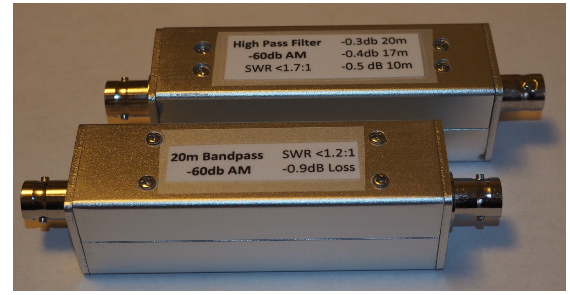
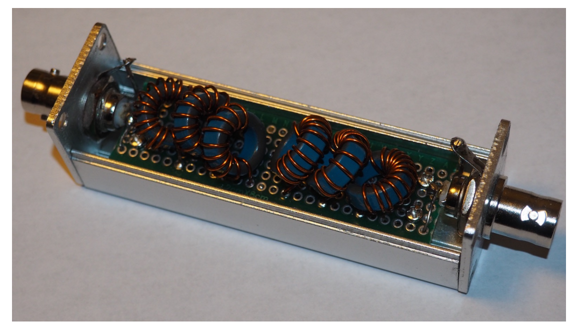
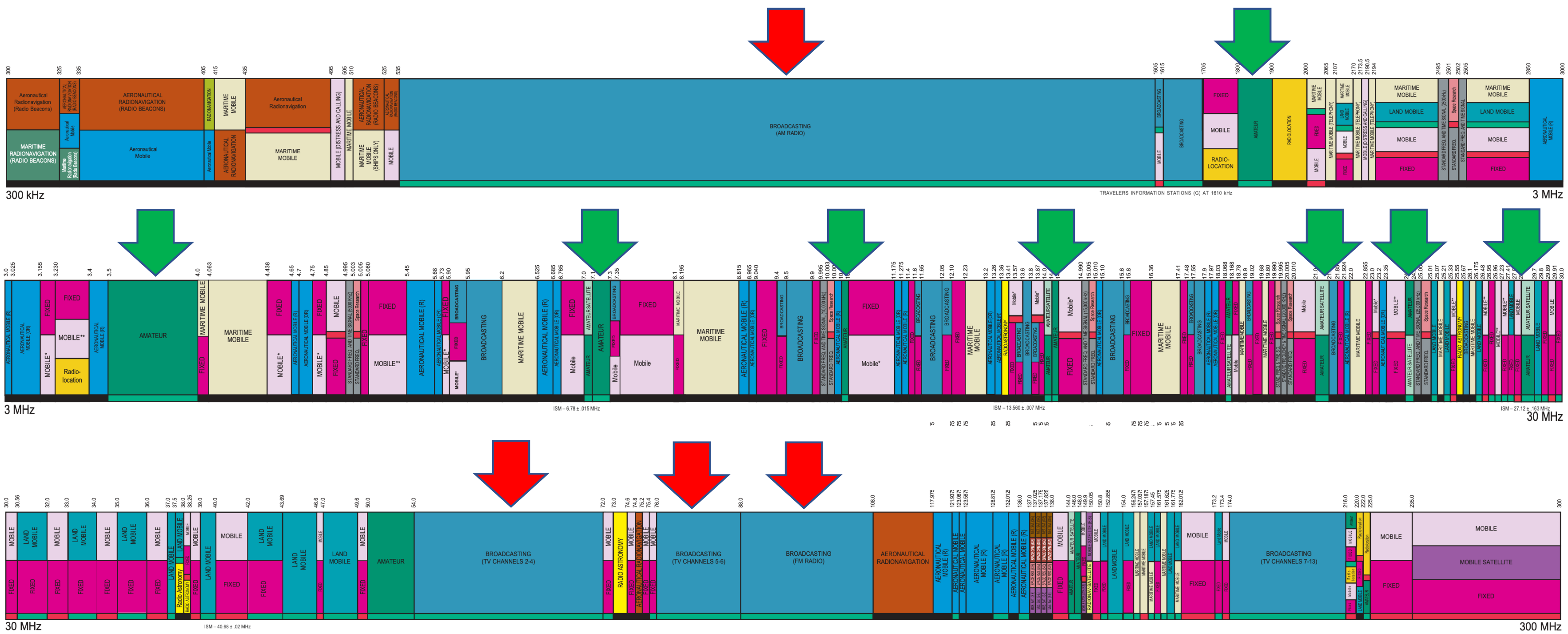


External Filters for Ham Radio

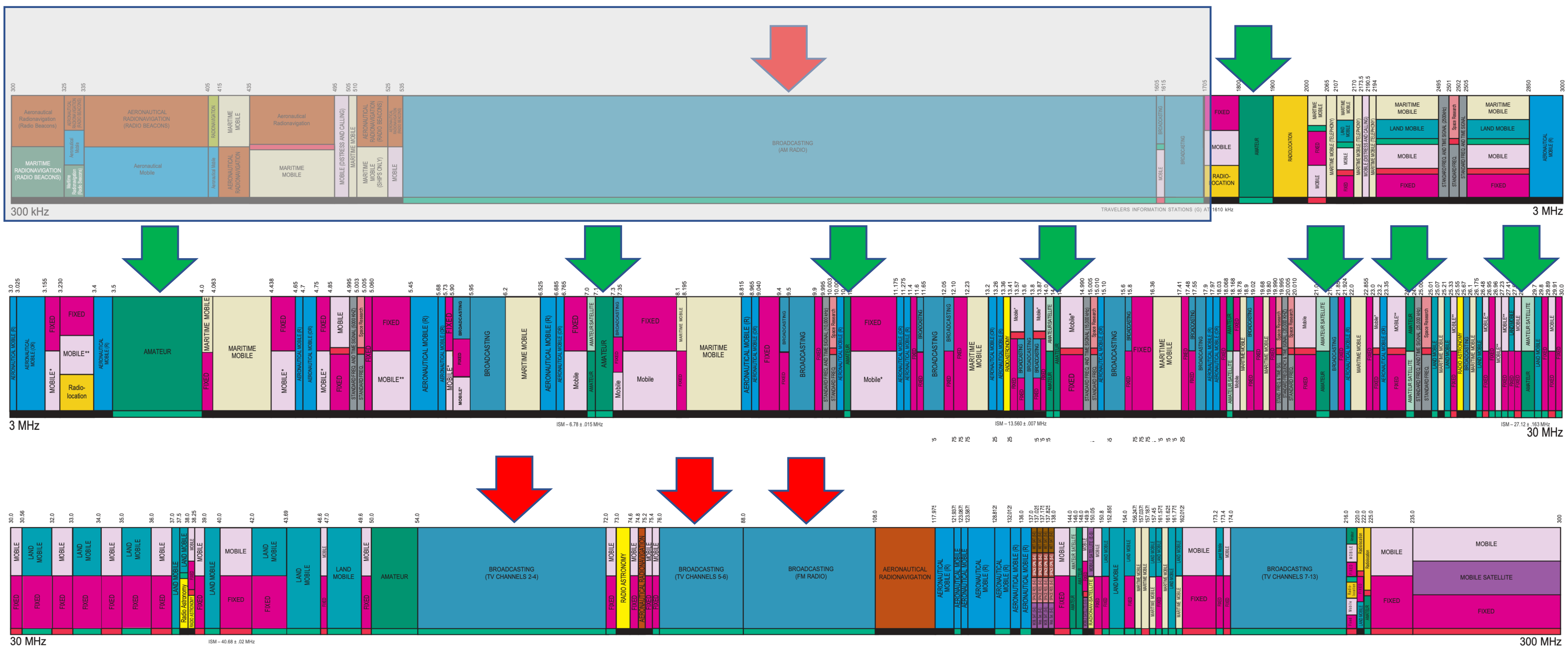
Dick Knight
N1OR



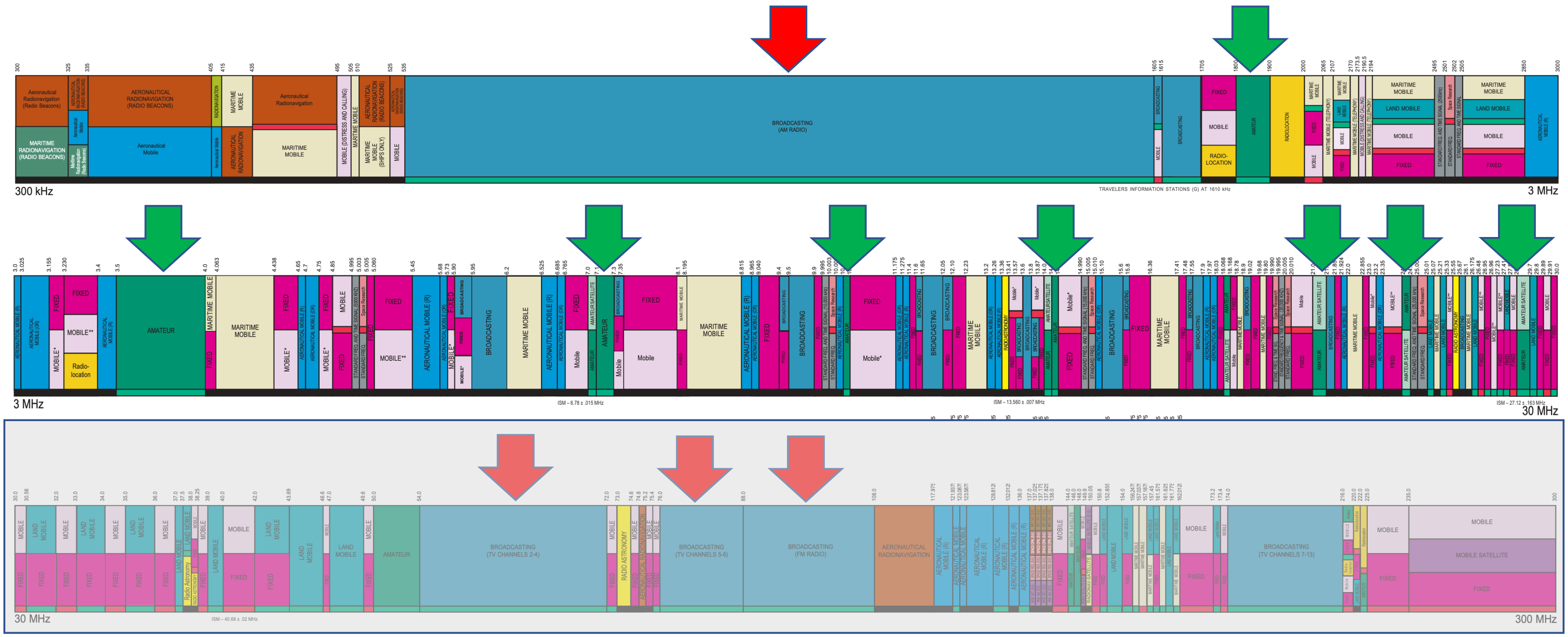
Filters for HF Ham Radio RF Interference



