# REVIEW OF PLANAR MICROSTRIP FILTERS FOR WIRELESS COMMUNICATION

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## ABSTRACT

Microstrip Filters are the essential part of the microwave system and play important role in many communication applications especially wireless and mobile communications. Microstrip line is one of the most popular type of planar transmission lines and is easily miniaturized and integrated with both passive and active microwave devices. These are getting popular due to their compact size, light weight, low cost and ease of fabrication. A novel microstrip planar filters for wireless communication systems has been proposed in this paper. The proposed is composed of a low pass filter, a bandpass filter, a high pass filter, and bandstop filter via wireless communication.

Scientists have developed a variety of approaches over the years, which can be utilized to achieve one or more of these design objectives.

Most communication system contains an RF front end which performs signal processing with RF filters. Planar based filters are popular and relatively practical to design. Band pass filters play a significant role in wireless communication systems. Transmitted and received signals have to be filtered at a certain center frequency with a specific bandwidth.

***Keywords*** *– Planar Micro-strip Filter , Quasi-lumped Element.*

## 1. INTRODUCTION

**Microstrip** is a type of electrical transmission line which can be fabricated using printed circuit board technology, and is used to convey microwave-frequency signals. It consists of a conducting strip separated from a ground plane by a dielectric layer known as the substrate. Microwave components such as antennas, couplers, filters, power dividers etc. can be formed from microstrip, the entire device existing as the pattern of metallization on the substrate. Microstrip is thus much less expensive than traditional waveguide technology, as well as being far lighter and more compact. Micro-strip was developed by ITT laboratories as a competitor to strip line (first published by Grieg and Engelmann in the December 1952 IRE proceedings).

The disadvantages of micro-strip compared with waveguide are the generally lower power handling capacity, and higher losses. Also, unlike waveguide, microstrip is not enclosed, and is therefore susceptible to cross-talk and unintentional radiation.

On a smaller scale, microstrip transmission lines are also built into monolithic microwave integrated circuits.

Microstrip lines are also used in high-speed digital PCB designs, where signals need to be routed from one part of the assembly to another with minimal distortion, and avoiding high cross-talk and radiation.

Microstrip is very similar to stripline and coplanar waveguide and it is possible to integrate all three on the same substrate.

For lowest cost, microstrip devices may be built on an ordinary FR-4 (standard PCB) substrate. However it is often found that the dielectric losses in FR4 are too high at microwave frequencies, and that the dielectric constant is not sufficiently tightly controlled. For these reasons, an alumina substrate is commonly used.

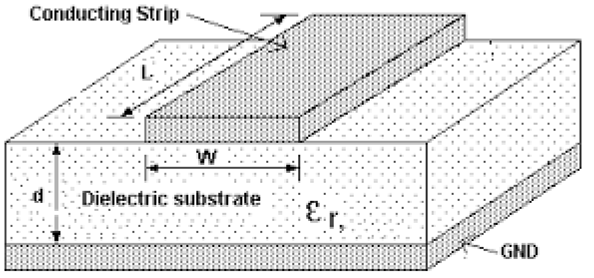


Fig.1: General structure of microstrip

Filters play important roles in many RF/microwave applications. They are used to separate or combine different frequencies. The electromagnetic spectrum is limited and has to be shared; filters are used to select or confine the RF/microwave signals within assigned spectral limits. Emerging applications such as wireless communications continue to challenge RF/microwave filters with ever more stringent requirements—higher performance, smaller size, lighter weight, and lower cost. Depending on the requirements and specifications, RF/microwave filters may be designed as lumped element or distributed element circuits; they may be realized in various transmission line structures, such as waveguide, coaxial line, and microstrip. The recent advance of novel materials and fabrication technologies, including monolithic microwave integrated circuit (MMIC), microelectromechanic system (MEMS), micromachining, high-temperature superconductor (HTS), and low-temperature cofired ceramics (LTCC), has stimulated the rapid development of new microstrip and other filters.

## 2. FILTER FUNCTION

**Four general filters function are desirable:-**

- Band-pass filter: select only a desired band of frequencies.
- Band-stop filter: eliminate an undesired band of frequencies.
- Low-pass filter: allow only frequencies below a cutoff frequency to pass.
- High-pass filter: allow only frequencies above a cutoff frequency to pass.

