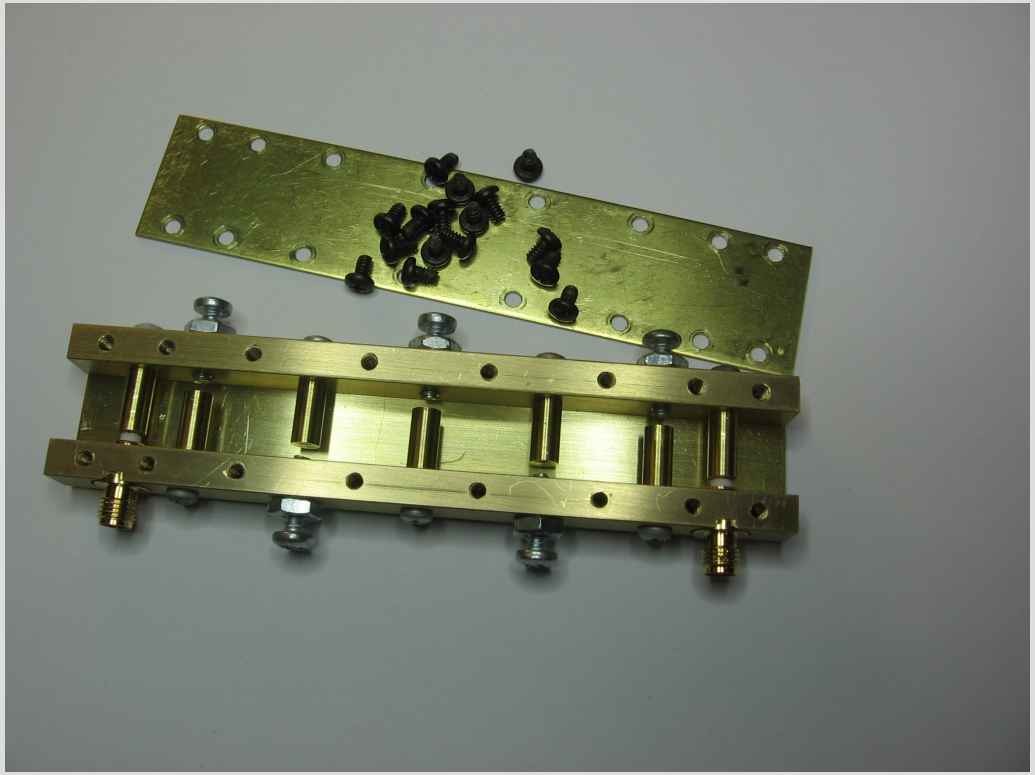
INTRFIL: Design and Construction of Round Rod Interdigitated Filters



