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Comparison and Analysis of Microstrip Low Pass Filter using DGS technique for WLAN Applications

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ABSTRACT

The Butterworth low pass filter (LPF) with defected ground structure (DGS) is studied and simulated for WLAN Applications. Also an elliptical low pass filter with defected ground structure is simulated for WLAN Applications. Both the low pass filters design are simulated on FR_4 substrate of relative permittivity is 4.3 and thickness 1.6mm. Calculation and comparison of the response of both low pass filters (LPF) with defected ground structure (DGS) was done. Results are simulated using computer simulation technology software (CST).

KEYWORDS

*BSF (Band Stop Filter), CST (Computer Aided Technology), DGS (Defected Ground Structure)**,** EBG (Electromagnetic Bandgap)**,** PBG (Photonic Bandgap)**.***

I. INTRODUCTION

Microstrip filters are very demanded because of its ease in fabrication, small size, and low cost, light weight in cellular mobile phone industry and in many integrated circuits. Many communication devices need a small size filter which can easily be fit inside the body of cellular phone, although attempt is always continuing to achieve Sharp cutoff, by making defect in its ground called the defect ground structure. It has been designed a simple microstrip filter for WLAN application. [1]

Also, Defected ground structure for microstrip line was most common topic for research at recent year. They are giving a lot of different structure for implementing DGS [2]. Microwave filter designs have been at the forefront of research in both industry and academia due to increasing specification levels and demand for advanced communication systems.

In addition to PBG (photonic bandgap) and EBG (electromagnetic bandgap) structure, DGS was created by etching different shapes in ground plane. Which increase the inductance and capacitance values of microstrip line, so the output is sharp stopband in case of LPF and undesired output response fluctuations will be eliminated [3-5] and increased bandwidth in case of BSF. DGS has property of rejecting electromagnetic wave in certain frequency and direction, and most important function of these structures is the filtering of frequency bands, and harmonics of the filter in microwave circuit.

The realizable filters that are in common use are Butterworth filter, Chebyshev filter and Bessel filter. Conventional micro-strip low pass such as stepped-impedance filters, semi lumped element filters are widely used in many RF/microwave applications.

In general, lowpass filters involves two main steps for the design of microstrip low pass filters. The first one is to select an appropriate lowpass prototype, choice of the type of response, including passband ripple and the number of reactive elements, will depend on the required specifications [6-10]. The next main step in the design of microstrip lowpass is to obtained a suitable lumped-element filter design. Filters are to find an appropriate microstrip realization that approximates the lumped element filter.

STEPPED IMPEDANCE BUTTERWORTH LOW PASS FILTER

In stepped impedance Butterworth LPF with L-C ladder type LPF with open circuited stub having frequencies of infinite attenuation at f = infinite. To find sharper cutoff for a given number of reactive elements it is desirable to use filter structure giving infinite attenuation at finite frequencies. Figure 1 shows a cascaded structure of alternating high- and low impedance transmission lines shows general structure of the stepped-impedance Butterworth lowpass microstrip filters, which use a. These are much shorter than the associated guided- wavelength, so as to act as semi lumped elements [8]. The low-impedance lines act as shunt capacitors whereas the high-impedance lines act as series inductors . Therefore, this filter structure is directly realizing the L-C ladder type of lowpass filters of figure 2.

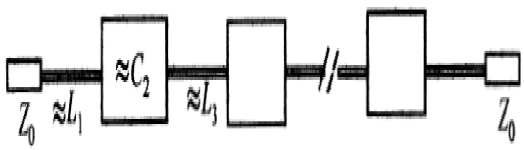

Figure 1: General structure of the stepped-impedance Butterworth lowpass microstrip filter.

