Microwave Band Pass Filters: Is Tuning Necessary?

By Richard M. Kurzrok, PE
RMK Consultants

Microwave band pass filters can be designed and developed in various configurations. Some of these filters are manufactured, tested, and shipped with no in-plant tuning. Other filters require alignment of individual resonators prior to testing. This can include adjustment of center frequencies using mechanical or electronic techniques.

In some situations, filter couplings also entail adjustments [1]. In this article, various band pass filter design considerations will be discussed as an overview without delving into the intricate details of specific design requirements.

Types of microwave band pass filters

Field tunable band pass filters inherently entail adjustability. The need for these tunable units has been substantially reduced by refinements in microwave systems architecture. Many band pass filters are designed using approximate equations. Developmental procedures (2,3), that experimentally determine filter couplings, can be quite effective in overcoming the limitations of available design equations. Coaxial band pass filter structures, such as comb line and interdigital, and waveguide band pass filters are often designed using resonator tuning screws. Band pass filters using planar (microstrip, stripline, and coplanar waveguide) construction, in single or multiple layers, usually do not require alignment. Filters, printed as planar circuits, sometimes require several design iterations.

Basic considerations

In the era of government electronics, microwave band pass filter production quantities usually were not large. Primary considerations were performance and reliability. Unit costs were of secondary concern. In the current era of commercial electronics, cost has become a very important specification. Elimination of microwave band pass filter tuning provides two areas of cost reduction: filter hardware is simplified and alignment labor costs are eliminated. Furthermore, significantly lower unit cost can result in the demise of repairs. Some defective microwave filters can be treated as throw-aways replaceable by available spares.

In many situations, the need for band pass filter tuning depends upon filter percent bandwidth [4, 5]. Filters with percent bandwidths in excess of twenty percent, are rarely tuned. Some filters with moderate bandwidths of five to twenty percent can be realized without tuning. Narrow band pass filters of less than five percent usually have needed factory adjustment of individual resonators. With the advent of temperature stable ceramic filters for small percent bandwidths, low cost filters have been achieved without tuning screws.

Technical advances in many areas have affected the art of microwave band pass filter design. New materials and manufacturing processes have facilitated performance enhancement and cost reduction. The advent of personal computers (5,6) has permitted judicious use of optimization techniques and electromagnetic simulation. This can substantially reduce the number of iterations required during filter design and development.

Future realization of some microwave band pass filters will entail monolithic microwave integrated circuits (MMICS) at the sub-system and systems levels. During the past decade, lumped circuit band pass filters have replaced

Band Pass Filters Without Tuning Screws	Band Pass Filters With Tuning Screws
Cost reduction	Can correct for manufacturing tolerances
Miniaturization	Can reduce model multiplicity
Reliability	Can correct for source/load mismatches
Unloaded Q not reduced by tuning screws	Can help optimize system or sub-system
Power handling not reduced by tuning screws	Can adjust for equalizations
Hermetic sealing not impacted (no bellows)	Can be adaptive units
No tuning screw vibration	Can help with stringent specifications
Can reduce or eliminate unit repairs	Electromagnetic simulation not always available
Compatible with system integration	Can provide comb line capacitive loadings

▲ **Table 1. Comparative features of microwave band pass filters without and with tuning screws.**

some transmission line filters at microwave frequencies. Active microwave band pass filters can ultimately engender total integration. Silicon germanium semiconductor material can provide an order of magnitude improvement in frequency coverage for some future personal computers and other microwave products.

Impact of mechanical and materials tolerances

Mechanical and materials tolerances can affect the performance of fixed tuned microwave band pass filters. Sometimes, filter requirements permit use of guard bands that can mitigate response shape aberrations that accompany actual tolerance variations. Stringency of filter specifications is intricately related to allowable performance degradation. As operating frequencies increase, resonator wavelengths become smaller. This exacerbates the impact of mechanical tolerances when manufacturing precision is approaching practical and cost effective limits. The current availability of computer-aided design and analysis software [5] is crucial in determining the sensitivities of band pass filter response shapes to mechanical and materials tolerances.

