International Journal of Future Generation Communication and Networking
Vol. 9, No. 10 (2016), pp. 209-216
http://dx.doi.org/10.14257/ijfgcn.2016.9.10.18

Performance Comparison of Microstrip Band-Reject Filters for Different Dielectric Materials

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Abstract

In this paper design of Microstrip band-reject filters have been presented for different dielectric materials on L-band applications. The various designs have also been compared with different dielectric constants and other performance parameters to check for viability and stability of designs on the considered frequency band. IE3D 14.1 simulation tool has been used for obtaining the Insertion loss and return loss performance of microstrip filter.

Keywords*: Microstrip Filters, Return Loss, IE3D EM Simulation, Scattering parameters, Insertion Loss*

1. Introduction

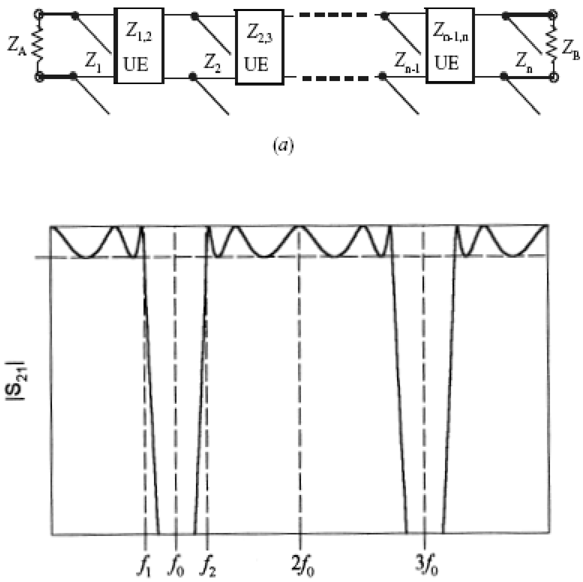
The present communication systems are going wireless at fast pace and need to have better quality of components, which are being used in wireless communication systems. Filters are one of the primary components used for selection of wanted signals to have communication with better performance. Microwave filters are commonly used for passing the desired band of frequencies and rejecting other frequencies for various modern microwave applications such as satellite-communication, Radar and mobile communication *etc* [1]. The work is focused on filter design, mathematical modeling of the filter designs along with the determining performance parameters like scattering parameters and losses. Almost every wireless communication systems have been brought in the microwave frequency range. In this range of frequency various active and passive components need to be fabricated with greater care and efficiency to obtain expected performance for better and efficient communication. The filters need much care and consideration as it is vital component in the communication systems to select the actual band of frequencies needed or need to be rejected, depending on the position of the filter in the communication system. Filters are an integral component of any microwave communication system. Filters are essential to perform task of separating, sorting of signals and impedance matching in communication systems [2]. Filters are also applicable in Radio Frequency front-ends as pre-select filters where pre-select filters select the desired frequency band. It is also highly recommended to have good quality of band reject filters with high insertion loss at its center frequency to reject selected pass band, which may be communicated in common media along with required base band [3]. In [3] microstrip dual-mode band reject filters using triangular patch resonators were investigated for the applications in microwave superconductivity, RF MEMS and LTCC technologies. In [4] compact left handed dual mode notch band stop filter has been

ISSN: 2233-7857 IJFGCN

proposed. The fabricated filter has the size of 11 mm x 50 mm, at the center frequency of 1.12 GHz, which sometimes may be used for some specific application. There is also need for having high quality low/high pass filters at this range of frequency as to give better options of selection for various required or not required band of frequencies. Most of the communication systems require an RF front end LNA and filters processing elements for analog signal at the input [6]. This stage is an important stage in any communication system and needs high quality of filtering devices. The microstrip filters are generally used in transmitters and receivers at frequency ranges beyond 800 MHz. There have been many designs, which are proposed by researchers for various types of filters [5-12]. The basic design structure of the filters has been investigated by revisiting primary characteristics of the material and their applications according to the required applications and requirements. The design is considered with standard patch and modifications thereon for achieving parameters as desired. Various types of dielectric materials are proposed for the design of microstrip filters in L- band of frequencies on microstrip patch which have reduced filter size drastically and have given better option for various design considerations and options to have sharp cutoff, improved bandwidth and high performance filter design. In this work performance comparison of Microstrip band reject filter is presented for various dielectric materials.

