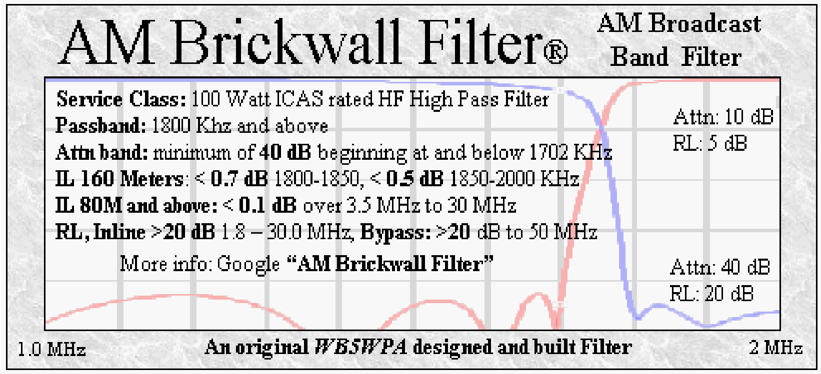
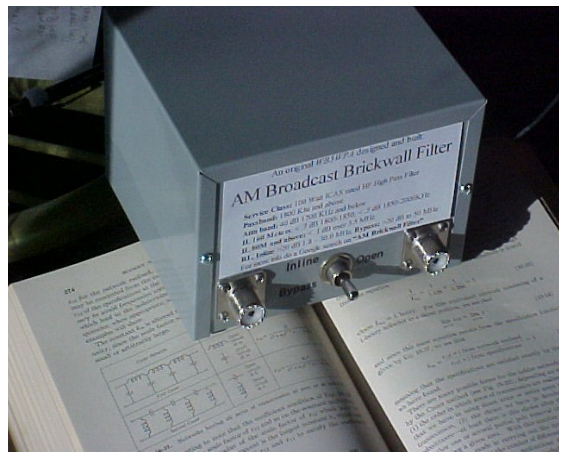
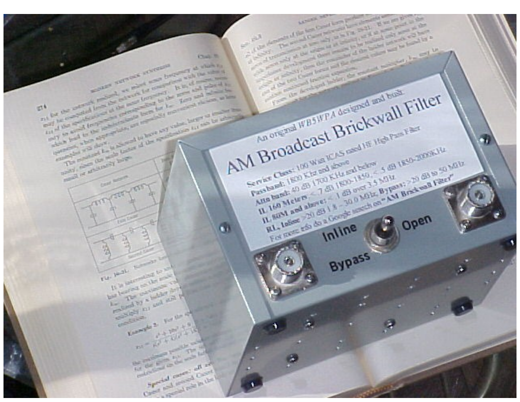


Purpose: This document details the design and performance of the *North Texas AM BrickWall Filter*. Various response plots, the schematic (showing parts values) and a *SPICE* simulation are presented; SPICE simulation is a must in a product of this kind because 'swept simulations' from *linear simulators* (like Agilent's, EESOF's *Touchstone* or *RFSIM99*) while yielding the shape and characteristics of the filter say nothing about the *voltages and currents* various components will be exposed to in operation when transmitting through the filter. At the lower band edge some of these quantities *can easily exceed* the ratings of components selected for use in this filter.