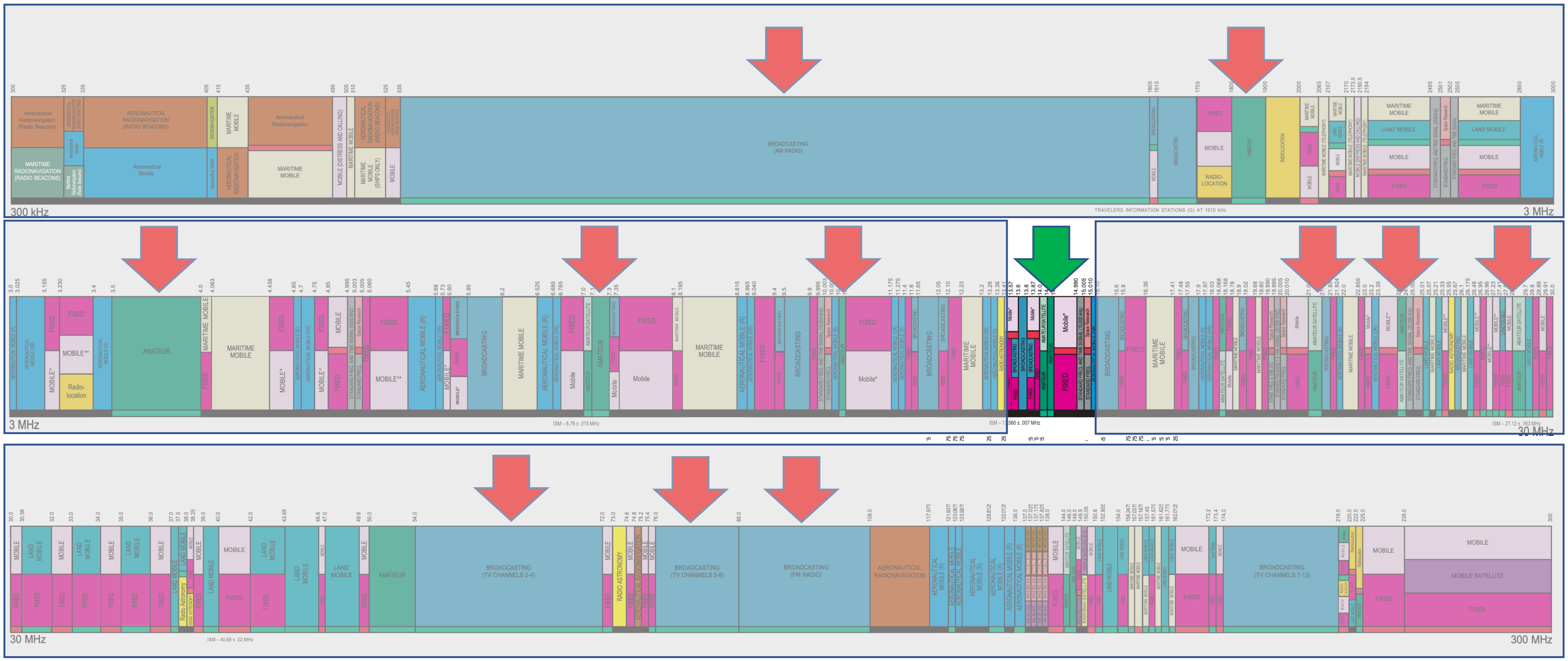
“High Pass” Filter for AM Radio Interference



“Low Pass” Filter for FM Radio and TV Interference



“Band Pass” Filter for Nearby Ham Radio Interference

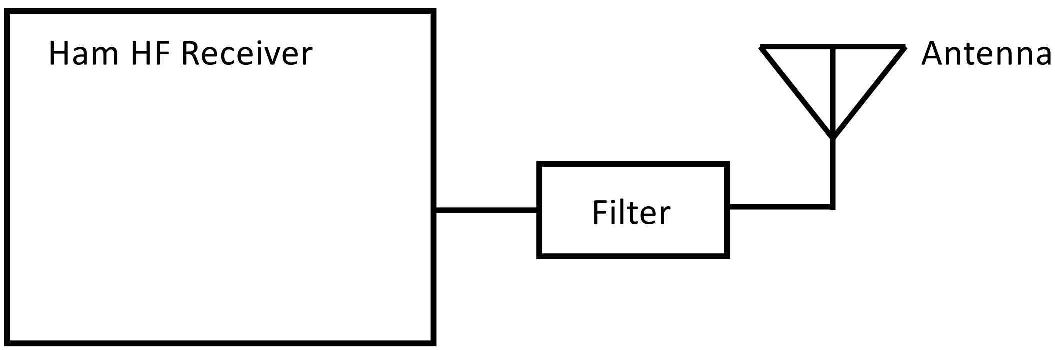


A Filter might be useful if …

- A powerful AM radio transmitter is near your location …
- A TV station or FM radio transmitter is near your location …
- Ham's are operating near each other (ex: Field Day)
- You have a Software Defined Radio

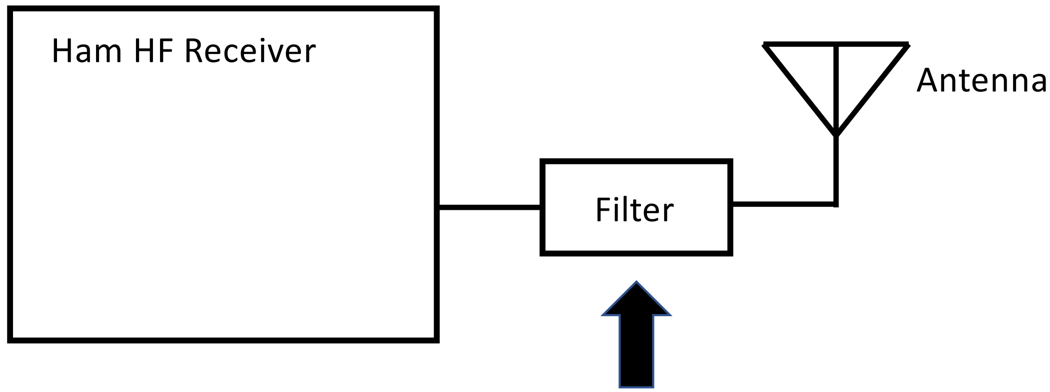
EXAMPLE: KD7DTS and KN6PHZ enjoy both operating highly portable QRP SDR rigs from local parks and peaks that are often also home to commercial AM or FM radio, TV or other transmitters. And they often operate at the same time on adjacent bands.

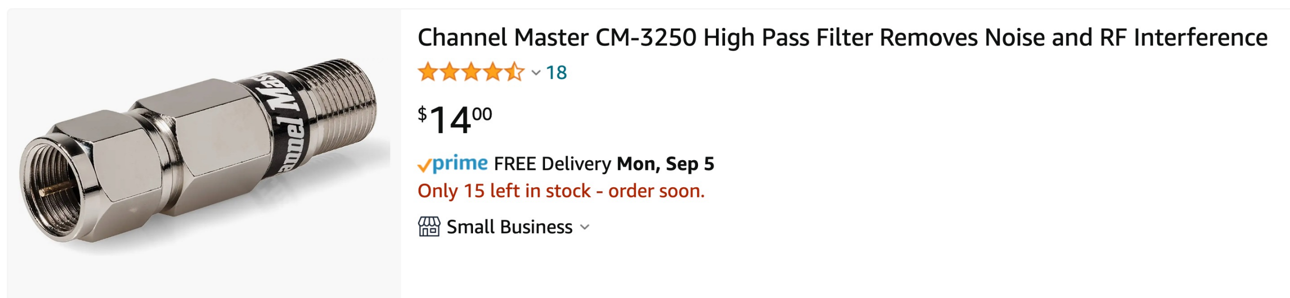
Adding an external filter to a radio ...



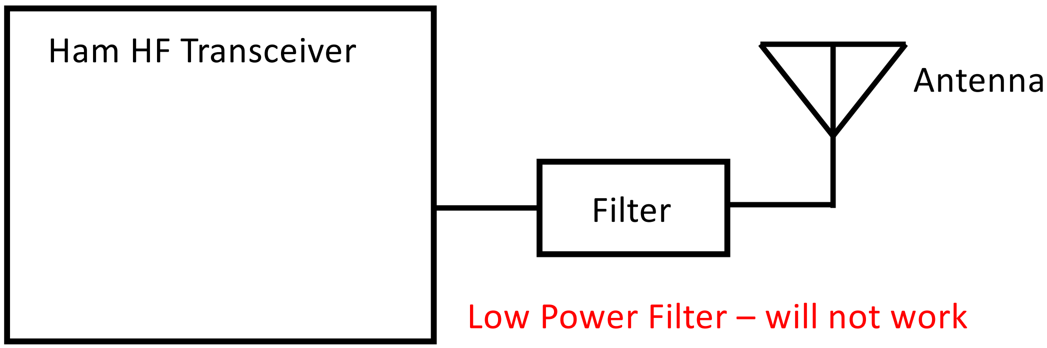
seems easy, ...

Adding an external filter to a radio

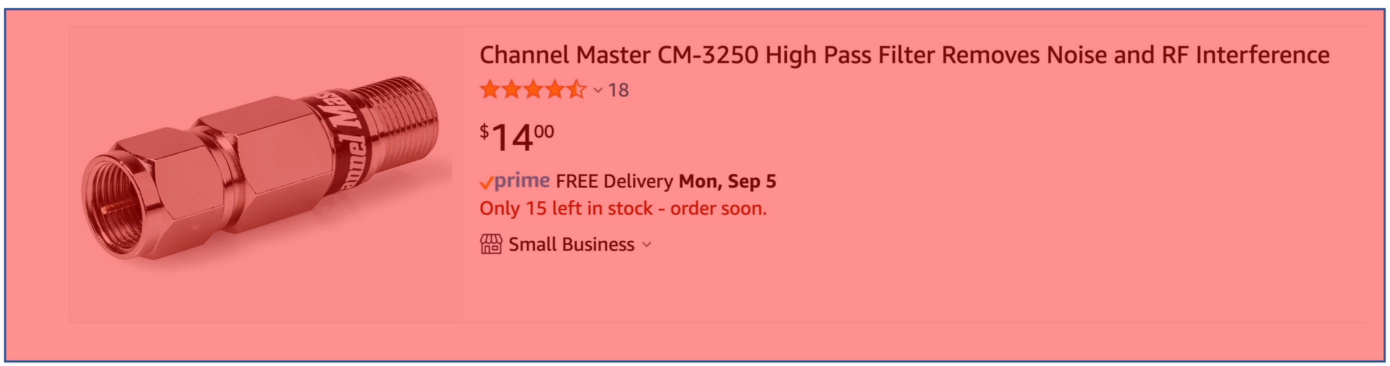




Adding an external filter to a ham transceiver

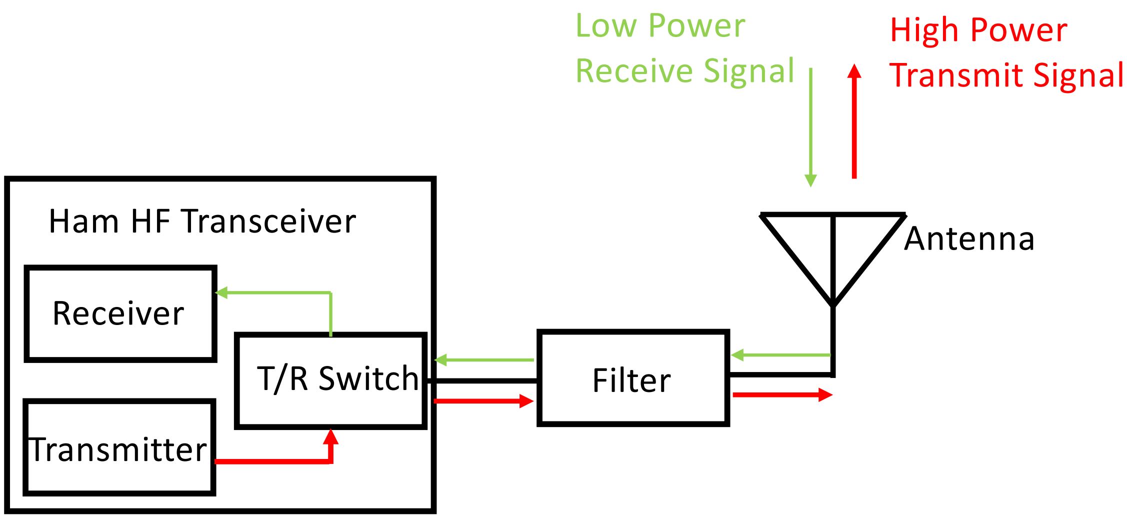


Low Power Filter – will not work



These inexpensive filters are designed for use with low power receivers!

