VOL. 3, NO. 4, AUGUST 2008 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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SEMICIRCULAR MICROSTRIP LOW PASS FILTER

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ABSTRACT
This paper presents semicircular microstrip low pass filter with the sharp rejection and wide stop band. The proposed filter design is based on the calculations of filter parameters from traditional Hi-Lo impedance method and is available in the literature of microstrip filter. To further improve the design performance, high impedance lines are magnetically coupled, resulting an attenuation pole near -3dB cut off point of the filter. This design gives insight in designing a low pass filter with reduced size of an arbitrary geographical shape.

Keywords: filter, microstrip low pass, Hi-Lo impedance, semicircular.

INTRODUCTION
Due to increasing constraint of reduction in size with optimum performance, design of many low pass filters are available in the literature with different methods. The conventional filter design method is normally not used now a days due to inherited deficiencies like slow roll off in the stop band, poor frequency response in the pass band, narrow stop band [1,2]. A number of methods are available in literature to design the low pass filter with the suitably selection of stub. Currently, filters have been designed using hairpin resonator [3], which requires lot of calculations using transmission parameters. DGS and PBG filters using high low impedance techniques have also been designed but it does not give a way to reduce size of filters [4,7]. Filters using inter digital capacitances based on even and odd mode analysis are also reported. Performances of this kind of filters are compatible with modern filter requirements [8], but needs extraction of capacitance, which is a cumbersome task. A simple microstrip low pass filter is proposed in [9] but it lacks sufficient return loss in pass band. A skirt type filter based on again even and odd mode filter design is also described [10] where a rectangular stub has been selected for realization. Here, a new filter using semicircular capacitive stub is proposed with reduced total effective area and the improved performance as compare to filter used in [10].

DESIGN ANALYSIS
A 3rd order Chebishev filter is considered for designing purpose. Method of analysis begins with the calculation of inductive and capacitive stubs with the help of traditional hi lo filter design [11]. The prototype value obtained from the existing table for the filter is converted in to the microstip stubs using the following formulas as:

For high impedance Z_H:

Length of inductance $l_1 = \left(\lambda_H/2\pi\right)\sin^{-1}\left(\omega L/Z_H\right)$ (1)

Parasitic Capacitance associated with inductance $C_L = \left(1/\omega Z_H\right).\tan\left(\pi l_1/\lambda_H\right)$ (2)

For low impedance, line Z_L:

Length of capacitance $l_2 = \left(\lambda_L/2\pi\right)\mathrm{Sin}^{-1}\left(\omega C Z_L\right)$ (3)

Parasitic Inductance associated with the capacitance $L_C = \left(Z_L/\omega\right).\tan\left(\pi l_2/\lambda_L\right)$ (4)

where Z_H is the high impedance and Z_L is the low impedance value. ω is the angular frequency. λ_H and λ_L are the wavelengths of high and low characteristic impedance. Even though filter realization using above equations shows a reduction in elements size, circuit shows a poor response. For improving the filter performance, technique reported in [10] is used. However, size of the filter and performance can be further improved if the capacitive stub is modeled as the parallel plate capacitance as shown

$C = C_P + C_f$ (5)

With C as the total capacitance, extracted from the design table; C_P is the parallel plate capacitance between metallic plate and ground plate and C_f is the fringing field capacitance associated with electric field lines passing through air via dielectric to the ground. Since parallel plate capacitance is directly proportional to the surface area, geometry of the plate may be changed while keeping C_P constant. With this logic, filter can be realized with the help of any kind of geometry.

EXISTING FILTERS DESIGN
A 3rd order Chebishev filter with -3dB cut off frequency at 2GHz and attenuation of 0.1 dB in pass band with port impedance 50Ω, is analyzed using the substrate of dielectric constant 3.2, thickness 0.762 mm. Prototype and real values of inductances and capacitance are shown in Table1. Assumed values of high and low impedances are considered 120 Ω and 20 Ω respectively [11].

VOL. 3, NO. 4, AUGUST 2008 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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Table-1. Value of Lumped elements.

Lumped element	Prototype value	Real value
L1	1.03	4.10nH
C2	1.14	1.81pF
L3	1.03	4.10nH

Conventional micro strip low-pass filter

Prototype values of inductances and capacitance are converted in to the microstrip structure [11] using equations (1) to (4). After reduction of parasitic values, the actual lengths of different stubs are obtained as shown in Table-2.

Table-2. Parameters of inductive and capacitive stubs.

Element	Length (mm)	Width (mm)	Effective area on the substrate (mm^2)
L1	6.79	0.322	19.34 X 6.94 mm^2
C2	5.76	6.94	
L3	6.79	0.322	

This kind of filter is not suitable for the modern communication system due to very poor stop band characteristic.

Skirt type low-pass filter

Here filter is designed using even and odd mode analysis [10]. Response of the filter is compatible with the modern communication system. The value of inductance and capacitance are also extractable from the conventional filter design technique. Resulting structure and its simulated response are shown in Figure-1 and Figure-2, respectively.