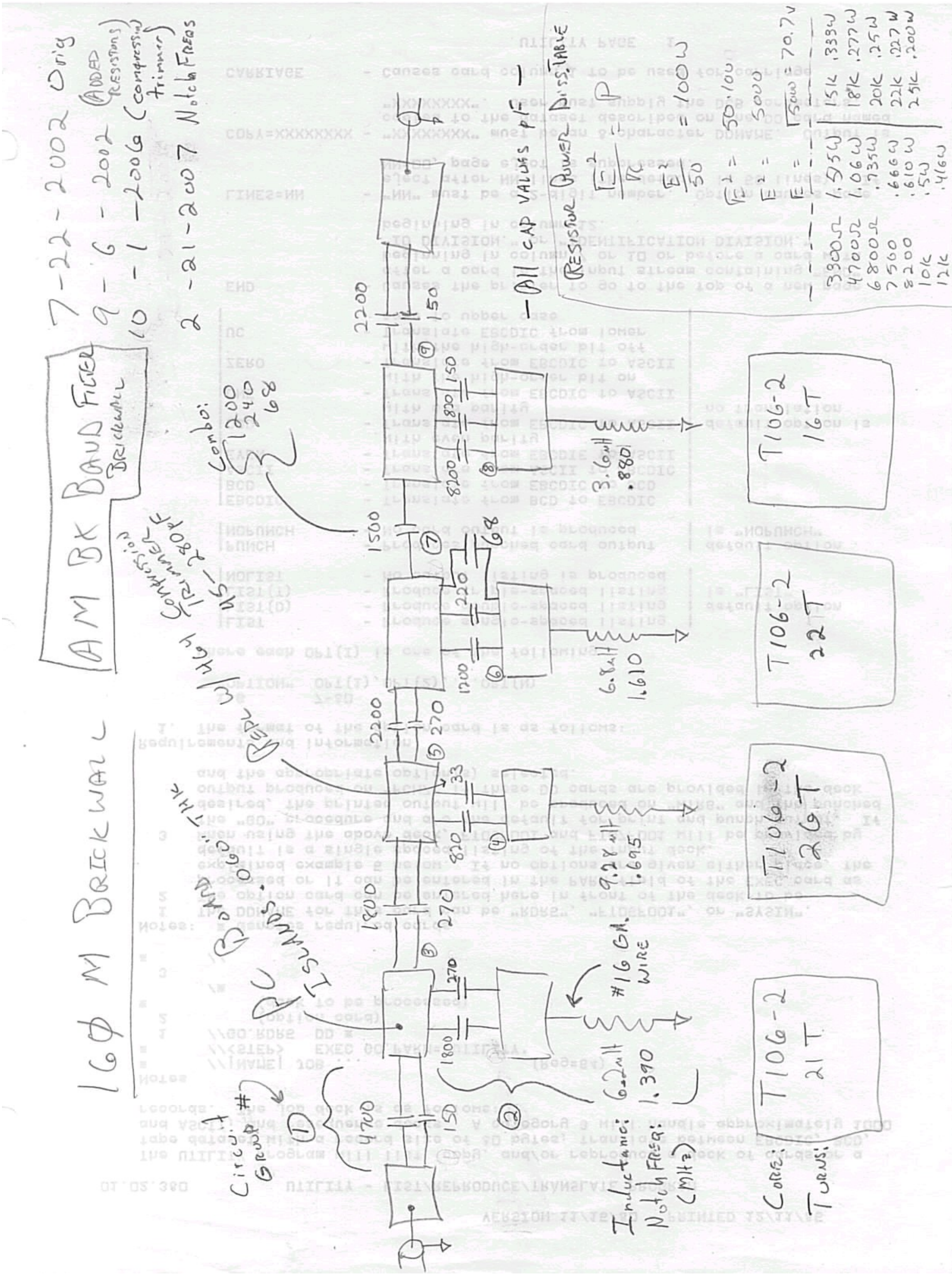
Background: This filter was an outgrowth from a request from a friend who experienced interference from a close-by 1700 MHz AM Broadcast station here in the North Texas area. Initially this station's COL (City Of License) was Sherman, but it was in the last few years 'moved in' to the North Texas area and it's COL changed to Richardson (the nighttime location was the only physical change that actually took place, the daytime 10,000 Watt site remains the same.)

Performance expectations have have been exceeded with this design; I and others have been thrilled with its effectiveness at eliminating AM Broadcast-Band interference.

