WHITEPAPER

Microstrip Filter Topologies

Introduction

In RF systems the behavior of Transmission Lines are important to understand when the transmitted frequency's wavelength is short enough that the length of the cable becomes a significant part of a wavelength. Microstrip refers to a type of planar transmission line technology that consists of a conducting strip separated from a ground plane by a dielectric substrate. Entire devices (antennas, couplers, filters and power dividers, for example) are formed from metallized patterns on the substrate, making Microstrip lighter, more compact and more affordable than alternative transmission line technologies such as waveguide.

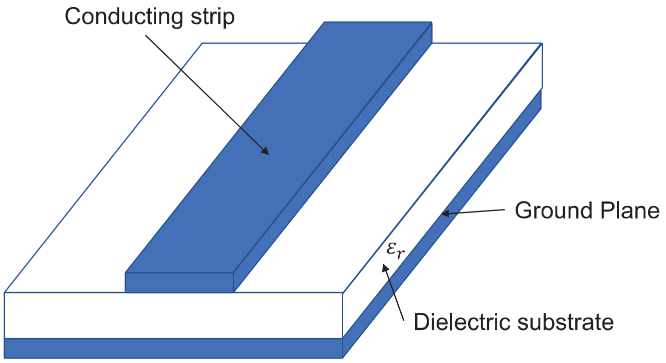
Microstrip was invented in 1952. Since then technology advancements in both the manufacturing of dielectric material for the substrate and thin film processing techniques for creating the components has led to its adoption in a wide range of applications.

This article is intended as a short introduction to some of the standard approaches to manufacturing Bandpass Filters with Microstrip Technology.

Microstrip Building Blocks

The structure of Microstrip Filters is very similar to that of circuits on a printed circuit board, but with the key distinction that the metal conductor patterns printed on the solid dielectric substrate are there to create resonators rather than just interconnects. The metal circuit patterns of strip elements are placed on a solid dielectric insulating layer with a metal ground layer below the dielectric. The fields surrounding the strip permeate two different media, with part of the field in the substrate and another in the air above the strip. The higher permittivity of the dielectric substrate causes the electric field to concentrate in the substrate, meaning field losses due to material choice become a factor. Standard PCB materials like FR4 can be used below 1GHz for low Q filters. Lower loss and increased Q can be found in ceramic materials.

Figure 1. A Microstrip transmission line.



The width of a strip element, the dielectric constant of the substrate and its thickness determine the characteristic impedance. Changing the characteristic impedance (by changing the structure of the strip element) creates a discontinuity in transmission characteristics, and it is this effect that is used to create distributed element systems that mimic the properties of a lumped element circuit. Discontinuities in the transmission line are engineered to present a reactive impedance to the wave propagating through the line, and these reactances can be designed to serve as approximations for lumped inductors, capacitors or resonators, depending on what is needed for the filter.

Steps up or down in impedance can be created by adjusting the width of the strip. An increase in impedance, for example, is created by narrowing the metal strip.

Figure 2. A step up in microstrip impedance.

If a transmission line is one half a wavelength long, the input impedance is equal to the load impedance. For a transmission line a quarter wavelength long, the input impedance is the inverse of the load impedance – a quarter wave length of line converts an open into a short and vice-versa. A transmission line a quarter wavelength long with a short circuit at the end will look like an open and act as a parallel resonant circuit, and a length of line a half wavelength long with an open at the end will present as an open and will also act as a parallel resonant circuit. Parallel resonant circuits can be used as one port resonators, making these structures some of the fundamental building blocks in microstrip filters and are often created with Stubs or a series of Coupled Lines.

Stubs are created by a strip element that comes to an end. A stub can be ended by a short circuit (a path to ground) or can be left open.

Figure 3. A short circuit stub, Quarter Wave.

Figure 4. An open circuit stub, Half Wave

Figure 5. Coupled Lines.

Coupled Lines can also act as resonators and can be left open or short, depending on the desired resonant characteristics.

By engineering the geometry of the metal strips standard filter types (Lowpass, Bandpass, Highpass and Notch) can be implemented in Microstrip and a range of standard topologies has been developed over the years – we are going to look at some of the well-known approaches to building Bandpass filters in Microstrip.

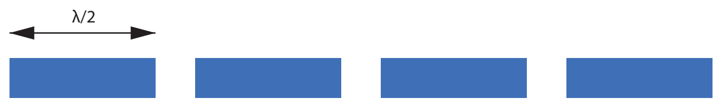
Classical Bandpass Filter Topologies can be grouped into those where the resonators are formed by a) half wavelength long open circuit lines and b) quarter wavelength long short circuit lines. Each approach has advantages and disadvantages. The following is intended as an introduction to these common topologies but there are many more innovative variants. Discuss your specific application needs with a Knowles Precision Devices DLI RF engineer to find the right configuration for your application.

Common Filter Topologies that utilize Half Wavelength, Open Circuit Lines

End-Coupled. This filter consists of sections of transmission line a half wavelength long at the center frequency f_0 of the bandpass filter which act as resonators and are coupled across capacitive gaps in the transmission line.

