

Improvement in Design of Hi-Lo Impedance Microstrip Low-pass Filter

K. R. Jha, M. Rai

School of Electronics and Communication Eng., Shri Mata Vaishno Devi University, Kakryal, Katra, Jammu and Kashmir (India), 182301, e-mail: jhagr@rediffmail.com, manishrai1968@yahoo.co.in

Introduction

Modern communication system specially wireless system requires a low pass filter with sharp cut off frequency, wider stop band and miniaturization in the circuit apart from a considerable power handling capacity and rejection of spurious noise at the harmonics of cut off frequency[1].

A traditional high low impedance microstrip low pass filter does not meet these requirements and has become the matter of the past. In the modern filter design, concept of hairpin resonator filter [2] depending up on the extraction of capacitance value is developed which needs many computations. Application of Defected Ground Structure (DGS) and Photonic Band Gap structure (PBG) structure leads to the same performance as traditional filter [3]-[4]. A new technique of designing microstrip low pass filter has been discussed in [5], which incorporates the concept of parallel microstrip line coupling with a rectangular stub. This type of the filter needs even and odd mode analysis.

In the present paper, a microstrip low pass filter is designed with the parameters extracted form the traditional high-low pass filter design method and a concept of coupling is added to bring the attenuation pole close to -3dB point. To minimize the effective area, a patch is manipulated and response is compared to show the way of miniaturization of the filter.

Design Analysis

The method of analysis of the filter is based on [6]. A third order Chebyshev lumped element filter is represented by the combination of two inductors in the series line and a capacitor in the shunt line. The prototype values obtained from the existing table for the filter is converted in to the microstrip stubs using the following formulas as:

For high impedance Z_H length of inductance:

$$l_1 = \left(\frac{\lambda_H}{2\pi} \right) \sin^{-1} \left(\frac{\omega l}{Z_H} \right). \quad (1)$$

Parasitic capacitance associated with inductance

$$C_L = \left(\frac{1}{\omega Z_H} \right) \cdot \tan \left(\frac{\pi l}{\lambda_H} \right). \quad (2)$$

For low impedance line Z_L length of capacitance:

$$l_2 = \left(\frac{\lambda_L}{2\pi} \right) \sin^{-1} \left(\omega C Z_L \right). \quad (3)$$

Parasitic inductance associated with the capacitance

$$L_C = \left(\frac{Z_L}{\omega} \right) \cdot \tan \left(\frac{\pi l}{\lambda_L} \right). \quad (4)$$

where Z_H is the high impedance and Z_L is the low impedance value. ω is the angular frequency and λ is the wave length of high and low characteristic impedance. Once the values of inductances and capacitance are fixed, placing inductive lines at the same side of the capacitance, different attenuation poles in the vicinity of -3dB point is achieved. It is due to the magnetic coupling of parallel lines for the different values of spacing between them. The variation in attenuation pole verses frequency for different separations between the lines is shown in the Fig 1.

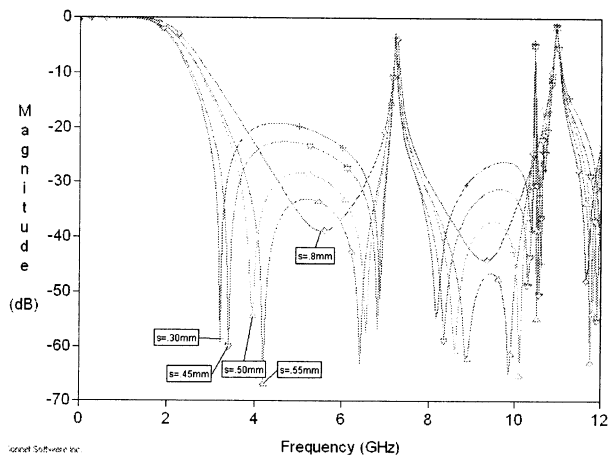


Fig.1. Attenuation pole variation

The capacitive stub is modeled in two parallel capacitances and given as

$$C = C_p + C_f , \quad (5)$$

with C as total capacitance extracted from the design table, C_p is the parallel plate capacitance and C_f is the fringing field capacitance associated with electric field lines passing through air via dielectric to the ground. C_p is directly proportional to the area of the metal plate. Different shape of the capacitance is possible in this way by keeping the total area constant.