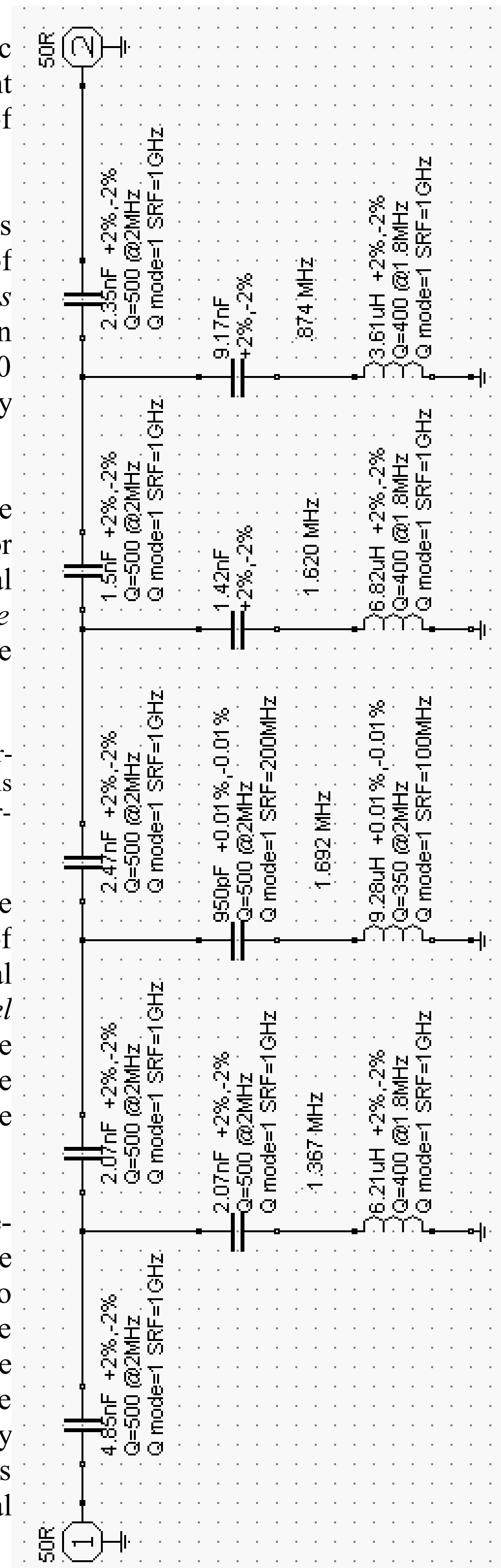


Contents:

Schematic and parts values; the 'as built' schematic for the prototypes:



Shown to the right is a screen capture of the schematic as entered into RFSIM99. The nominal component values are shown along with the 'notch' of frequency of each series tuned section.



While a linear simulation program like RFSIM99 is fully capable of calculating the frequency response of this filter, RFSIM99 does not give *parametric values* of the currents and voltages seen by each element in the circuit when the filter is in use (at say, the 100 Watt input power level at the most *critical* frequency of 1.8 MHz).

In a filter designed out of necessity to operate as close to various component's upper 'ratings' (voltage for caps, current or magnetic saturation for toroidal inductors) it is important to know the *worst-case operating parameters* and make wise, cost effective decisions in the choice of components.

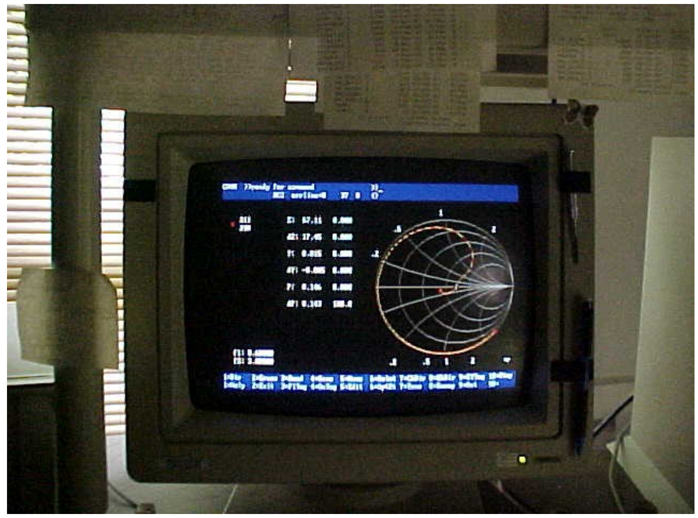
Side note: For competitive cost reasons no one pays for 10x over-design margin components in a product when the competition is building what the market is willing to accept with only 1.2x over-design margin!

There are other factors or choices that affect the performance of this filter, such as the choice of physical material such as wire-size used in the toroidal inductors. Larger wire means more *copper in parallel* yielding lower series resistance and *RF losses* in the inductor; this is an important factor even though one may be talking about twenty (20) inches of 16 guage wire.

Other physical factors such as the amount of wire-surface exposed to air; smaller guage wire wound close to the toroid and glued to it results in the wire acting to 'heat' the toroidal core along with heat generated by the intrinsic *magnetic core losses* seen in the toroid. The use of somewhat loosely-wound 16 guage wire on the toroid core allows *direct cooling* of the wire by immersion in air as opposed to when that wire is tightly wound around (and cemented to) the toroidal core.

Swept Modeled Response

Design/simulation/optimization pursuant to construction of the first prototype was performed on a DOS version of EESOF on a 33 MHz 386 Intel PC with the required *Numeric Co-processor* (an option in the early days of the PC and often required for certain high-performance engineering software packages). Seen to the right is an S11 plot shown on a Smith Chart in Touchstone.