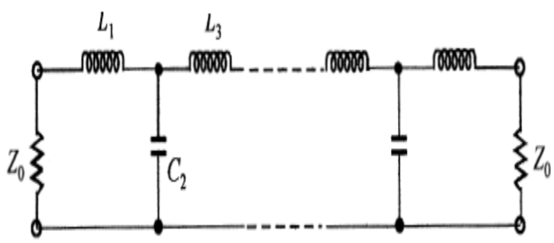

Figure 2: L-C ladder type of lowpass filter.

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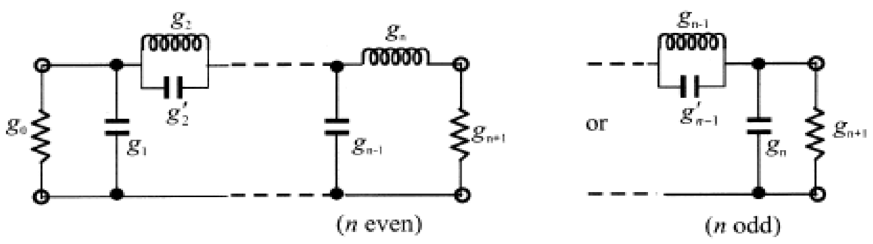
ELLIPTICAL LOW PASS FILTER

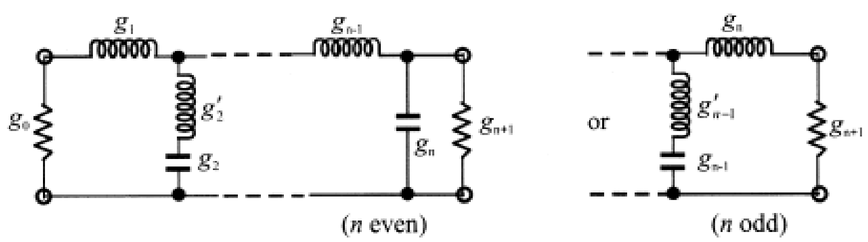
Figure 3 illustrates two commonly used network structures for elliptic function lowpass prototype filters. In Figure 3(*a*), the series branches of parallel-resonant circuits are introduced for realizing the finite-frequency transmission zeros, since they block transmission by having infinite series impedance (open-circuit) at resonance. The g_i for odd i(i = 1, 3, · · ·) represent the capacitance of a shunt capacitor For this form of the elliptic function lowpass prototype [Figure 3(*a*)],, g_i for even *i*(*i* = 2, 4, · · ·) represent the inductance of an inductor, and the primed g_i' for even i(i = 2, 4, · · ·) are the capacitance of a capacitor in a series branch of parallel-resonant circuit. The series-resonant circuits are used for implementing the finite-frequency transmission zeros for the the response that is equal-ripple in both the passband and stopband and in the elliptic function response is used for the dual realization form in Figure 3(*b*). The transfer function for this type of response is

$$|S_{21}(j\Omega)|^2 = \frac{1}{1+\varepsilon^2 F_n^2(\Omega)} \quad (1)$$

For the dual realization form in Figure 3(*b*), the shunt branches of series-resonant circuits are used for implementing the finite-frequency transmission zeros, since they short out transmission at resonance. In this case, referring to Figure 3(*b*), g_i for odd i(i = 1, 3, · · ·) are the inductance of a series inductor, g_i for even i(i = 2, 4, · · ·) are the capacitance of a capacitor, and primed g_i' for even i(i = 2, 4, · · ·) indicate the inductance of an inductor in a shunt branch of series-resonant circuit. Again, either form may be used; because both give the same response [11-12] shunt branches, since them short out transmission at resonance. In this case, referring to Figure 3(*b*), g_i for odd i(i = 1, 3, · · ·) are the inductance of a series inductor, g_i for even i(i = 2, 4, · · ·) are the capacitance of a capacitor, and primed g_i' for even i(i = 2, 4, · · ·) indicate the inductance of an inductor in a shunt branch of series-resonant circuit. Again, either form may be used, because both give the same response [11-12]



(a)



(b)

Figure 3: Lowpass prototype filters for elliptic function filters with (a) series parallel-resonant branches, (b) its dual with shunt series-resonant branches.