## 3. FILTER TECHNOLOGIES

In general, most RF and microwave filters are most often made up of one or more coupled resonators, and thus any technology that can be used to make resonators can also be used to make filters. The unloaded quality factor of the resonators being used will generally set the selectivity the filter can achieve. The book by Matthaei, Young and Jones provides a good reference to the design and realization of RF and microwave filters. Generalized filter theory operates with resonant frequencies and coupling coefficients of coupled resonators in a microwave filter. The fields in the microstrip extend within two media-air above and dielectric below- so that the structure is inhomogeneous. Due to this inhomogeneous nature, the microstrip does not support a pure TEM wave. This is because that a pure TEM wave has only transverse components, and its propagation velocity depends only on the material properties, namely the permittivity and the permeability. However, with the presence of the two guided-wave media (the dielectric substrate and the air), the waves in a microstrip line will have no vanished longitudinal components of electric and magnetic fields, and their propagation velocities will depend not only on the material properties, but also on the physical dimensions of the microstrip.

## 4 .FILTER ANALYSIS

Filter networks are essential building elements in many areas of RF/microwave engineering. Such networks are used to select/reject or separate/combine signals at different frequencies in a host of RF/microwave systems and equipment. Although the physical realization of filters at RF/microwave frequencies may vary, the circuit network topology is common to all. At microwave frequencies, voltmeters and ammeters for the direct measurement of voltages and currents do not exist. For this reason, voltage and current, as a measure of the level of electrical excitation of a network, do not play a primary role at microwave frequencies. On the other hand, it is useful to be able to describe the operation of a microwave network such as a filter in terms of voltages, currents, and impedances in order to make optimum use of low-frequency network concepts of a microwave network such as a filter in terms of voltages, currents, and impedances in order to make optimum use of low-frequency network concepts.

## 5. LOWPASS FILTER

A **low-pass filter** is a filter that passes signals with a frequency lower than a certain cutoff frequency and attenuates signals with frequencies higher than the cutoff frequency. The amount of attenuation for each frequency depends on the filter design. The filter is sometimes called a **high-cut filter**, or **treble cut filter** in audio applications. A low-pass filter is the opposite of a high-pass filter. A band-pass filter is a combination of a low-pass and a high-pass filter.

A general structure of the stepped-impedance lowpass microstrip filters, which cascaded structure of alternating high and low impedance transmission lines. These are much shorter than the associated guided wavelength, so as to act as semilumped elements.

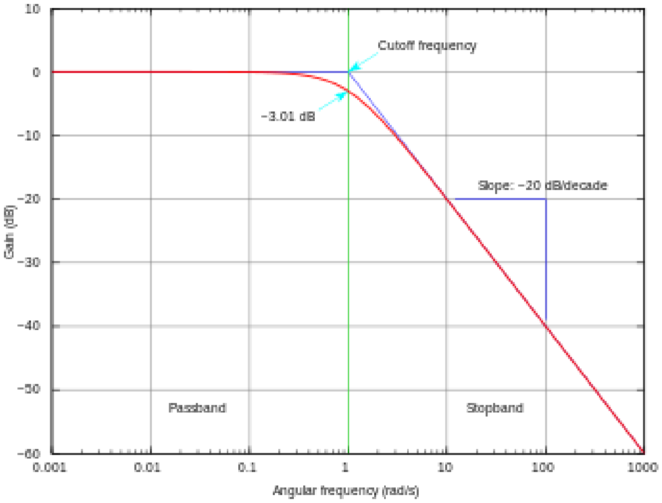


Fig.2: The gain magnitude frequency response of a first-order, (one-pole) low-pass filter. Power gain is shown in

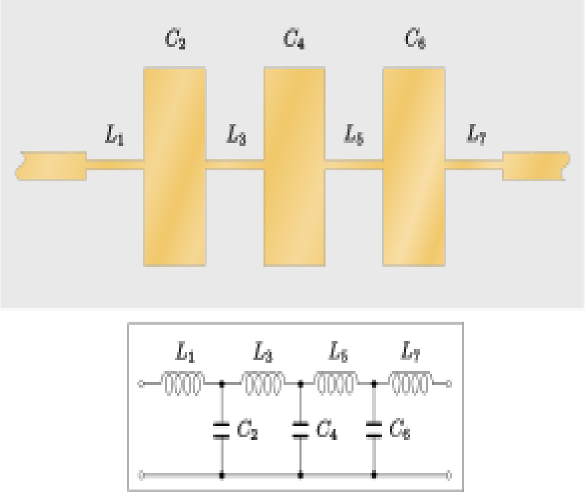


Fig.3: Stepped-impedance low-pass filter formed from alternate high and low impedance sections of line.

