# Filters

WHAT ARE THEY AND WHY DO WE NEED THEM?

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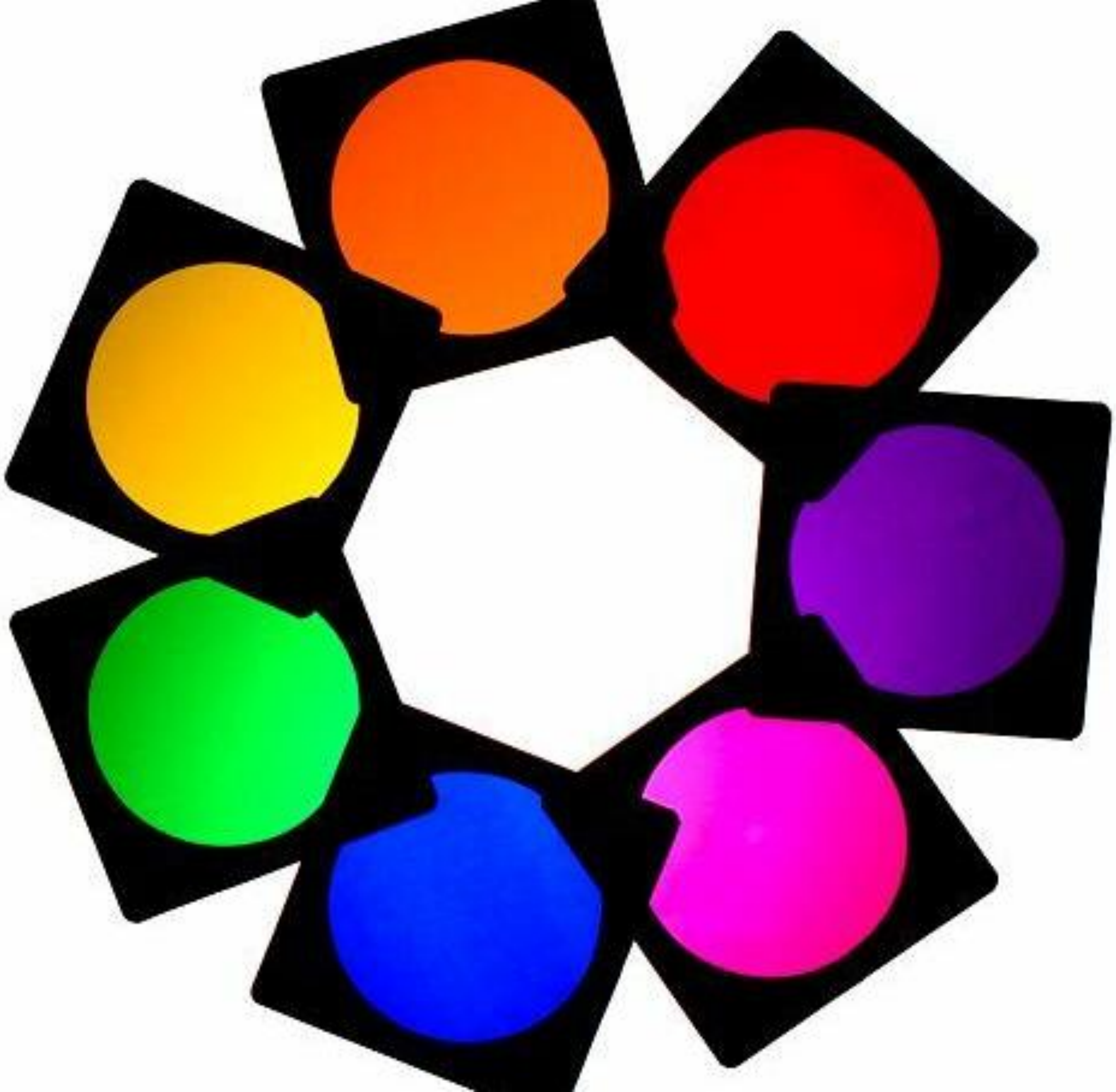
# Air Filters

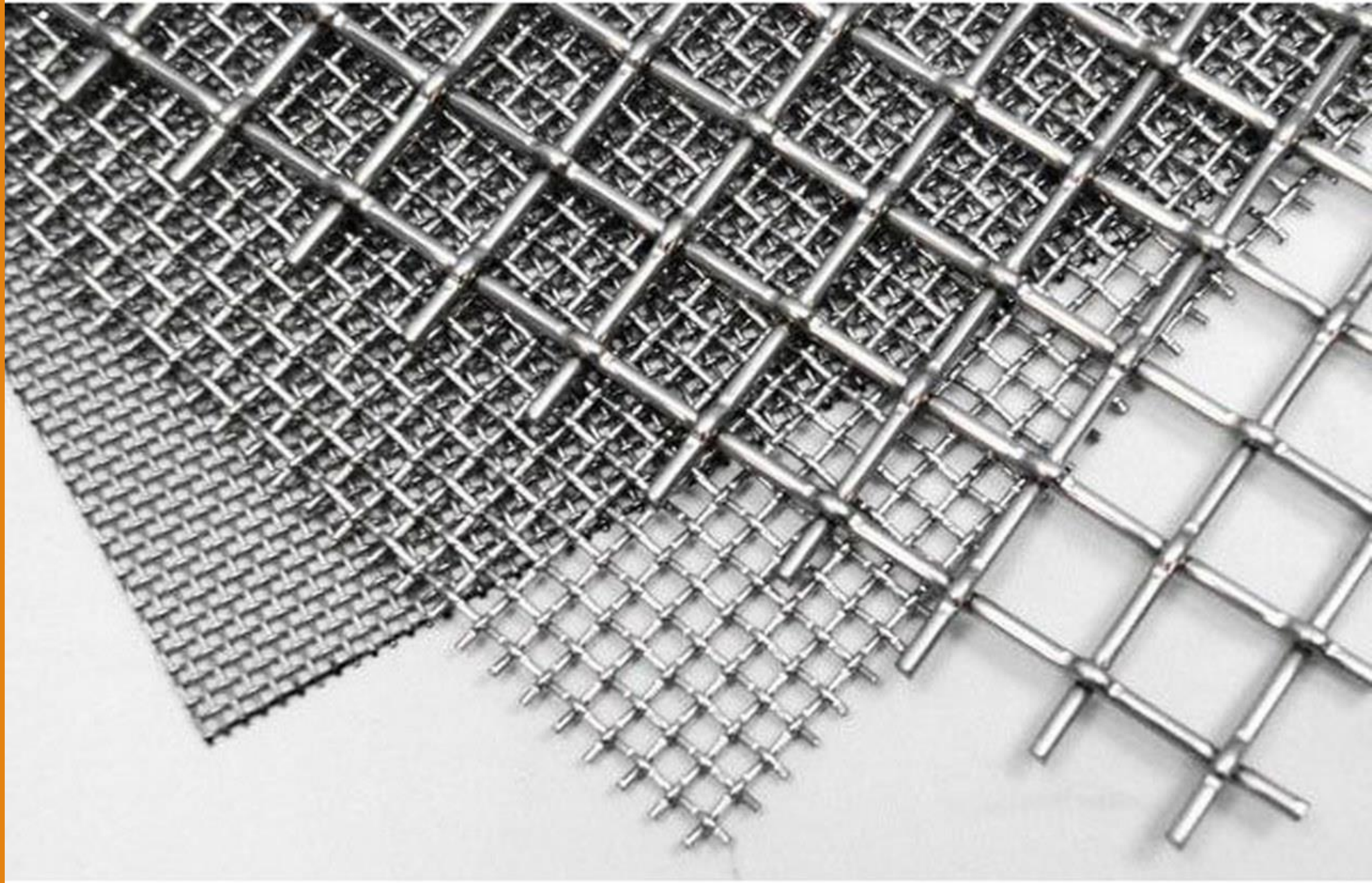
# Oil Filters

# Light Filters



# Microwave Oven Filter

# Rock Filters



# Noise Filters

# Virus Filters

# Coffee Filters

# What are Filters?

According to Merriam-Webster – “a device or material for suppressing or minimizing waves or oscillations of certain frequencies (as of electricity, light, or sound)”

Amateur radio operators know that Filters are used in many areas of electronics. One of the main areas where they are used is within the radio frequency or RF domain.

RF filters are used to remove or accept signals that fall in certain areas of the radio spectrum.