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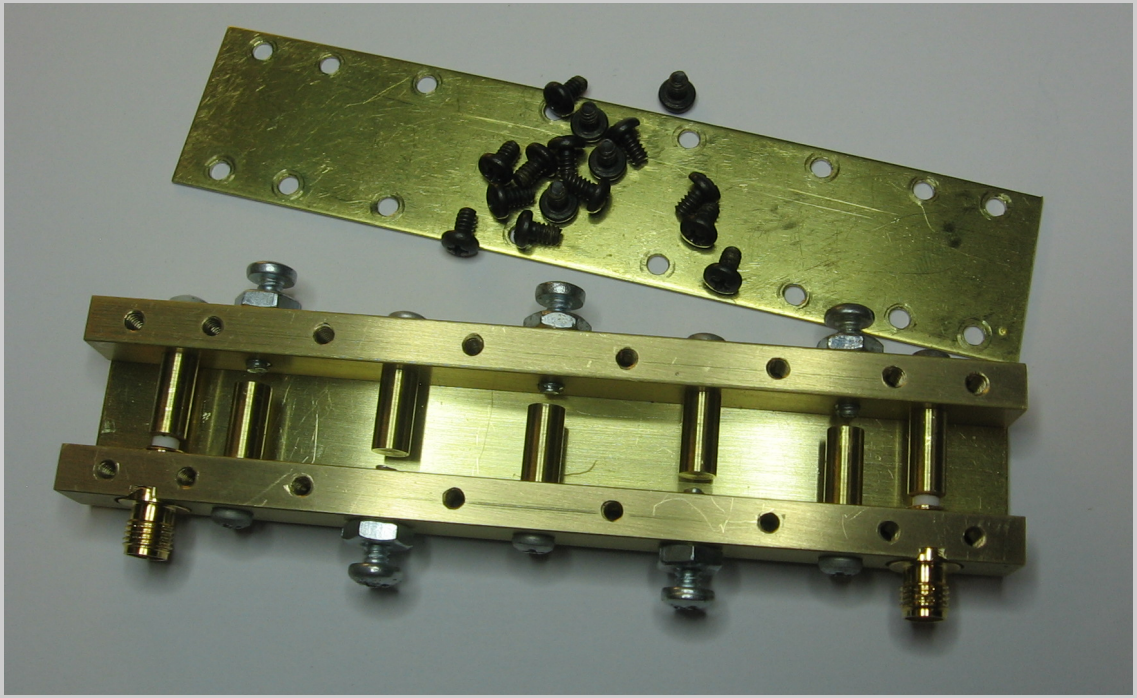
Microwave Update 2023
Windsor, CT

INTRFIL: round rod interdigital filter program

- **Exercise to extend the 1985 Ham Radio filter program**
  - HR program made good filters but tap points problematic at high frequency
    - BW and ripple hard to control
  - No upper/lower limit on INTRFIL, usable from 500 to 6000 MHz, maybe beyond
- **Written in Pascal**
  - Source code available under General Public License (GPL)
    - GPL doesn't preclude commercial use but NO warranty, use at own risk
    - Can be freely modified and/or shared but must remain under GPL
      - Anyone want to write a nice GUI for INTRFIL?
    - Intended for anyone to use and not intended or supported as commercial software
  - Executables available or run on Windows, Mac, or Linux with Free Pascal Compiler and Geany IDE (Both available under GPL)

Example Filter



5760 MHz 5 resonator filter created with INTRFIL

35 MHz (3 dB) bandwidth for a transverter with 28 MHz IF

Note there are 7 rods. The end rods are coupling rods

The lid is 1.00 in wide

Overview

- **INTRFIL Example**
  - Running INTRFIL
  - Center Frequency, Adjusting Rod Length and Loss Estimates
  - Error messages
- **QUCS Simulation (Quite Universal Circuit Simulator)**
  - Simulated and Measured results
- **Construction Notes**
- **Inside INTRFIL (time permitting)**

Running INTRFIL

Bold denotes required inputs (not in actual program)

INTRFIL: Interdigitated Filter Program Version 1.0
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Number of elements? 5
Center frequency (MHz) 5760
Butterworth (1) Chebychev (2) ? 2
Ripple Bandwidth (MHz) 30
Bandpass ripple (DB) 0.05
3 dB Bandwidth (MHz) = 35.26 Ripple Return Loss = 19.4 dB
Load impedance 50
ground plane spacing in = 0.375
rod dia in = 0.1875

Calculated 3 dB BW & return loss for Chebychev filters

Slab line impedance

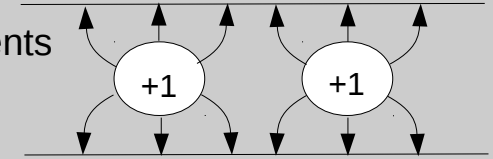
Equivalent coax impedance

Even, Odd Mode Impedances & Coupling

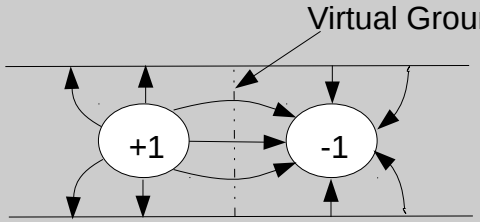
d/h = 0.500 Slab Zo = 55.76 Co-ax Zo = 56.08