The high impedance lines act as series inductors and the low-impedance lines act as shunt capacitors. Therefore, this filter structure is directly realizing the L-C ladder type of lowpass filter.

- $Z_{OC} < Z_O < Z_{OL}$, where $Z0C$ and $Z0L$ denote the characteristic impedances of the low and high impedance lines, respectively, and $Z0$ is the source impedance, which is usually 50 ohms for microstrip filters.

- A lower$Z_{0C}$ results in a better approximation of a lumped-element capacitor, but the resulting

decibels (i.e., a 3db decline reflects an additional half-power atenuation).Low-pass filters exist in many different forms, including electronic circuits (such as a *hiss filter* used in audio), anti-aliasing filters for conditioning signals prior to analog-to-digital conversion, digital filters for smoothing sets of data, acoustic barriers, blurring of images, and so on. The moving average operation used in fields such as finance is a particular kind of low-pass filter, and can be analyzed with the same signal processing techniques as are used for other low-pass filters. Low-pass filters provide a smoother form of a

An optical filter can correctly be called a low-pass filter, but conventionally is called a*long pass* filter (low frequency is long wavelength), to avoid confusion. In general, the design of microstrip.

### 5.1 Stepped impedence lowpass filter

linewidth *WC* must not allow any transverse resonance to occur at operation frequencies.

- A higher $Z_{0L}$ leads to a better approximation of A lumped-element inductor, but $Z_{0L}$ must not be difficulty.

The element values of the lowpass prototype filter, which are usually normalized to make a source impedance $g0 = 1$ and a cutoff frequency = 1.0, are then transformed to the L-C elements for the desired cutoff frequency and the desired source impedance, which is normally 50 ohms for microstrip filters. Having obtained a suitable lumped-element filter design, the next main step in the design of microstrip lowpass filters is to find an appropriate microstrip realization that approximates the lumped element filter. In this section, we concentrate on the second step. Several microstrip. The specifications for the filter under consideration are:-

Cutoff frequency $fc$= 1 GHz
Passband ripple 0.1 dB
Source/load impedance $Z_o$ = 50 ohms

## 6. BANDPASS FILTER

A **band-pass filter** is a device that passes frequencies within a certain range and rejects (attenuates) frequencies outside that range. An example of an analogueelectronic band-pass filter is an RLC circuit (a resistor–inductor–capacitor circuit).These filters can also be created by combining a low-pass filter with a high-pass filter.

Bandpass is an adjective that describes a type of filter or filtering process; it is to be distinguished from passband, which refers to the actual portion of affected spectrum. Hence, one might say "A dual bandpass filter has two passbands." A bandpass signal is a signal containing a band of frequencies not adjacent to zero frequency, such as a signal that comes out of a bandpass filter.

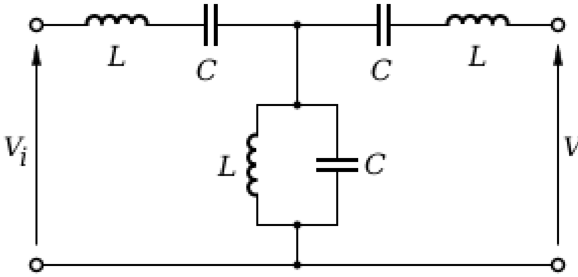


Fig.4: A medium-complexity example of a band-pass filter.