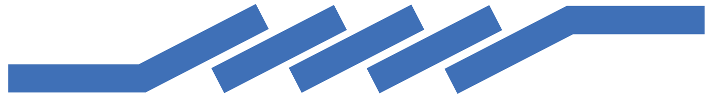
Edge-Coupled. This filter is constructed so that adjacent resonators are parallel to each other along half of their length. This arrangement gives relatively large coupling between resonators, and as a consequence, this topology has the advantage of wider bandwidth compared to the end coupled approach.

Figure 6. An End-Coupled Filter.



Frequency Range	>10GHz
Typical Bandwidth	2-10%
Pros	The advantage of end coupling over edge coupling is that the width of the filter can be much less and the widths of all resonator strips are the same. Good for Narrow Bandwidth applications Provides High Rejection Roll Off
Cons	Increased Part Length Higher Insertion Loss compared to other methods

Figure 7. An Edge-coupled Filter.



Frequency Range	>10GHz
Typical Bandwidth	4-20%
Pros	The advantage of parallel or edge coupling over end coupling is that the filter length can be reduced by approximately half, a symmetrical frequency-response curve is obtained, and the parallel arrangement provides relatively large coupling for a given spacing between resonators, enabling wider bandwidth than end-coupled microstrip filters.
Cons	Higher Passband Slope

Hairpin. The Hairpin is obtained if we imagine folding the resonators in the parallel coupled filter, resulting in a 'U' shape.

Figure 8. A Hairpin Filter.

Frequency Range	>10GHz
Typical Bandwidth	4-30%
Pros	Wide Bandwidth Flat Passband Slope
Cons	Increased Part Width

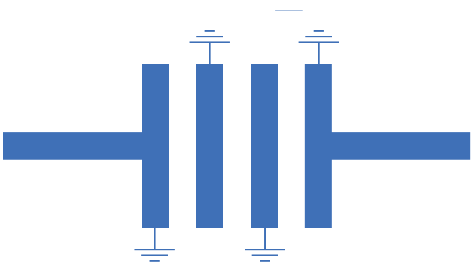
Common Filter Topologies that utilize Quarter Wavelength, Closed Circuit Lines

Interdigital filters. In this topology each resonator is a quarter wavelength long and is terminated in a short-circuit at one end with other end being left open-circuit, with the orientation alternating.

A **Combline** bandpass filter consists of an array of couple quarter wavelength resonators. Each resonator consists of a line element, which is short-circuited at one and has a lumpled capacitace loaded at the other end between the line element and ground.

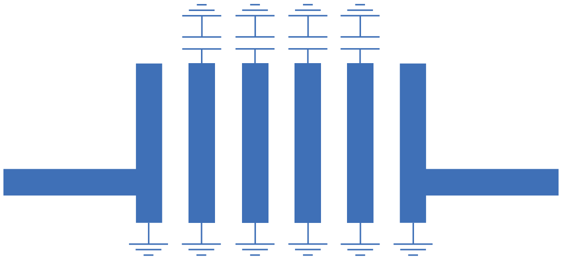
The **Pseudocombline** filter is made up from an array of coupled quarter wavelength resonators. The resonators consist of line elements that are open circuited at one end and have a lumped capacitance at the other end between the line element and ground.

Figure 9. An Interdigital Filter.



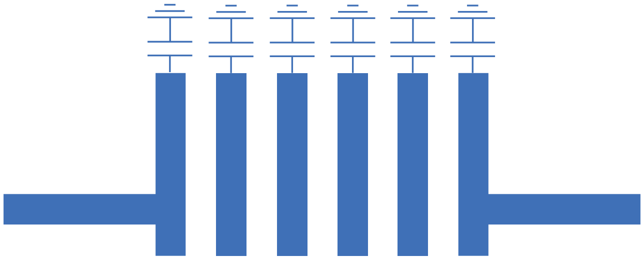
Frequency Range	<10GHz
Typical Bandwidth	10-50%
Pros	Low Insertion Loss Narrower than 1/2 wave structures Symmetrical Rejection
Cons	More sensitive to manufacturing variation

Figure 10. A Combline Filter.



Frequency Range	<10GHz
Typical Bandwidth	10-50%
Pros	Low Insertion Loss Narrower than 1/2 wave structures High Side Transmission Zero
Cons	More sensitive to manufacturing variation Asymmetric response Requires Lumped Capacitors

Figure 11. A Pseudo-Combline Filter



Frequency Range	<10GHz
Typical Bandwidth	10-50%
Pros	Low Insertion Loss Narrower than Combline High Side Transmission Zero
Cons	More sensitive to manufacturing variation Asymmetric response Requires Lumped Capacitors

Conclusion

Choosing between Half Wavelength, Open Circuit Line implementations vs. the Quarter Wavelength, Closed Circuit approach, and then selecting topologies within those categories depends a great deal on your specific application requirements.

Further, a noted 'Disadvantage' in an approach (such as an increased sensitivity to Manufacturing Tolerances) need not rule an approach out, rather it is a factor to take into consideration when selecting a manufacturing process to produce your specific design. So in such a case look for an approach that has a high level of control over Manufacturing Tolerances.

The best approach is to have a conversation with a DLI filter design expert at Knowles Precision Devices.

Hopefully this article provides some additional context and background on which to base a conversation about your specific design needs.