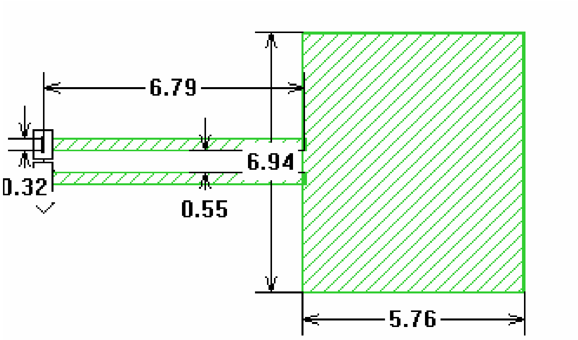

Figure-1. Skirt type low-pass filter.

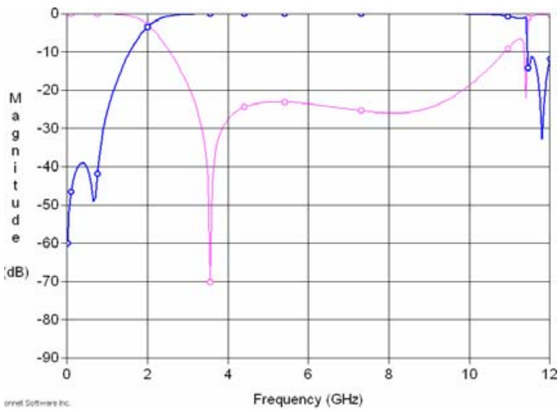

Figure-2. Response of Figure-1.

Total effective area of this filter is 87.10 mm^2 and single attenuation pole occurs at the frequency 3.55 GHz. Although along with sharp cut off frequency and wide stop band, the filter shows a reduction of 35.11% of area as compare to conventional filter, yet there is a possibility of further reduction in the size by using arbitrary shape of the capacitive patch.

PROPOSED SEMICIRCULAR MICROSTRIP LOW PASS FILTER

Now analysis is done with the help of the classical filter design technique with the added feature of magnetic coupling as discussed earlier. Capacitive rectangular stub may be replaced by a semicircular patch of radius of 5.03 mm and corresponding area of 39.90 mm^2 as shown in the Figure-3. Since the capacitive patch remains constant, response in the pass band is not changed with the existing filter response shown in the Figure-2. However, stop band characteristic is improved due to reduction in the fringing field produced at the sharp edge and bend. Response of this proposed filter is shown in

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Figure-4. However, for reducing the total effective area of substrate, high impedance lines are bent.

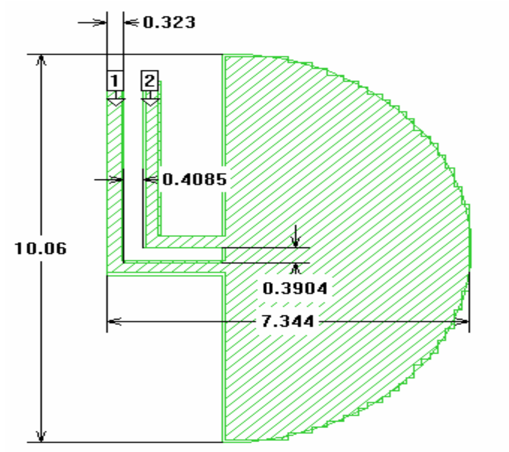

Figure-3. Proposed semi circular microstrip filter.

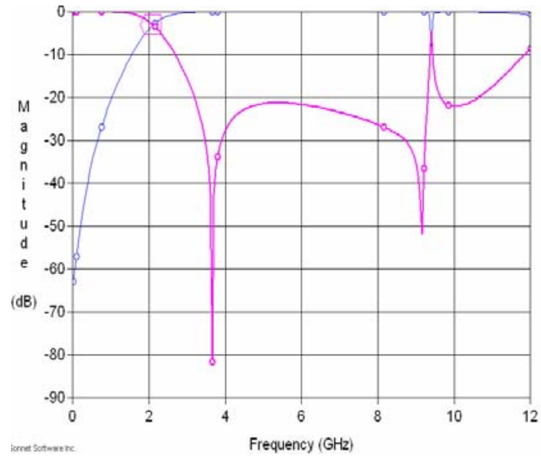

Figure-4. Response of Figure-3.

RESULTS AND CONCLUSIONS

Results have been summarized in tabular form as shown in Table-3.

Table-3. Simulated results.

Filter structures	**Capacitive patch area** mm^2	**Effective area on substrate** mm^2
Conventional low- pass filter	39.97	134.22
Skirt type low-pass filter	39.97	87.10
Semicircular low-pass filter	39.90	74.18

It is observed from table that proposed design requires total area 74.18 mm^2, a 14.82% improvement over existing skirt filter area. However, attenuation pole in the skirt filter is -72dB at 3.55 GHz whereas first attenuation pole in the proposed filter is -85dB at 3.65 GHz. The frequency shift in attenuation pole is attributed to the shift in -3dB point, which is 2.1 GHz in the proposed filter design. The frequency deviation at -3dB point is only 0.1GHz i.e. 5%, which is in the tolerance range and is expected to give an exact result after fabrication. Finally, from the simulated Figure 4 , a attenuation zero at 9.7GHz is not appearing at the harmonics of fundamental frequency of 2.1GHz and hence it's impact on the filter characteristics can be ignored. Also, due to the wide stop band, proposed design is quite efficient for the suppression of spurious signals.

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VOL. 3, NO. 4, AUGUST 2008 ISSN 1819-6608
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