II. PROCEDURE

LPF was design at the cut off frequency of f_c in GHz and formula which is used for the design of LPF is

Synthesis of *W*/*h*

$$\frac{W}{h} = \frac{8\, e^{A}}{e^{2A} - 2} \tag{2}$$

With

$$A = \frac{Z_c}{60}\left[\frac{\varepsilon_r + 1}{2}\right]^{0.5} + \frac{\varepsilon_r + 1}{\varepsilon_r + 1}\left[0.23 + \frac{0.11}{\varepsilon_r}\right] \tag{3}$$

Where Zc=Zo = 50Ω and ε_r (dielectric constent) = 4.4, W= width, h= height of dielectric which is taken as 1.6mm.

Effective dielectric constant of dielectric material given by equation (13) and (14)

For *W*/*h* ≤ 1:

$$\varepsilon_{re} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + 12\,\frac{h}{w}\right)^{-0.5} \tag{4}$$

For W/h>1

$$\varepsilon_{re} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[\left(1 + 12\,\frac{h}{w}\right)^{-0.5} + 0.04\left(1 - \frac{w}{h}\right)^{2}\right] \tag{5}$$

Whereas guided wavelength is given by equation (6)

$$\lambda_g = \frac{300}{f(\text{GHz})\sqrt{\varepsilon_{re}}} \tag{6}$$

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ε_{re} = Effective dielectric constant

Values of inductor and capacitor are given by

$$C_i = \frac{1}{2\,\pi\, Z_0 f_c} g'_i \;, L_i = \frac{1}{2\,\pi\, f_c} Z_0 g_i \qquad (7)$$

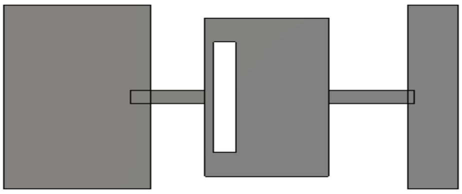
For i = 1, 2, 3, ... , 6.

Calculation of length of inductor and capacitor is done using formula

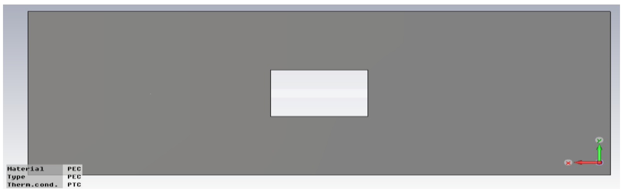
$$l_{Li} = \frac{\lambda_{gL}\,(f_c)}{2\pi} \sin^{-1}\left(2\,\pi\, f_c \frac{L_i}{Z_{oc}}\right) \qquad (8)$$

$$l_{Ci} = \frac{\lambda_{gc}\,(f_c)}{2\,\pi} \sin^{-1}(2\pi\; Z_{0C}\, C_i) \qquad (9)$$

The proposed design of 3rd order Butterworth low pass filter shown in Figure 4.



(a)



(b)

Figure 4: (a) front view of proposed designed micro-strip 3rd order Butterworth stepped impedance function LPF (b) Back view of ground structure of the designed micro-strip 3rd order Butterworth stepped impedance function LPF.