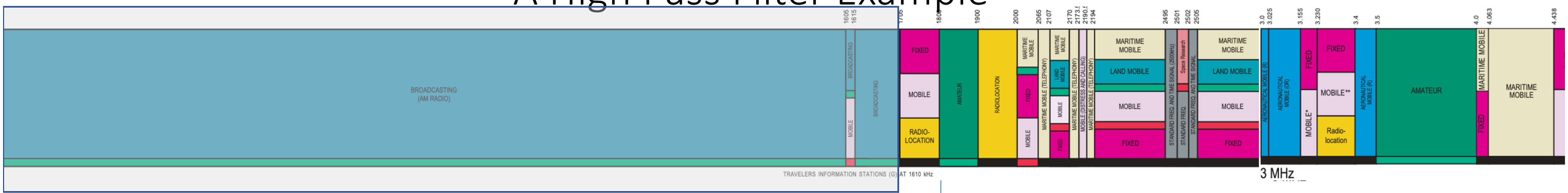
Adding an external filter to a ham transceiver

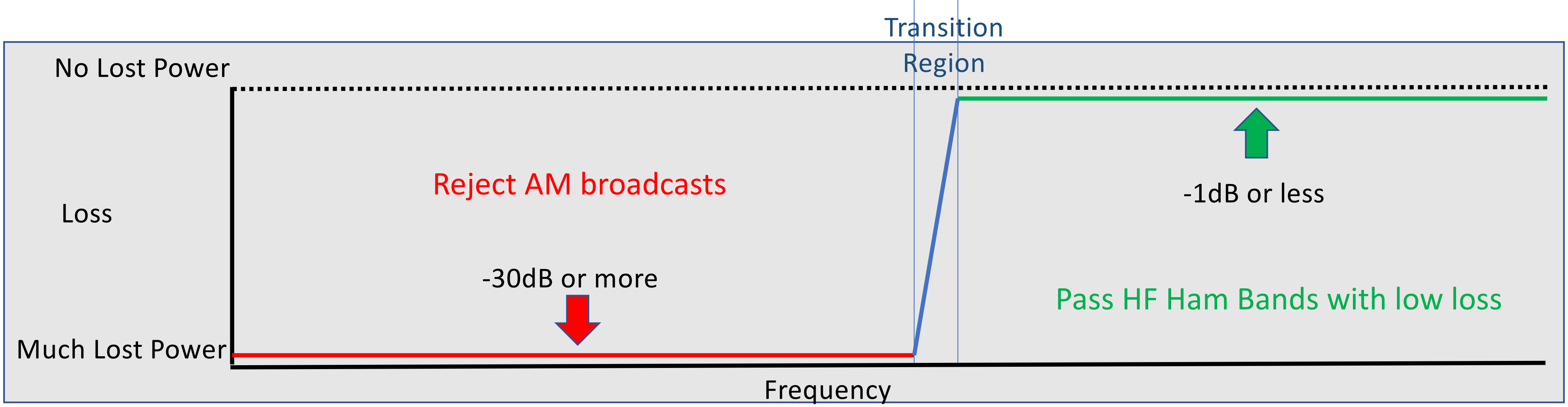


The filter must handle the full output power with minimal loss!

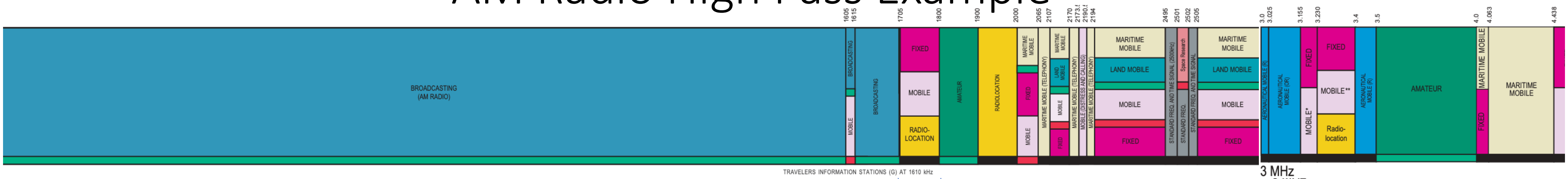
Specifying the right filter:

A High Pass Filter Example

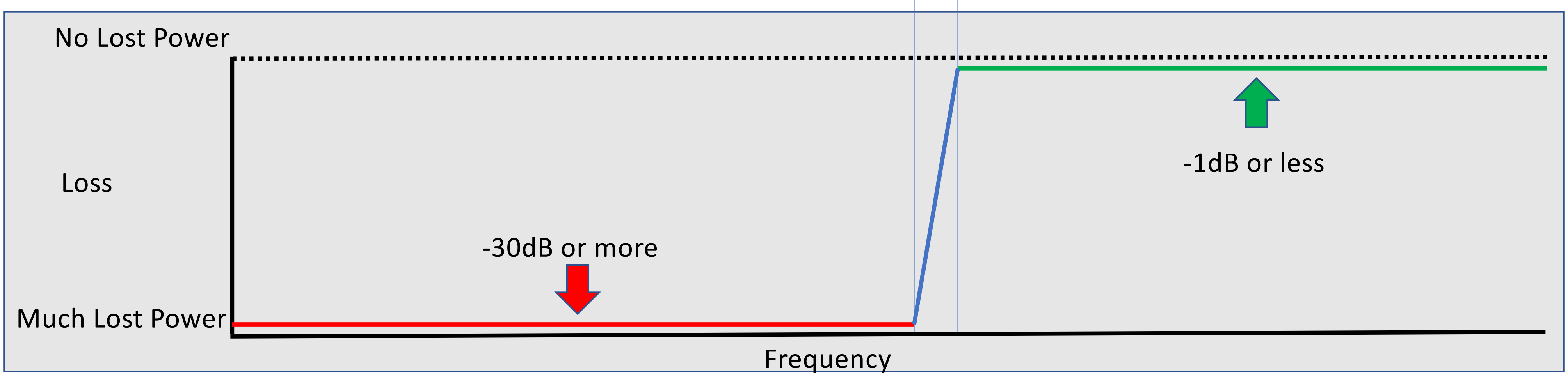




Specifying the right filter:
AM Radio High Pass Example



Power Handling:	Greater than Transceiver Output Power
Loss in Reject Band:	As High as Possible (-30db or better)
Loss in Pass Band:	As Low as Possible (<1db)
Transition Region:	As Narrow as Possible
50 ohm I/O Match	Close to 50 Ohms (<1.5:1 VSWR)



Finding the Right Filter

Things to consider:

A. How many filters (of various types) are desired

B. Cost of each filter, cost for total of all filters desired

C. Electrical specifications: see previous slide

D. User needs: Size, Weight, Cost, Ruggedness, Connectors, Style

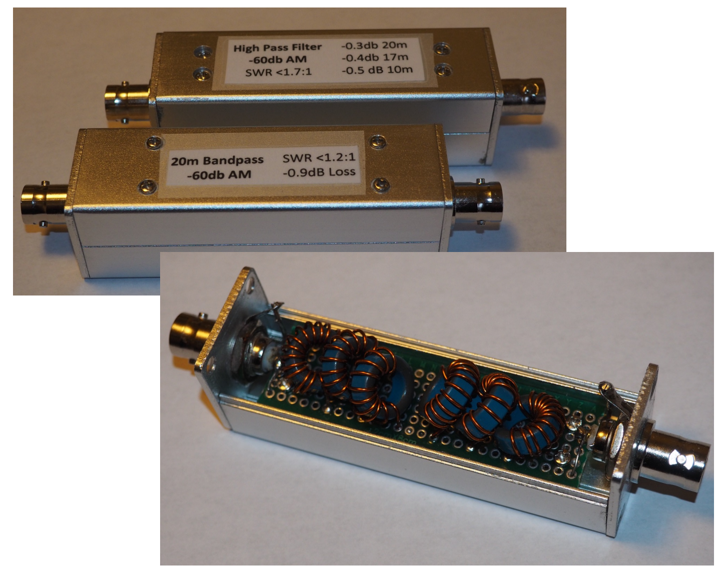
E. Personal preference:
   . Prefer to purchase a quality product
   . Would like an accessible DIY kit project yielding a quality filter
   . Enjoy DIY design and construction (and perhaps learning new technologies)

Example Filters

DLW High Pass

MiniKits High Pass

N1OR DIY High Pass



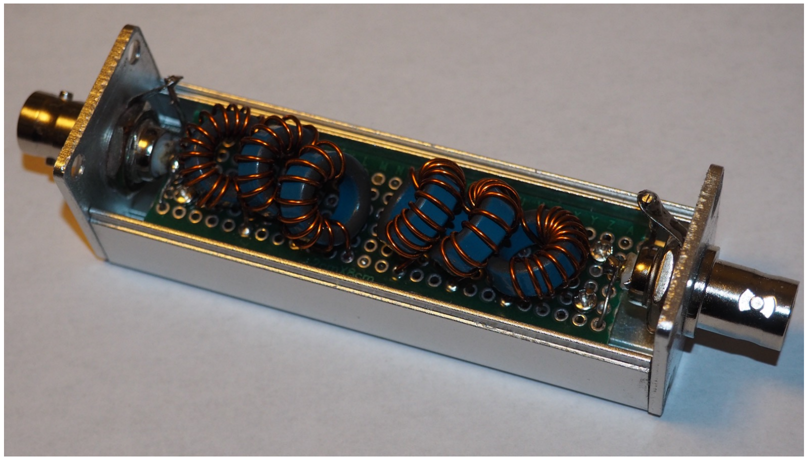
MFJ Low Pass

SOTAbeams 2m
(note connectors)

Snapshot of Filter Sources

		High Pass	Low Pass	Band Pass	2 Meters	Power	~ Cost
Commercial Products							
DLW Associates		x				200W	$195
MFJ			x			1,500W	$125
DX Engineering		x	x	x	x	200-1,500W	$125-700
SOTAbeams					x		$125
E-bay		Various offerings , mostly from China				~100-200W	~$60
DIY Kits							
Minkits		x	x	x		10/50/100W	$60
	Requires:						
	Soldering iron/solder						
	Small hand tools						
	Drill/bits						
	Multimeter						
DIY							
Various on internet, e-bay		x	x	x	x	10W	
						(100W with care,	
	Requires:					1000W good luck!)	
	Above plus:						
	NanoVNA						
	Toroid cores						
	Capacitors						
	"Magnet" wire						
	Insulated wire						
	Circuit boards						
	Mechanical package						
	Connectors						

