How-to-Make Better RFI Filters using Stubs

Case Study: The NW6E 2-meter Pager Rejection Filter

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Pager Rejection Filter for 2 Meters

- ***Performance specifications***
  - Notch 152.5 MHz paging transmitter frequency
  - Pass 2-meter repeater band 145 MHz to 148 MHz
  - Notch depth greater than 20 dB on 152.5 MHz
  - Insertion loss less than 1/2 S-unit in repeater band
  - VSWR less than 2 in amateur repeater band
- ***Simple hardware technology***
  - Modular “plug-’n-play” construction
  - Made from coaxial transmission line segments and stubs
  - Connected with T connectors (BNC female or SO-239)
  - Only short-circuited stubs allowed
  - Design variables are
    - Network topology
    - Segment lengths
    - Characteristic impedances

Non-50/75 Ohm Coaxial Transmission Lines

Impedance	Types
12.5 Ω	RG192, RG193, RG194
25 Ω	RG73, RG191, RG230, RG328 M17/124
35/37 Ω	RG83, RG100, RG264
93/95 Ω	RG7, RG22, RG43, RG57, RG62, RG71, RG111, RG130, RG131, RG133, RG180, RG294, RG317 M17/15, M17/30, M17/56, M17/90, M17/95, M17/100, M17/137, M17/139, M17/177, M17/178, M17/182, M17/185, M17/195,
100 Ω	RG285, RG287, RG383
125 Ω	RG23, RG24, RG63, RG79, RG89, RG160 M17/16, M17/31, M17/218
140 Ω	RG102
150 Ω	RG72, RG125
185 Ω	RG114 M17/47, M17/208
190 Ω	RG146

Small Diameter Coax Types

0.18 to 0.25 inch O.D. for BNC Connectors

Z_0	Line Types	v_f	150 MHz dB/100’	150 MHz dB/λ
35 Ω	RG100			
50 Ω	ETS1-50T	0.82	2.20	0.118
	LMR 300	0.85	2.40	0.134
	LMR 240	0.84	3.01	0.166
	9258-RG8/X	0.82	3.85	0.207
	LMR 200	0.83	3.98	0.217
	LMR 195	0.80	4.44	0.233
	9210-RG58/U	0.66	4.67	0.202
	9211-RG58A/U	0.75	4.92	0.242
	M17/28-RG58	0.66	5.63	0.243
93 Ω	6539Y8-RG62/U	0.84	3.30	0.182
	9269-RG62A/U	0.84	3.30	0.182
	M17/30-RG62	0.81	3.50	0.186
	M17/90-RG71	0.81	3.50	0.186
	M17/97-RG210	0.85	3.50	0.195
	M17/185	0.81	3.50	0.186
	M17/195	0.85	3.50	0.195
	8255-RG62B/U	0.84	3.60	0.198
95 Ω	M17/177	0.695	7.71	0.351

Larger Diameter Coax Types

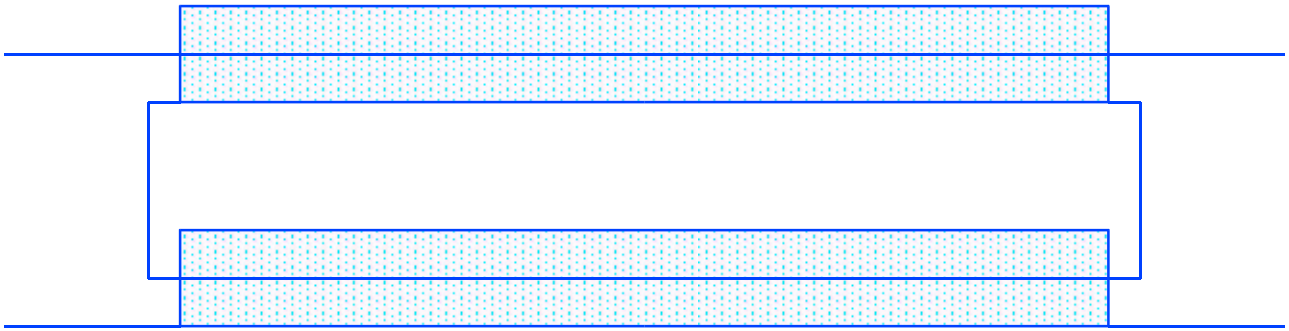
0.40 to 0.42 inch O.D. for UHF Connectors

Z_0	Line Types	v_f	150 MHz dB/100’	dB/λ
35 Ω	RG83	0.66	3.46	0.150
50 Ω	LDF2-50	0.88	1.28	0.074
	LMR 400	0.85	1.54	0.086
	9913-RG8/U	0.84	1.57	0.087
	9913F7-RG8/U	0.83	1.78	0.097
	9914-RG8	0.82	1.78	0.096
	M17/74-RG213	0.66	2.52	0.109
95 Ω	M17/100-RG133	0.66	2.74	0.118
	M17/15-RG22	0.66	2.81	0.122
	M17/182	0.66	2.81	0.122
125 Ω	9857-RG63/U	0.84	1.92	0.106
	M17/31-RG63	0.86	2.35	0.133
	M17/218	0.86	2.35	0.133
185 Ω	M17/47-RG114	0.85	4.29	0.239
	M17/208	0.83	4.29	0.233

How to Double a Line's Impedance

Unbalanced Configuration

Use equal line lengths.
Keep lines spaced several diameters apart.
Use ferrite beads along both shields.