Existing Filters Design

A 3rd order Chebyshev filter with -3dB cut off frequency at 2GHz and attenuation of 0.1 dB in the pass band , substrate of dielectric constant 3.2, thickness 0.762 mm,50 ohm port impedance is used to demonstrate the effect of variation in the geometric shape of the capacitive stub and effective area. The prototype values 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 [6].

Table1. 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

A. Conventional Micro strip Low-pass Filter

The prototype values of inductances and capacitance are converted in to the microstrip structure [6]-[7] 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	19.34X6.94 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.

B. Skirt type Low Pass filter

In this filter design, two inductive lines are placed at the same side of the capacitive stub. The response of the filter is characterized by sharp cut off frequency and wide stop band [5]. Effective area is also reduced in comparison to the conventional filter. The structure of the filter and its response are shown in Fig. 2 and Fig. 3 respectively.

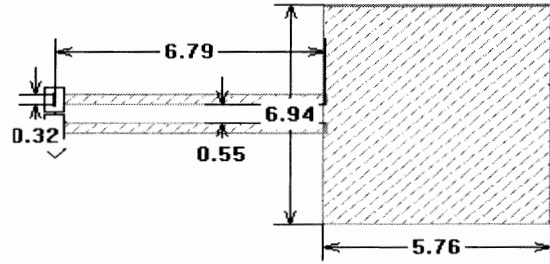


Fig.2. Single sided microstrip low pass filter

The total effective area of this filter is 12.55X 6.94 mm² and single attenuation pole occurs at the frequency 3.55 GHz. Area of the structure can be reduced in the subsequent proposed microstrip low pass filters.

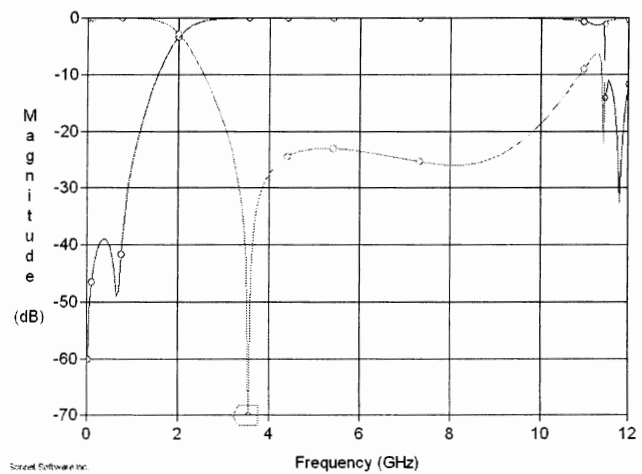


Fig. 3. Response of Fig. 2

Proposed Inset Fed Microstrip Low Pass Filter

From the structure shown in the Fig. 2, a portion of metal of size 3.682X 2.54 mm² is truncated to make room for the inductive stub as shown in the Fig. 4. The simulated response of the proposed design is shown in Fig 5. Due to reduction in the effective area of capacitive patch, -3db point shifts to 2.4 GHz. Since the capacitance is directly proportional to the surface area of the patch, the reduction in capacitance causes -3db point to shift to higher frequency.