# Basic types of RF Filters

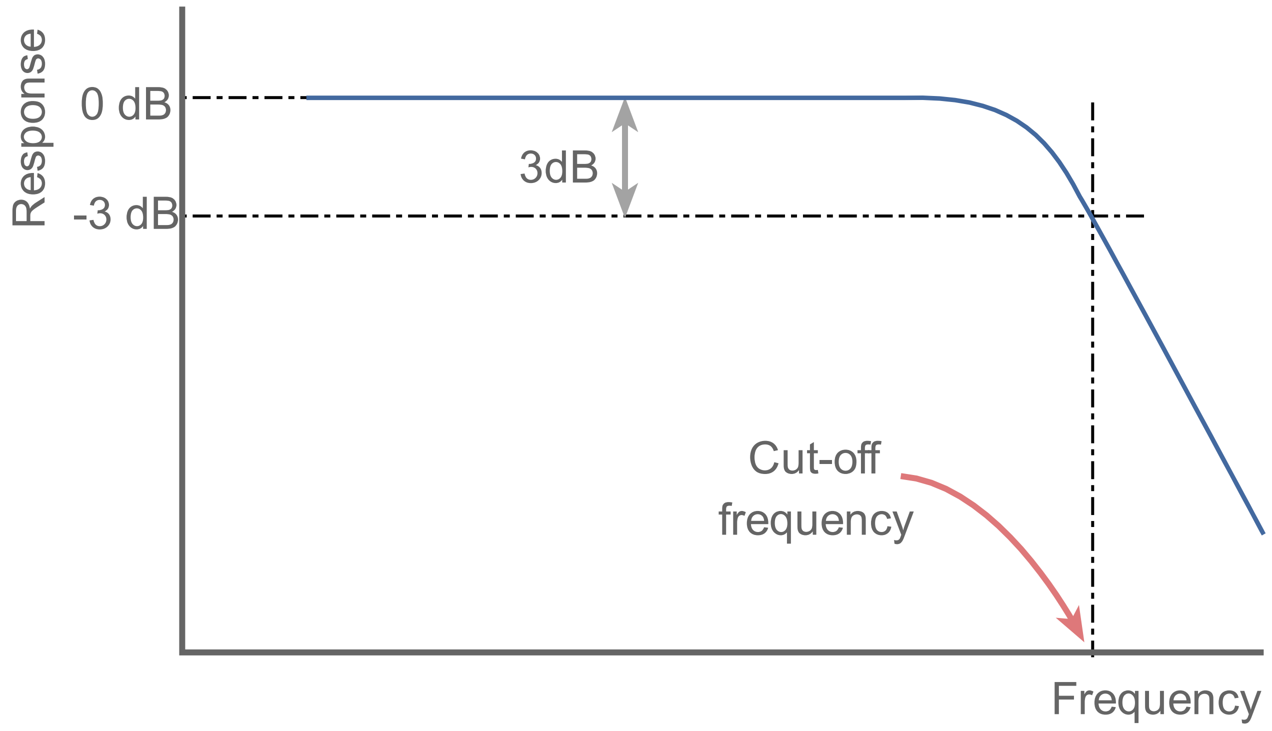
There are four types of filter that can be defined.

- Low Pass Filter
- High Pass Filter
- Band Pass Filter
- Band Reject Filter

Each different type rejects or accepts signals in a different way, and by using the correct type of RF filter it is possible to accept the required signals and reject those that are not wanted.

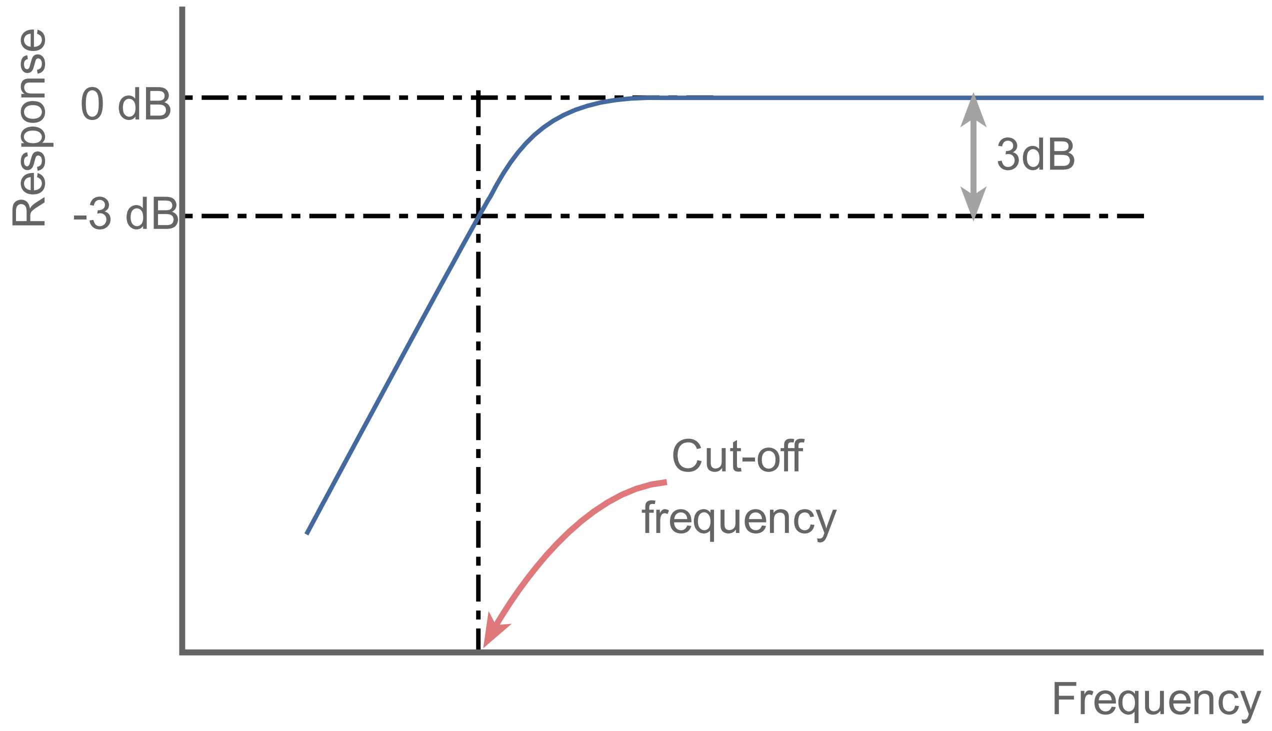
# Low pass filter

As the name indicates the low pass filter is a form of filter that only allows through the lower frequencies. Typically it is nominally flat until the cut-off point, and then it rolls off.



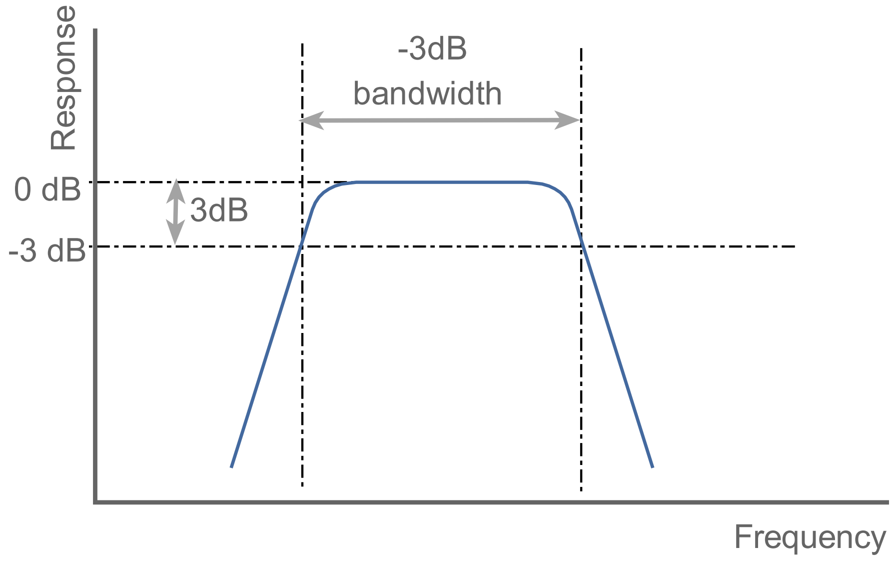
# High pass filter

The high pass filter is in many ways the inverse of the low pass filter. It only allows signals through that are higher than the cut-off frequency. Above this point it is nominally flat, and below the RF filter cut-off frequency the response falls away at a rate determined by the order of the filter.



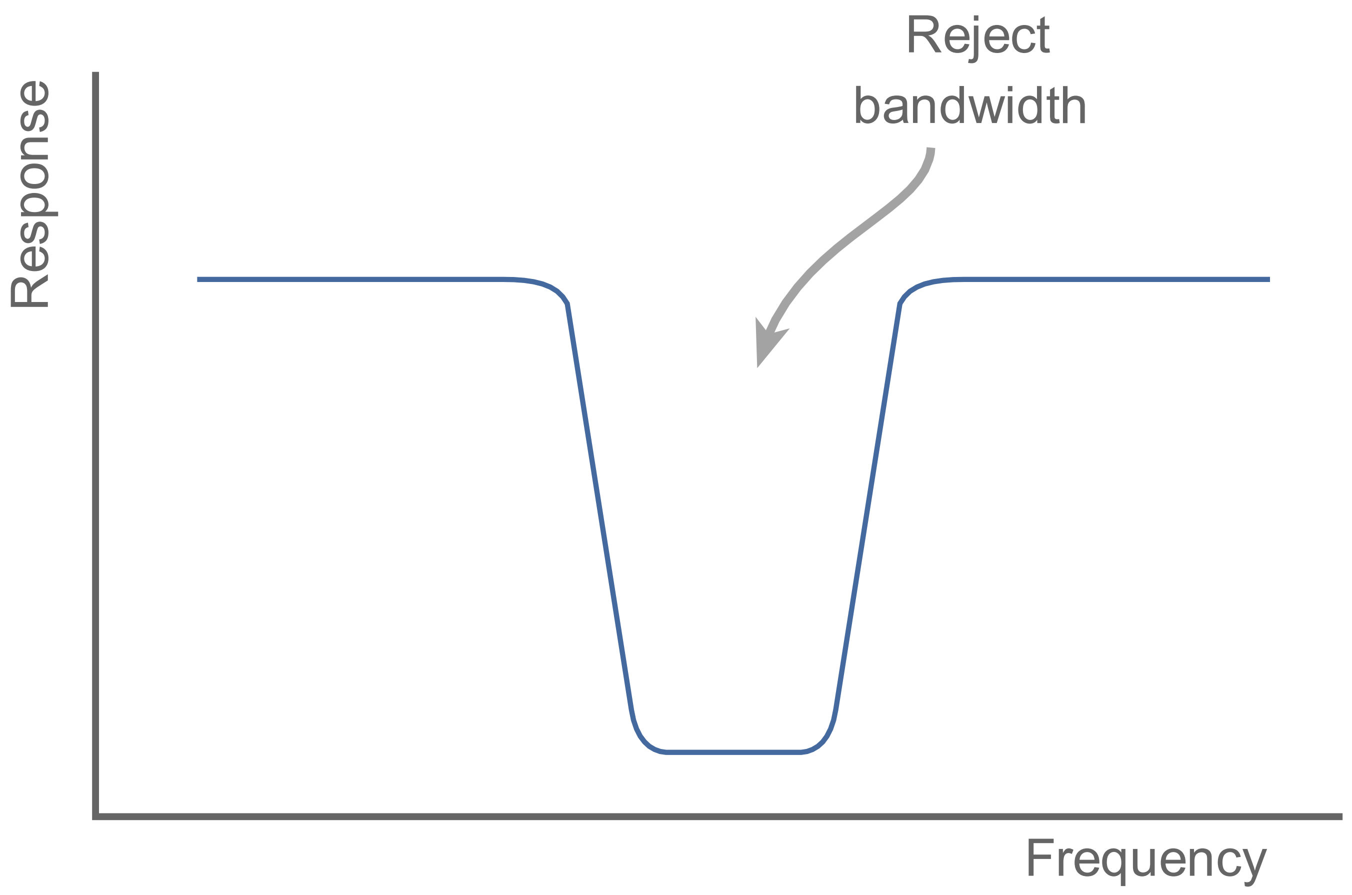
# Band pass filter

The band pass RF filter only allows through signals within certain frequencies. Above and below the cut-off frequencies, the signals will be attenuated and within the accepted band of radio frequencies, signals will be passed through.



# Band reject filter

The band reject filter is the opposite of a band pass filter, as it rejects signals within a certain RF band. This form of RF filter is often used to remove unwanted signals that are know to exist in a system.



# Characteristics of RF Filters

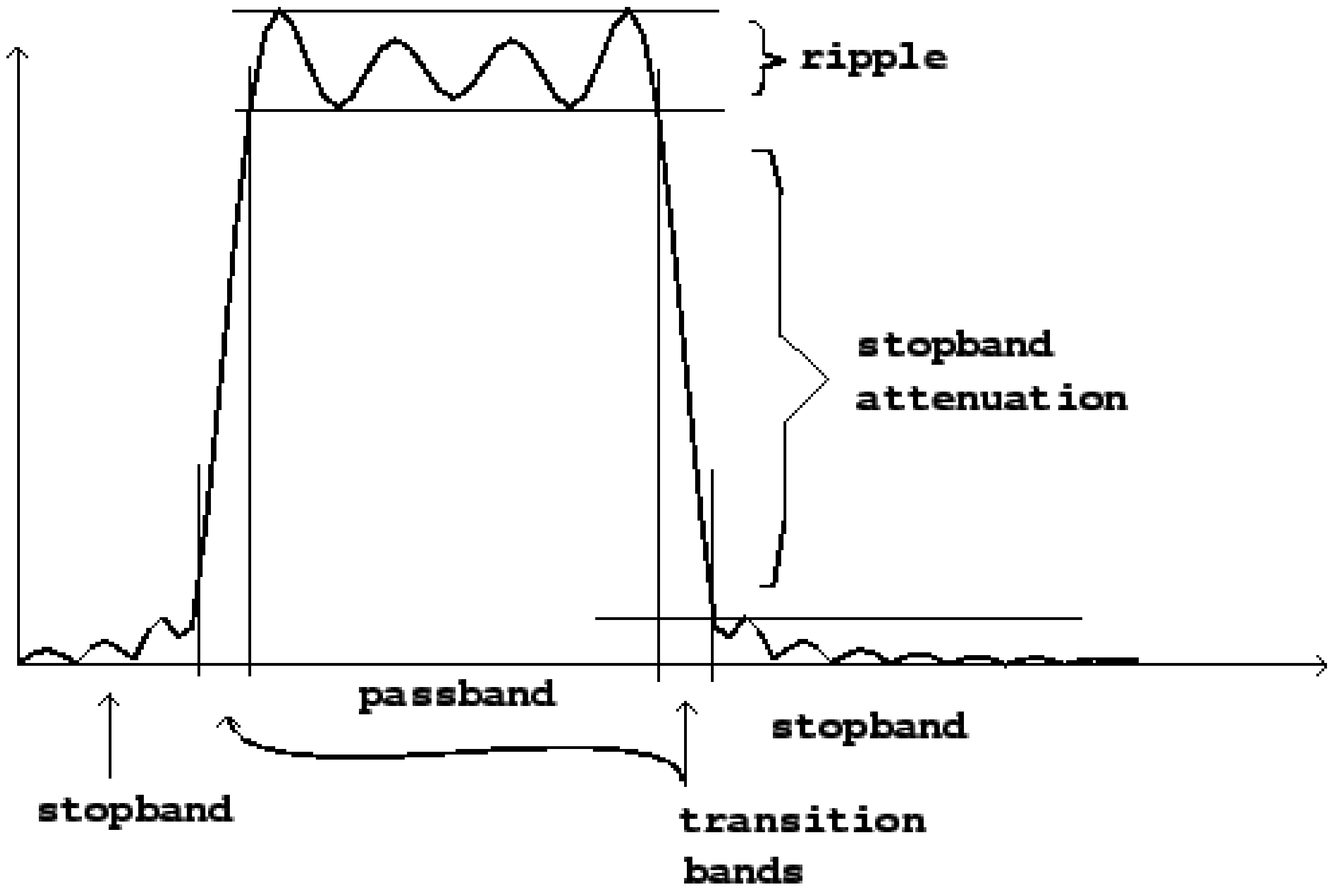
A filter allows signals through in what is termed the pass band. This is the band of frequencies below the cut off frequency for the filter.

The cut off frequency of the filter is defined as the point at which the output level from the filter falls to 50% (-3 dB) of the in band level, assuming a constant input level. The cut off frequency is sometimes referred to as the half power or -3 dB frequency.

The stop band of the filter is essentially the band of frequencies that is rejected by the filter. It is taken as starting at the point where the filter reaches its required level of rejection.

# Important Filter Specifications

RF filters, along with all filters have a variety of different specifications which relate to their performance.



# RF Filters Classifications

**Constant-k:** The constant-k filter has the advantage of it being very easy to calculate values for the different components.

**Chebyshev:** This filter provides fast roll off after the cut off frequency is reached.

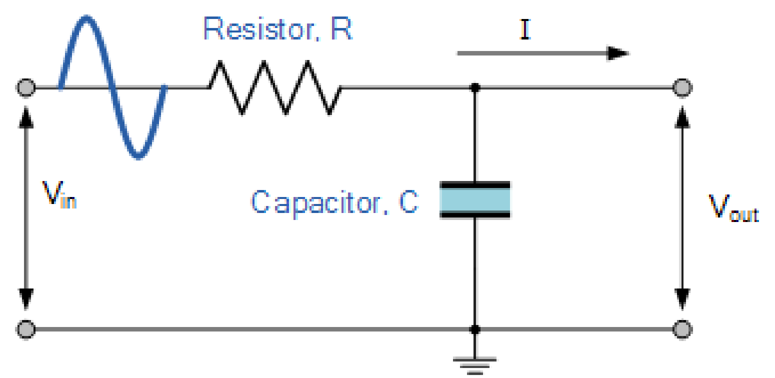
**Butterworth Filter:** This type of filter provides the maximum in band flatness, although it provides a lower stop-band attenuation than a Chebyshev filter.

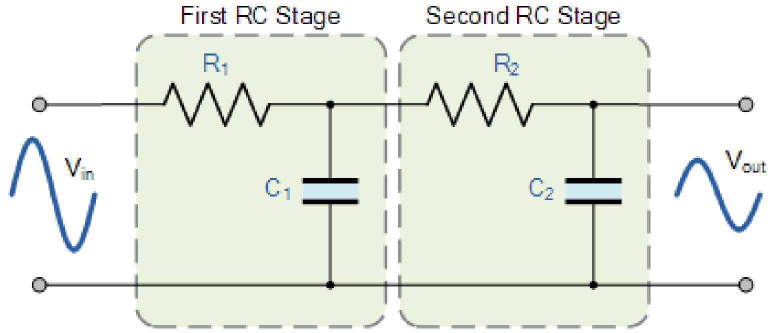
**Bessel:** This filter provides the optimum in-band phase response and therefore also provides the best step response.

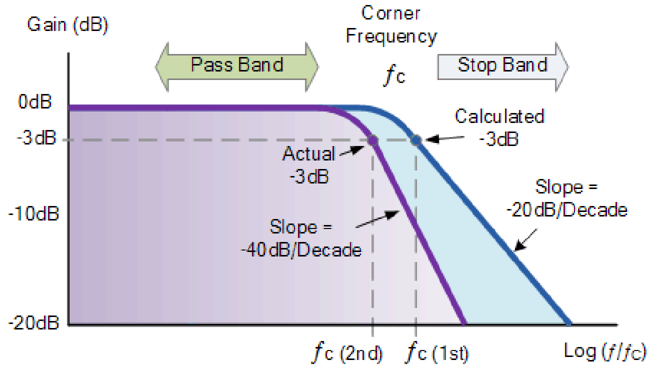
**Elliptic:** This filter, also known as the Cauer filter has significant levels of in band and out of band ripple.

# Low Pass Filter

A Low Pass Filter is a circuit that can be designed to modify, reshape or reject all unwanted high frequencies of an electrical signal and accept or pass only those signals wanted by the circuit designer.

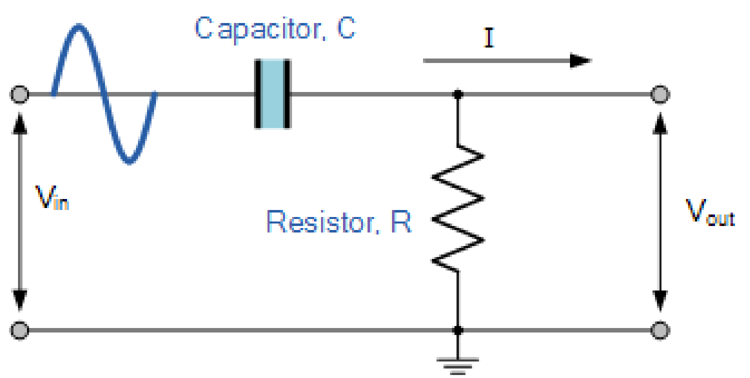


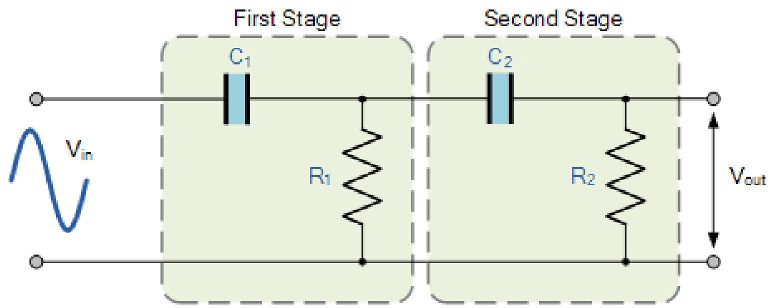



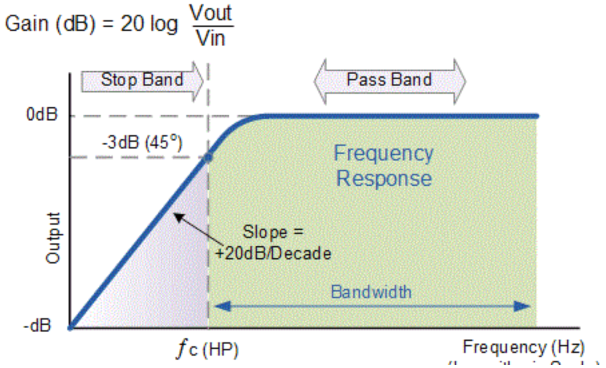



# High Pass Filter

A High Pass Filter is the exact opposite to the low pass filter circuit as the two components have been interchanged with the filters output signal now being taken from across the resistor.

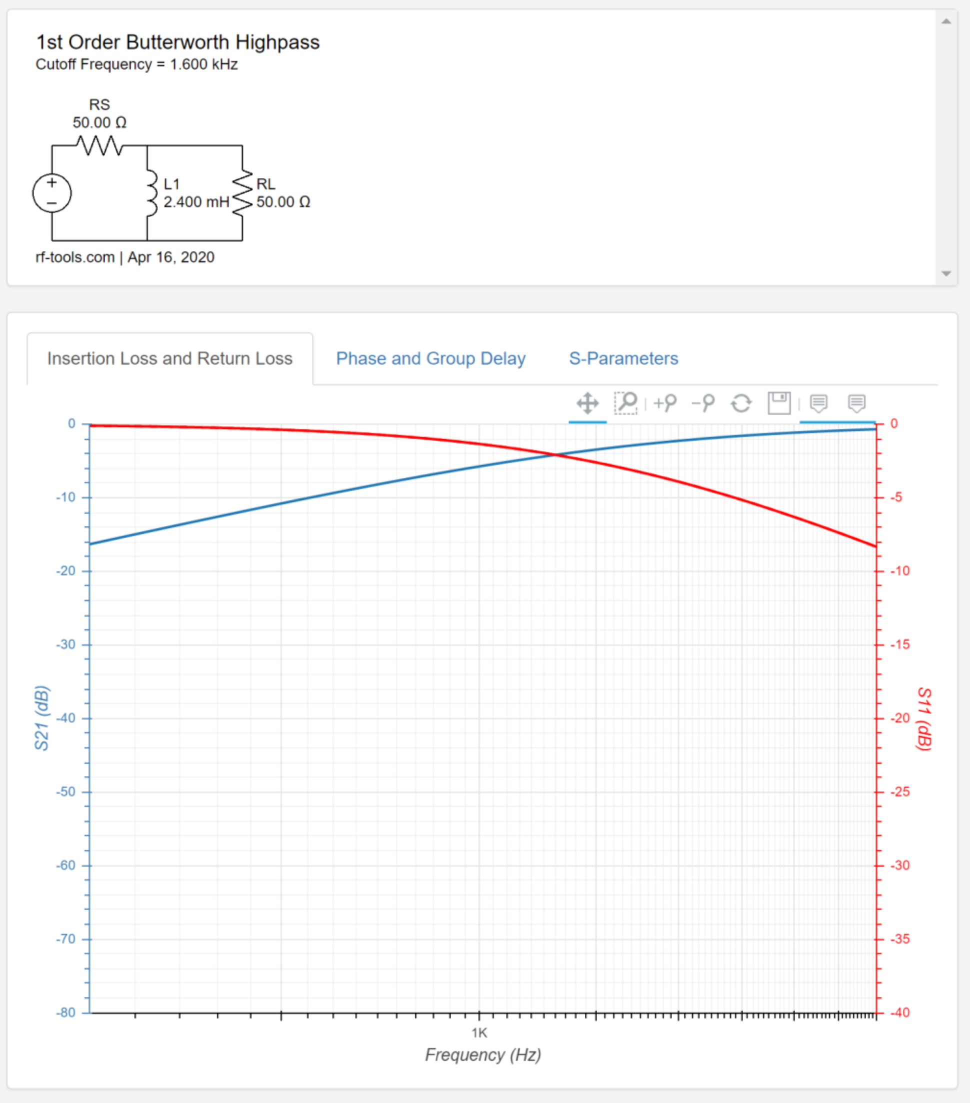


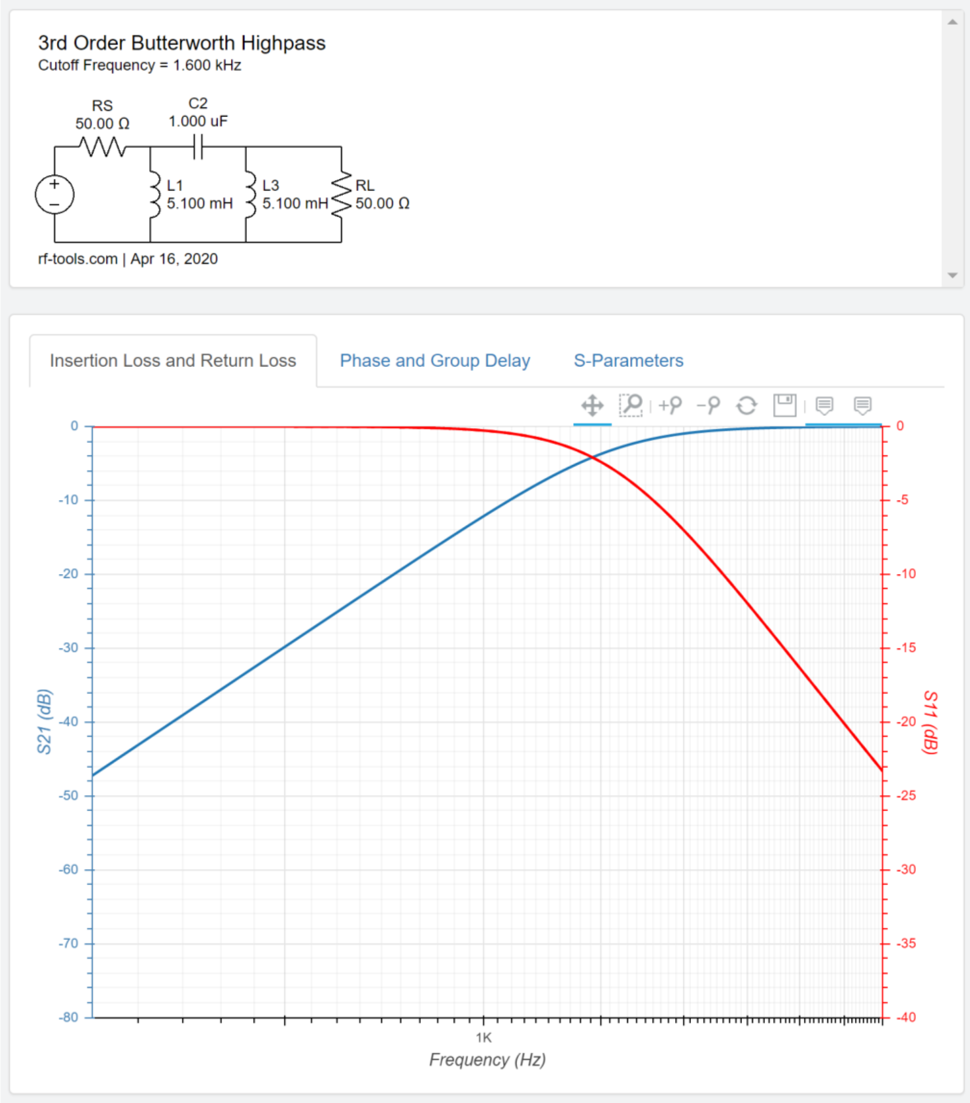
# 1st-order filter

Also called “poles”



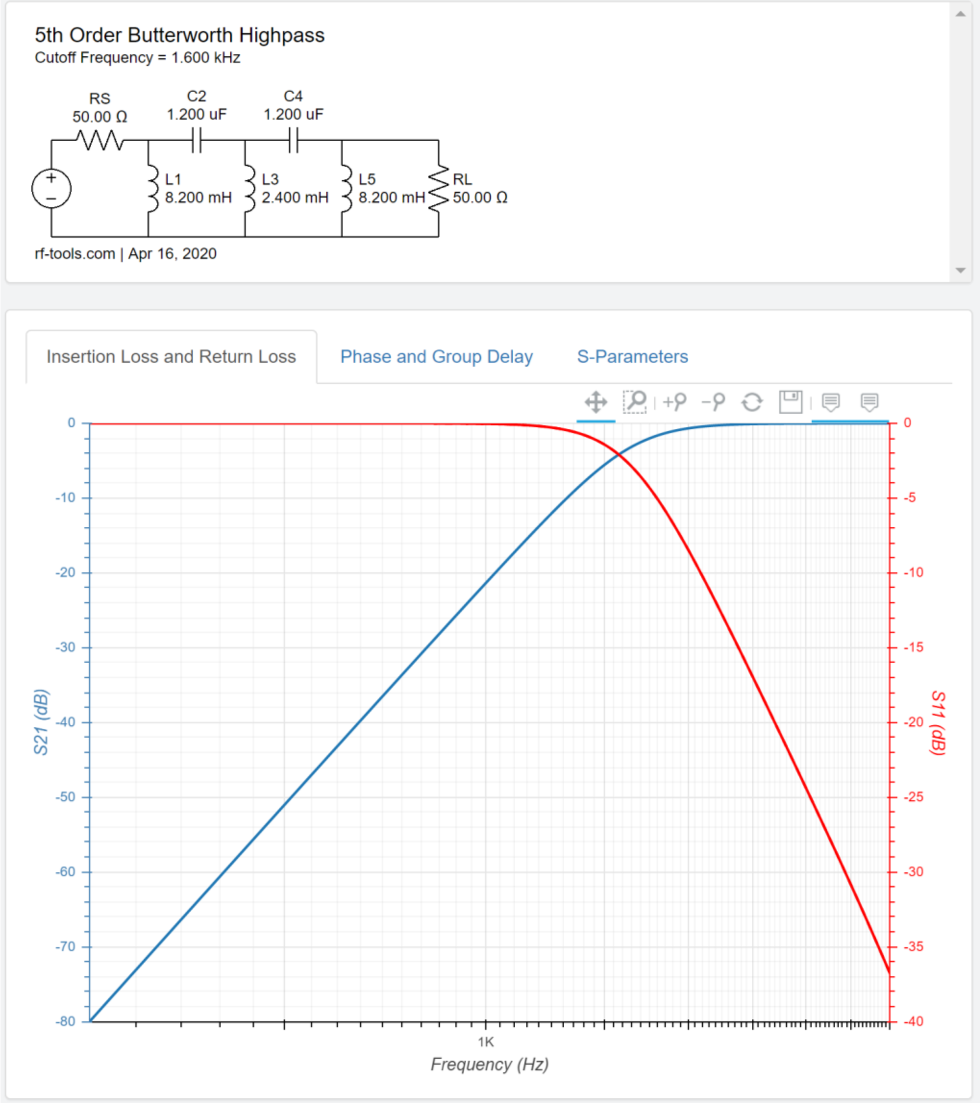
# 3rd-order filter

Also called "poles"



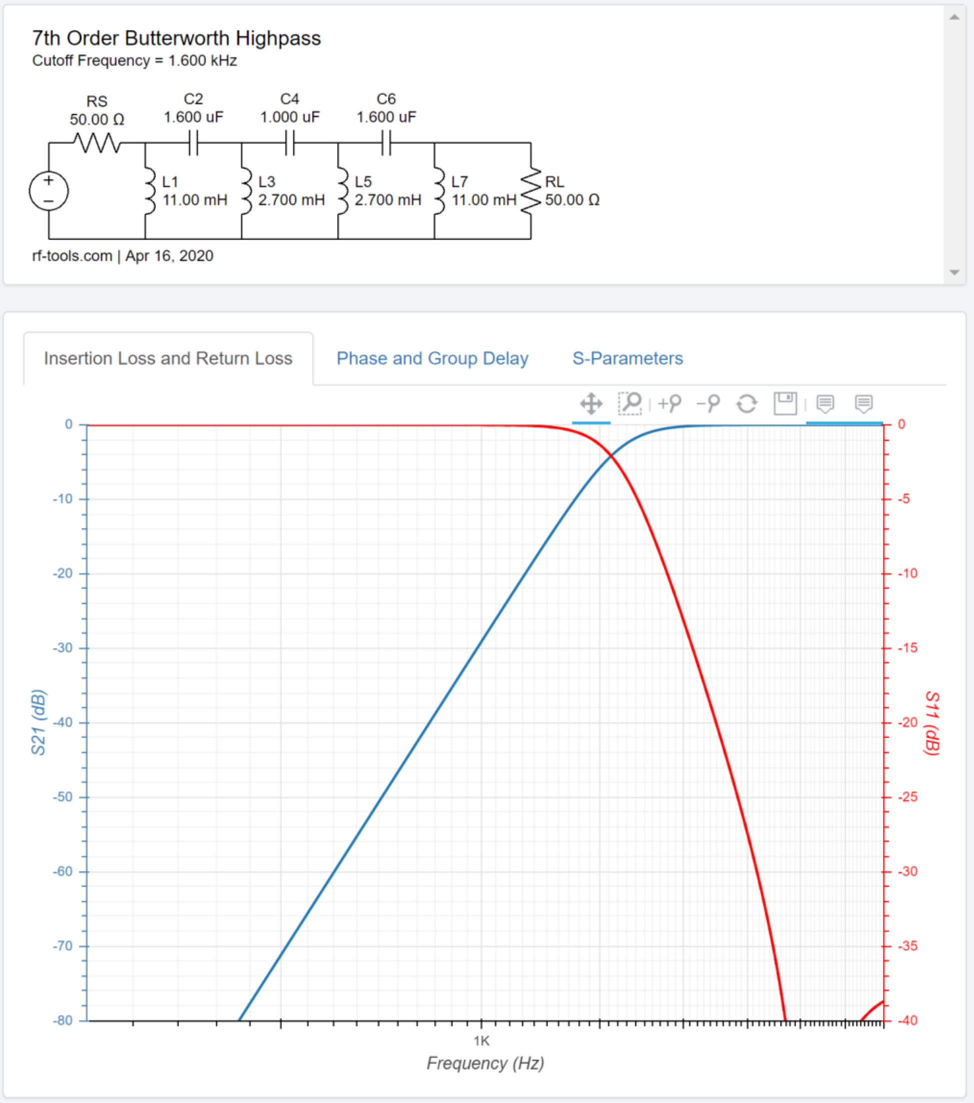
# 5th-order filter

Also called “poles”



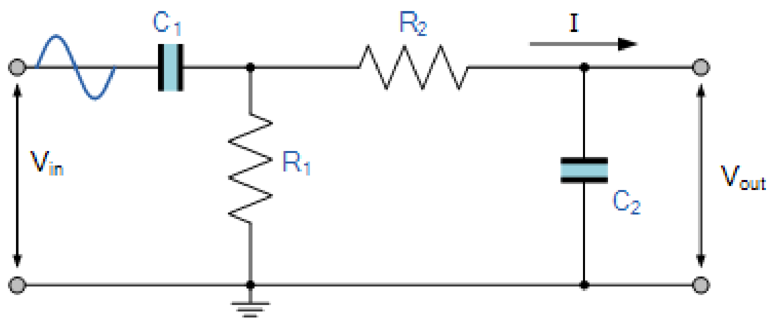
# 7th-order filter

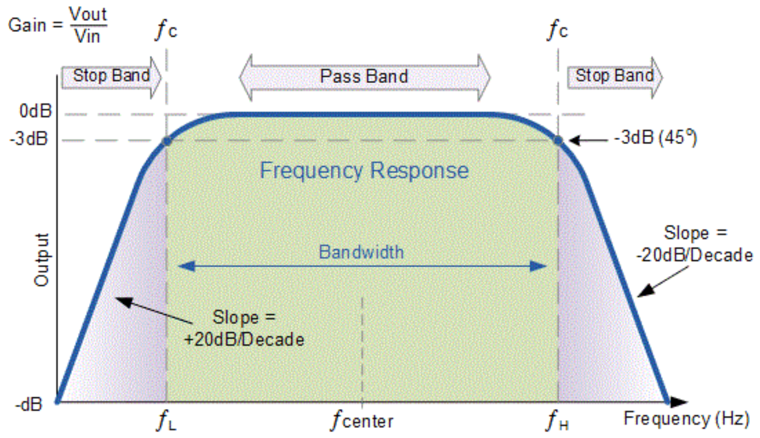
Also called “poles”



# Band Pass Filter

Passive Band Pass Filters can be made by connecting together a low pass filter with a high pass filter.