The 3rd order Butterworth stepped-impedance low pass filter were design using rectangular shape defected ground structure. The dimensions of the proposed low pass filter calculated at the center frequency of 2 GHz using electromagnetic equations. The simulated graph of 3rd order stepped impedance Butterworth Low pass filter as shown in Figure 5

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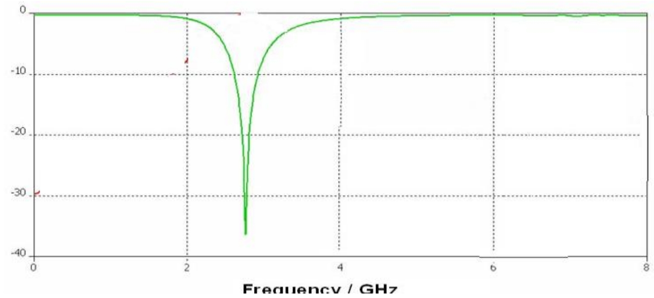
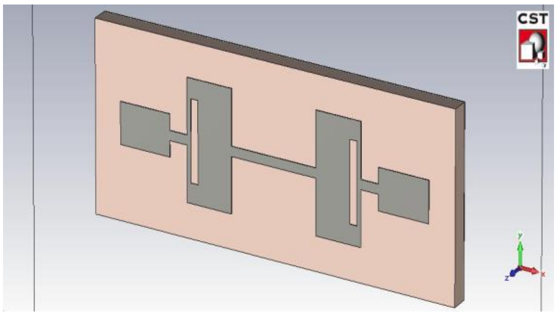
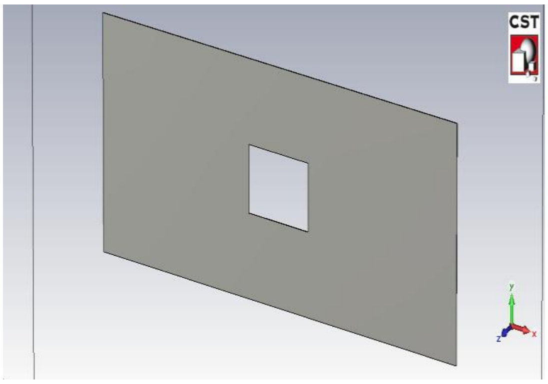


Figure 5: Simulated graph of 3rd order stepped impedance Butterworth Low pass filter

The proposed design of the 5th order stepped impedance Butterworth Low Pass Filter is shown in the Figure 6. FR_4 lossy material with dielectric constant of 4.4, substrate height of 1.6mm and loss tangent 0.02 was used in the designing of low pass filter. A rectangular shaped slot of dimension 6mm X 4mm is introduced in the centre of the ground plane which shows the ground as defected. One rectangular shaped slot of equal size is introduced in the both capacitor part (C2 & C4) of the proposed design of microstrip Butterworth low pass filter. Dimension of rectangular shaped slots is 0.7mm X 6mm and it is placed form the 0.4mm far away from the inductor part (L1 & L5) of the design.



(a)



(b)

Figure 6: (a) Front view of proposed designed 5th order microstrip stepped impedance butterworth function LPF.

(b) Back view of ground structure of the designed microstrip stepped impedance function LPF.

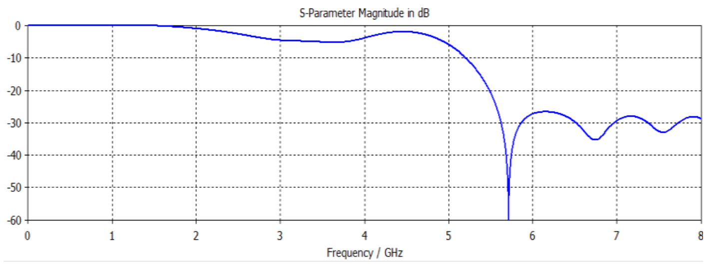


Figure 7: Simulated result of stepped impedance 5th order Butterworth low pass filter with DGS.

From the response shown in figure7, it is clear that the cut-off frequency is found to be 5GHz for stepped-impedance low pass filter. Hence stepped impedance low pass filter is capable of passing the frequency less than 5GHz & reject the frequency after 5GHz.

