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# "Get it Right the First Time" When Specifying Filters

By Sam Benzacar and Joesph Pillari
Anatech Electronics

Here is a set of practical guidelines that one company has developed to help guide their customers in the selection of the right filter type and the development of realistic performance specifications

This note presents eight important tips to help engineers specify filters for RF and microwave applications. Following these guidelines can help trim costs, reduce production delays and, of course, obtain the intended level of performance for your system.

In a classic case of what you don't know *can* hurt you, design engineers with advanced knowledge of digital electronics are discovering an urgent need to brush up on RF basics when it comes to specifying filters for wireless devices. Failure to take into account the fundamental aspects of filter types and minimum specification requirements can result in products that fail during test, thus incurring costly production delays as the product goes back to the drawing board. On the other hand, knowing how to accurately specify filters helps yield products that meet production benchmarks and function correctly in the hands of the customer. In effect, this knowledge helps contain production expenses while upping the product's chance of success in the marketplace.

## Back to the Basics

The fierce competition for band space in today's wireless world dictates an ever-increasing attention to filter performance. Inaccuracies in specifying the correct filter ultimately translate into frequency conflicts that come back to bite the design team in the form of cross-talk, dropped calls, loss of data and interrupted network connections.

The problem of incomplete or inaccurate specification of filters partly rests on today's emphasis on digital electronics in the electronics marketplace. By some accounts, 80-90% of new electronic design engineers are software- and digital-oriented. These are the engineers who can benefit most from these fundamental guidelines. There is often a knowledge gap, but no matter that the intelligence being transmitted is in digital form, when it travels through the "ether" via radio or microwave, the carrier always obeys the laws of electromagnetic physics.

Fortunately, a quick refresher on some of the more essential elements of filter performance specifications can aid engineers in correctly calling out filters that meet the needs of their particular application. Doing it right the first time saves time and money, ensuring more bang for the buck when ordering these indispensable components.

## 1) Know the basic response curves

Basic response curves for filters include: a) bandpass; b) lowpass; c) highpass; d) bandstop; e) diplexer and f) duplexer. The respective characteristics of each type determines which frequencies get through and which don't.

Far and away, the most common among this group is the bandpass filter. All engineers know that a bandpass filter allows signals between two specific frequencies to pass, but discriminates against signals at other frequencies. Examples include surface acoustic wave (SAW) filters, crystal filters, ceramic and cavity filters. As a point of reference, the cavity bandpass filters manufactured by Anatech Electronics cover a frequency range from 15

Lumped Components Bandpass Filters

| Frequency Range (MHz) | Number of Sections | 3dB BW % | VSWR (max) | Impedance In/Out | Response | Avg. Input Power | Temp (deg. C) | Shock | Vibration |
|---|---|---|---|---|---|---|---|---|---|
| 1 to 1000 | 2 to 12 | 5 to 100 | 1.5:1 | 50 or 75 Ohms | Chebyshev | 2 to 20 watts | -25 to +70 | 30G 11 msec | 10G 5 to 200Hz |

Lumped Components Lowpass Filters

| Frequency Range (MHz) | Number of Sections | VSWR (max) | Impedance In/Out | Response | Relative humidity | Avg. Input Power | Temp (deg. C) | Shock | Vibration |
|---|---|---|---|---|---|---|---|---|---|
| 0.1 to 5000 | 2 to 18 | 1.5:1 | 50 or 75 Ohms | Chebyshev | 0-80% | 2 to 100 watts | -25 to +70 | 30G 11 msec | 10G 5 to 2000 Hz |

Lumped Components Highpass Filters

| Frequency Range (MHz) | Number of Sections | VSWR (max) | Impedance In/Out | Response | Relative humidity | Avg. Input Power | Temp (deg. C) | Shock | Vibration |
|---|---|---|---|---|---|---|---|---|---|
| 0.1 to 6000 | 2 to 10 | 1.5:1 | 50 or 75 Ohms | Chebyshev | 0-80% | 2 to 100 watts | -25 to 70 | 30G 11 msec | 10G 5 to 2000Hz |

Lumped Components Bandstop Filters

| Frequency Range (MHz) | Number of Sections | 3dB BW % | VSWR (max) | Impedance In/Out | Response | Avg. Input Power | Temp (deg. C) | Shock | Vibration |
|---|---|---|---|---|---|---|---|---|---|
| 1 to 1000 | 2 to 12 | 5 to >100 | 1.5:1 | 50 or 75 Ohms | Chebyshev | 2 to 20 watts | -25 to +70 | 30G 11 msec | 10G 5 to 200Hz |

Lumped Components Diplexers & Duplexers

| Frequency Range (MHz) | Number of Sections | 3dB BW % | VSWR (max) | Impedance In/Out | Response | Avg. Input Power | Temp (deg. C) | Shock | Vibration |
|---|---|---|---|---|---|---|---|---|---|
| 5 to 700 | 2 to 10 | 5 to >100 | 1.5:1 | 50 or 75 Ohms | Chebyshev | 2 to 20 watts | -25 to +70 | 30G 11 msec | 10G 5 to 200Hz |

**Table 1 · A summary of the ranges for typical specifications of various types of filters using lumped components.**

MHz to 20 GHz with bandwidths from 1% to 100%. For all manufacturers, the passband of a filter is usually defined at the 0.5 dB, 1 dB, or 3 dB attenuation points on either side of the center frequency.