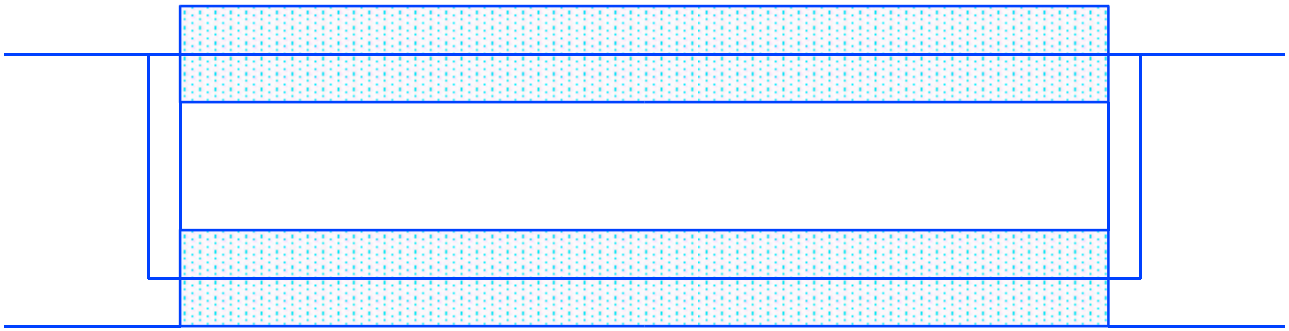


$$Z_0' = 2Z_0$$

How to Halve a Line's Impedance

Unbalanced Configuration

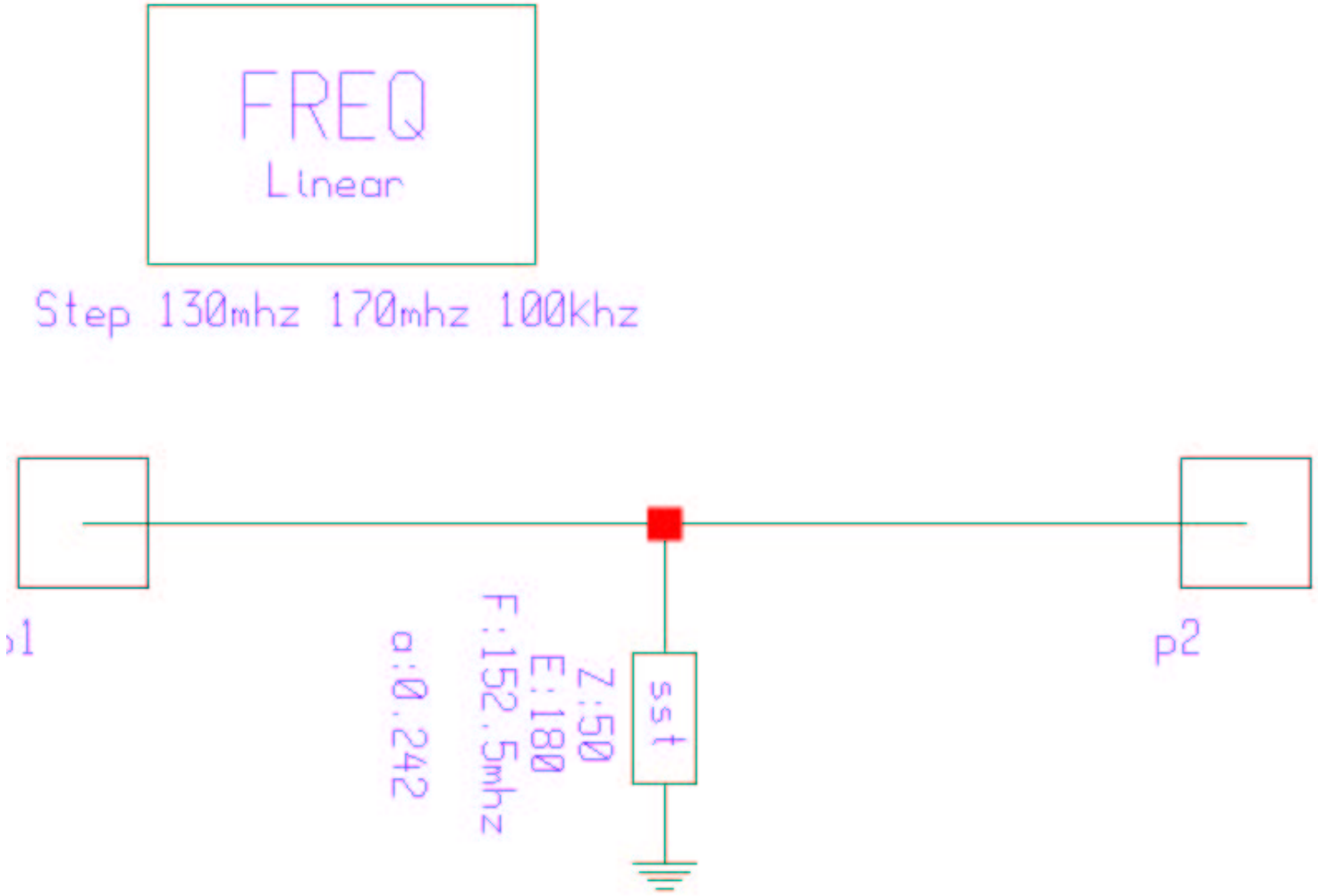
Use equal line lengths.
OK if shields touch.