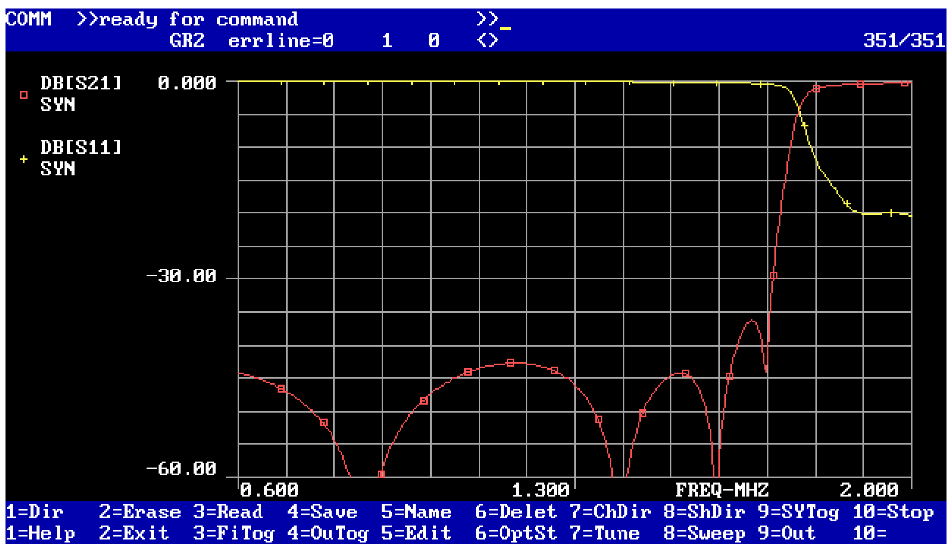


The filter started out life as simulation what-if using EESOF's ESYN. I specified, for design, a high-pass Elliptical filter, specifying stopband, passband, ripple and insertion loss and # of poles. Designs using 3, 4 and 5 poles were generated using ESYN then simulated with Touchstone; the best result by far considering all trade-offs was the 4 stopband-pole design.

Modeled S21 (Thru Loss) and S11 (Return Loss) performance in Touchstone

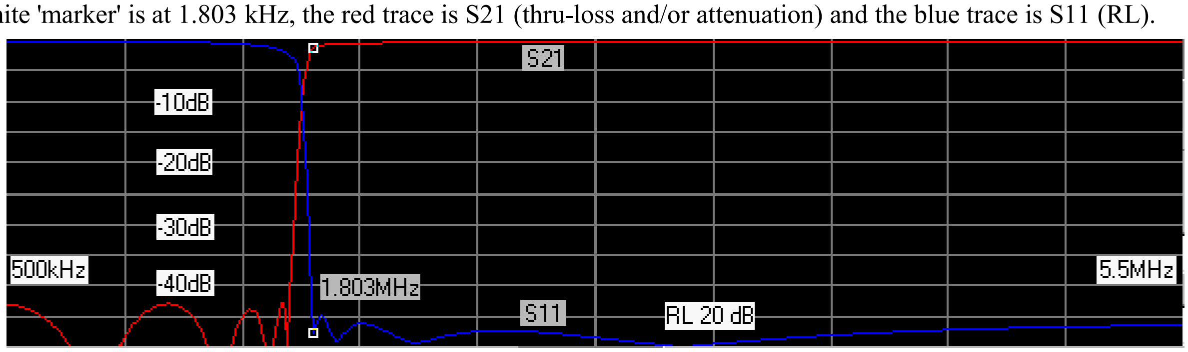
The S21 plot to the right depicts the thru-loss; note how the attenuation 'picks up' below 1.800 MHz.

The S11 on the plot depicts the quality of the 'match' to 50 Ohms; RL (S11) shows around 20 dB in this plot. Modeled performance actually is a little pessimistic compared to actual filter's performance.