Calculated odd/even impedances and coupling coefficients

Zoo[0] = 46.81	Zoe[0] = 53.19	K = 0.0639
Zoo[1] = 49.62	Zoe[1] = 49.97	K = 0.0035
Zoo[2] = 49.67	Zoe[2] = 49.92	K = 0.0026
Zoo[3] = 49.67	Zoe[3] = 49.92	K = 0.0026
Zoo[4] = 49.62	Zoe[4] = 49.97	K = 0.0035
Zoo[5] = 46.81	Zoe[5] = 53.19	K = 0.0639



Even Mode
Zoo



Odd Mode
Zoe

$$K = \frac{Zoo - Zoe}{Zoo + Zoe}$$

Odd/even impedances for fixed d/h = 0.500 with s/h rod spacings

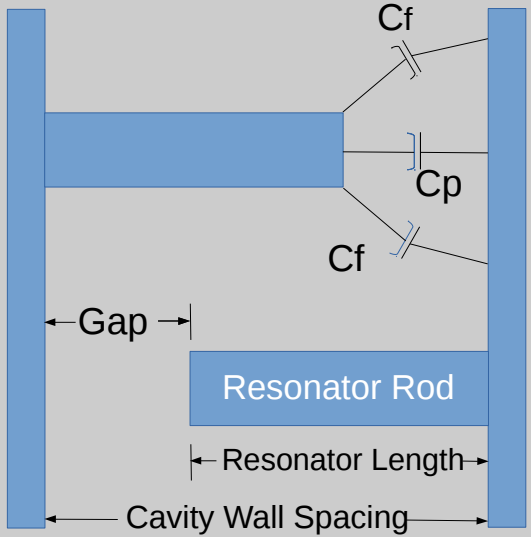
Zoo = 51.92 Zoe = 59.01 s/h[01] = 0.5953 c - c = 0.411 in
Zoo = 55.45 Zoe = 55.84 s/h[12] = 1.4481 c - c = 0.731 in
Zoo = 55.51 Zoe = 55.80 s/h[23] = 1.5238 c - c = 0.759 in
Zoo = 55.51 Zoe = 55.80 s/h[34] = 1.5238 c - c = 0.759 in
Zoo = 55.45 Zoe = 55.84 s/h[45] = 1.4481 c - c = 0.731 in
Zoo = 51.92 Zoe = 59.01 s/h[56] = 0.5953 c - c = 0.411 in

Iterative estimate of rod spacing (Error message possible)

Parameters for filter cavity length = wavelength/4

Ct = 0.2016 pf Cf = 0.1251 pf Cp = 0.0765 pf
l = 0.386 in gap = 0.081 in lamda/4 = 0.512 in

Cap loading & rod length estimate



Cavity spacing width can be adjusted +/- 10% of wavelength/4
Spacing = (in) 0.5

Parameters for Filter cavity

Ct = 0.1845 pf Cf = 0.1251 pf Cp = 0.0593 pf
New Ct Rod Length = 0.395 in New gap = 0.105 in Rod + gap = 0.500 in

Iterative estimate of new cap loading & rod length (Error message possible)