$$Z_o' = \frac{Z_o}{2}$$

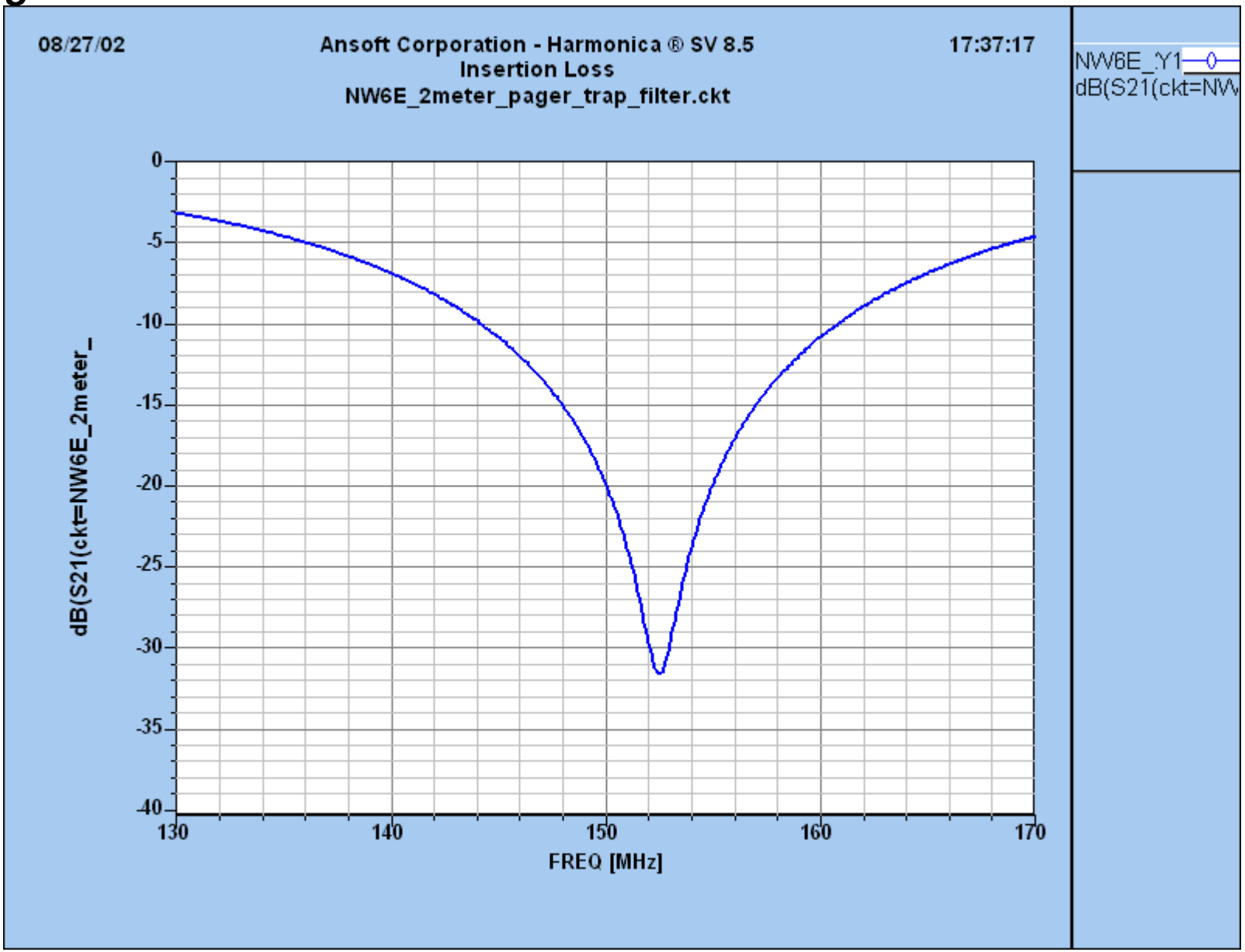
Initial Attempt: The Classic Trap Filter