The proposed design of elliptic-function low pass filter is shown in Figure8. The 3rd order elliptic function low pass filter was designed using rectangular shape ground structure. The dimensions of the proposed low pass filter were calculated at the center frequency of 5 GHz. LPF is printed on the FR_4 lossy substrate of dielectric constant 4.3, loss tangent 0.02 and thickness of 1.6 mm with dimension of length 30 mm and width 16.5 mm.

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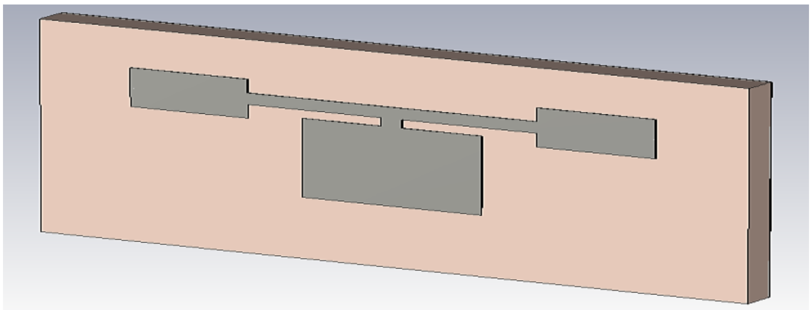

(a)

(b)

Figure8: (a)Front View of Proposed 3rd order Elliptic Low Pass Filer (b)Back View of Proposed 3rd order Elliptic Low Pass Filer.

The simulated result of the 3rd order low pass Elliptical filter is shown in the Figure 9. The graphs were obtained after the simulation by CST software. This graph shows that the cut off frequency is at 5 GHz which means that the signals were passing before this frequency. Also after 5 GHz, the signal shows attenuation of –35 to –40 dB (means good stop band). Return loss before 5 GHz is below –10 dB which shows proper impedance matching.

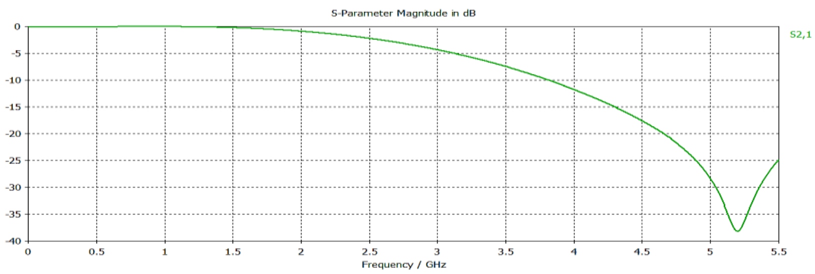

Figure 9: Simulated result of stepped impedance 3rd order Elliptic low pass filter using DGS.

The proposed design of elliptic - function low pass filter shown in Figure 10. The 5th order elliptic function low pass filter was design using rectangular shape ground structure. The dimensions of the proposed low pass filter calculated at the center frequency of 5 GHz using electromagnetic equations.

LPF is printed on the FR_4 lossy substrate of dielectric constant 4.4, loss tangent 0.02 and thickness of 1.6mm with dimension of length 30mm and width 16.5mm.

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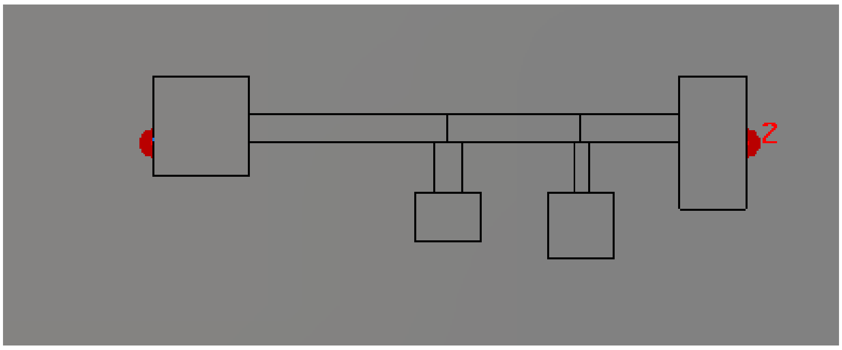
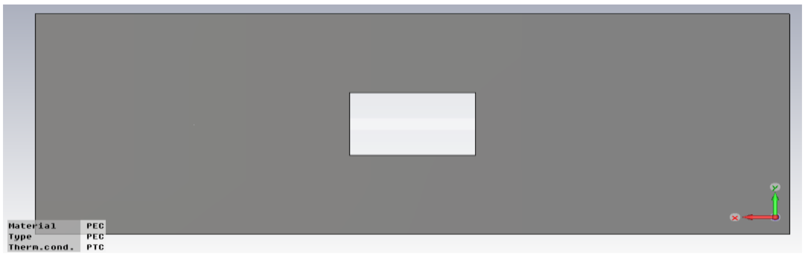