2. Fundamental Design of Microstrip Band- Reject Filters

Band-reject filters can be designed using microstrip line [1-4]. These filters are having narrow-band and wide-band applications. The fundamental design of a band-reject filter with open-circuited stubs is shown in Figure 1 where the shunt quarter-wavelength and open-circuited stubs are separated by unit elements (connecting lines) that are a quarter wavelengths long at the mid-stop-band frequency. Filtering characteristics of the filter then entirely depends on design of characteristic impedances Z_i for the open-circuited stubs, and characteristic impedances $Z_{i,i+1}$ for the unit elements, as well as two terminating impedances Z_A and Z_B.



(b)

Figure 1. Band-Stop Filter with Open-Circuited Stubs. (*a*) Basic Design of Filter using Transmission line (*b*) Insertion Loss Versus FreQUENCY Characteristic of Filter

First step for designing of such type of filter is to find out the dimensions of filter using microstrip line design equations by performing some mathematical modeling [1]. For determining the bandwidth of filter, fractional bandwidth (*FBW)* is used which is represented in mathematical form by equation (1).

$$FBW= \frac{f_2 - f_1}{f_0} \quad (1)$$

f_0 is the mid-stop-band frequency of the corresponding band-stop filter. f_1 and f_2 are the corner frequencies. Element values of band-reject filters for 3-pole(n=3) open circuited stubs are given in table 1 [1].

Table 1. Prototype Parameters of Band-Reject Filters for Passband Ripple Constant (ε) of 0.1005 for Three Open Stubs

FBW	$g_1 = g_3$	g_2	$J_{1,2} = J_{2,3}$
0.3	0.16318	0.26768	0.97734
0.4	0.23016	0.38061	0.92975
0.5	0.37754	0.63292	0.83956
0.6	0.46895	0.79494	0.78565
0.7	0.56896	0.97488	0.73139
0.8	0.67986	1.17702	0.67677
0.9	0.80477	1.40708	0.62180
1.0	0.94806	1.67311	0.56648
1.1	1.11601	1.98667	0.51082
1.2	1.15215	2.06604	0.49407
1.3	1.37952	2.49473	0.43430
1.4	1.67476	3.05136	0.37349
1.5	2.07059	3.79862	0.31262

The tabulated elements are the normalized admittances, and for a given reference impedance Z_0, the line impedances are determined by

$$Z_A = Z_B = Z_0$$
$$Z_i = Z_0/g_i$$
$$Z_{i,i+1} = Z_0/J_{i,i+1} \quad (2)$$

An optimum microstrip band-reject filter with three open-circuited stubs (n = 3) and a fractional bandwidth *FBW* of 0.5 at a mid stop band frequency (f_0)1.8 GHz has been designed. From Table 1, the normalized element values have obtained which are $g_1= g_3$ = 0.3774, g_2 = 0.63292, and $J_{1,2}$ = $J_{2,3}$ = 0.83956. The filter is designed to match 50 Ω terminations. Therefore, *Z*0 = 50 ohms, and the Connecting line impedance for the filter network representation has been calculated by using equation (2).

$$Z_A = Z_B = Z_0 = 50\Omega$$
$$Z_1 = Z_3 = 132.43\Omega$$
$$Z_2 = 78.998\Omega$$
$$Z_{1,2} = Z_{2,3} = 59.55\Omega$$

Here Z_1, Z_2, Z_3 are Stub line impedance and Z_0, $Z_{1,2}$ and $Z_{2,3}$ are Connecting line impedance. Dimensions of open circuited stubs and connecting lines are determined using microstrip line design equations for different impedances values and dielectric constants. In this paper, three different types of dielectric materials are used for microstrip filter design and performance of the microstrip filters are compared for different dielectric substrate.

3. Performance Comparison of Microstrip Band- Reject Filters

Three Dielectric materials are mostly used as a substrate for fabrication of Microstrip filters.