Estimated resonator Q = 1040.2 Filter Q = 192.0
Loss = 5.27 dB

Loss estimate from filter material

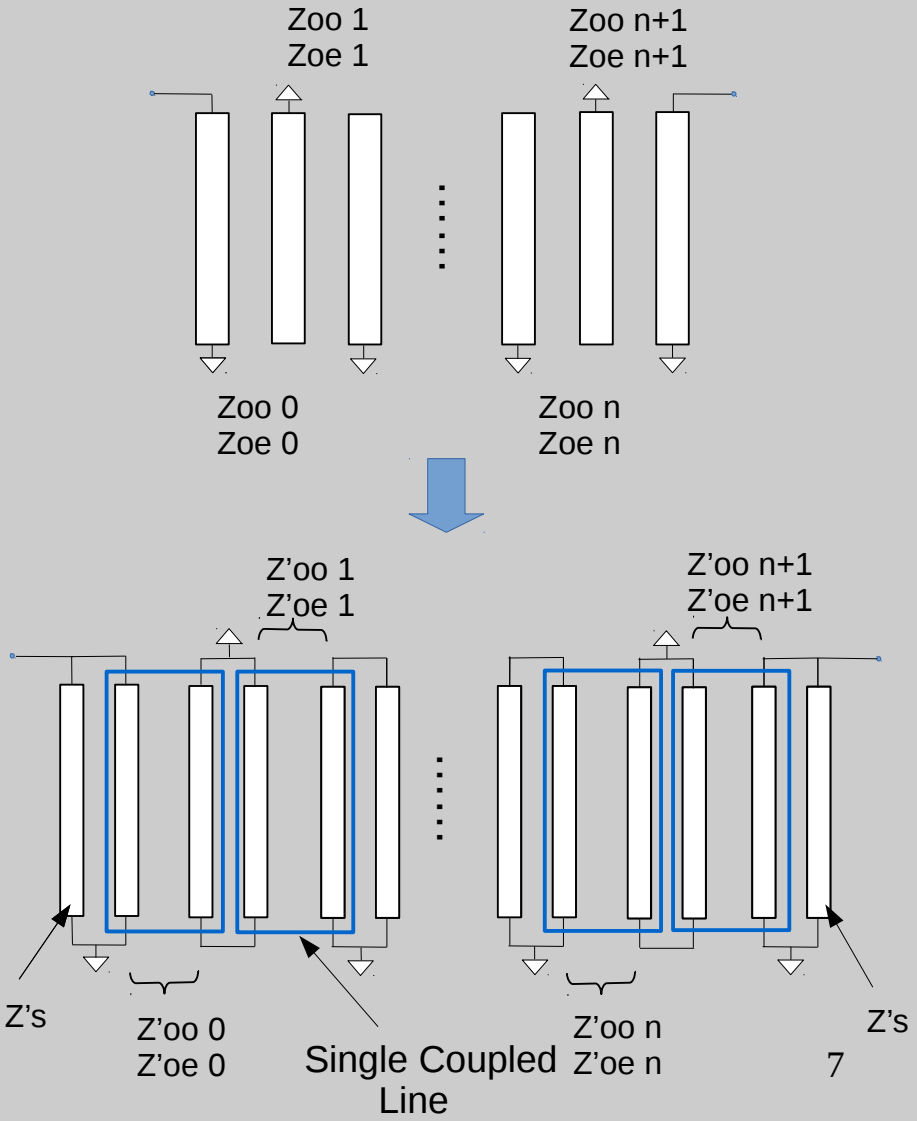
Simulation with QUCS

Data for simulation model using coupled lines

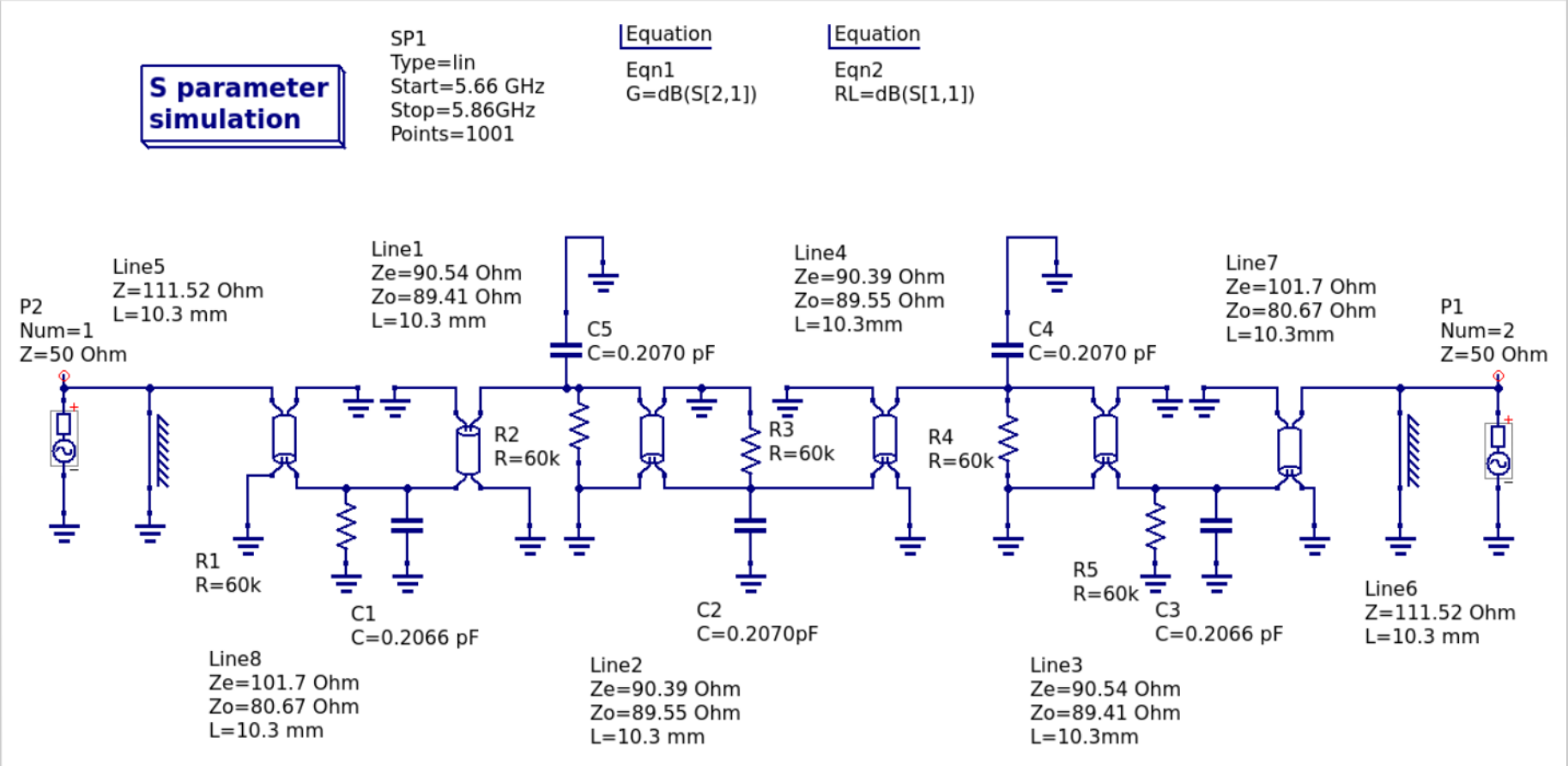
Zs = 111.52

Zooprime = 80.66 Zoeprime = 101.71
Zooprime = 89.40 Zoeprime = 90.54
Zooprime = 89.55 Zoeprime = 90.39
Zooprime = 89.55 Zoeprime = 90.39
Zooprime = 89.40 Zoeprime = 90.54
Zooprime = 80.66 Zoeprime = 101.71