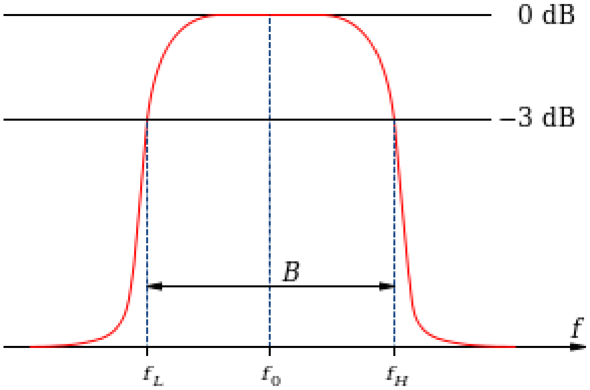


Fig.5: Bandwidth measured at half-power points (gain -3 dB, √2/2, or about 0.707 relative to peak) on a diagram showing magnitude transfer function versus frequency for a band-pass filter.

### 6.1 End Coupler Half Wavelength Resonator Filter

The general configuration of an end-coupled microstrip bandpass filter is illustrated, where each open-end microstrip resonator is approximately a half guided wavelength long at the midband frequency $f_o$ of the bandpass filter. The coupling from one resonator to the other is through the gap between the two adjacent open ends, and hence is capacitive. In this case, the gap can be represented by the inverters, which are of the form. These *J*-inverters tend to reflect high impedance levels to the ends of each of the half-wavelength resonators, and it can be shown that this causes the resonators to exhibit a shunt-type resonance.

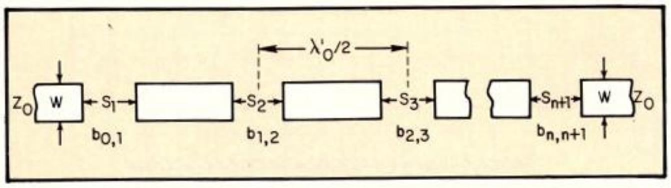
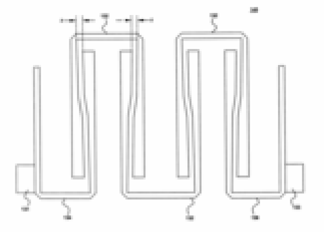


Fig.6: Half wavelength end coupled

### 6.2 Hairpin-Line Bandpass Filters

Hairpin-line bandpass filters are compact structures. They may conceptually be obtained by folding the resonators of parallel-coupled, half-wavelength resonator filters, which were discussed in the previous section, into a “U” shape. This type of “U” shape resonator is the so-called hairpin resonator. Consequently, the same design equations for the parallel-coupled, half-wavelength resonator filters may be used. However, to fold the resonators, it is necessary to take into account the reduction of the coupled-line lengths, which reduces the coupling between resonators. Also, if the two arms of each hairpin resonator are closely spaced, they function



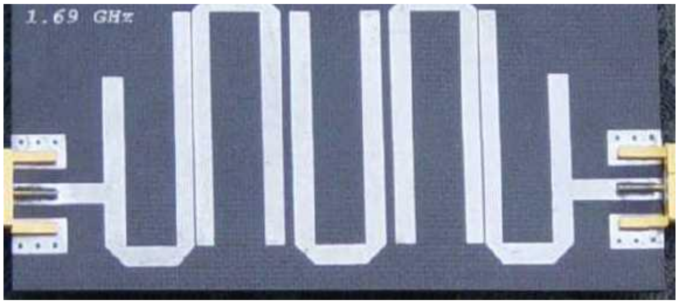


Fig.7: Hairpin- Line Bandpass Filter

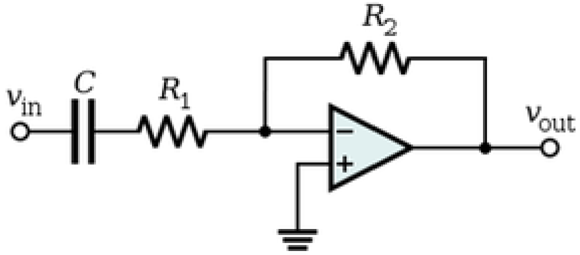
as a pair of coupled line themselves, which can have an effect on the coupling as well. To design this type of filter more accurately, a design approach employing full-wave EM simulation will be described. For this design example, a microstrip hairpin bandpass filter is designed to have a fractional bandwidth of 20% or *FBW* = 0.2 at a midband frequency *f*0 = 2 GHz. A five-pole (*n* = 5) Chebyshev lowpass prototype with a passband ripple of

0.1 dB is chosen. The lowpass prototype parameters, given for a normalized lowpass cutoff frequency _c = 1, are $g0 = g6 = 1.0$, $g1 = g5 = 1.1468$, $g2 = g4 = 1.3712$, and $g3 = 1.9750$. Having obtained the lowpass parameters, the bandpass design parameters.