Half-Wavelength Shorted Stub in Shunt



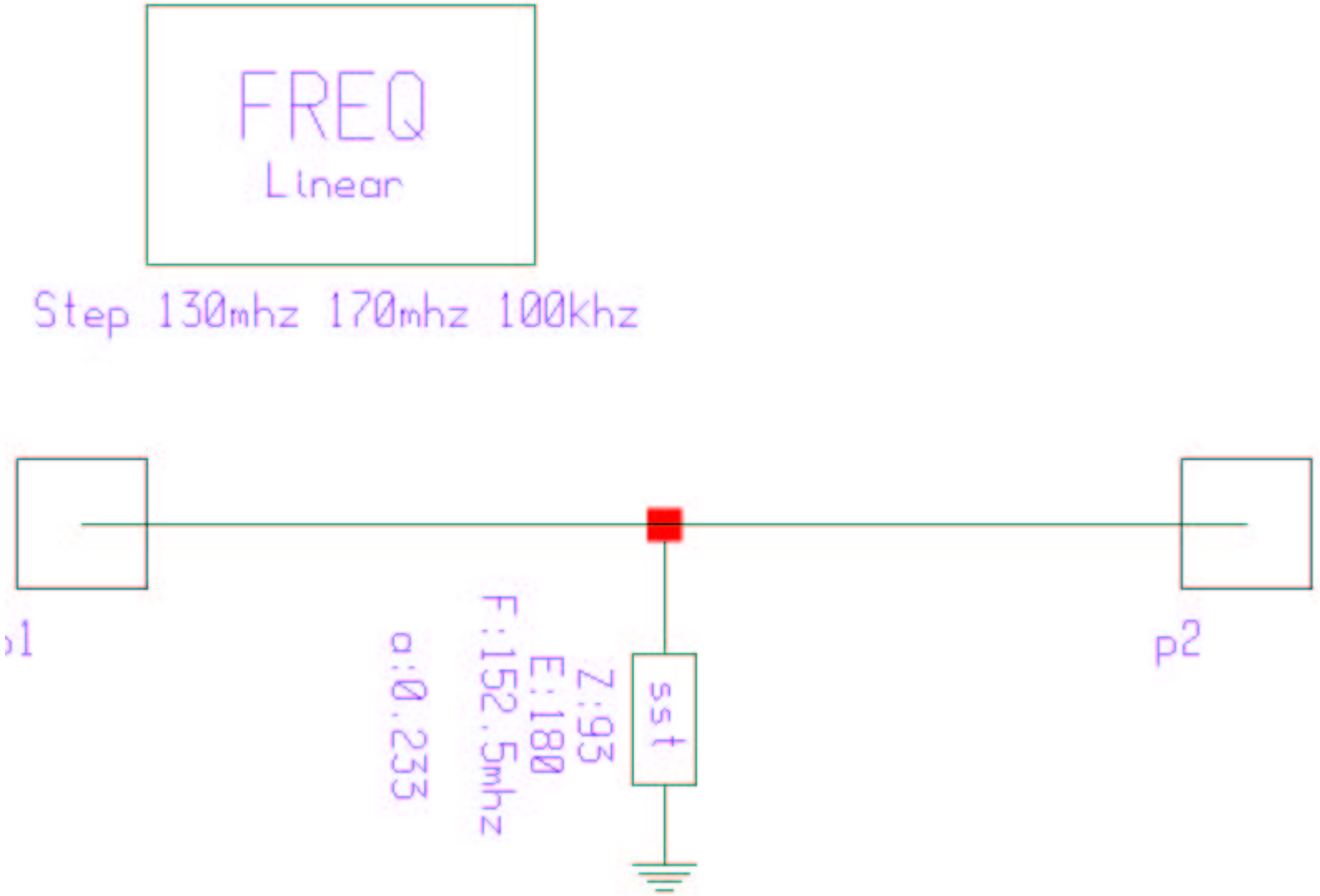
Good Notch Depth

But High Insertion Loss in 2-Meter Band!