(a)



(b)

Figure 10: Proposed 5th order Elliptic Low Pass Filer.

(a) Front View (b) Back View

The simulated result of the 3rd order low pass filter is shown in the Figure 5.11. The graphs obtain after the simulation by CST Software. This graph shows the cut-off frequency is at 5 GHz means that the signals were passing before this frequency.

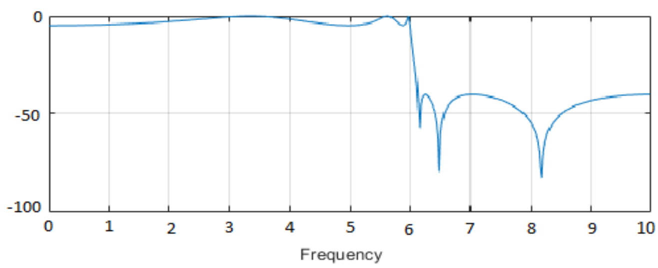


Figure 5.11: Simulated result of 5th order Elliptical low pass filter with DGS.

III. RESULTS

A sharp rate of cutoff with reduce label of sideband fluctuation of the response achieved by introducing the slots in the ground plane structure which is behave as defected so that the low consumption takes place and use the dielectric FR_4 is 4.3 make the circuit as an ideal and passes the most of the signal at the desires frequency and the graphical structure is maximally flat and the try to make the minimum insertion loss and increase the directivity, efficiency and gain.

Table1: COMPARISON BETWEEN 3RD ORDER BUTTERWORTH AND ELLIPTICAL LPFs

TYPE	*Insertion loss*	*directivity*	*Gain*	*efficiency*	*cutoff*
Butterworth LPF	-38	5.38	7.8dB	21.22	2GHz
Elliptical LPF	-37	4.782	6.082dB	19.42	5 GHz

Table2: COMPARISON BETWEEN 5TH ORDER BUTTERWORTH AND ELLIPTICAL LPFs

TYPE	*Insertion loss*	*directivity*	*Gain*	*efficiency*	*cutoff*
Butterworth LPF	-60	4.87	3.52dB	11.55dB	5GHz
Elliptica-l LPF	-59	3.36	2.29dB	10.26dB	5 GHz

V.CONCLUSION

The proposed designs was implemented and analyzed at the centre frequency 5GHz. A sharp rate of cutoff with reduce label of sideband fluctuation of the response achieved by introducing the slots in the ground plane structure which is behave as defected and two equal slots of rectangular shaped in the structure of stepped impedance microstrip low pass filter using Butterworth function . Also, 3rd order elliptic function microstrip low pass filter was achieved good return loss response at the centre frequency of 5 GHz.

It has been found that simulated results of 5th order microstrip Butterworth stepped impedance Butterworth low pass filter are in good agreement and better in comparison with proposed 5th order elliptic function microstrip low pass filter and also we can see from Table 1 that 3rd order microstrip Butterworth stepped impedance low pass filter are in good agreement and better in comparison with proposed 3rd order elliptic function microstrip low pass filter

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