Designing and Building a Filter - DIY

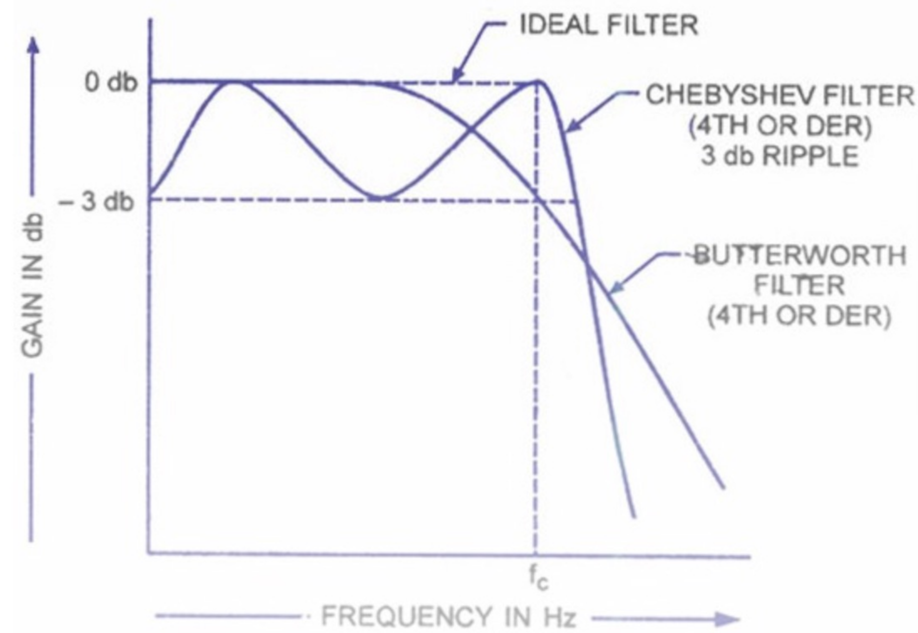


- Design and Simulation
  - Design for Performance
  - Design for "buildability"
    - Tools for Filter Design and Simulation
    - Tools for Circuit Analysis and Optimization
- Component Selection and Assembly
  - Mechanical Assembly Technology
  - Capacitors and Inductor Selection/Fabrication and Optimization
    - Use of nanoVNA
    - Other tools and techniques
- Evaluation and Optimization
    - Use of nanoVNA and the Smith Chart

Select a Filter Type

Chebyshev: “equal ripple”
- . A bit more bandwidth
- . Steeper band edge “roll off”

Butterworth: “maximally flat”
- . Smooth pass band
- . **I find these easier to build with adequate isolation**

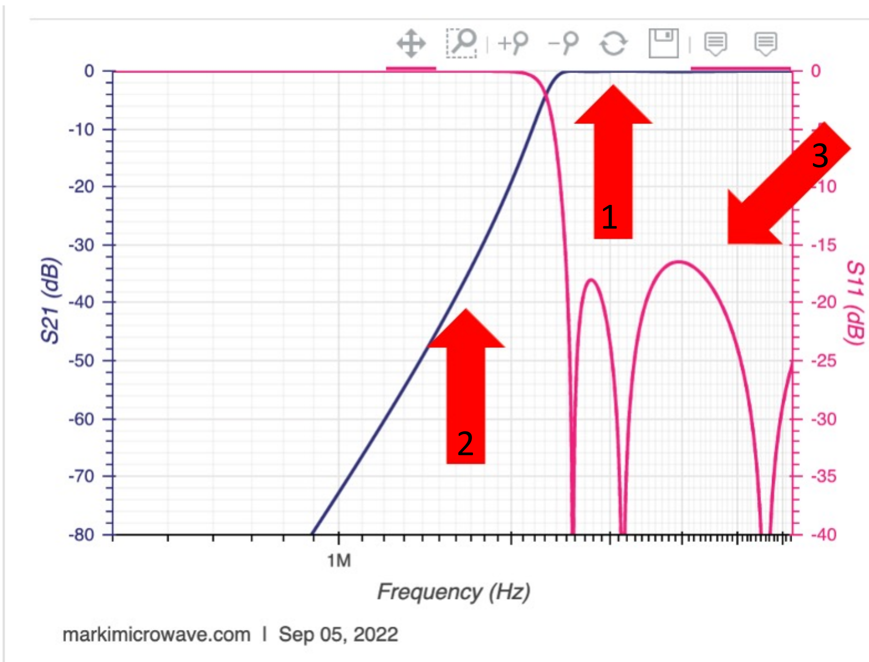


Chebyshev and Butterworth Filter

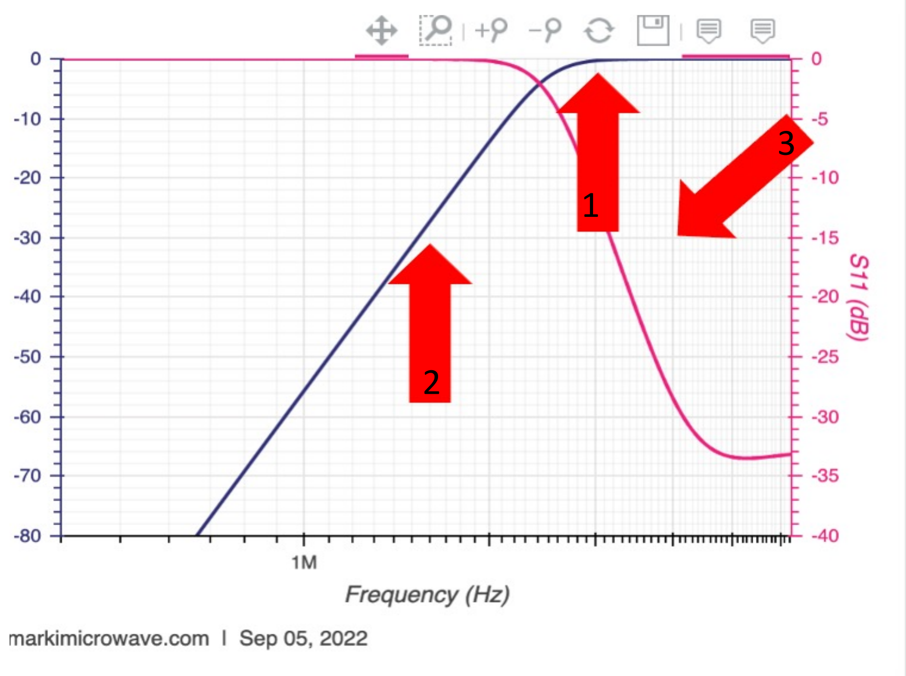
Source:
https://www.quora.com/
Which-of-these-is-better-Chebyshev-filters-or-Butterworth-filters

Chebyshev vs. Butterworth HP Filters

Chebyshev



Butterworth



Example 1 Find an Existing Filter Design to Build

- Use an Existing Design
  - Example:

    http://www.arrl.org/files/file/Technology/tis/info/pdf/8809017.pdf

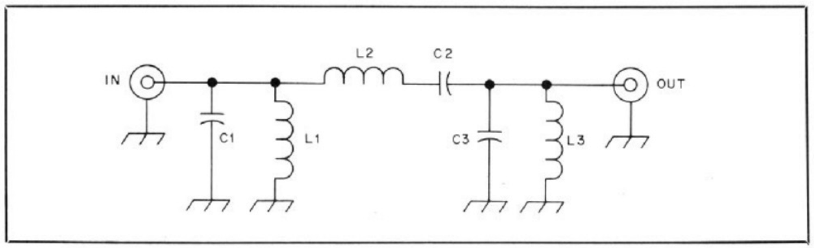


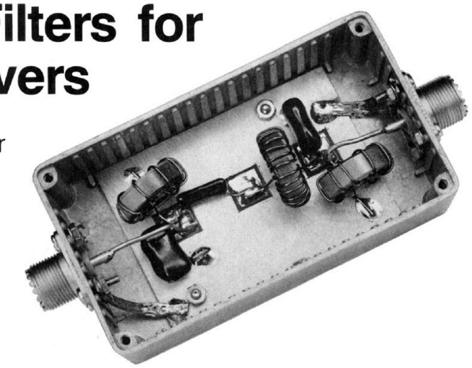
Fig 1—Schematic diagram of the three-pole Butterworth band-pass filters.

Table 1
HF Band-Pass Filter Specifications

Band (MHz)	C1/C3 (pF)	C2 (pF)	L1/L3 (μH)	L2 (μH)	T-68-6 core L1/L3 (no. turns)	T-68-6 core L2	T-80-6 core L1/L3 (no. turns)	T-80-6 core L2	F_r (MHz)
1.8	4000	400	2.2	22	22	69	23	70	1.75
3.5	2000	200	1.1	11	16	48	16	50	3.38
7	1000	100	0.55	5.5	11	35	11	35	6.78
14	500	50	0.28	2.8	8	25	8	25	13.56
21	330	33	0.18	1.8	7	20	7	20	20.65
28	250	25	0.14	1.4	6	17	6	18	27.39

Band-Pass Filters for HF Transceivers

Do your multiple-transmitter Field Day or contest efforts suffer from intrastation interference? These handy and inexpensive filters can help!



By Lew Gordon, K4VX
PO Box 105
Hannibal, MO 63401

This filter will be modeled in the next section to demonstrate use of modeling tools.

Many filter "prescriptions" for HP, LP and BP filters are available on-line or as kits.

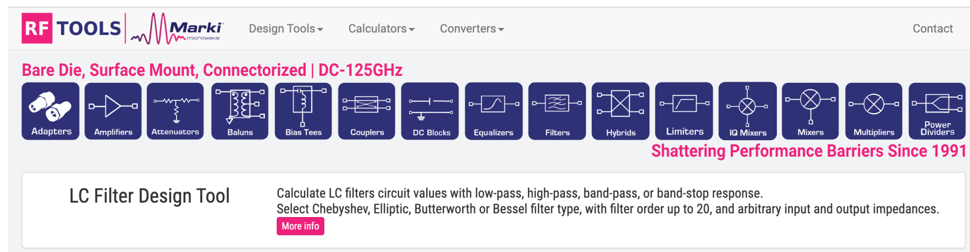
The tools described in the next section support analysis of existing designs or new designs "from scratch".

Example 2 Unique Filter Design and Analysis

- A Way to Design with Professional-Level Tools – Free, On-line:

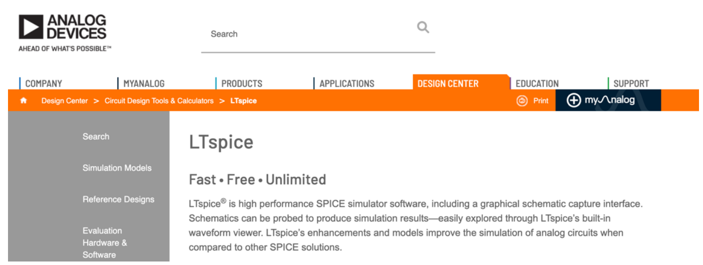
Filter Design Analysis

Filter Modeling



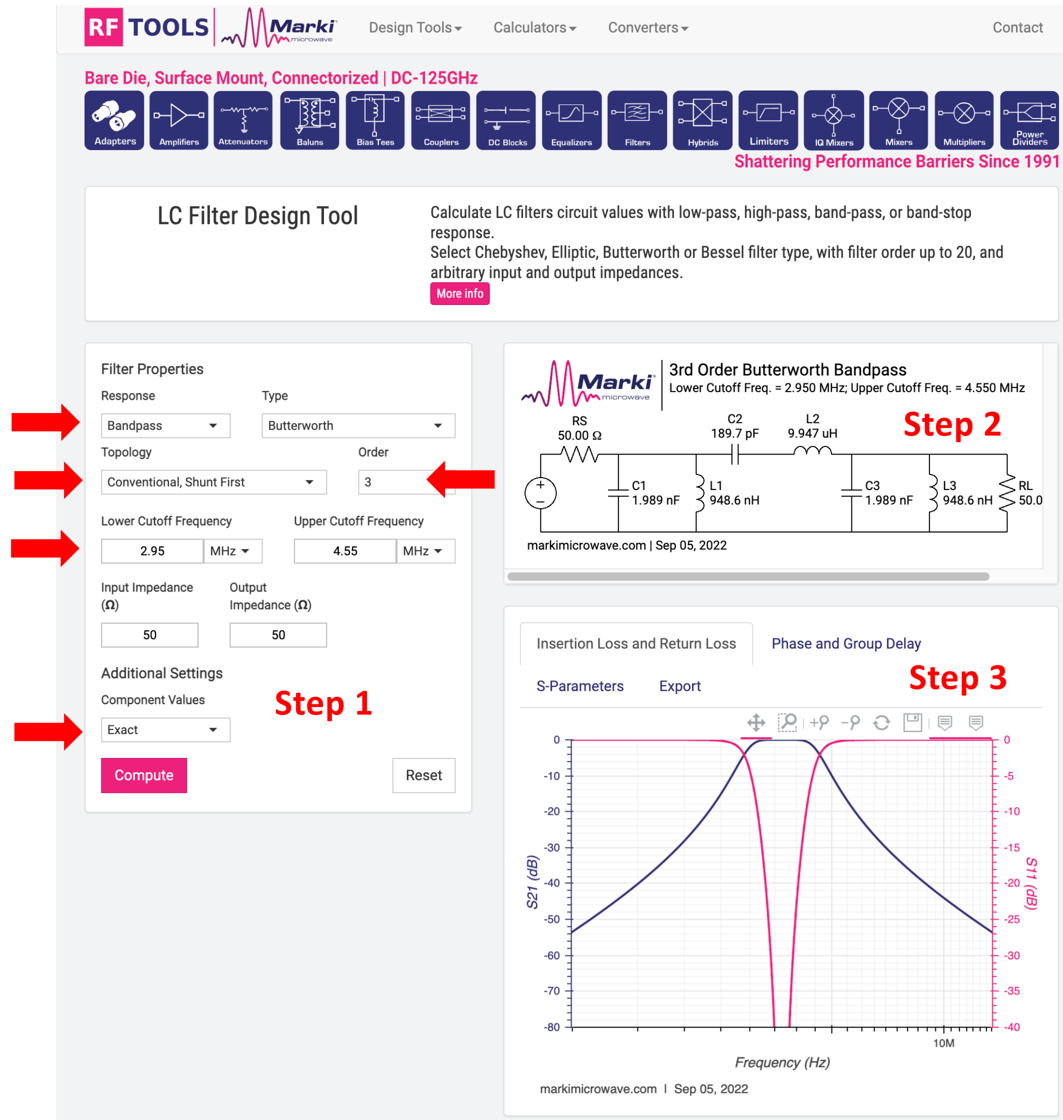
https://rf-tools.com/lc-filter

https://rf-tools.com/lc-filter/description.html



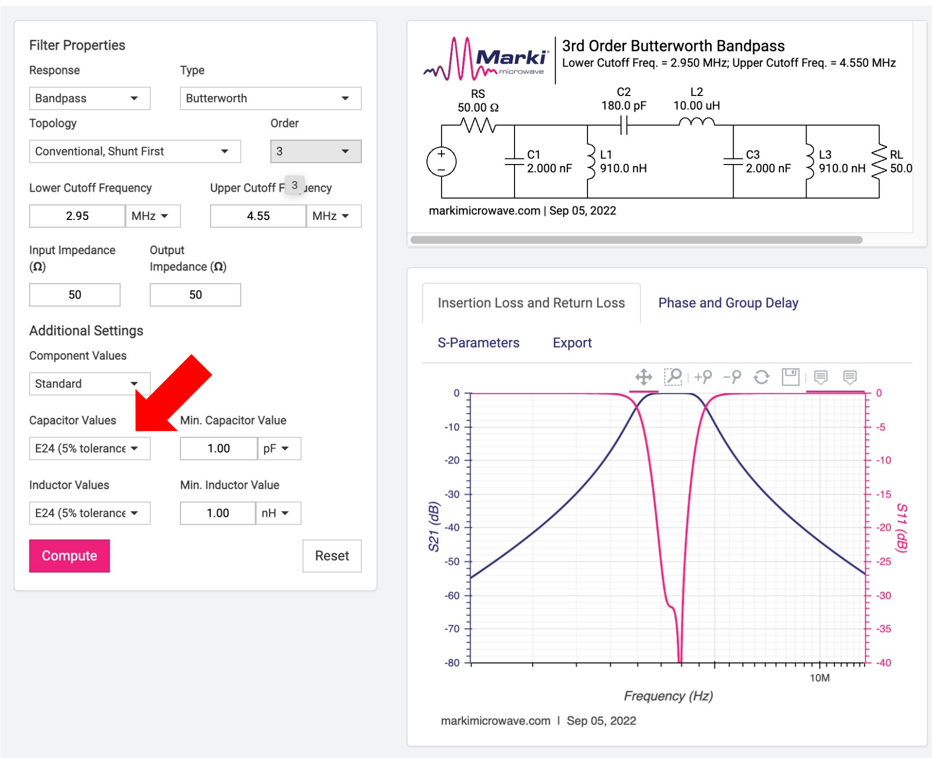
https://www.analog.com/en/design-center/design-tools-and-calculators/ltspice-simulator.html

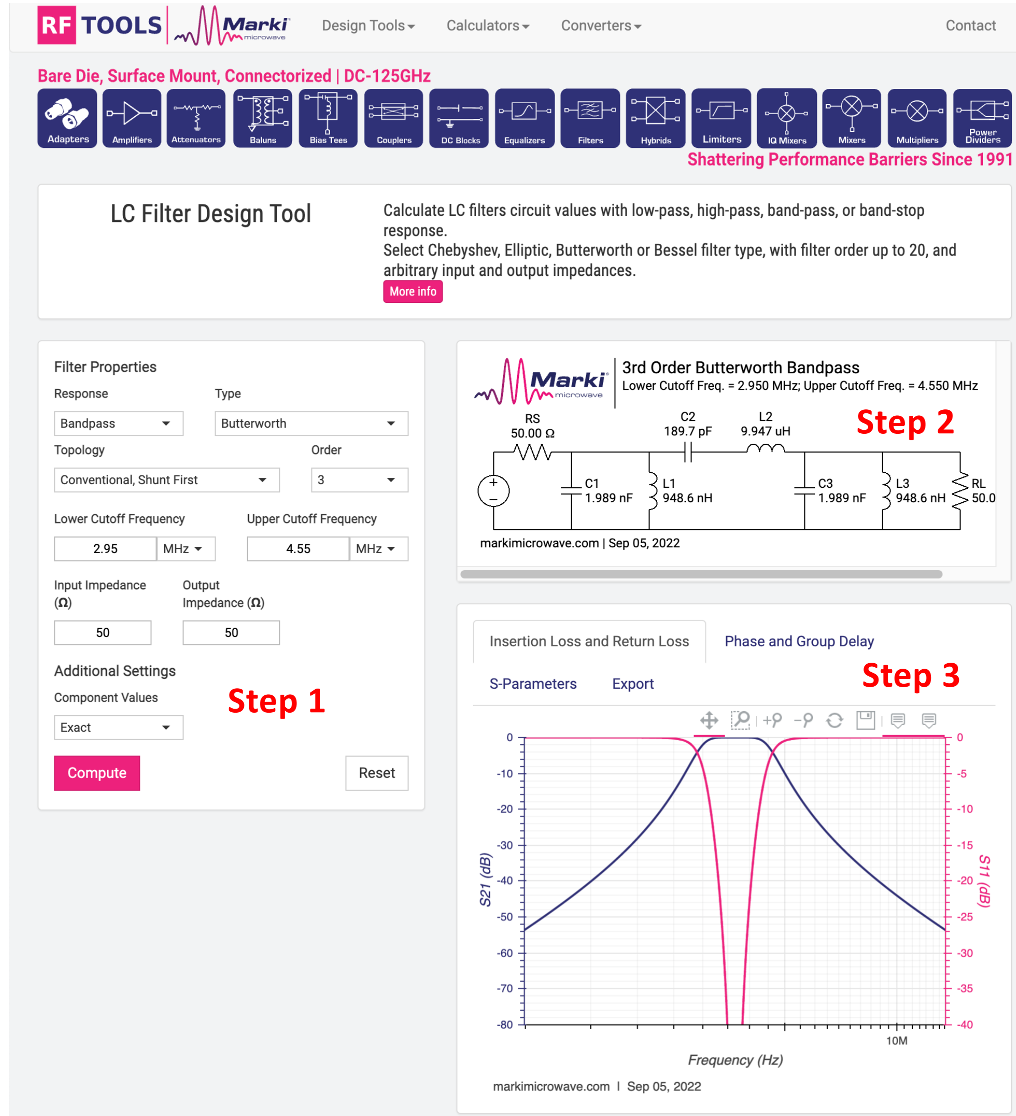
DIY Design: Demo Tools with the 3.5MHz Filter from Example 2



DIY Design: 3.5MHz Bandpass Example

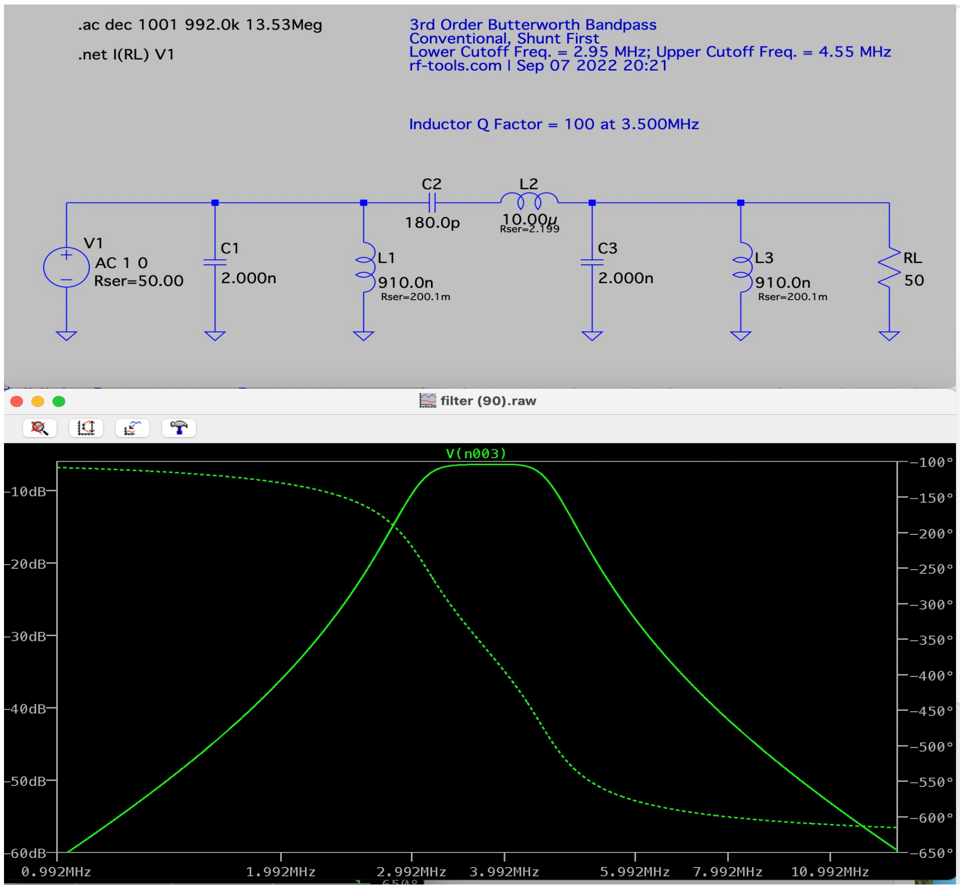
Step 4: Add "real world tolerances"