### 2) Include all necessary filter specifications

It may be hard to believe, but too many times an engineer will send out a short RFQ for "a 100 MHz bandpass filter"—a statement that is the 180° opposite of "too much information." A filter supplier can hardly fill an order in such an information vacuum.

Providing all the necessary information begins with detailing all the frequency parameters such as: a) the center frequency; b) the cut-off frequency; and c) rejection frequencies. Filter type determines the specified frequency. For bandpass and band reject filters, the specified frequency is the center frequency. For lowpass and highpass filters, the specified frequency is the cut-off frequency.

To be totally complete, engineers should also specify a wide range of performance characteristics such as: a) stopband attenuation; b) isolation; c) insertion loss; d) return loss; e) group delay; f) shape factor; g) input/output impedance(s); h) relative attenuation; i) passband ripple; j) ultimate rejection; and k) operating temperature range.

### 3) Do not seek unrealistic filter characteristics

Cases exist when an engineer has made a request such as, "I want a passband extending from 1490 to 1510 MHz, and I want 70 dB of rejection at 1511 MHz." This cannot be done. In reality, the rejection is gradual, not a sharp drop off, so a more realistic specification would specify the rejection at an offset of approximately 10% from the center frequency.

Another instance involves broad requests for a filter that "rejects everything above 1960 MHz," for example. In this case, the engineer must be reminded of the near-impossibility of attenuating every frequency from that rejection frequency out to infinity. Some boundaries must be set. A more realistic approach might involve attenuating out to 2 or 3 times the specified rejection frequency.

### 4) Shoot for a reasonable VSWR

Often used as a measure of the filter efficiency, the voltage standing wave ratio ranges from 1 to infinity and expresses the amount of reflected energy. A value of 1 indicates that all of the energy passes. Any greater value indicates that a portion of the energy is reflected, i.e. wasted.

However, in the real world of electronic circuits, a 1:1 VSWR is almost impossible to attain over a span of frequencies. Typically, a ratio of 1:5 represents a more nominal goal. Requesting anything lower than that corresponds to a decreasing benefit to cost ratio. Do so only if system requirements demand lower VSWR.

### 5) Consider power handling

Power handling is the rated average power in watts beyond which the performance of the filter may degrade or fail.

Also note that filter size is driven somewhat by the power handling requirements. In general, the greater the power, the larger the footprint of the filter on the circuit card or in the enclosure. While manufacturers like Anatech stay constantly at work creating new algorithms to accommodate these competing interests, upfront planning here can save costs.

### 6) Factor in isolation for simultaneous, two-way communications

An especially important aspect in diplexers, isolation represents the filter's ability to reject the transmit frequency while simultaneously looking at the receive channel, and vice versa. The more isolation, the better the two can be separated. This separation translates into cleaner transmitted and received signals.

### 7) Be aware of tradeoffs

Higher performance usually incurs higher costs. All the more reason why accurate specifying—which curtails unneeded extremes—helps avoid unnecessary expenses.

Beyond that, other factors deserve weighing against each other. For example, the closer the rejection frequencies are to the center frequency, the more complex the filter. In some cases this may result in greater insertion loss.

Additionally, higher performance usually necessitates a filter with a larger foot print. For example, a very sharp transition from passband to rejection requires a more complex filter with a greater number of cavities and sections. But when real estate on a circuit card is at a premium, performance may have to be scaled back.

### 8) Find a manufacturer who can balance competing demands

While not an inherent characteristic of filter performance, as much care should go into identifying a filter vendor as specifying the component itself. A quality, on-shore manufacturer who specializes only in filters can oftentimes create a custom part to accommodate a shortcoming in the product design.

At Anatech, for instance, parameters such as insertion loss, selectivity, and power handling capacity can be enhanced by using special design techniques. In-house design and manufacturing capabilities allow center frequencies, for example, to be shifted without scrapping the original circuit design of a product. By the same token, last-minute packaging changes can be handled by changing an input/output connector from one type to another. Such flexibility can save a project from cost overruns.

Since 1990, Anatech Electronics has responded to the changing RF and microwave marketplace with a product line that includes bandpass, lowpass, highpass, and bandstop filters; crystal filters; diplexers and duplexers, ceramic, cavity and monoblock filters for WiMax applications; as well as filters for WiFi applications. All components are ruggedly built to meet stringent military and commercial specifications.

### Author Information

Sam Benzacar is founder and president of Anatech Electronics, a manufacturer/distributor of custom and standard RF and microwave products. He has a Masters degree in Electrical Engineering with an emphasis in microwave and electromagnetic fields, and is an IEEE engineering association member. He has over 30 years of electronics industry experience, including positions as a design engineer, test and manufacturing manager, executive manager, and customer support manager.

Joseph Pillari is Technical Support Engineer at Anatech Electronics.

For more info, contact Anatech Electronics, Inc. Tel: 973-772-4242; email: sales@anatechelectronics.com; or at www.anatechelectronics.com.