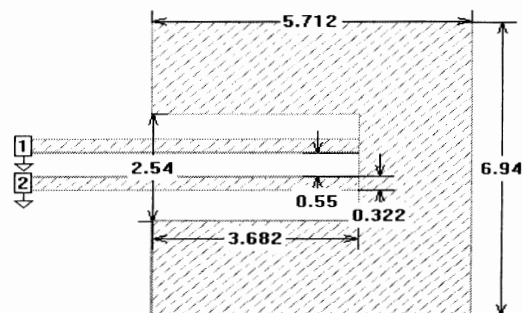


Fig. 4. Truncated structure

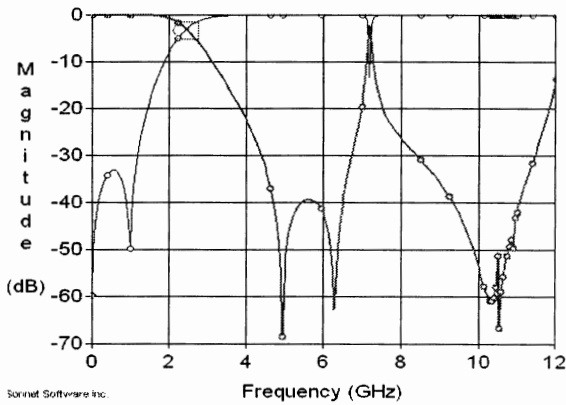


Fig.5. Response of the truncated structure

However, shift in -3dB point is comparatively less (0.4 GHz). It is because that a fraction of reduced capacitance after the truncation is compensated by increased fringing field capacitance (C_f) at the newly created edge.

Now, to optimize the proposed Inset fed filter response at 2 GHz, same cut off frequency of the skirt filter, area of the capacitive patch shown in Fig. 4 is increased by 10.43% as shown in Fig. 6. But this increased area of the truncated structure is still less than the area of skirt type filter. The simulated response of the proposed filter is shown in Fig. 7.

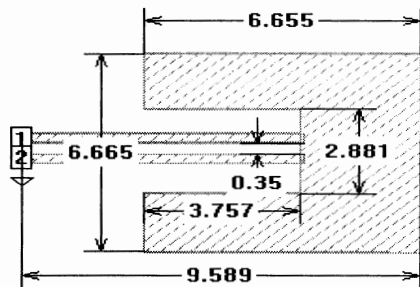


Fig. 6. Proposed Inset Fed Low Pass filter

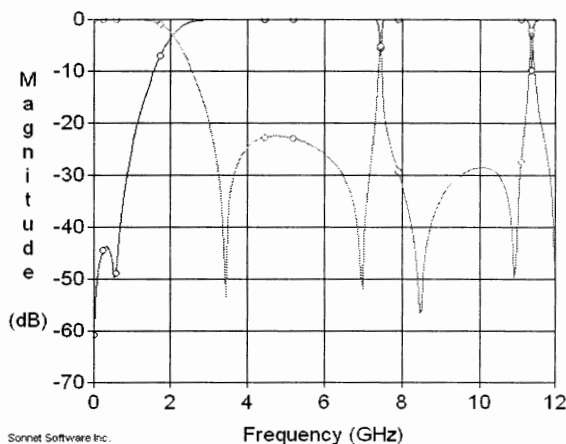


Fig. 7. Response of Proposed Filter

Results and Conclusions

Finally, results are compared in tabular form as shown in Table 3. This shows a reduction in patch size as well as the total area of the proposed Inset Fed filter over the existing conventional as well as skirt type filters.

Table 3. Comparative Simulated Results

Filter Structures	Capacitive Patch Area mm^2	Effective Area on Substrate mm^2
Conventional Low Pass Filter	39.97	134.21
Skirt Type Low Pass Filter	39.97	87.09
Inset Fed Low Pass Filter	33.48	63.70

The results show that a miniaturization in the conventional low pass filter is possible by exploring the capacitive path and result remains comprehensive one. In the proposed Inset Fed filter, due to the number of attenuation poles in the stop band, the curve does not reach near the -20dB line and attenuation reduces subsequently at the higher frequency. In the pass band, the return loss is below -30db for Skirt type filter, which further reduces to a level below -40db and the pass band maximum attenuation is below 0.01 dB for proposed Inset fed low pass filter design.

But due to the resonating nature of the structure, the attenuation zero is -6dB at 7.1GHz. This limitation can be ignored as it is not appearing at the harmonics of the fundamental cut off frequency and hence a wide stop band can be achieved.