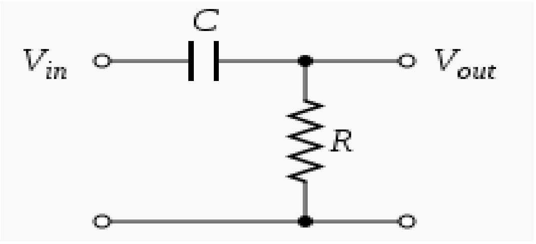
## 7. HIGHPASS FILTER

These filter include quasilumped element and optimum distributed highpass filters, narrow-band and wide-band bandstop filters, as well as filters for RF chokes.

A **high-pass filter** is an electronic filter that passes signals with a frequency higher than a certain cutoff frequency and attenuates signals with frequencies lower than the cutoff frequency. The amount of attenuation for each frequency depends on the filter design. A high-pass filter is usually modeled as a linear time-invariant system. It is sometimes called a **low-cut filter** or **bass-cut filter**. High-pass filters have many uses, such as blocking DC from circuitry sensitive to non-zero average voltages or radio frequency devices. They can also be used in conjunction with a low-pass filter to produce a bandpass filter.



An active high-pass filter



An passive high-pass filter

Fig.8: High-pass filter

### 7.1 Quasilumped Highpass Filter

Highpass filters constructed from quasilumped elements may be desirable for many applications, provided that these elements can achieve good approximation of desired lumped elements over the entire operating frequency band. Care should be taken when designing this type of filter because as the size of any quasilumped element becomes comparable with the wavelength of an operating frequency, it no longer behaves as a lumped element.

The simplest form of a highpass filter may just consist of a series capacitor, which is often found in applications for direct current or dc block. For more selective highpass filters, more elements are required. This type of highpass filter can be easily designed based on a lumped-element lowpass prototype , where $g_i$ denote the element values normalized by a terminating impedance $Z_o$ and obtained at a lowpass cutoff frequency.

## 8. BANDPASS FILTER

A **band-pass filter** is a device that passes frequencies within a certain range and rejects (attenuates) frequencies outside that range.

An example of an analogue electronic band-pass filter is an RLC circuit (a resistor–inductor–capacitor circuit). These filters can also be created by combining a low-pass filter with a high-pass filter.

*Bandpass* is an adjective that describes a type of filter or filtering process; it is to be distinguished from passband, which refers to the actual portion of affected spectrum. Hence, one might say "A dual bandpass filter has two passbands." A *bandpass signal* is a signal containing a band of frequencies not adjacent to zero frequency, such as a signal that comes out of a bandpass filter.

An ideal bandpass filter would have a completely flat passband (e.g. with no gain/attenuation throughout) and would completely attenuate all frequencies outside the passband. Additionally, the transition out of the passband would be instantaneous in frequency.

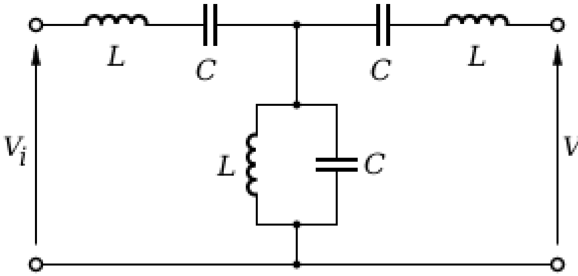


Fig.9: A medium complexity example of a band-pass filter.

In practice, no bandpass filter is ideal. The filter does not attenuate all frequencies outside the desired frequency range completely; in particular, there is a region just outside the intended passband where frequencies are attenuated, but not rejected. This is known as the filter roll-off, and it is usually expressed in dB of attenuation per octave or decade of frequency. Generally, the design of a filter seeks to make the roll-off as narrow as possible, thus allowing the filter to perform as close as possible to its intended design. Often, this is achieved at the expense of pass-band or stop-band ripple.