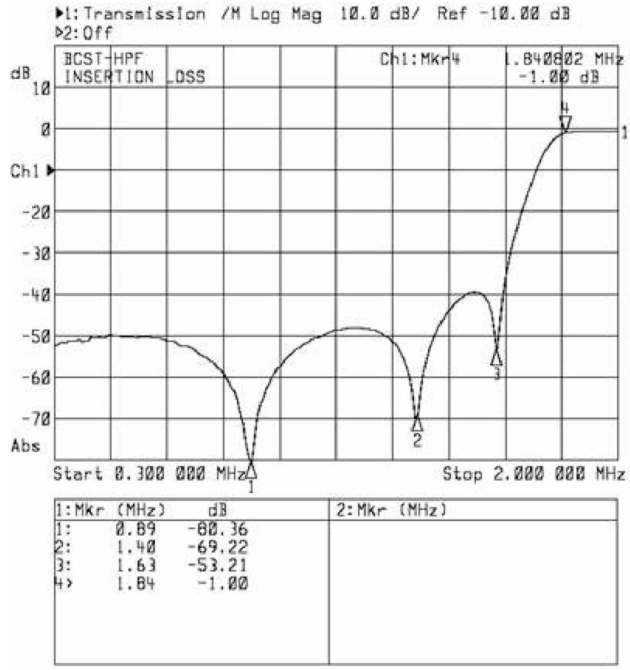
Modeled S21 and S11 performance in RFSIM99

I edited a screen capture of the RFSIM99 response and added the various value tags in the image below. The square white 'marker' is at 1.803 kHz, the red trace is S21 (thru-loss and/or attenuation) and the blue trace is S11 (RL).



Engineering Performance Measurements

Network Analyzer sweep performance



The actual insertion loss in-band measures less on later versions of the AM BrickWall Filter than on earlier versions. I experimented early one with some hand-wound air-core coils about 2 inches in diameter. The amount of copper in such a coil adversely affected 'Q' compared to the much-reduced amount of wire needed when using a toroidoil-core inductor *even though* magnetic core losses on toroidal inductors is higher than for air-core coils .

Manual Bench Performance

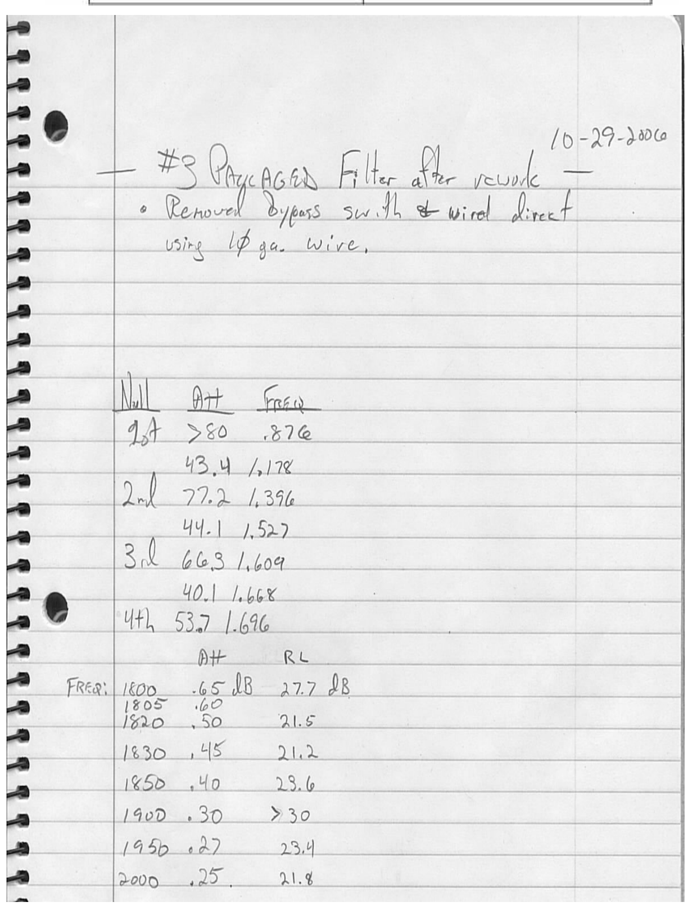
Rejection: Minimum 40 dB

Attenuation notches as follows:

0.870 MHz	>80 dB
1.390 MHz	77 dB
1.609 MHz	66 dB
1.696 MHz	53 dB

Insertion loss (IL) in-band:

1.800 MHz	0.65 dB
1.805 MHz	0.60 dB
1.820 MHz	0.50 dB
1.850 MHz	0.40 dB
1.900 MHz	0.30 dB

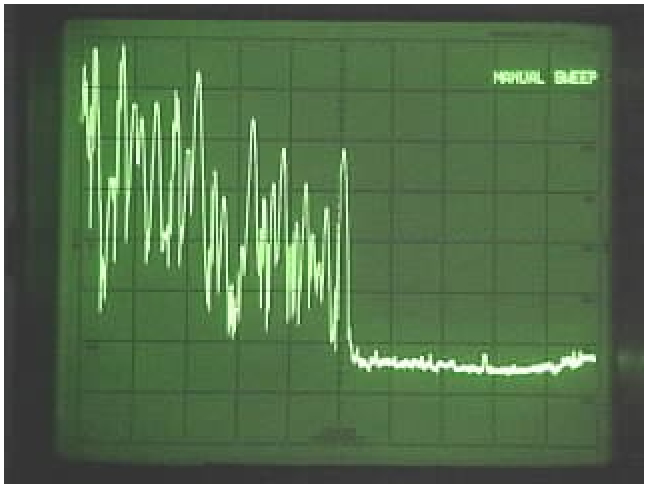


Test equipment used to take the data for the measurements shown on the right:

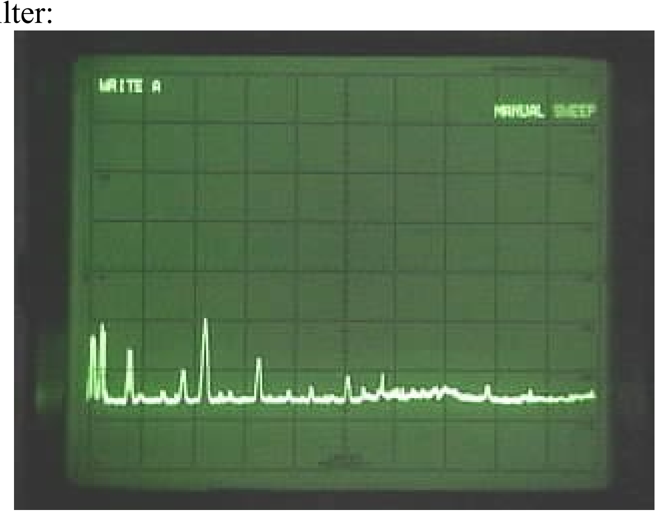
1. HP 8640B Signal Generator
2. HP 8405A Vector Voltmeter
3. Narda Model 3020 Bi-Directional Coupler (used for RL msmts)
4. Misc. Pads (e.g. on output of sig gen)
5. VVM RF Tee adapters

Performance seen in use

Without AM Brickwall Filter:



With AM Brickwall Filter:



The center frequency for the two pictures above is 1.7 MHz. Insertion loss in the 160 Meter band is less than .8 dB at the very low end of the band (1.8 MHz) and less than .5 dB at the high end (2.0 MHz) of the band.

For the above pictures an active antenna was used as the off-air signal source. An active antenna is a fairly 'flat' across several octaves in frequency and therefore a good source to demonstrate the response of this filter.

This particular active antenna itself is relatively immune - contributes relatively little to 'intermodulation' products - which result when the strong signals from numerous AM Broadcast sites in and around the DFW area which can 'mix' in a receiver's front end. When a Wadely-Loop tuned Radio Shack DX-302 is used with with this active antenna the 20 dB RF attenuator 'pad' must be switched-in when near the AM Broacast Band - unless the AM Brickwall Filter is placed in-line .

SPICE Simulation Results

SPICE result output:

```
 7-21-2002 File: HPE4SW29.txt

Comments from .cir file:
* 07-22-2002 FILT02 LOOK AT CAP CURRENTS
* 7-20-2002 GOT TO RUN IN RSPICE95
*            TRANSFER CURVE LOOKS A LOT LIKE TOUCHSTONE CURVE!

Test conditions:

 Source: 200 VPk AC source in series with 50R0 (VIN  1 0  AC=200)
 Term:   50R0.

Test results:
```