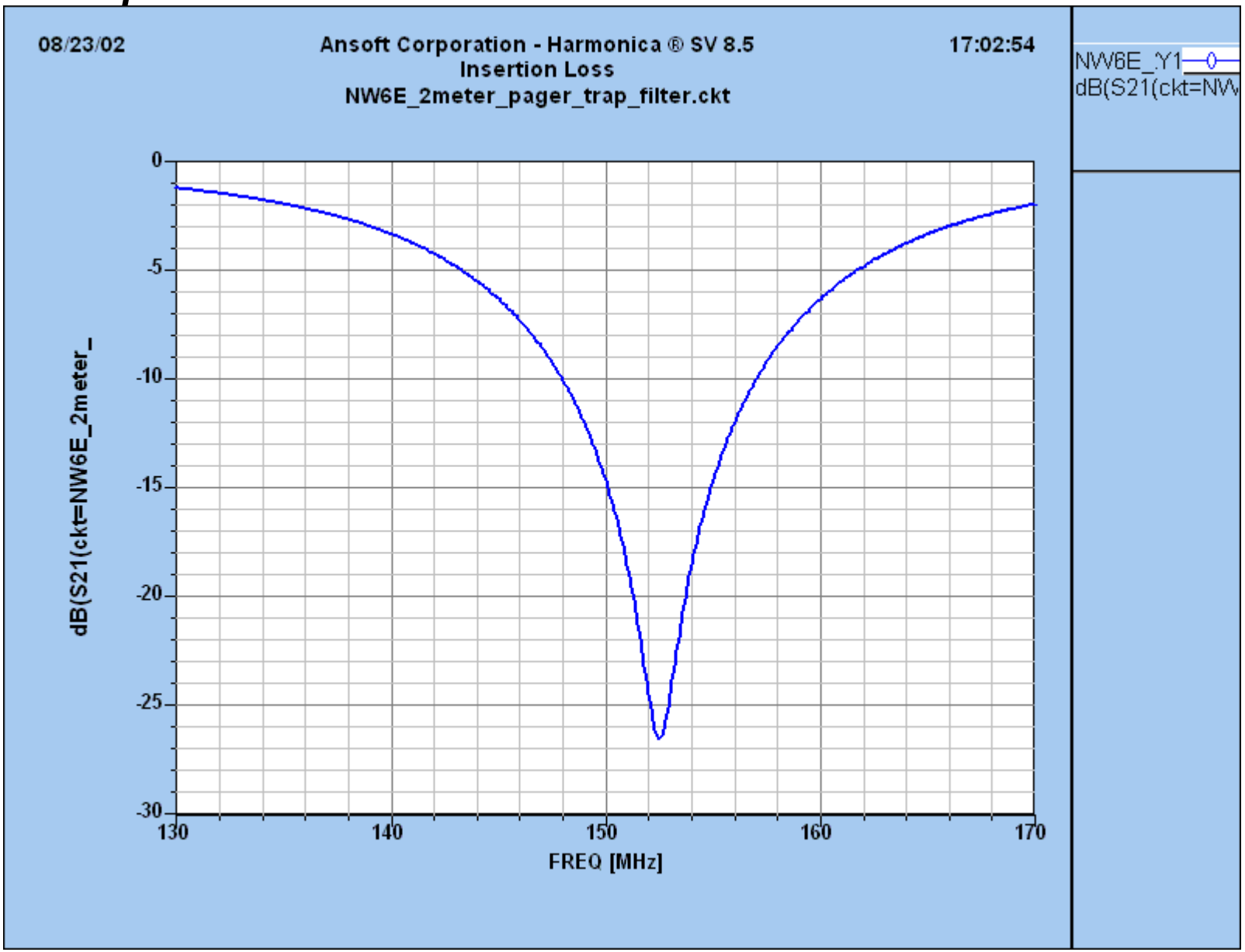
K6OIK's First Modification

Change Stub to RG62 High-Impedance Coax



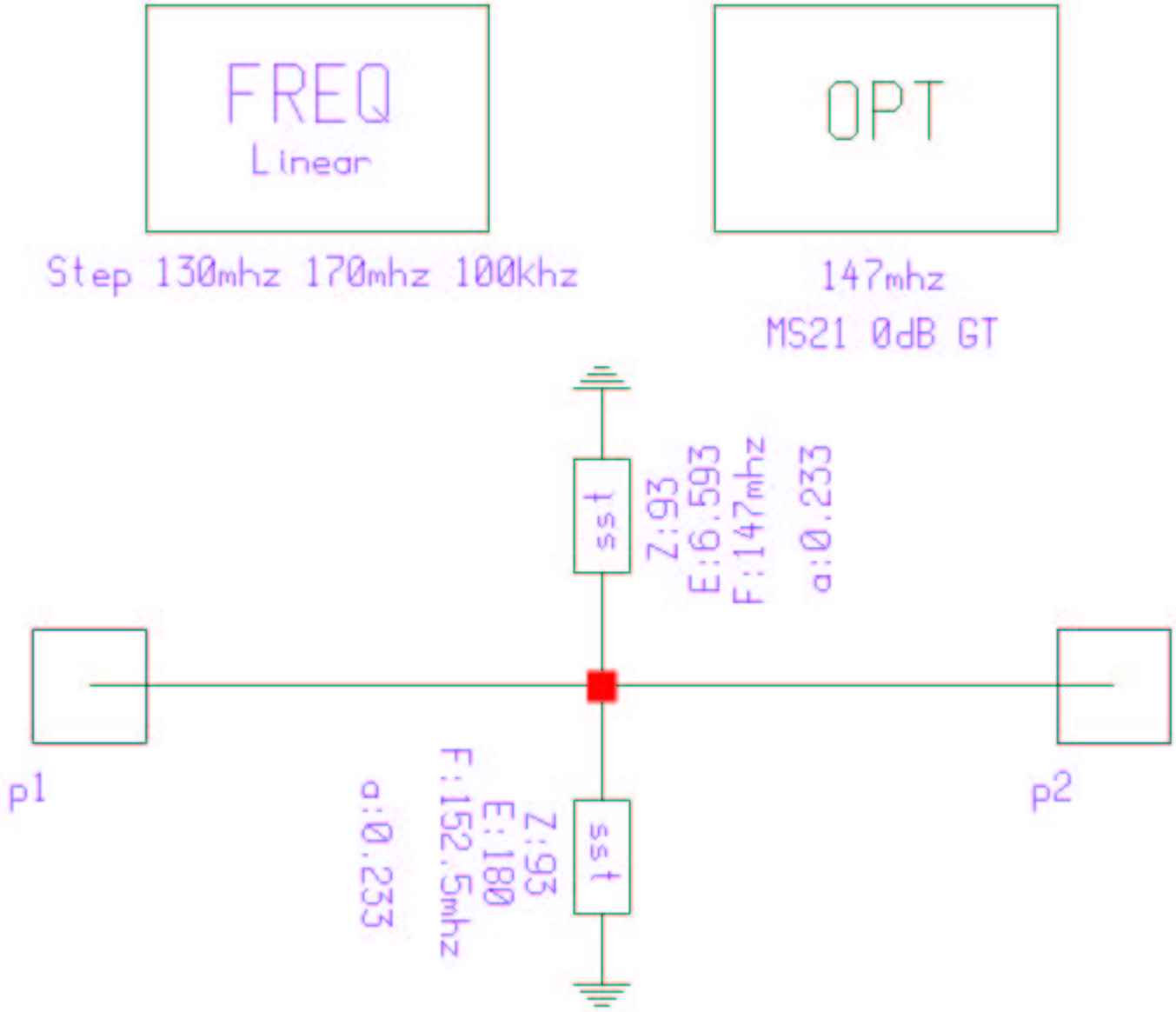
Reduced Insertion Loss in 2-Meter Band

But More Improvement Needed!