Impact of resonator quality

Microwave band pass filter performance is quite dependent on the unloaded Q's of the filter resonators [4, 5]. Unloaded Q's are dependent upon resonator size and geometry, conductor surface finish, and materials properties. Filter quality is a function of unloaded Q, percent bandwidth, and nominal filter response shape. Inadequate unloaded Q can result in unacceptable filter pass band dissipation losses. In an extreme situation, a band pass filter with sharp selectivity can deteriorate into a frequency sensitive attenuator. Filter quality also affects filter power handling capabilities. As average power increases, excessive filter dissipation losses can cause overheating that could lead to equipment failure. As peak power increases, narrow gaps, sharp corners, poor surface finish, and materials properties can contribute to voltage breakdown.

Impact of filter interfaces

Actual band pass filter response shapes are dependent upon both the filter and the source/load interfaces. Mismatched source impedances and load impedances can appreciably degrade band pass filter performance. Some current systems use passive interface buffers. Future integrated systems will use active buffers. Ultimate interface corrections can employ feedback control techniques with embedded microprocessors.

Computer-aided analysis software [5] can determine filter responses under specific conditions of source/load terminations. Other computer software can predict the effects of perturbed filter responses, on communications systems performance, for prescribed modulation techniques.

Advantages and disadvantages

The pros and cons of microwave band pass filter tuning are a complex area where considerations of cost, performance, and operations are interrelated. Some of these features have been summarized in Table 1. The applicability of these considerations can change as electronic technology advances and equipment cost considerations become more dominant.

Some application considerations

1. Wireless handsets entail very low unit cost and high production volume. They will probably never use tunable microwave band pass filters.

2. Digital data links at T1 rates have non-critical transmission specifications. Tunable microwave band pass filters will seldom, if ever, be required.

3. High speed digital data and video at satellite earth stations can have stringent transmission and reflection specifications. High quality tunable microwave band pass filters are often needed for current performance optimization.

4. Satellite repeaters in aerospace environment require equipment with no movable parts. Microwave band pass filters must be provided without tuning screws.

Conclusions

The elimination of tuning in microwave band pass filters is a desirable objective. This design simplification is not always viable. For short-term new applications, manufacturing volume, unit cost objectives, and the complete range of applicable electrical, mechanical, and environmental specifications will determine the appropriate design tradeoffs. Many existing products, using tunable microwave band pass filters, will be continued to be manufactured. The non-recurring costs of redesign will often prohibit some possible product improvements.

Enhanced communications systems architecture and ongoing advances in systems/subsystems integrated circuits will reduce and possibly eliminate the need for tuning microwave band pass filters in future equipment. This could entail further improvements in computer-aided design and analysis plus expanded use of embedded microprocessors. ■

References

1. R.M. Kurzrok, "Direct Coupled Coaxial and Waveguide Bandpass Filters," *IRE Transactions MTT*, Vol. MTT-10, May 1962: 218-219.

2. M. Dishal, "A Simple Design Procedure for Small Percentage Bandwidth Round-Rod Interdigital Filter," *IEEE Transactions MTT*, Vol. MTT-13, September 1965: 696-698.

3. R.M. Kurzrok, "Nodal Voltages Offer Key to Filter Design," *Micro-waves & RF*, April 1999: 72-84 and May 1999: 67-69.

4. G.L. Matthaei, L. Young and E.M.T. Jones, "Microwave Filters, Impedance Matching Networks, and Coupling Structures," New York: McGraw-Hill, 1964.

5. R.W. Rhea, *HF Filter Design and Computer Simulation*, Atlanta: Noble Publishing Company, 1994

6. S. Bila, et al, "Direct Electromagnetic Optimization of Microwave Filters," *IEEE Micro-wave Magazine*, Vol. 2, March 2001: 46-51.

Author information

Richard M. Kurzrok, PE, is an independent consultant specializing in filters and equalizers from baseband through microwave frequencies. He may be reached at RMK Consultants, 82-34 210th Street, Queens Village, NY, 11427-1310; Tel: 718-776-6343; Fax: 718-776-6087; or E-mail: rmkconsulting@ aol.com.