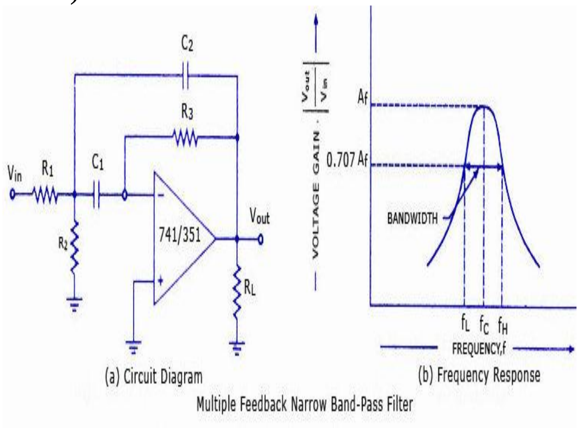
A band-pass filter can be characterised by its Q-factor. The Q-factor is the inverse of the fractional bandwidth. A high-Q filter will have a narrow passband and a low-Q filter will have a wide passband. These are respectively referred to as narrow-band and wide-band filters.

### 8.1 Narrow Bandpass Filter

It shows two typical configurations for TEM or quasi-TEM narrow-band bandstop filters. A main transmission line is electrically coupled to half-wavelength resonators, a main transmission line is magnetically coupled to half-wavelength resonators in a hairpin shape. In either case, the resonators are spaced a quarter guided wavelength apart. If desired, the half-wavelength, open-circuited resonators may be replaced with short-circuited, quarter-wavelength resonators having one end short-circuited.

Narrow bandpass filters are designed to isolate a narrow region of the infrared spectrum. This is accomplished using a complex process of constructive and destructive interference. Narrow bandpass filters have bandwidths (measured at half-peak transmittance levels) less than 6% of the centre of wavelength value.

When ordering, the bandwidth can be expressed as a percentage of the centre wavelength, or can be given in microns. The filters exhibit high peak transmission (typically greater than 60%) combined with high attenuation levels outside the passband (typically less than 0.1%).



(a) Circuit Diagram (b) Frequency Response

Multiple Feedback Narrow Band-Pass Filter

Fig.10: Narrow Bandpass Filter

### TYPICAL CHARACTERISTICS

Available wavelength range - ~2 to 20µm

Tolerance on CWL - To customers requirements, but standard tolerances are typically - +/-0.3% for a 1% bandwidth filter to +/-1% for a 6% bandwidth filter

Peak transmittance - Typically >60% (depending on wavelength and bandwidth)

Available bandwidths - Typically 0.9% to 6%.

Blocking (attenuation) - Typically <0.1% from 0.3µm to far infrared.

## 9. FILTER CHARACTERISTICS

The filter having only one pair of transmission zeros (or attenuation poles) at finite frequencies gives much improved skirt selectivity, making it a viable intermediate between the Chebyshev and elliptic-function filters, yet with little practical difficulty of physical realization [1–4]. The transfer function of this type of filter is

Some important filter families designed in this way are:

- Chebyshev filter, has the best approximation to the ideal response of any filter for a specified order and ripple.
- Butterworth filter, has a maximally flat frequency response.
- Bessel filter, has a maximally flat phase delay.
- Elliptic filter, has the steepest cutoff of any filter for a specified order and ripple.

### 10. Filter Synthesis

The transmission zeros of this type of filter may be realized by cross coupling a pair of nonadjacent resonators of the standard Chebyshev filter. Levy has developed an approximate synthesis method based on a lowpassprototypefiltershowninFigure10.2,wheretherectangular boxes represent ideal admittance inverters with characteristic admittance *J*. The approximate synthesis starts with the element values for Chebyshev filters.

## 11. Microstrip Filter Realization

Some filter configurations comprised of microstrip open-loop resonators to realize this type of filtering characteristic in microstrip. Here the numbers indicate the sequence of direct coupling. Although only the filters up to eight poles have been illustrated, building up of higher-order filters is feasible. There are other different filter configurations and resonator shapes that may be used for the realization.

As an example of the realization, an eight-pole microstrip filter is designed to meet the following specifications:-

Center frequency 985 MHz
Fractional bandwidth *FBW* 10.359%
40dB Rejection bandwidth 125.5 MHz
Passband return loss –20 dB

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