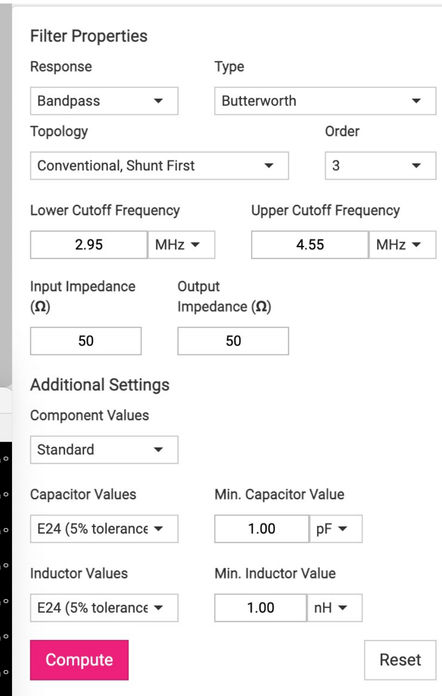


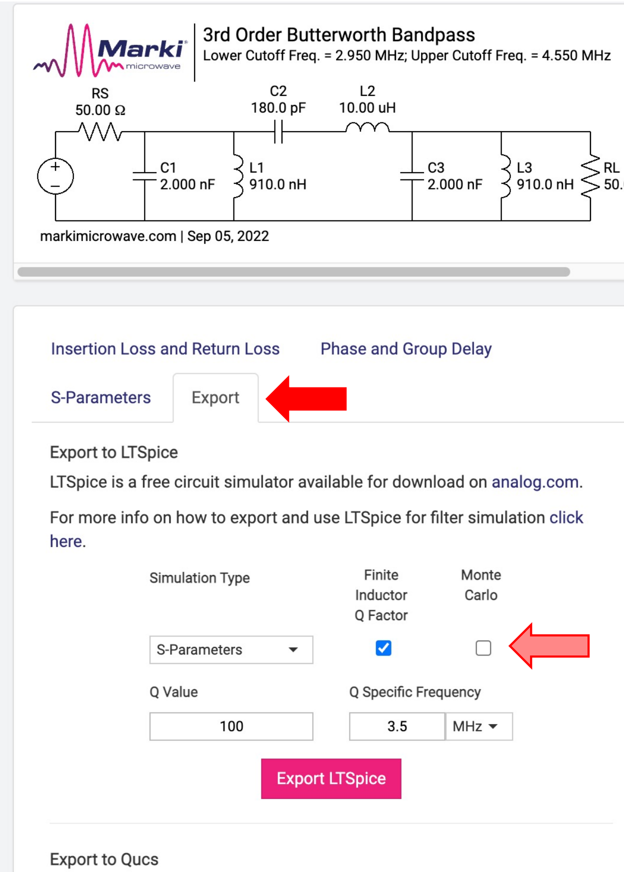


DIY Design: 3.5MHz Bandpass Example

Step 5: Export to Spice

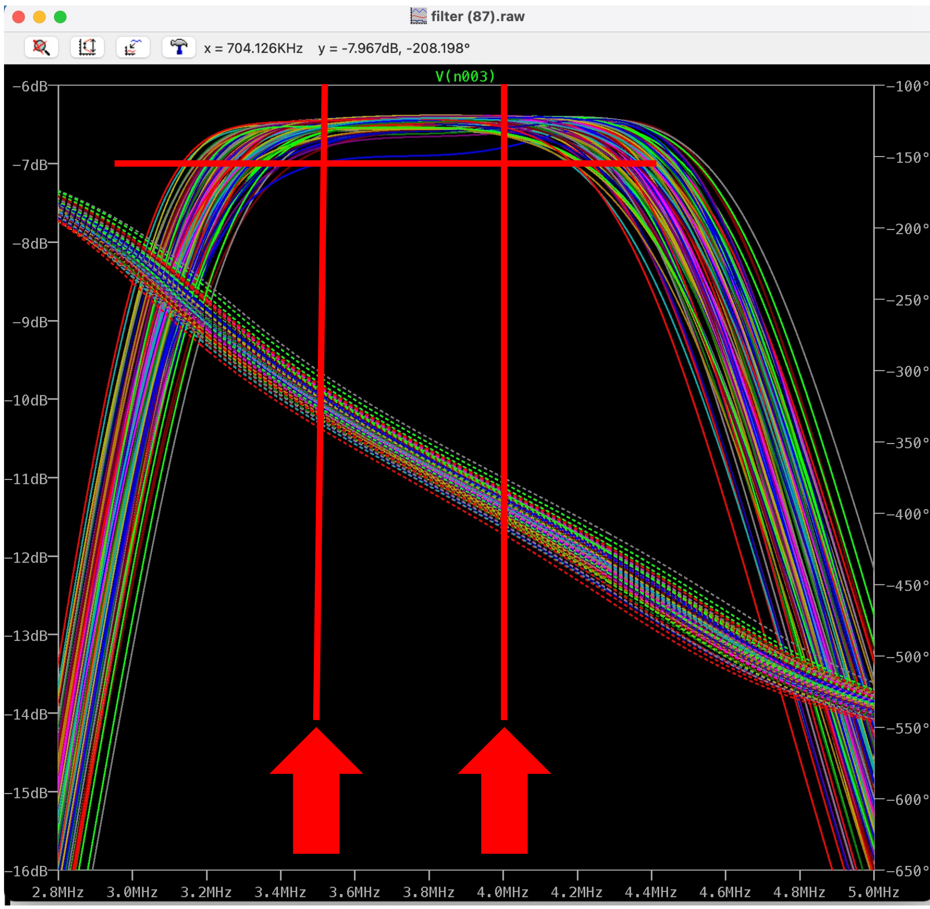


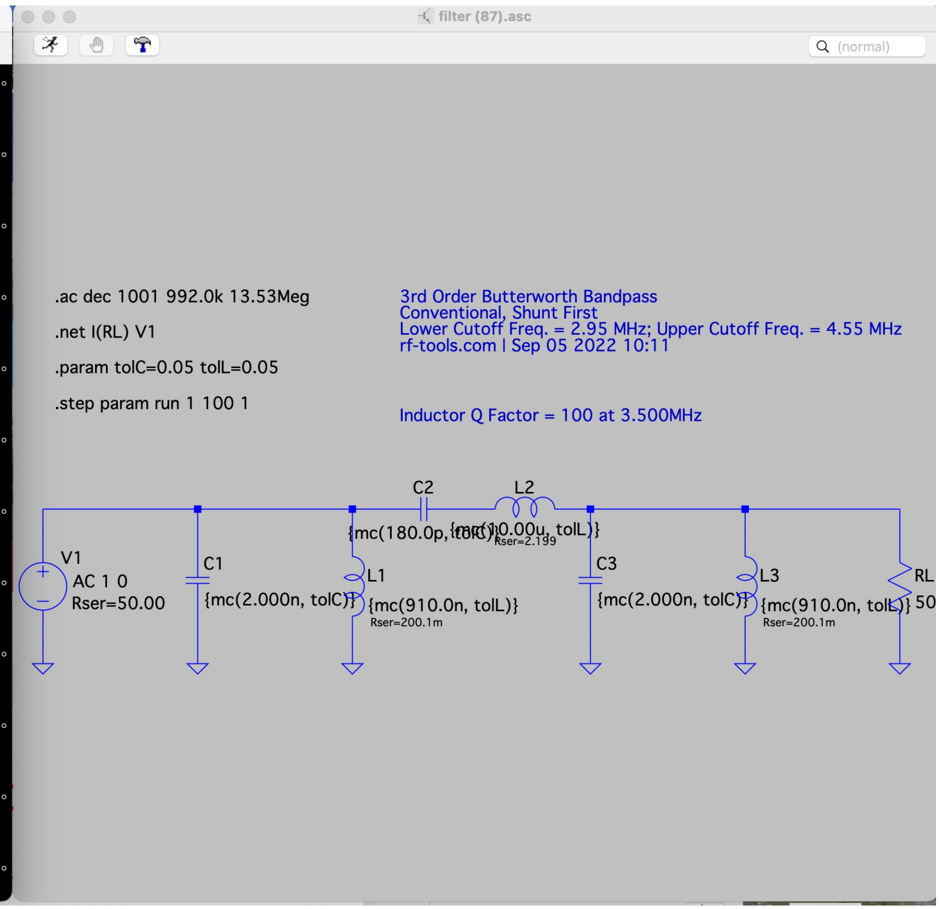




DIY Design: 3.5MHz Bandpass Example

Step 7: Explore Design Performance

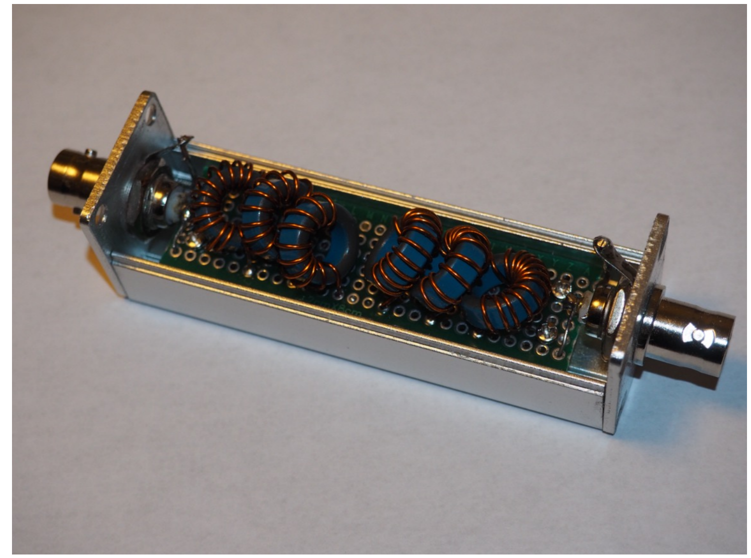


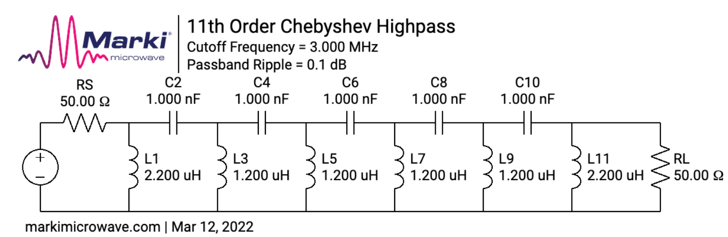


Example 3 Filter Construction and Test

N1OR High Pass Design as Reference Example

- Mechanical construction
- Selecting components (using nanoVNA)
- Building toroidal inductors
- Testing filter performance (using nanoVNA)
- DIY vs. Commercial Performance