K6OIK's Second Modification

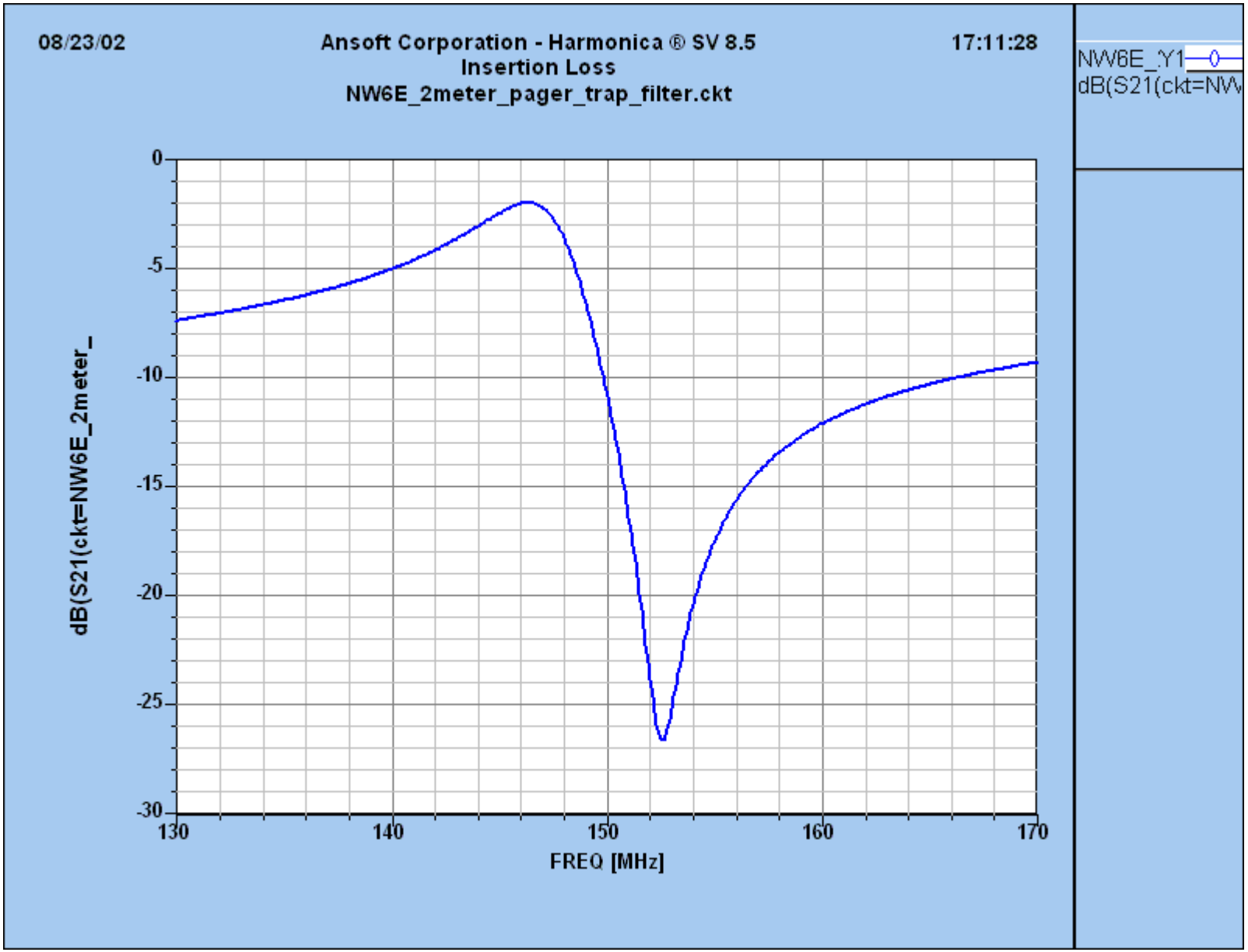
Second Stub Peaks 2-Meter Response via Inductance



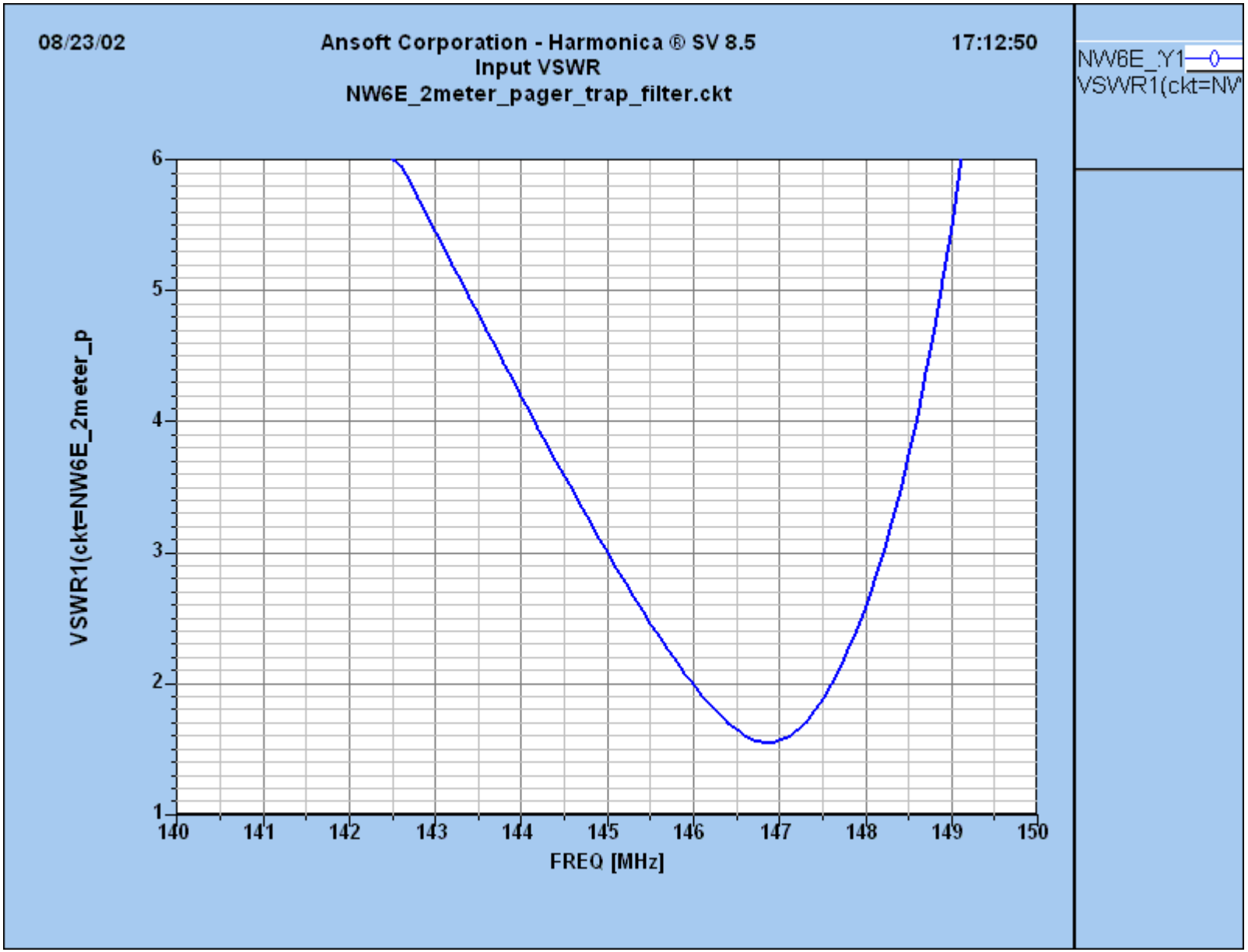
How It Works

- ***Notch frequency is above pass frequency***
- ***Primary rejection stub acts like a series resonant circuit at the notch frequency and has capacitive reactance at the lower pass frequency***
- ***Second stub in parallel with primary stub provides inductive reactance at the pass frequency and resonates with the capacitive reactance of primary stub***
- ***The combination acts like a parallel resonant circuit at the pass frequency, i.e. high shunt impedance***
- ***Notch depth and insertion loss at pass frequency are limited only by line losses of stubs***

Frequency Response of Two-Stub Filter

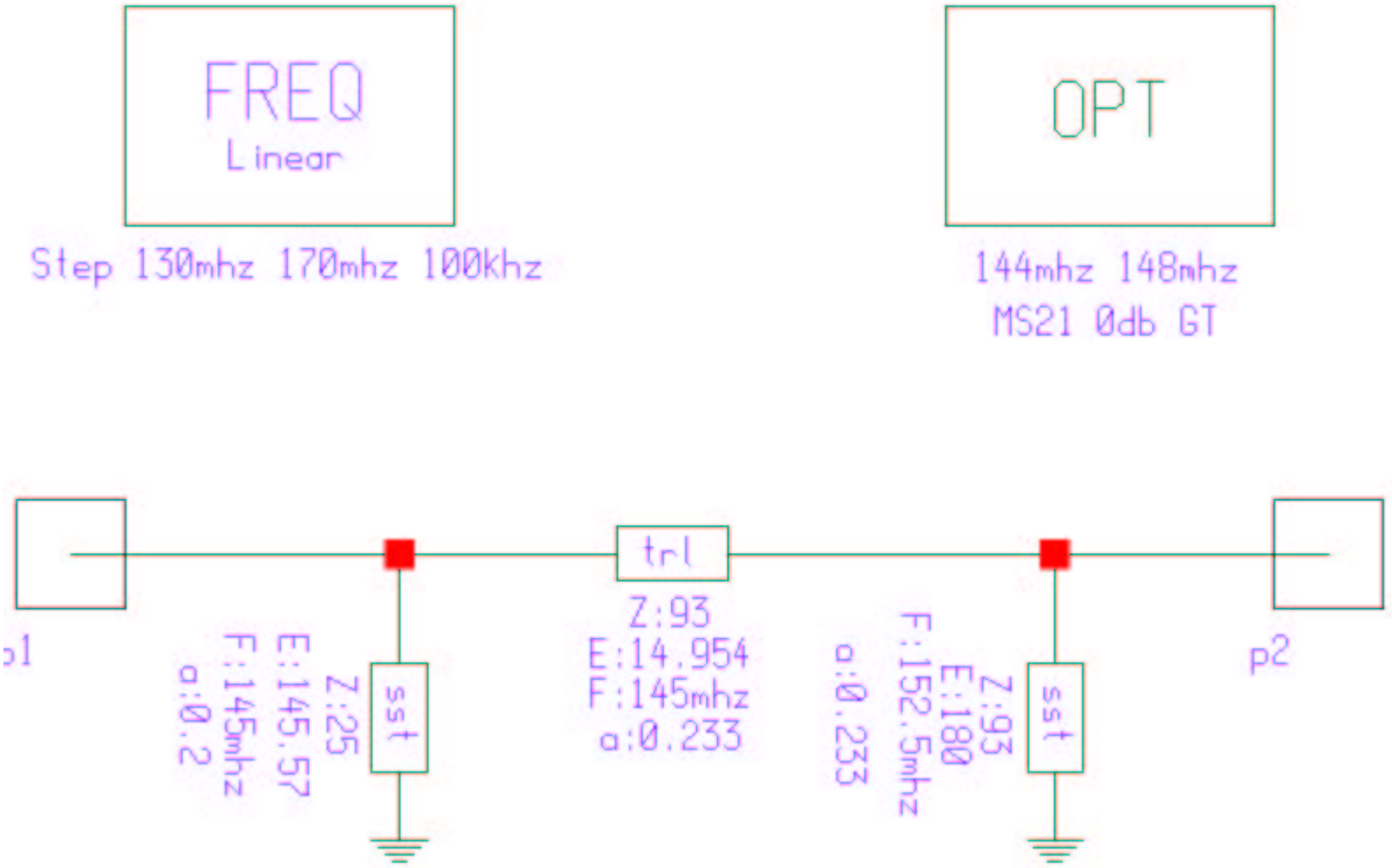


Input VSWR of Two-Stub Filter

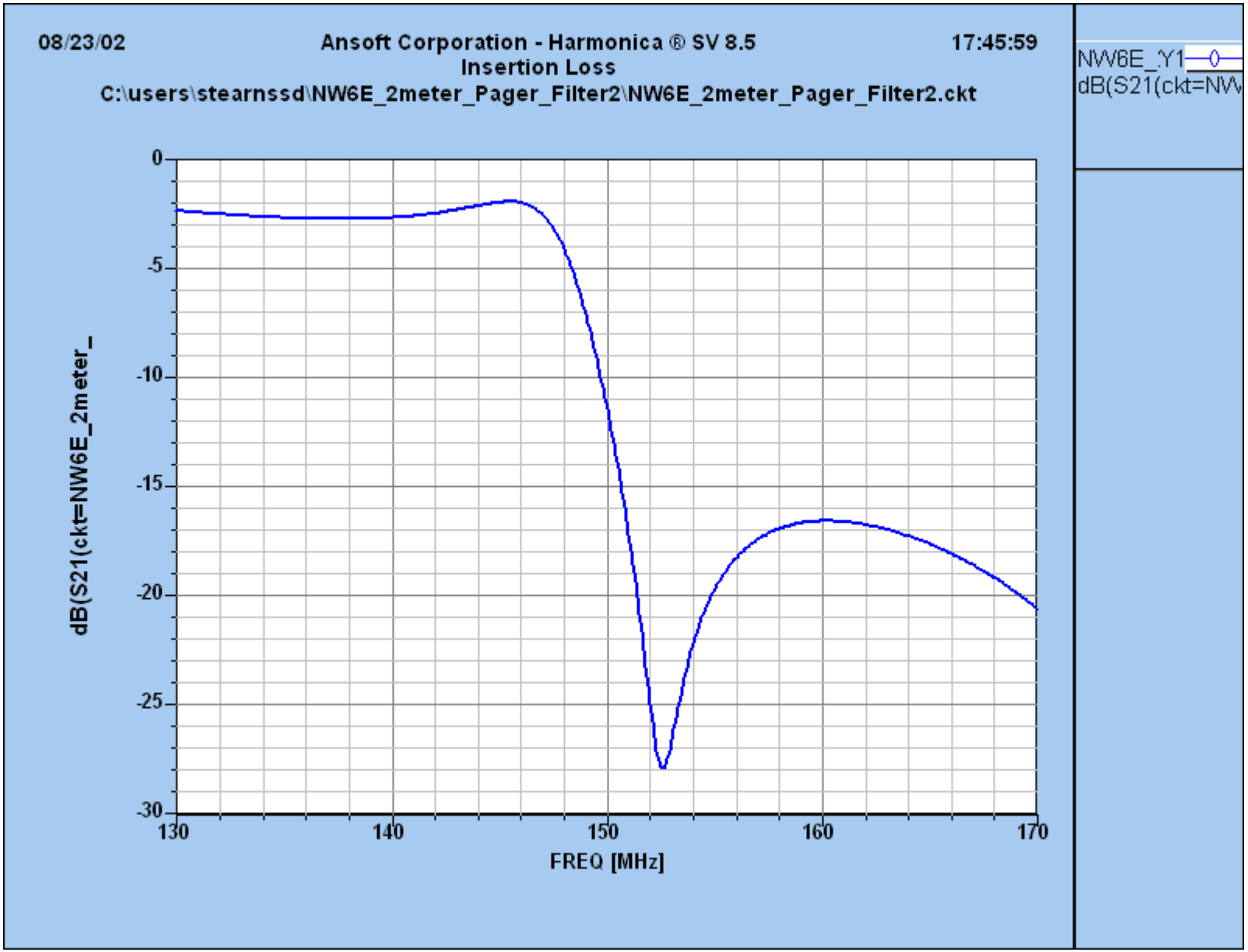


K6OIK's Third Modification

Transmission Line between Stubs Gives LPF Response



Insertion Loss of Improved Two-Stub Filter



Input VSWR of Improved Two-Stub Filter