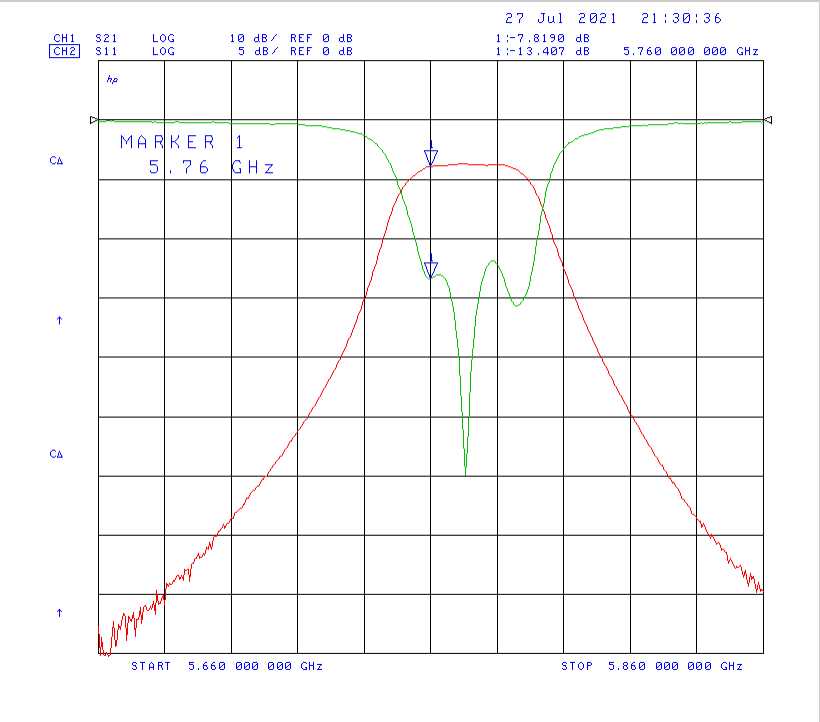
Ct = 0.1845 pf Bar length = 10.044 mm



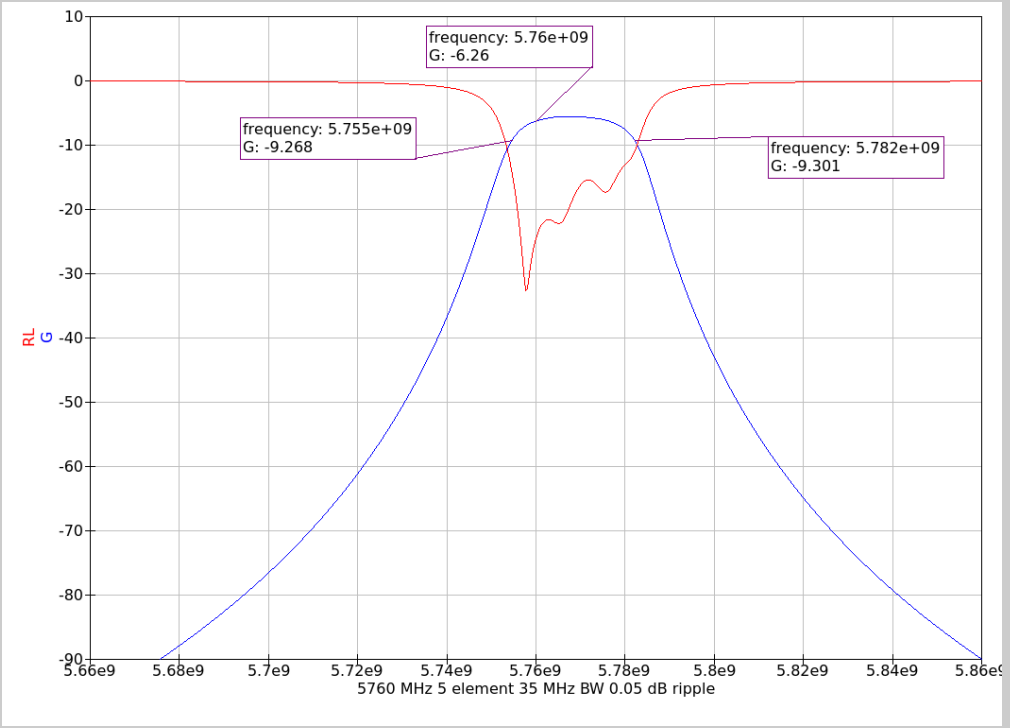
QUCS Simulation



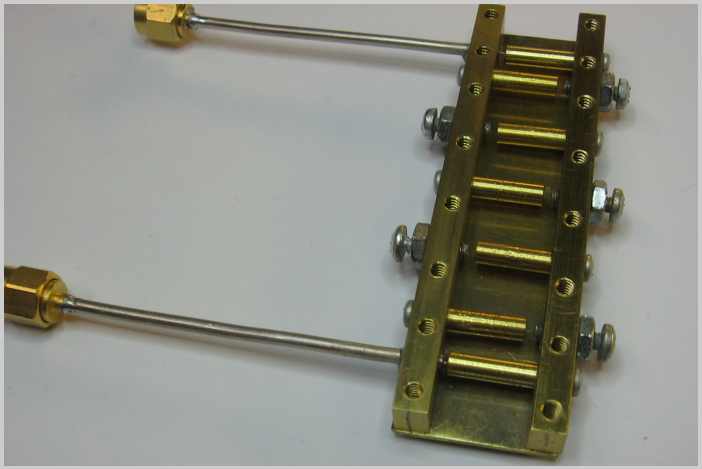
Center frequency trimmed with C1-C5 Lines lengthened 2.5% Loss added with R1-R5

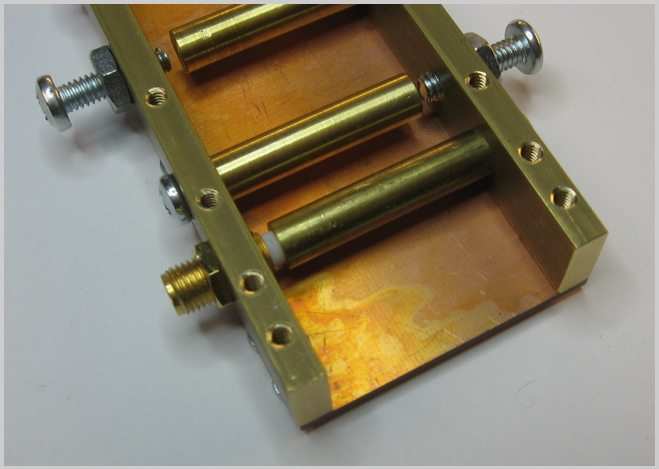


Measured Insertion & Return Loss.
3 dB BW = 36.96 MHz (calculated 35.26 MHz)
Midband Loss = 7.5 dB (calculated 6.27 dB)
33.4 dB dwn @ 28 MHz removed
56.5 dB dwn @ 56 MHz removed



Simulated Insertion & Return Loss.
3 dB BW = 27 MHz
Midband Loss = 6.26 dB.
INTRFIL Center frequency tends to be high, rods lengthened 2.5% & tuned to 5760 MHz