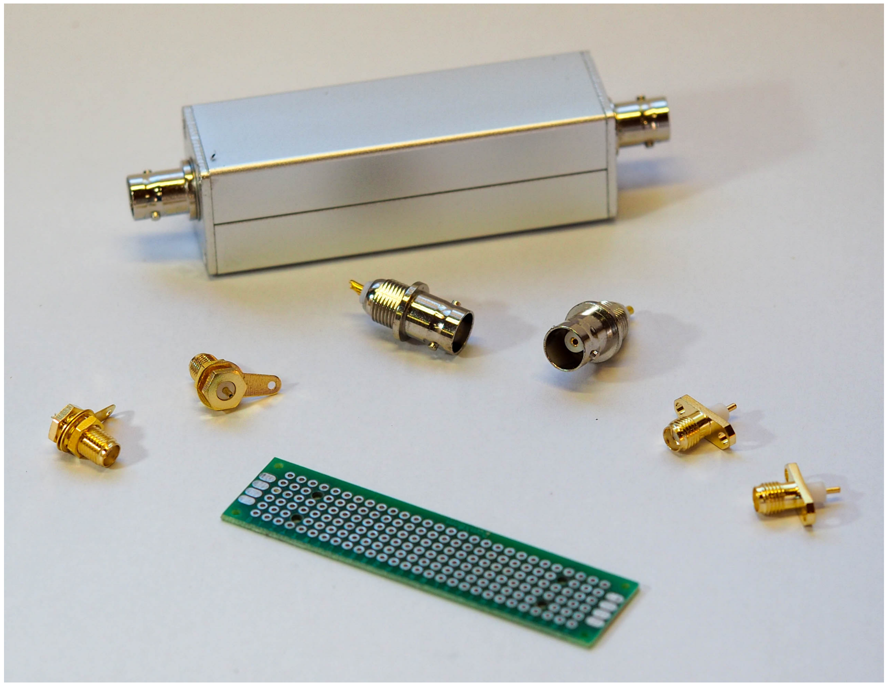




Mechanical Design Choices

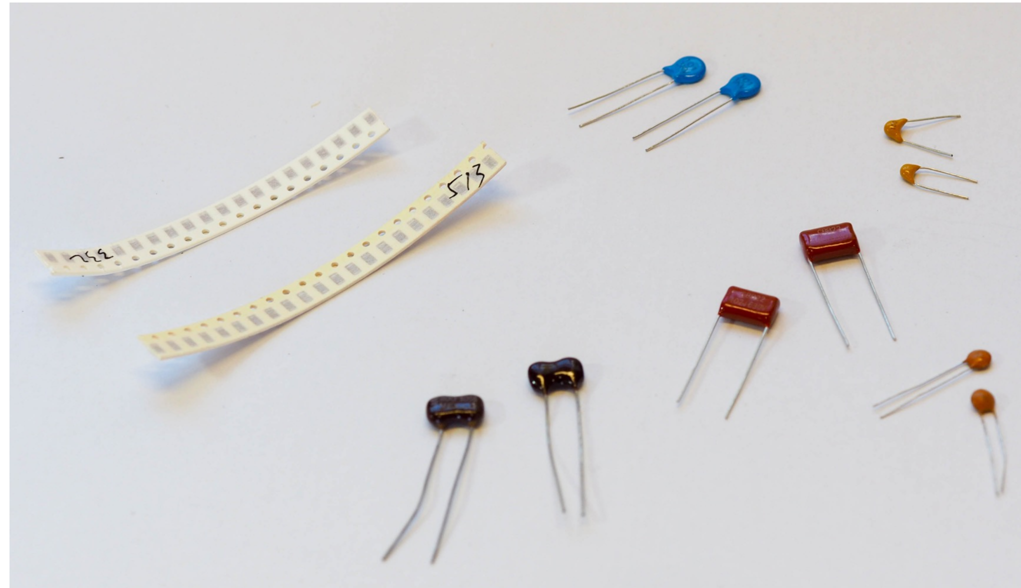
- Case: Size/Style Project Box: Many Choices, **Extruded Aluminum**
- Components: **Leaded** or Surface Mount, Microstrip; Fixed or Variable
- Interconnect: Blank Circuit Board, **Project Board**, Custom
- Connectors: SMA, **BNC**, TNC, N

Choices in Bold for Following Example Project



Capacitors

Choices in Bold for Following Example Project

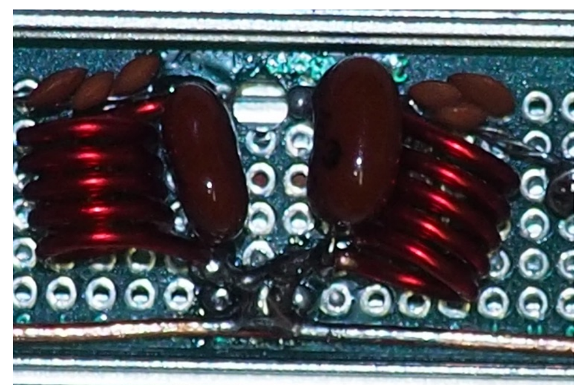


- Style: **Leaded**, Surface Mount, Through Hole (Air Variable)
- Voltage/Power Rating (10W minimum - tested to >50W)
- Self Resonance Frequency
- Values available to match design?
- Loss ("Q"):
  - Many materials have too much loss for "low loss" filters
  - Low loss types: **Silver Mica**, Polystyrene, Ceramic (some types), Air Variable

Inductors

Amidon Winding Calculator
https://coil32.net/online-calculators/amidon-iron-powder-cores-calculator.html

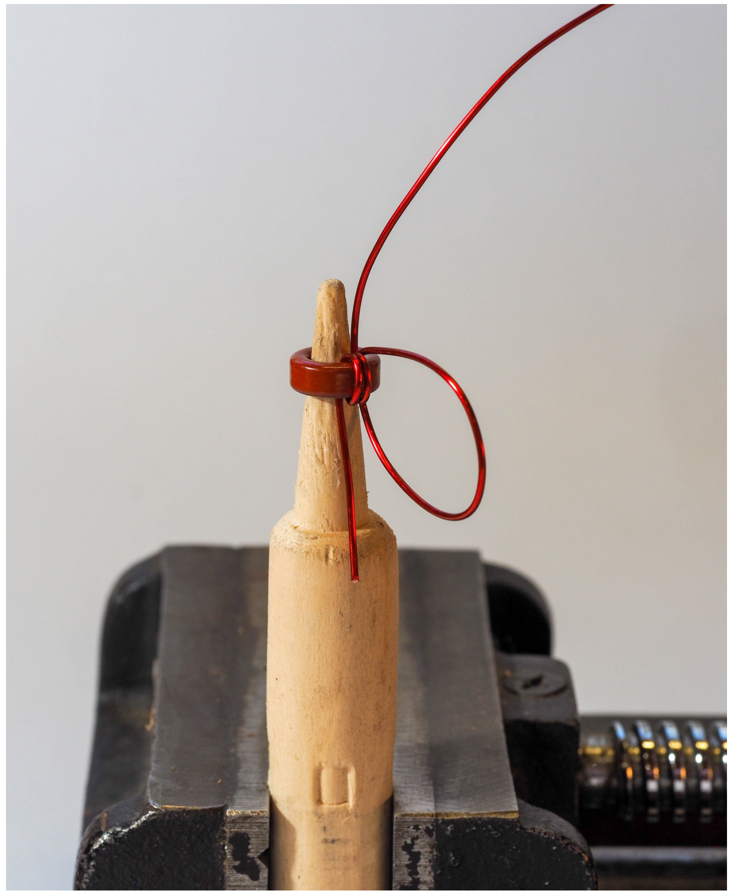
Air Core Calculator
https://hamwaves.com/inductance/en/index.html#input



- Usually a **DIY Item** in HF Filters
- Style: AirCore (Helical), **Iron Powder Toroid**, …
- Voltage/Power Rating
- Self Resonance Frequency
- Practical Value Range
- Loss (“Q”): Very Critical Limitation for Filter Loss

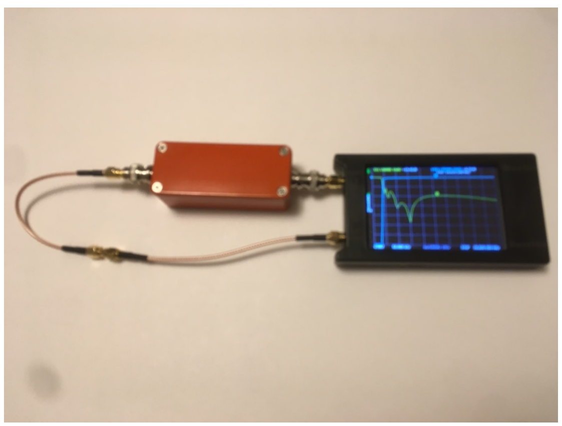
Choices in Bold for Following Example Project

Simple Tool to Make Toroid Winding Easy

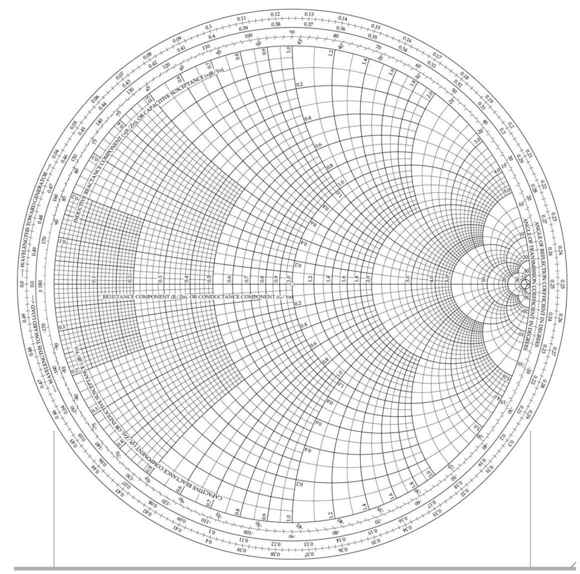


Vector Network Analyzer
. nanoVNA's are inexpensive
. Cover frequencies to >1.5GHz
. Many functions for evaluating
<u>component</u> and <u>filter performance</u>

Test and Optimization: Powerful Tools



Smith Chart Display
. Takes some effort to understand/use
. Often not covered in youtube intros
. Powerful visualization tooll
. Tremendously useful for optimization