Inband Voltages, shunt-branch caps

FREQ	V(11)	V(200)	V(300)	V(400)	VDB(6)
>1.800E+06,	1.226E+02	1.988E+02	>5.423E+02	3.167E+02	3.879E+01
1.820E+06,	1.181E+02	1.779E+02	4.548E+02	2.921E+02	3.915E+01
1.840E+06,	1.150E+02	1.605E+02	3.995E+02	2.672E+02	3.934E+01
1.860E+06,	1.113E+02	1.444E+02	3.608E+02	2.448E+02	3.946E+01
1.880E+06,	1.071E+02	1.302E+02	3.305E+02	2.251E+02	3.953E+01
1.900E+06,	1.029E+02	1.186E+02	3.050E+02	2.079E+02	3.959E+01
1.920E+06,	9.914E+01	1.094E+02	2.827E+02	1.930E+02	3.962E+01
1.940E+06,	9.618E+01	1.024E+02	2.629E+02	1.800E+02	3.965E+01
1.960E+06,	9.405E+01	9.701E+01	2.453E+02	1.687E+02	3.967E+01
1.980E+06,	9.268E+01	9.280E+01	2.294E+02	1.587E+02	3.969E+01
2.000E+06,	9.196E+01	8.939E+01	2.151E+02	1.500E+02	3.971E+01

Inband Currents, shunt-branch caps

FREQ	V(11)	I(VM11)	I(VM12)	I(VM13)	I(VM14)
>1.800E+06,	1.226E+02	4.681E+00	>5.845E+00	5.069E+00	3.379E+00
1.820E+06,	1.181E+02	4.236E+00	4.956E+00	4.726E+00	3.444E+00
1.840E+06,	1.150E+02	3.863E+00	4.401E+00	4.371E+00	3.446E+00
1.860E+06,	1.113E+02	3.513E+00	4.019E+00	4.048E+00	3.423E+00
1.880E+06,	1.071E+02	3.203E+00	3.720E+00	3.763E+00	3.384E+00
1.900E+06,	1.029E+02	2.948E+00	3.470E+00	3.512E+00	3.338E+00
1.920E+06,	9.914E+01	2.749E+00	3.250E+00	3.294E+00	3.288E+00
1.940E+06,	9.618E+01	2.599E+00	3.054E+00	3.104E+00	3.236E+00
1.960E+06,	9.405E+01	2.487E+00	2.879E+00	2.939E+00	3.185E+00
1.980E+06,	9.268E+01	2.404E+00	2.720E+00	2.795E+00	3.135E+00
2.000E+06,	9.196E+01	2.339E+00	2.576E+00	2.667E+00	3.087E+00

Inband Currents, series caps

FREQ	I(VM1)	I(VM2)	I(VM3)	I(VM4)	I(VM5)
>1.800E+06,	1.577E+00	>4.184E+00	>3.495E+00	2.720E+00	1.741E+00
1.820E+06,	1.644E+00	>3.922E+00	>3.288E+00	2.779E+00	1.813E+00
1.840E+06,	1.695E+00	3.759E+00	3.102E+00	2.787E+00	1.853E+00
1.860E+06,	1.772E+00	3.604E+00	2.958E+00	2.776E+00	1.878E+00
1.880E+06,	1.865E+00	3.445E+00	2.849E+00	2.753E+00	1.895E+00
1.900E+06,	1.955E+00	3.287E+00	2.766E+00	2.724E+00	1.907E+00
1.920E+06,	2.030E+00	3.139E+00	2.705E+00	2.692E+00	1.915E+00
1.940E+06,	2.087E+00	3.007E+00	2.659E+00	2.660E+00	1.921E+00
1.960E+06,	2.126E+00	2.892E+00	2.624E+00	2.628E+00	1.926E+00
1.980E+06,	2.149E+00	2.796E+00	2.597E+00	2.598E+00	1.931E+00
2.000E+06,	2.160E+00	2.715E+00	2.575E+00	2.569E+00	1.935E+00

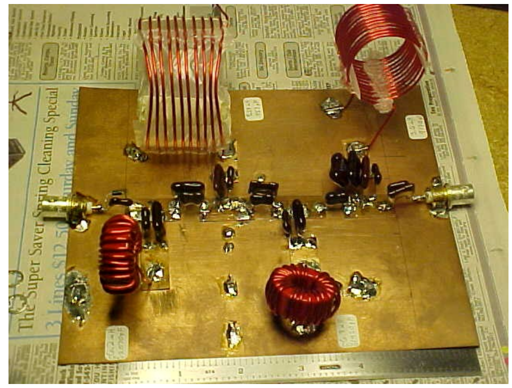
Notes: 1) Arrows next to measured values above denotes operation close to or over device current or voltage limits.
2) Numbers in parenthesis refer to SPICE nodes; refer to circuit description on next sheet for ckt definition.

