Tunable Combline Filter Using 60 Degree Resonators

This design uses resonators longer than the typical 45 degrees

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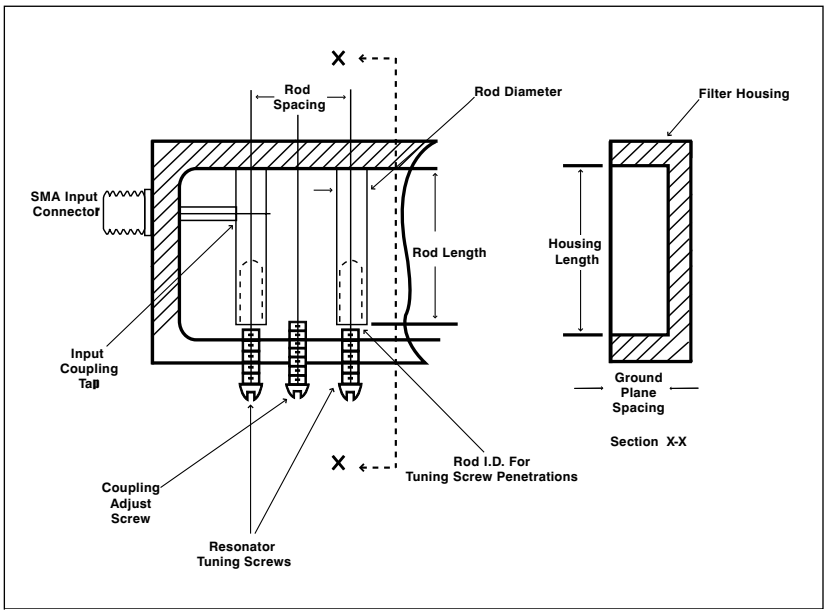
Combline band pass filters [1] employ direct-coupled, air dielectric, TEM resonators whose magnetic and electric fields are in phase opposition. As a result, nominal 90 degree resonators become decoupled. Foreshortening of resonator lengths is necessary for a viable design.

A commonly used resonator length is 45 degrees [1], although the use of longer resonators has been suggested [2]. A more recent design [3] has used a resonator length of about 27 degrees. In this article, we will discuss tunable combline band pass filters with 60 degree resonators.



▲ **Figure 1. Mechanical details of the combline band pass filter.**

Tunable combline filter design

Many combline band pass filters are fixed tuned to a specific center frequency. Other combline filters are factory adjusted or field tuned to a range of different center frequencies. Adjacent combline resonators provide maximum interstage coupling when the resonator length is close to 53 degrees. By using resonators of 60 degrees, tunability over a range exceeding 1.5 is readily achievable. Mechanical details of the tunable combline filter are shown in Figure 1. The filter uses slabline construction with round rods between ground planes. With the physical dimensions indicated in Table 1, a combline filter can be designed and constructed for a tuning range from 0.95 to 1.45 GHz.

Input and output singly loaded Qs are realized by tapping [3, 4]. This is implemented by securing the connector center conductor to the first and last resonators using conductive epoxy.

Combline filter performance

Nominal 1 GHz combline filters, with nine or eleven poles, have been designed, constructed and tested for 3 dB bandwidths of 60, 90 and 130 MHz. Insertion losses have been compatible with unloaded Qs of 1000, without use of silver plating. These filters have percent bandwidths that are somewhat wider than those of commercially available ceramic filters.

At selected center frequencies within the tun-

Dimension or Material	Value
Ground Plane Spacing	0.625 inch
Resonator Rod Diameter	0.250 inch
Resonator Rod Length	1.625 inches
Filter Housing Interior Length	1.750 inches
Housing Wall Thickness and Cover Thickness	0.250 inch and 0.187 inch
Resonator Rod Inner Diameter	0.170 inch x 0.625 inch deep
Resonator Tuning and Coupling Screws	#6–32 Round Head-Brass w/SS Hardware
Housing Material	Aluminum Alloy 2024-T351
Rod Material	Aluminum Alloy 6061-T651
Input and Output Connectors	SMA male

▲ **Table 1. Tunable combline filter details using air dielectric resonators.**

ing range, swept frequency alignment is performed for return loss and amplitude responses. Both resonator tuning screws and interstage coupling screws are adjusted during filter alignment. The coupling screws are parallel to the tuning screws and are attached to the open-circuit end of the filter housing. Insertion of the coupling screws increases the interstage couplings. At the center frequency of maximum interstage coupling, the rod spacing is slightly greater than the correct spacing. This ensures that the coupling screws will have appropriate adjustment range.

Combline filter tradeoffs

Important tradeoffs for combline filters are summarized in Table 2. As filter resonators are foreshortened, approximate relative unloaded *Q*s follow the rule of thumb relationship (5):

- Unloaded *Q* proportional to sin (θ) squared where θ is the resonator electrical length.
- The relative TEM spurious responses are coarse estimates that neglect the resonator impedance and tuning capacitance. TE_{11} spurious responses have not been considered in Table 2. The physical sizes are approximate relative volumes that neglect the housing wall thickness, input and output connectors, and screw protrusions.

The use of air dielectric combline bandpass filters is not the best approach for all applications. When miniaturization, small percent bandwidths, temperature stability and low cost, high volume production are needed, nominal 90 degree ceramic resonators are often preferable. These filters usually employ capacitive interstage couplings rather than electromagnetic interstage couplings. Ceramic filters usually are not tunable.

Electrical Length Degrees	Relative Unloaded *Q*	Tuning Range	Spurious Passband	Physical Size
30	0.25	Very limited	X9	0.33
45	0.5	Limited	X6	0.50
60	0.75	Available	X4.5	0.67
90	1.00	Not Usable	X3	1.00

▲ **Table 2. Combline band pass filter design tradeoffs for air dielectric resonators.**

Conclusions

By using 60 degree resonators, useful combline band pass filter can be realized to cover tuning ranges of 1.5. The 60 degree resonators have higher unloaded *Q*s than customary combline filters. This provides cost savings by permitting some filters to be constructed without silver plated parts. This is usually the case for filter percent bandwidths of about 10 percent. Combline filters with resonator lengths of 45 degrees or less are more favorable from the standpoints of physical size and spurious passband. ■

References

1. G.L. Matthaei, L. Young, and E.M.T. Jones, *Microwave Filters, Impedance Matching Networks, and Coupling Structures,* McGraw-Hill, New York, 1964: 497–506, 516–518.
2. G.D. O'Clock, Jr., "Tunable Frequency Range and Mismatch Adjustment for Comb-Line Bandpass Filters," *IEEE Trans. MTT,* Vol. MTT-20, March 1972: 238–239.
3. R. Rhea, *HF Filter Design and Computer Simulation,* Noble Publishing, Atlanta, GA, 1994: 329–337.
4. M. Dishal, "A Simple Design Procedure for Small Percentage Bandwidth Round Rod Interdigital Filters," *IEEE Trans. MTT,* Vol. MTT-13, September 1965: 696–698.
5. R. M. Kurzrok, "Design of Comb-Line Bandpass Filters," *IEEE Trans. MTT,* Vol. MTT-14, July 1966: 351–353.

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