Toroid Inductor

50 Ohm Resistor

Polystyrene Capacitor

Component Values vs. Frequency

nanoVNA in Smith Chart Mode

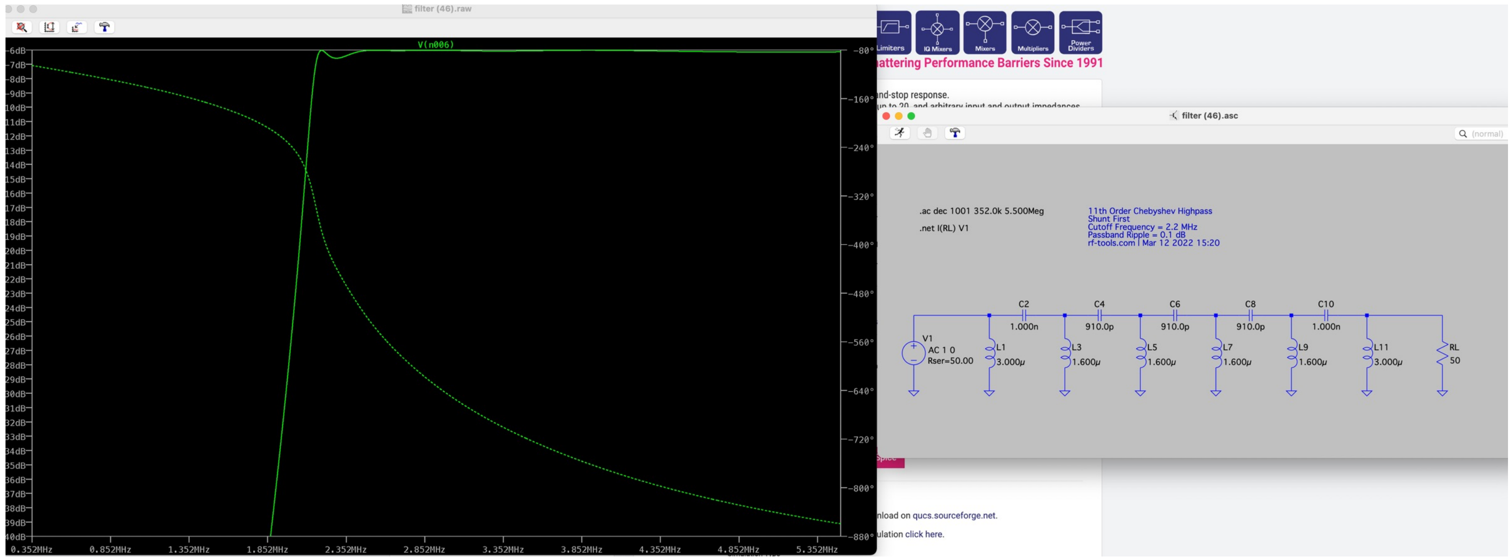
Resonant Frequency

Inductor and Capacitor in Parallel

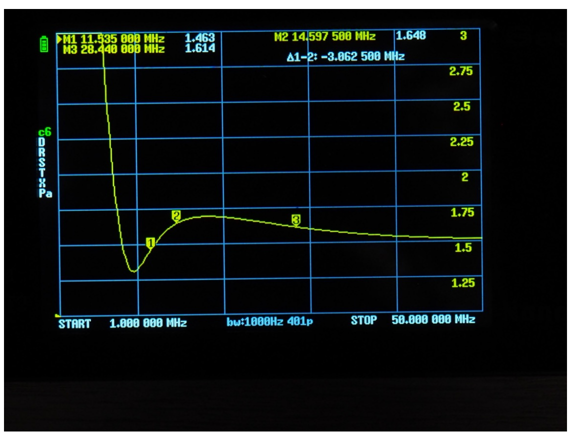
Try it yourself: Explore the Smith Chart at https://www.will-kelsey.com/smith_chart/

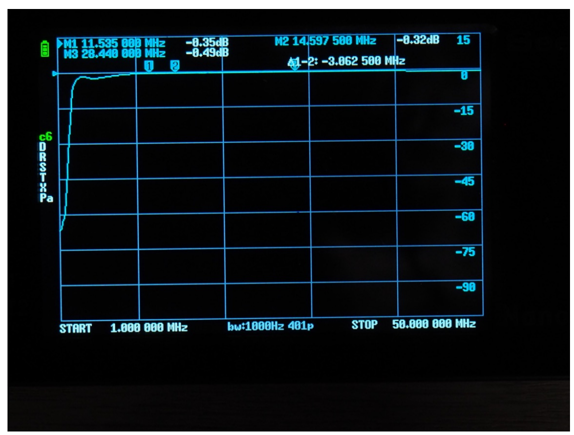
Putting it All Together!

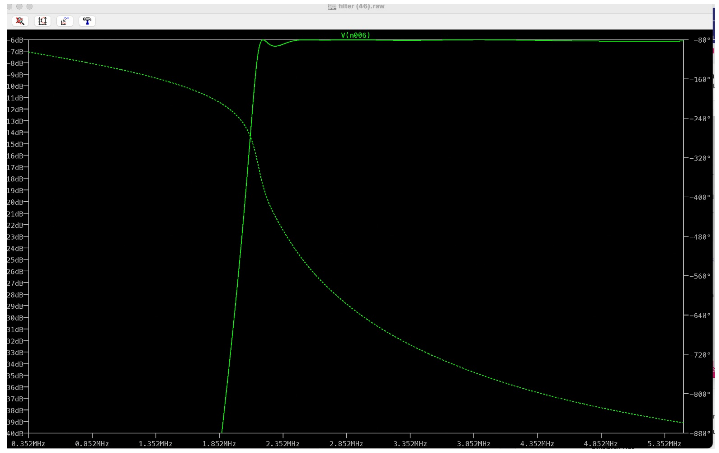
N1OR DIY High Pass Filter



Design vs. Actual Performance







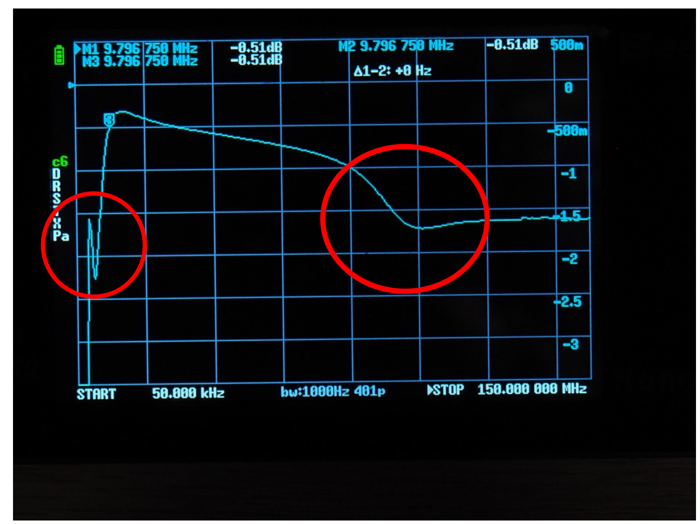
"Perfect" Simulation Model

Beware of Differences from the Model

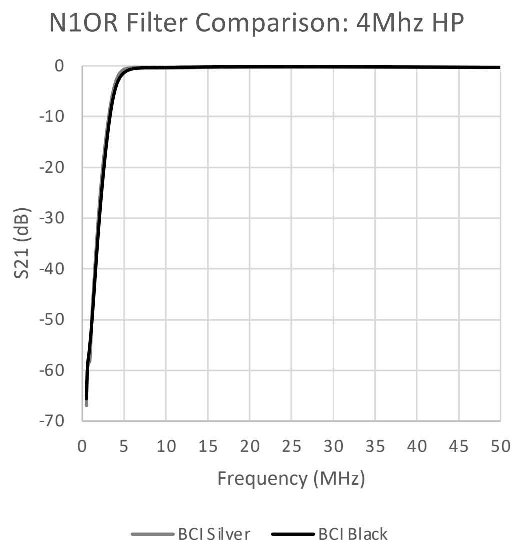
. Often does not matter if outside frequencies of interest

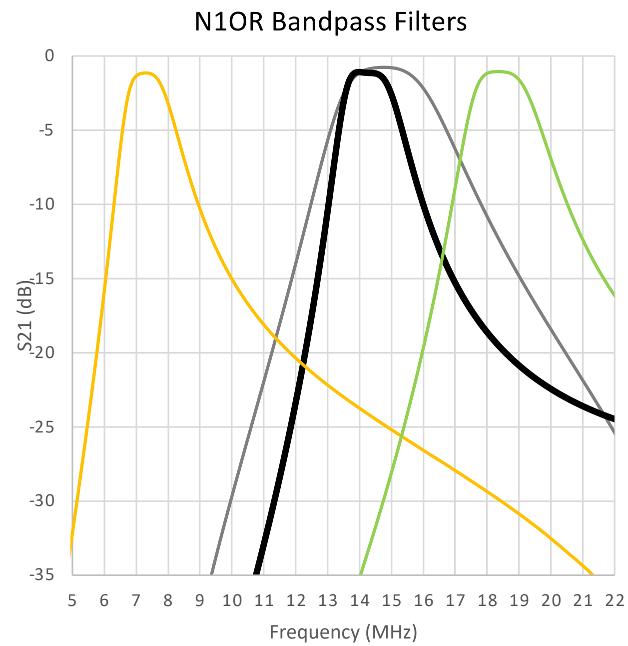
. Typically created by imperfect models of real components

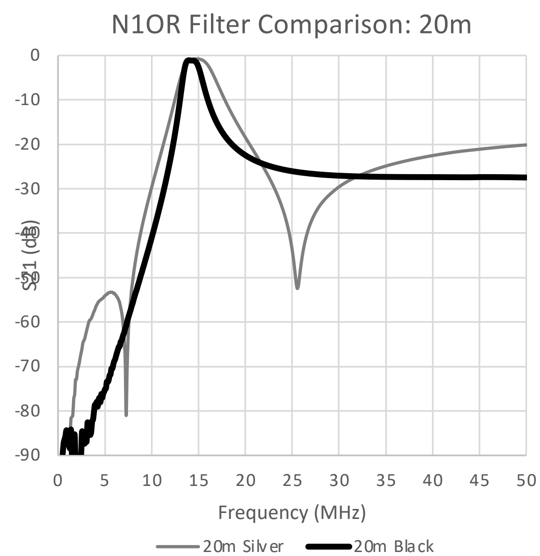
. Magnetic coupling can often be eliminated by "shielding" within the filter



How well do DIY filters* stack up?







*Silver/Black refer to the N1OR filter case colors: 20m Silver 20m Black 40m Silver 17m Silver

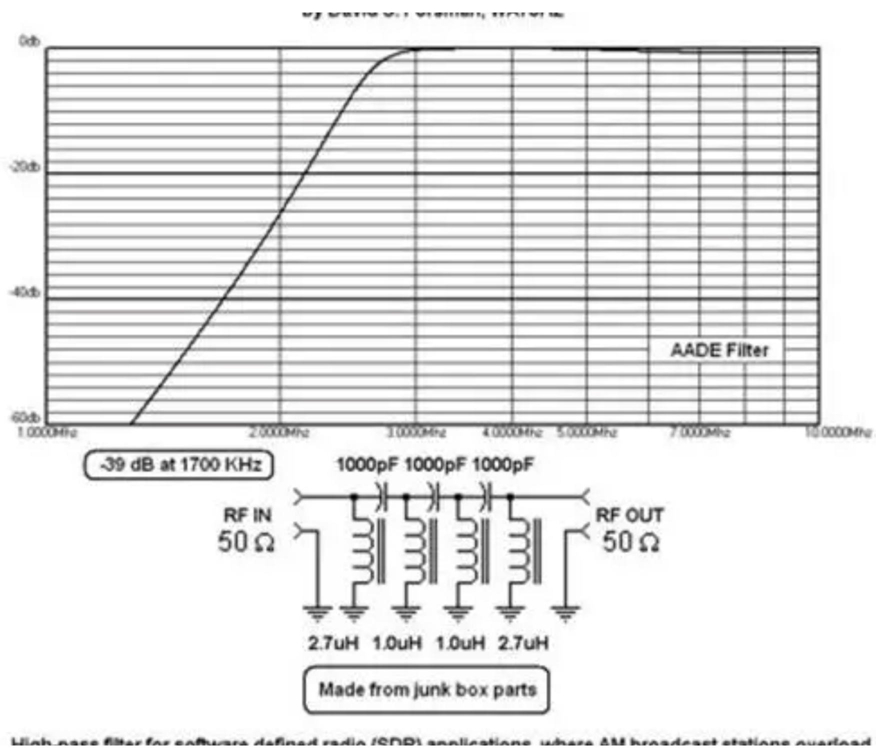
Thank you for your engagement!

- Thank you to the W6TRW Club for the opportunity to present!
- Special thanks to KD7DTS for inspiring this project, for identifying operator needs, and for filter test and analysis!

Appendix

- 1. A “Junk Box” high pass filter, with web link
- 2. Smith Chart plotter, with web link

A Simple "Junk Box" DIY Filter



https://swling.com/blog/2016/02/a-simple-homebrew-high-pass-filter/

Resonant Circuit Example

https://www.will-kelsey.com/smith_chart/