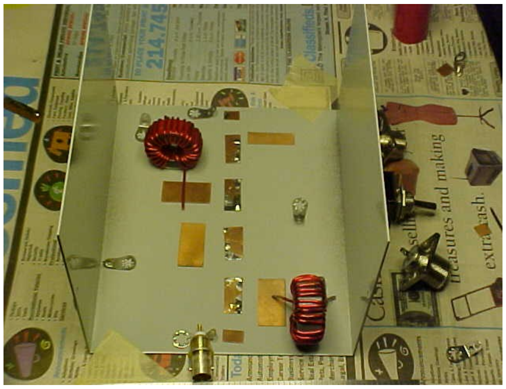
SPICE Circuit Topology:

```
HIGH PASS 160M FILTER

HPE4SW29

****     INPUT LISTING

**************************************************

* 7-20-2002 GOT TO RUN IN RSPICE95
* TRANSFER CURVE LOOKS A LOT LIKE TOUCHSTONE CURVE

VIN  1  0  AC=2
RS99 1  6  1000000           ; DC Return for SPICE
R1   1 11  50.15             ; Input termination Impedance (Nominally 50 Ohms)

                             ; ** Circuit Group 1 **
C1  11  2  4850P             ; Input cap, 4700 + 150 pF

                             ; ** Circuit Group 2 **
R11 2  20  0.23              ; DC Resistance of series cap and inductor
L11 20 200 6.270UH           ; Inductor
C11 200 0  2082P             ; Cap to gnd
R21 200 0  1000000           ; High value R used as DC Return for SPICE

                             ; ** Circuit Group 3 **
R2  2  21  0.15              ; Interstage cap DC Resistance
C2  21  3  2070P             ; Interstage cap value

                             ; ** Circuit Group 4 **
R12 3  30  0.550             ; DC Resistance of series cap and inductor
L12 30 300 9.230UH           ; Inductor
C12 300 0  953PF             ; Cap to gnd
R22 300 0  1000000           ; High value R used as DC Return for SPICE

R3  3  31  0.15              ; Interstage cap DC Resistance
C3  31  4  2470PF            ; Interstage cap value

R13 4  40  0.16              ; and so on ...
L13 40 400 7.050UH
C13 400 0  1415PF
R23 400 0  1000000

R4  4  41  0.15
C4  41  5  1500PF

R14 5  50  0.05
L14 50 500 3.709UH
C14 500 0  9170PF
R24 500 0  1000000

C5  5  61 2350PF
R5  61  6  .15
RT9 6   0   50               ; Output termination Impedance
```

Note: 'Circuit Group' numbers refer to circuit group numbers on schematic.

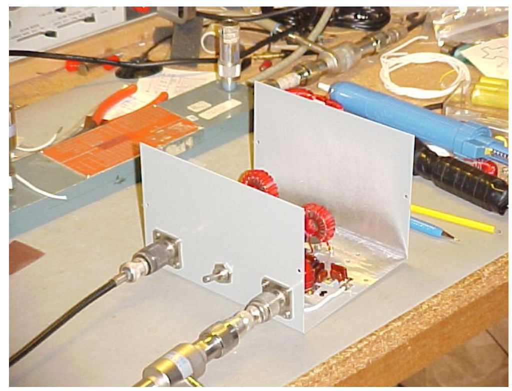
Early bread-board prototype using both air-core and ferrite-core inductors; BNC connectors soldered directly to the board can be see on left and right sides of board:

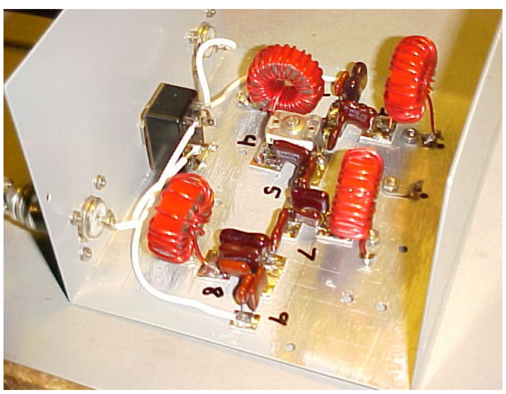




<--Prototype being laid out in Bud-box enclosure using PC board 'islands' for circuit connections

Bench testing – part of a Vector Voltmeter probe adapter can be seen in this picture as well as a dual-directional Narda coupler for RL tests --->





<--- A prototype with all ferrite-core toroids; this model has a bypass switch installed.

Transmit tests using a Kenwood TS-680s on 160M at 1.82 MHz to check component self-heating due to various losses including dielectric, wire (copper loss), and core loss: