Anatech Technical Reference Series

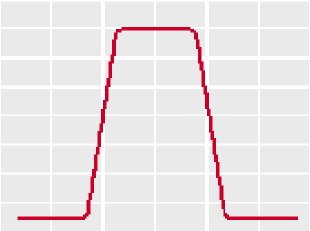
USEFUL DEFINITIONS FOR SPECIFYING ANATECH FILTERS

OVERVIEW

This document defines parameters that are important to understand when specifying Anatech filters and filter-based products. Many of the parameters or specifications described below apply to other Anatech products as well, such as directional couplers, power dividers, and circulators.

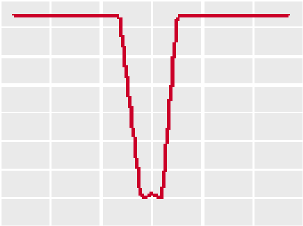
TYPES OF FILTERS

Bandpass filter: Passes energy within a certain bandwidth and rejects frequencies below and above this bandwidth.



Bandpass response

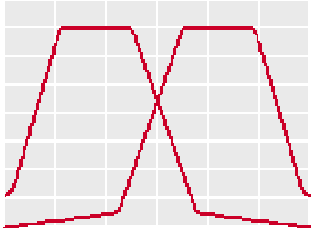
Bandstop or band-rejection filter: Passes most frequencies without disrupting them but significantly attenuates frequencies over a specific region. A bandstop filter is essentially the opposite of a bandpass filter. A notch filter is a specific type of bandstop filter that has a narrow stopband.



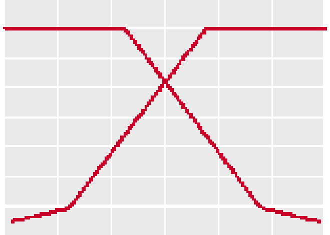
Bandstop (notch) response

Diplexers and duplexers: These devices are both used to combine two ports into a common port with a high degree of isolation between them so they can employ a single antenna without interfering with each other.

A diplexer is used to combine signals or channels at widely different frequencies and a duplexer can accommodate frequencies or channels that are much closer to each other. Consequently, diplexers are used to combine channels in wireless base station transceivers (for example) and duplexers are used to combine signals in radar or other systems in which the two frequencies are far apart.



Duplexer response



Diplexer response

Anatech duplexers and diplexers are manufactured from either ceramic, cavity, or SAW filters.

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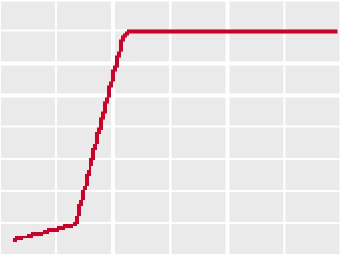
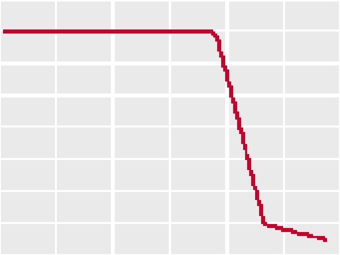
Highpass filter: Passes energy above a specified cutoff frequency, and rejects signals at frequencies lower than the cutoff frequency.



Highpass response

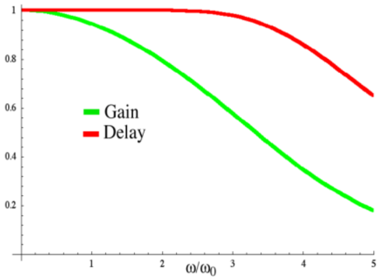
Lowpass filter: Allows energy from DC to a specified (cutoff) frequency to pass with little or no attenuation while energy above this frequency is rejected.



Lowpass response

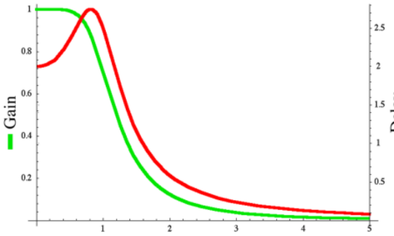
BASIC FILTER RESPONSES

Bessel or Gaussian responses are recommended when minimal group delay variation is desired. Both responses exhibit linear phase characteristics at the expense of selectivity. Like the Butterworth responses, they have no ripple in the passband or the stopband. The Bessel response has fairly good amplitude and transient characteristics. The Bessel response is appealing because it is optimized to obtain “maximally-flat” group delay or linear phase characteristics in the filter’s stopband.



Bessel filter response

The **Butterworth** (maximally-flat) response has no ripple in the passband or stopband. Attenuation is about 6 dB per octave per section. Butterworth filters are usually normalized for an attenuation of 3 dB at the cutoff frequency.



Butterworth filter response

The **Chebyshev** response has ripple in the passband but no ripple in the stopband. The amount of ripple can be controlled and is directly proportional to standing-wave ratio and reflection coefficient. The cutoff frequency is specified at attenuation equal to the passband ripple. The Chebyshev response is more selective than the Butterworth response at the expense of increased insertion loss and greater group delay.

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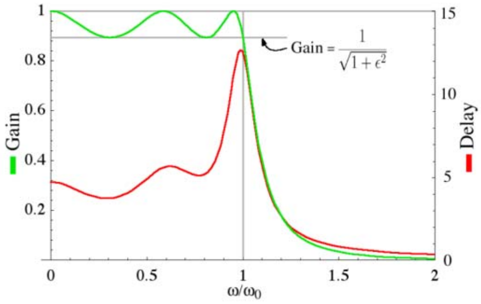
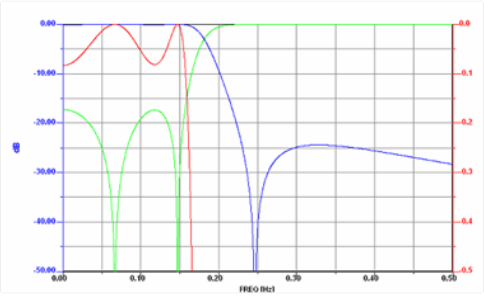
The **elliptic (Cauer)** response has ripple in the passband and stopband. The amount of ripple in the passband and in the stopband can be controlled. As with the Chebyshev response, ripple is proportional to standing-wave ratio and reflection coefficient. Filters with an elliptic response are more selective than Chebyshev types but exhibit more group delay variation in the passband.



Chebyshev response



Elliptic filter response

KEY FILTER DEFINITIONS

These definitions are important to understand when specifying filters of any type.

Center frequency (Fo): The midpoint between the two 3-dB (half-power reduction) points in the passband of a bandpass filter (or bandstop filter), and is normally expressed as the arithmetic mean of the 3-dB points.

Cut-off frequency (Fc): The boundary between the passband and a stopband of a highpass or lowpass filter. That is, it is the transition point at which energy begins to be attenuated by a filter rather than allowing it to pass through (the point in the filter response at which a transition band and passband meet).

Dissipation: This is the energy loss in a filter that results from the non-ideal characteristics of its individual components, such as the resistivity in an inductor or capacitor, core saturation, resistance of connecting wires, and metal conductivity.

This specification becomes very important with filters designed to handle high RF input power levels because energy loss or high dissipation can cause the filter to fail.

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Group delay (GD): This specification relates to the phase linearity of a filter versus frequency. Since a phase delay occurs at the output of a filter it is important to know if this phase shift is linear with frequency. If the phase shift is nonlinear with frequency, the output waveform will be distorted. Linear phase shift will result in constant group delay since the derivative of a linear function is a constant.

Impedance: This value, specified in ohms, is the filter's source (input) and the terminating (output) impedances. Input and output impedance should match the impedance of the transmission path in which the filter is placed. An impedance of 50 ohms is almost universal throughout RF and microwave system designs, although an impedance of 75-ohms is used in cable television systems.

Insertion Loss (IL): This is the ratio of signal amplitude before a filter to the amplitude at its output. At any frequency it is defined as: IL=10Log(Pl/Pin), where Pl is the load power and Pin is the power from the input source. Insertion loss should be as low as possible regardless of the power-handling ability of the filter.

For example, heat dissipation increases at higher power levels, and lower insertion loss can help reduce it. When signal levels are low, high insertion loss can reduce the output after the filter to an unacceptable level.

Isolation: This relates to the ability of a diplexer or duplexer to reject the transmit (Tx) frequency without affecting the receive (Rx) frequency, and the ability to reject the receive (Rx) frequency without affecting the transmit (Tx) frequency. This is called Rx/Tx isolation and the greater the isolation the more effectively the filter can isolate the Rx from the Tx and vice versa. Higher values of isolation translate into cleaner transmit and receive signals.

Passband: The spectral region in which a filter has the least attenuation and thus allows the most signal to pass. Passband is usually defined at the 0.5 dB, 1 dB, or the 3 dB (half-power) points or others depending on the requirements of the host system design.

Power handling: This is the RF input power beyond which the performance of the filter may degrade or fail, expressed in watts (W). It is typically specified as a continuous wave (CW) value, as an average value that is usually 10 times its CW rating, or both.

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Q factor: This is the ratio of a filter's center frequency to its bandwidth. For a bandpass filter, Q factor is actually the loaded Q factor since the driving and terminating load impedances are connected to the filter when it is inserted into a network. In contrast, unloaded Q factor represents the performance of the components used to make the filter. Unloaded Q is not a key element of filter specification because it is adequately represented by the filter's other characteristics.

Rejection: The level, expressed in decibels, at which a filter will attenuate a signal outside its passband. It is specified either at a single frequency or frequencies or a range of frequencies. A filter's rejection is often also often referred to as its attenuation.

Relative attenuation: The attenuation difference measured from a filter's minimum attenuation point to its desired rejection point. Relative attenuation is usually specified in decibels related to the carrier (dBc). Higher values of attenuation are desirable.

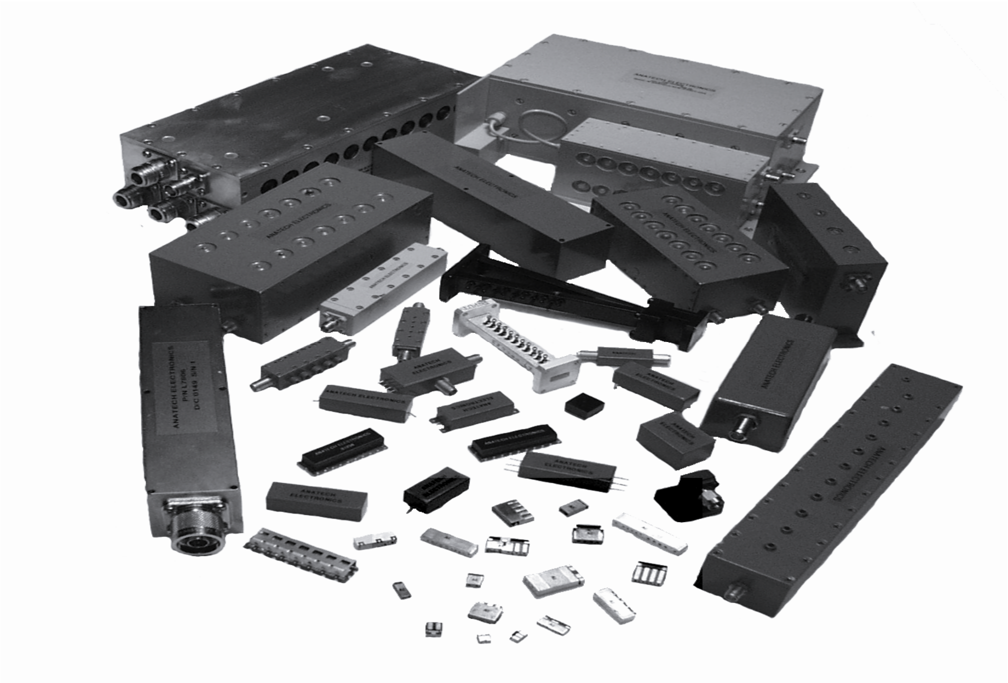
Return Loss (RL): Return loss is an indicator of how close the input and output impedance of the filter is to an ideal impedance value. Return loss at any frequency is defined as: RL=-10Log(Pr/Pin) where Pr is the power reflected back to the input signal source. Higher values of return loss indicate a better impedance match.

Ripple: This specification relates to how flat a filter's response is in its passband and is normally expressed in decibels. The amount of ripple in a filter will affect its return loss: the greater the ripple the worse the return loss and vice versa.

Shape factor: The shape factor of a bandpass filter is the ratio of its stopband bandwidth to its 3-dB bandwidth and is a measure of its rejection characteristics. For example, if a filter's 40-dB bandwidth is 40 MHz and the 3-dB bandwidth is 10 MHz, the shape factor will be 40/10=4. It is generally more useful to simply refer to the filter's stopband rejection and bandwidth.

Stopband rejection: The ratio of the unwanted frequency components at the input of the filter to those after it. It is a key filter performance specification because it equates to its rejection capability. Values can range from 20 to 100 dB.

VSWR (Voltage Standing Wave Ratio): This is the ratio between the maximum and minimum values of a standing wave on a transmission line. It indicates the impedance mismatch between ideal and actual values. Return loss and VSWR are related, as RL=-20Log[(VSWR-1)]/(VSWR+1)]. An ideal (although unattainable) VSWR is 1:1.



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