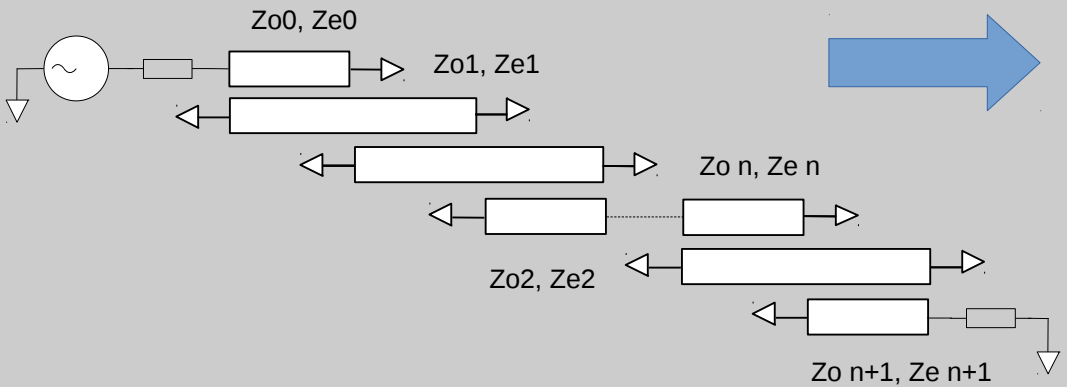


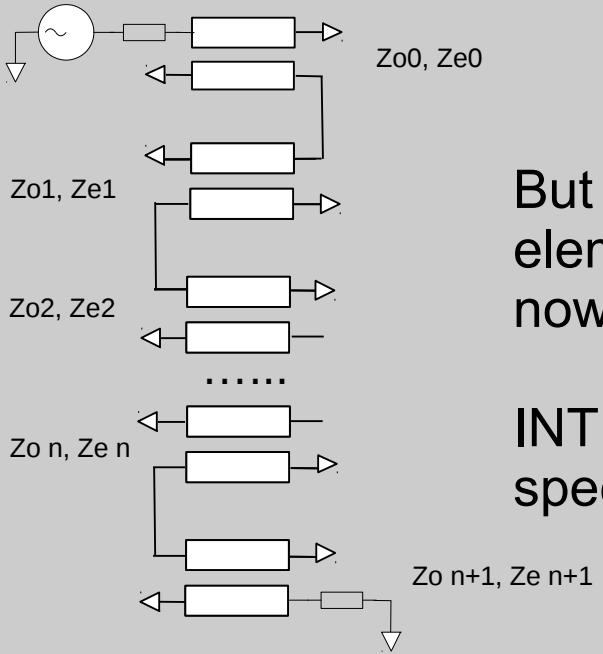
Construction Notes

- **Test filters made with a table top milling machine & lathe**
  - Screws ½ way between each bar and ends open after a couple of diameters
- **SMA connectors screwed in (1/4-36 tap) or 0.85” coax soldered in sidewalls**
- **d/h = 0.5 convenient with standard sized material**
  - bars & rods obtained from www.onlinemetals.com
- **Walls made with K&S brass strips, PCB material & 0.05” AL sheet**
- **Simpler methods with K&S strips and 0.141 coax rods?**

Inside INTRFIL

Matthaei edge coupled filter (reference in paper) folded in half for an interdigitated structure

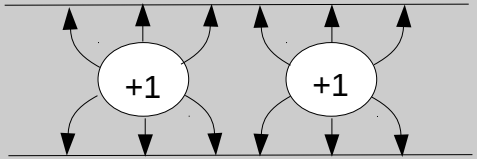




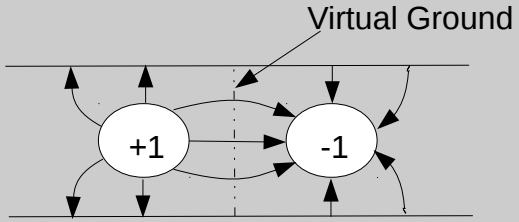
But doubles BW, elements in series now in parallel

INTRFIL divides specified BW by 2

Inside INTRFIL



Even Mode
Zoo



Odd Mode
Zoe

$$K = \frac{Zoo - Zoe}{Zoo + Zoe}$$

d/h is fixed and s/h adjusted to produce calculated value of K.

K is a function of Zoo/Zoe which are complex functions of d/h and s/h:

$$K = f(Zoo/Zoe) = f(d/h, s/h)$$

An iterative algorithm determines s/h for a given K with d/h fixed but may not converge for some values of K, BW or ripple. INTRFIL reports a “failed to converge” error. Small changes in BW or ripple usually fixes this.

In Summary

- **INTRFIL more complex than hairpin or pipe cap filters but much higher performance particularly in the stopband.**
  - Stopband performance important in reducing out of band emissions and mutual interference when groups of microwavers gather
  - 3 and 5 element filters for 1.3, 2.3 & 5.7 GHz made with INTRFIL
- **Detailed paper with 2.3 & 5.7 GHz filters to be published in QEX**
  - Referenced papers available
  - Mechanical drawings

Getting INTRFIL

- **Source and executables available from me or Blue Ridge Microwave Society group site: groups.io/g/brms**
  - Must register to see “Files” folder
  - Version 1.1 edited to output metric dimensions
    - All internal calculation done in cm
  - MUD 1989 WGFIL waveguide filter program is also available on BRMS (executable and Pascal source)