# Filter Uses

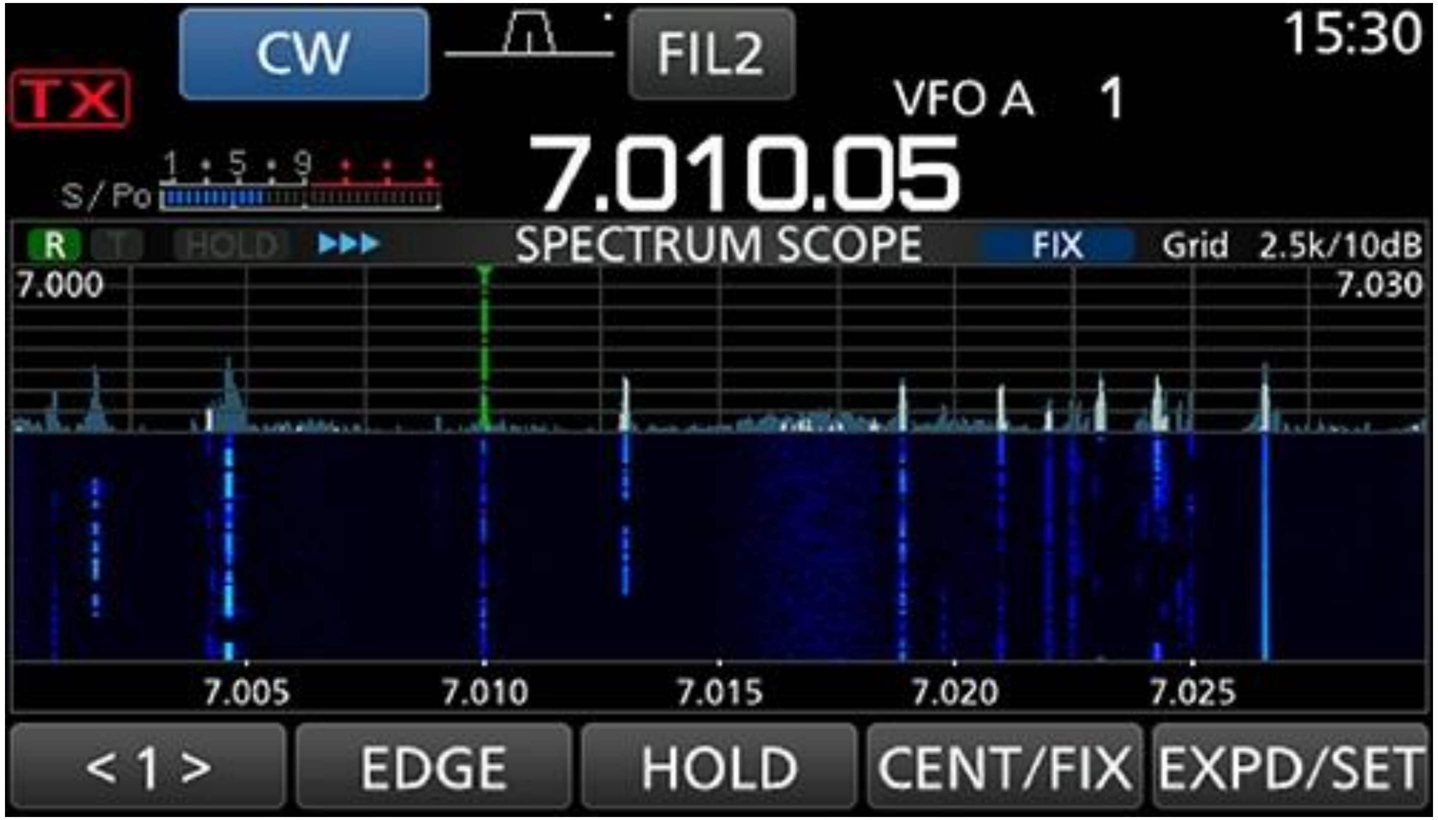
- CW
- SSB
- Duplexers
- Triplexers
- Repeaters

# CW Filter

Typically 300 Hz or 500 Hz.

# CW Filter

IC-7300 Spectrum Scope.

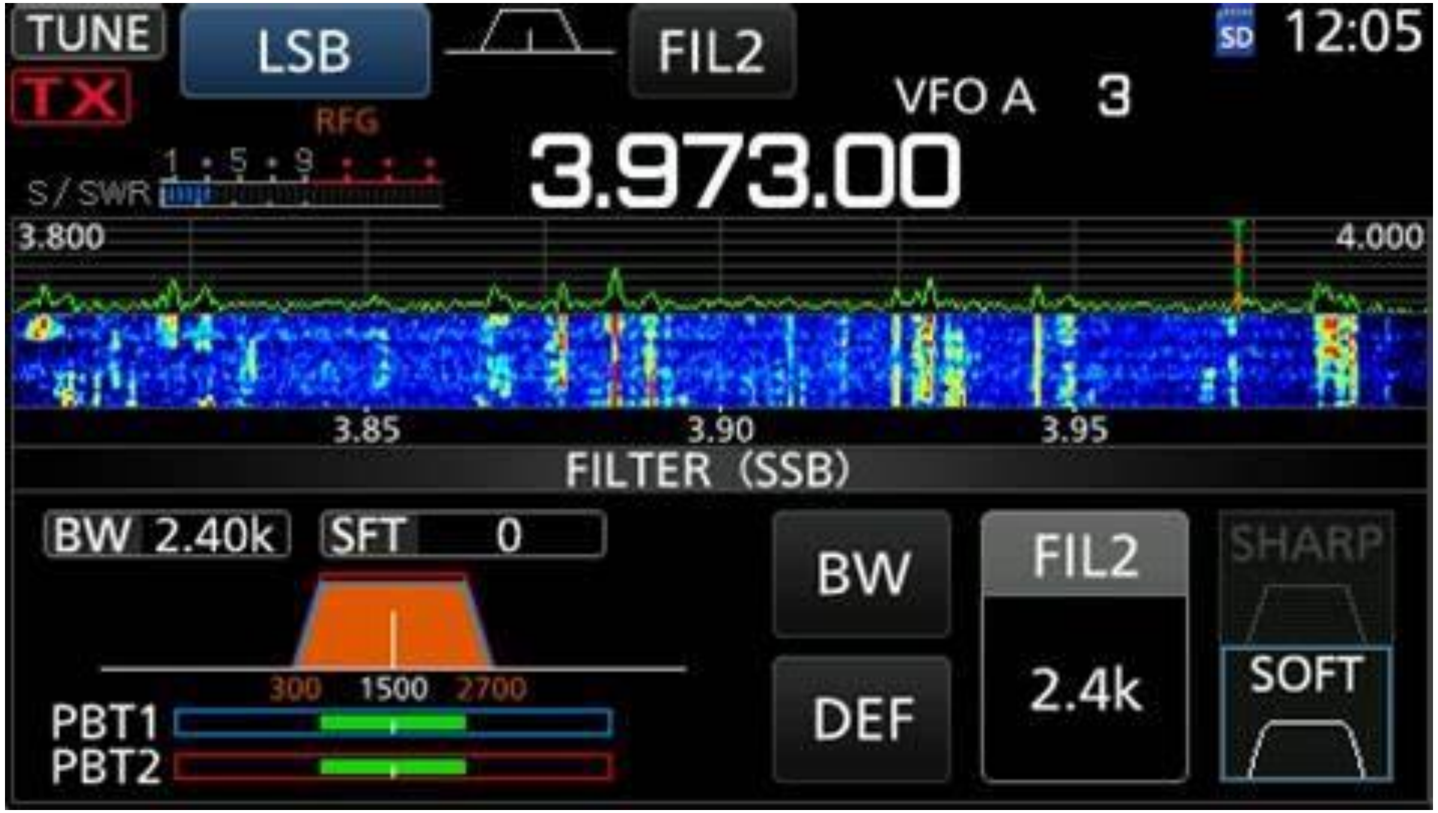


# SSB Filter

Typically 1.8 kHz, 2.4 kHz or up to 3 kHz.

# SSB Filter

Setting the filter specifications.

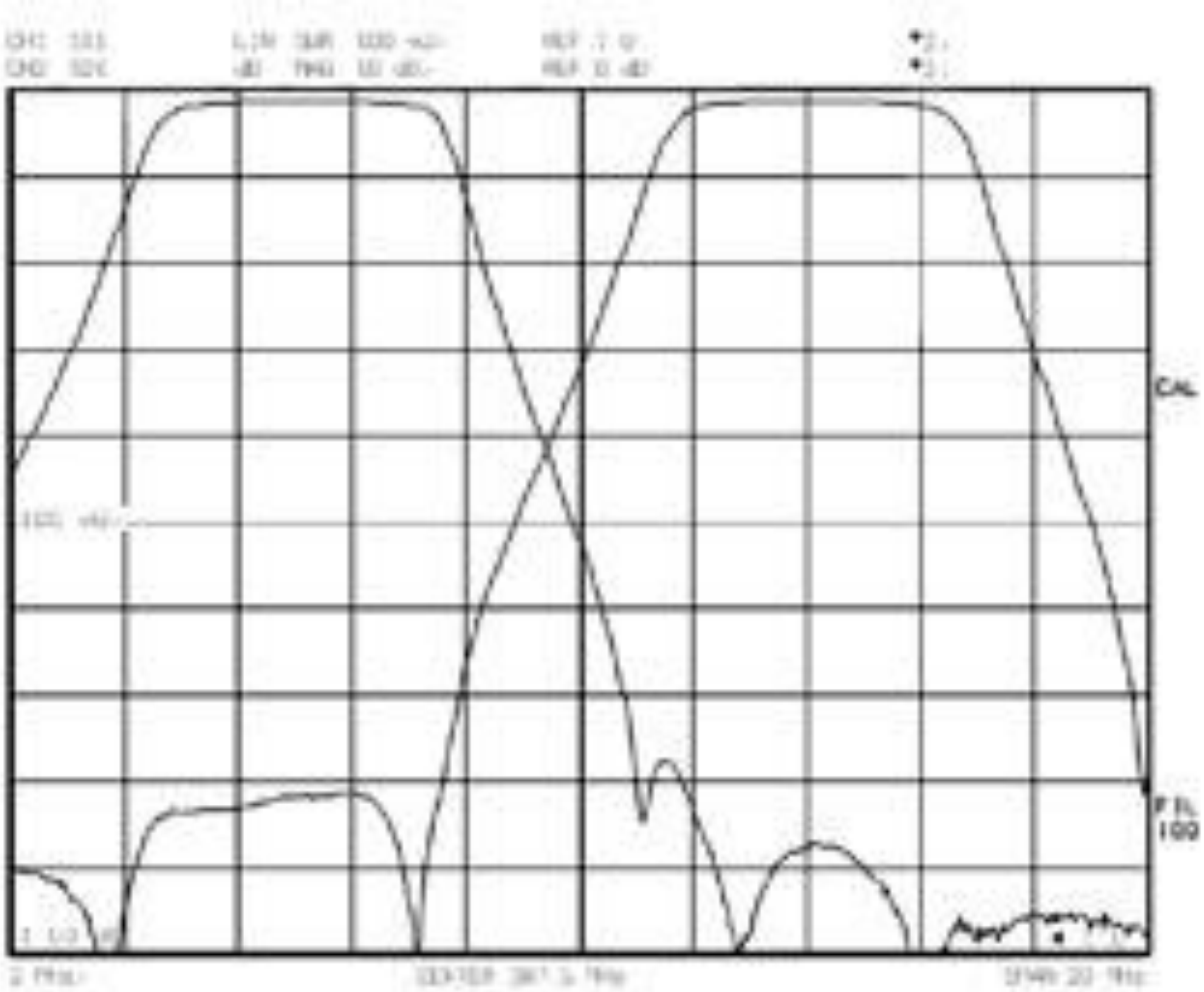


# Diplexers

Aren’t they the same?

# Diplexers

Response Curve

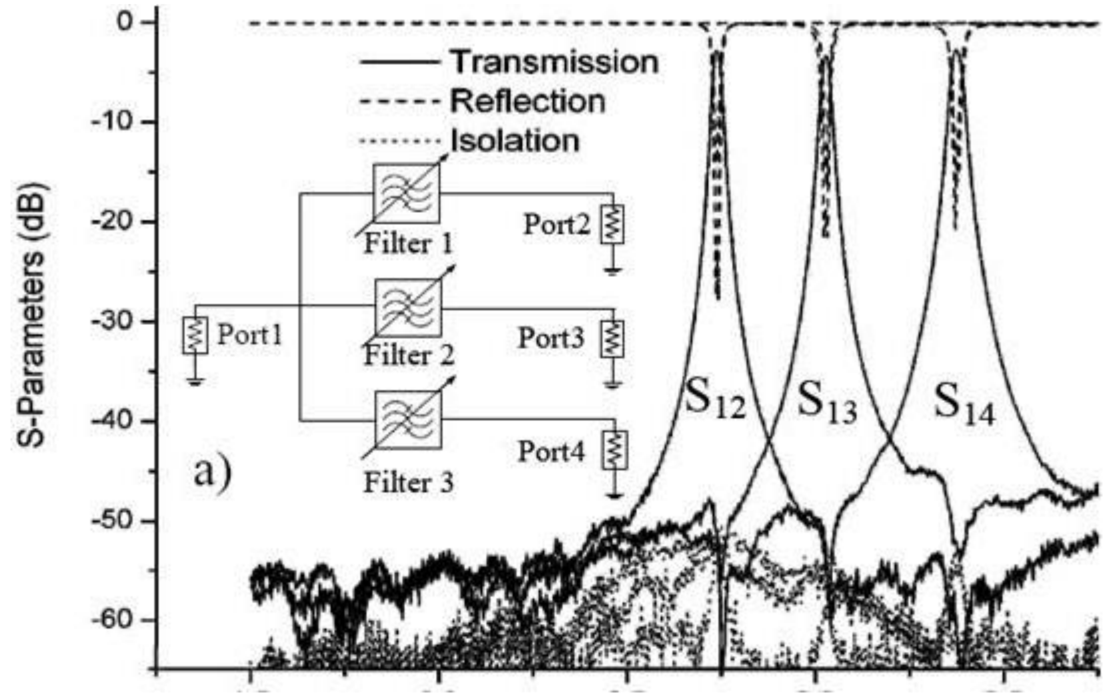


# Triplexers


ANTENNA
Dunestar
HF TRIPLEXER
BANDPASS FILTER INPUTS
20M
15M
10M
Dunestar
300-14
Dunestar
300-21
Dunestar
300-28

# Triplexers

Response Curve

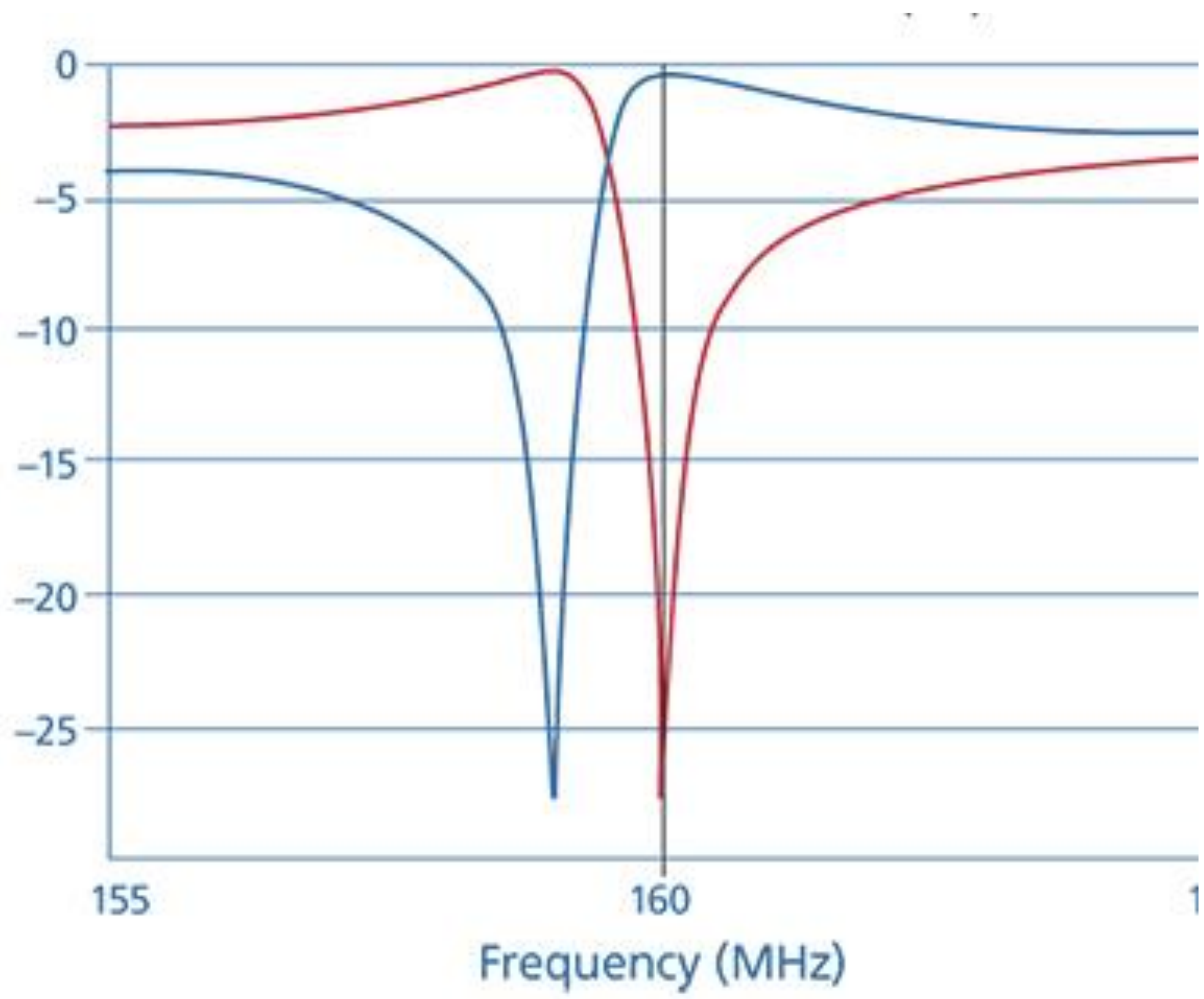


# Repeaters

Cavity Filters

# Repeaters

Cavity Response Curve



## Software

# Filter Design

# Circuit Design

# Filter Design

This is the hard way.

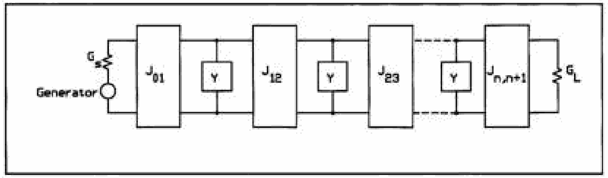



**Figure 4. Admittance inverter coupled bandpass filter.**

$$K_{adj(i,j+1)} = \frac{K_{i,j+1}}{F(\theta)} \qquad (5)$$

Where:

$$F(\theta) = \frac{2}{\tan(\theta)\,[\,\cot(\theta) + \theta\csc^2(\theta)\,]} \qquad (6)$$

Where $\theta$ is the electrical length of the resonator in radians.

If fringing capacitance beyond the nearest neighbor resonator is neglected, it is possible to describe TEM mode propagation along the structure in terms of two orthogonal modes designated as even and odd. They have different characteristic impedances which are intimately related to the total static capacitances of the rods to ground when in one or the other mode. The total static capacitances are related to the mutual capacitance between successive rods $C_m$ and the self-capacitance $C_g$ of each rod (2). Figure 3 shows that the total capacitance measured between one rod and ground when the rods are driven in the odd mode is (2):

$$C_o = C_g + 4C_m \qquad (7)$$

Total capacitance measured between one rod and ground when the rods are driven in the even mode is:

$$C_e = C_g \qquad (8)$$

From equations 7 and 8:

$$C_m = \frac{C_o - C_e}{4} \qquad (9)$$

Now, adjusted coupling coefficients can be related (equation 5) to these capacitances via:

$$K_{adj(i,j+1)} = \frac{C_m}{C_o + 2C_m} \qquad (10)$$

To obtain the spacing, Cristal's (2) graphs are used to interpolate the desired $C_m$ & $C_g$ for given spacing. Alternatively, a less accurate method can be used. This involves replacing the round rods with infinitesimal line charges located at the center of each cylinder using the method of images. It gives a correct asymptotic form to the solutions of the actual round rod problems in the even and odd mode. The following are the equations per Cristal's second-order correction.

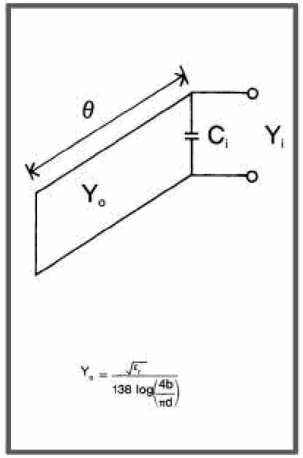



**Figure 5. Shorted stub resonator.**

$$\frac{\varepsilon}{C_{odd}} = \frac{1}{2\pi}\ln\left|\frac{(\pi/4)(d/b)}{\sqrt{1-(d/2b)^4}} - \frac{1}{2}\ln\left[1-\left(\frac{d/b}{2C/b}\right)^4\right] + 2\sum_{m=1}^{\infty}(-1)^m \ln\tanh[(m)(\pi/2)(C/b)]\right| \qquad (11)$$

$$\frac{\varepsilon}{C_{even}} = \frac{1}{2\pi}\ln\left|\frac{(\pi/4)(d/b)}{\sqrt{1-(d/2b)^4}} + \frac{1}{2}\ln\left[1-\left(\frac{d/b}{2C/b}\right)^4\right] + 2\sum_{m=1}^{\infty}\ln\tanh[(m)(\pi/2)(C/b)]\right| \qquad (12)$$

$$\text{where } C = s + d \qquad (13)$$

**Equivalent Circuit**

In order to simulate the response of such a filter, an equivalent circuit is needed. This is done by Matthaei's (1) generalized bandpass filter using admittance inverters. For this model, the resonators are shorted transmission lines (90 degrees) that are loaded with lumped capacitors. J (or admittance) inverters are formed from stubs of electrical length $\theta$ (1). Note that negative admittances will be absorbed into adjacent resonator admittances. Loading capacitors are calculated from:

$$C_i = \frac{1}{W_o Z_o \tan(\theta)} \qquad (14)$$

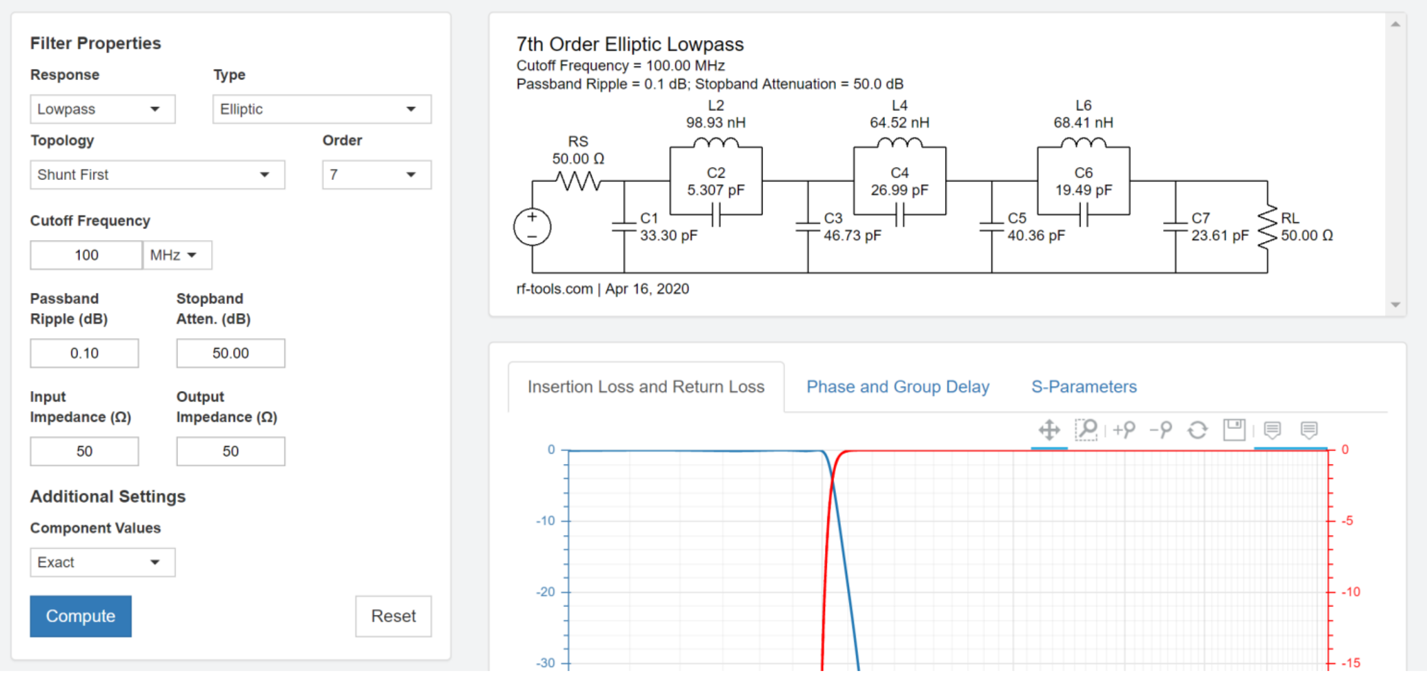
Series shorted stub admittances are calculated from:

$$Y_{i,i+1} = \frac{K_{i,i+1}}{Z_o F(\theta)} \qquad (15)$$

An input admittance inverter which determines the series coupling capacitor to external circuits is obtained from (1):

# Filter Design

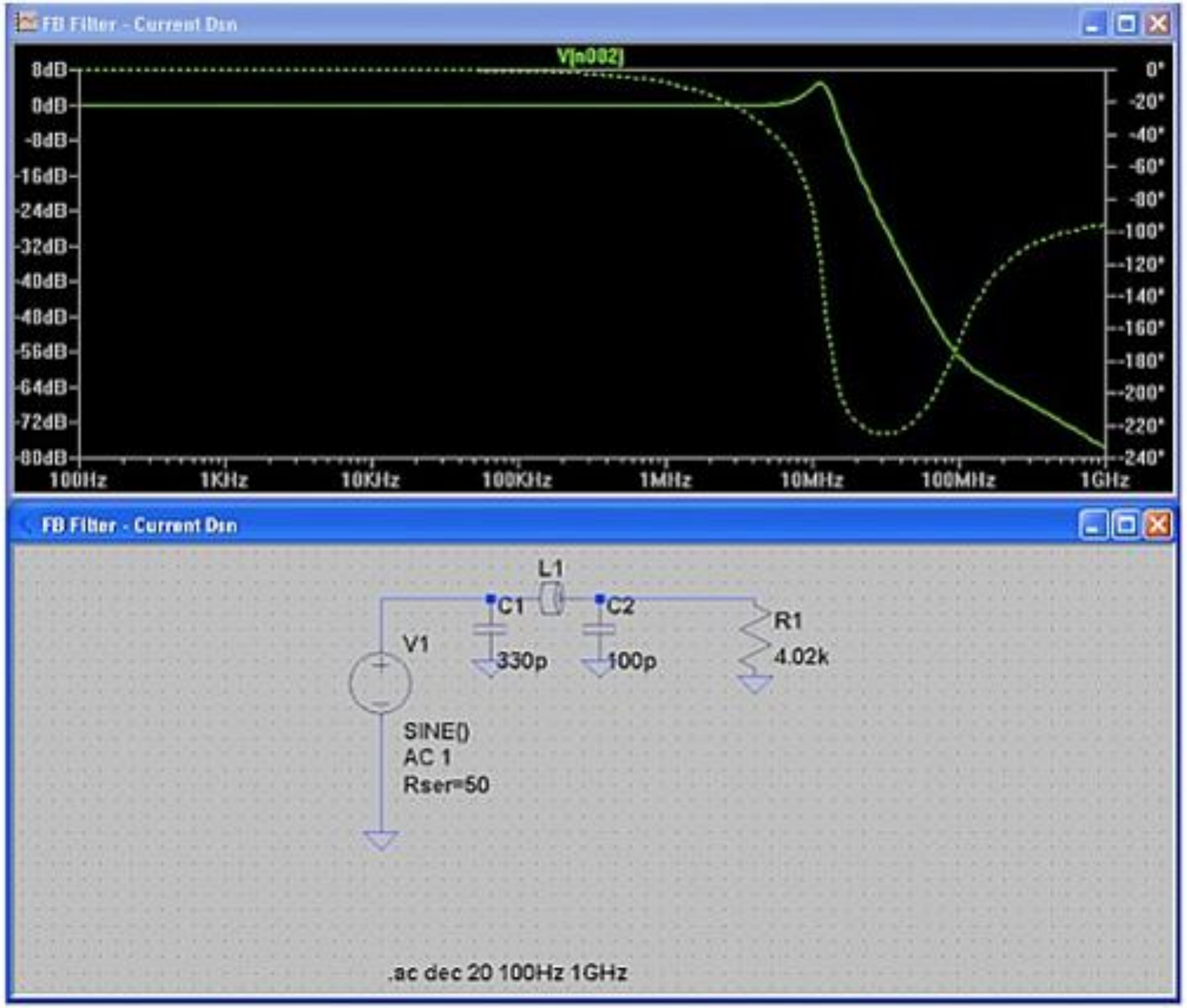
LC Filters Design Tool - Calculate LC filters circuit values with low-pass, high-pass, band-pass, or band-stop response.




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

# Circuit Design

LTspice - is a high performance SPICE simulation software, schematic capture and waveform viewer with enhancements and models for easing the simulation of analog circuits.



Thank you!

# Questions?

# Links

Filter Design

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

Circuit Design

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