References

1. **Tu, Wen-Hua, Chang K.** Compact Microstrip Low- Pass Filter with Sharp Rejection // IEEE Microwave and Wireless Components Letters. – June 2005. – Vol. 15, No. 6.
2. **Hsies L. H., Chang K.** Compact Elliptic-Function Low-Pass Filters Using Microstrip Steeped-Impedance Hairpin Resonators // IEEE MTT. – 2003. – Vol. 51, No. 1. – P. 193–199.
3. **Rumsey I., Picket-May M., and Kelly P.K.** Photonic bandgap structure used as filters in microstrip circuits // IEEE Microwave Guided Wave Lett. – Oct. 1998. – Vol. 8, No. 10. – P. 336–338.
4. **Ahn D., Park J. S., Kim C. S., Kim J., Qian, Y. and Itoh T.** A design of the low-pass filter using the novel microstrip defected ground structure // IEEE Trans. Microwave Theory Tech. – Jan. 2001. – Vol. 49. – P. 86–92.
5. **Rui Li, Dong H Kim.** New Compact Low-Pass Filter with Board Stopband and Sharp Skirt Characteristics // APMC 2005 Proceedings.
6. **Fooks E. H., Jakarevicius R. A.** Microwave Engineering using Microstrip Circuits. – Prentice Hall of Australia, 1990. – P. 167–169.
7. **Hong J. S., Lancaster M. J.** Microstrip Filters for RF/Microwave Applications. – John Wiley and Sons Inc.
8. **Sonnet Lite ver.11.55.**

Received 2008 04 01

K. R. Jha, M. Rai. Improvement in Design of Hi-Lo Impedance Microstrip Low-pass Filter // Electronics and Electrical Engineering. – Kaunas: Technologija, 2008. – No. 7(87). – P. 11–14.

A microstrip low-pass filter with the sharp rejection and wide stop band is presented. The circuit model is developed and analyzed based on traditional hi-lo impedance technique. Achieving the attenuation pole in vicinity of the desired -3dB point, magnetic coupling is added. For improving the design and miniaturization of the circuit, capacitance associated with shunt arm of the 3rd order low pass filter is explored. Comparison of proposed low pass filter has been done with existing filters in respect to effective structure as well as capacitive patch area. The filter design is simulated and dimensions are tuned to meet the desired frequency response. Ill. 7, bibl. 8 (in English; summaries in English, Russian and Lithuanian).

К. Р. Джа, М. Раи. Усовершенствование проектирования фильтра низких частот на основе микрополосной линии // Электроника и электротехника. – Каунас: Технология, 2008. – № 7(87). – С. 11–14.

Описывается микрополосной низкочастотный фильтр с широкой полосой затвора. Теория такого фильтра основана применением традиционного низкочастотного и высокочастотного импедансного метода. Для получения ослабления -3дБ применяется магнитное сцепление. Исследуется влияние шунтирующей емкости до третьего порядка и даются сравнения с существующими фильтрами. Представлены экспериментальные результаты. Ил. 7, библи. 8 (на английском языке; рефераты на английском, русском и литовском яз.).

K. R. Jha, M. Rai. Žemadažnio mikrojuostelinio filtro projektavimo patobulinimas // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2008. – Nr. 7(87). – P. 11–14.

Pateiktas mikrojuostelinis žemadažnis didelio selektyvumo filtras su plačia užtvarine juosta. Elektrinės grandinės modelis sukurtas ir išanalizuotas remiantis tradiciniu didelio ir mažo impedanso metodu. Norint pasiekti slopinimą -3 dB zonoje, taikomas magnetinis susiejimas. Projektui patobulinti ir komponentui sumažinti tirta trečios eilės žemo dažnio filtro šuntuojančiosios atšakos talpa. Siūlomasis filtras palygintas su esamais analogais, atsižvelgiant į struktūros efektyvumą bei talpinės zonos plotą. Filtras sumodeliuotas ir jo matmenys pakoreguoti norimai dažninei charakteristikai gauti. Il. 7, bibl. 8 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).