(1) RT/Duroid 6010 LM which has Dielectric Constant (ε_r) of 10.2 , Thickness(h)=0.635 mm, Loss tangent (δ) =0.0023

(2) Dielectric Material FR4 Substrate which has the following properties : Dielectric Constant (ε_r) =4.4 , Thickness(h)=1.6 mm, Loss tangent (δ) =0.02

(3) RT/Duroid 6006: Dielectric Constant (ε_r) = 6.15 , Thickness(h)=1.27 mm, Loss tangent (δ) =0.0027

(1) For Dielectric Material RT/Duroid 6010 LM: It has Dielectric Constant (ε_r) = 10.2, Thickness (h)=0.635 mm, Loss tangent (δ) =0.0023

The widths and quarter guided wavelengths linked with the characteristic admittances of microstrip line can be derived with the help of designed equations and are summarized in Table 2.

Table 2. Basic Design Parameters of First Microstrip Filter

Line Impedance	Line width W(mm)	Quarter guided wavelength L=λg0/4(mm)
Z1 & Z3	W1=W3=0.02	L1=L3=17.44
Z2	W2=0.2	L2=16.67
Z1,2 &Z2,3	W1,2=W2,3=0.4	L1,2=L2,3=16.32
ZA & ZB	W0=0.59	

The basic design of microstrip filter is shown in Figure 2 which is obtained by using some mathematical calculations with the help of design equations for microstrip filter and plotted by using IE3D electromagnetic simulation software. It consists of three stubs of quarter guided wavelength long linked with each other with the help of connecting microstrip lines. The 50 ohm terminating microstrip line is used for connecting the 50 ohm load/port so that input is provided to the microstrip filter through input port and output characteristics response is measured from the output port. The total area of the proposed design of microstrip filter is 678.65 mm^2 which is more compact as compared to existing designs [2-8]. Length of the proposed filter is 37.64 mm and width of the proposed filter is 18.03 mm.

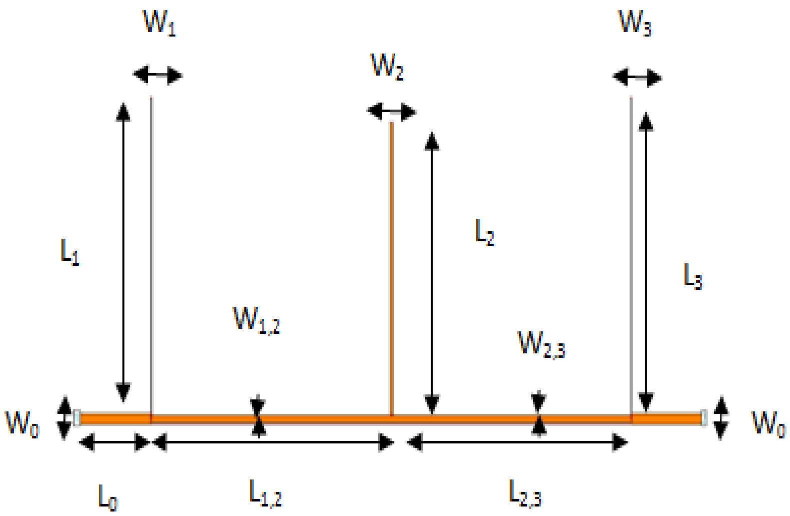


Figure 2. Fundamental Design of First Microstrip Filter for RT/Duroid 6010 LM

(2) For Dielectric Material FR4 Substrate: This material has the following properties:
Dielectric Constant (εr =4.4), Thickness h=1.6 mm, Loss tangent (δ) = 0.02
Table 3 represents the basic design parameters of microstrip band-reject filter for FR4 dielectric substrate.

Table 3. Basic Design Parameters of Second Microstrip Filter

Line Impedance	Line width W(mm)	Quarter guided wavelength L=λg0/4(mm)
Z1 & Z3	W1=W3=0.3	L1=L3=24.68
Z2	W2=1.55	L2=23.66
Z1,2 &Z2,3	W1,2=W2,3=2.3	L1,2=L2,3=23.32
ZA & ZB	W0=3.1	

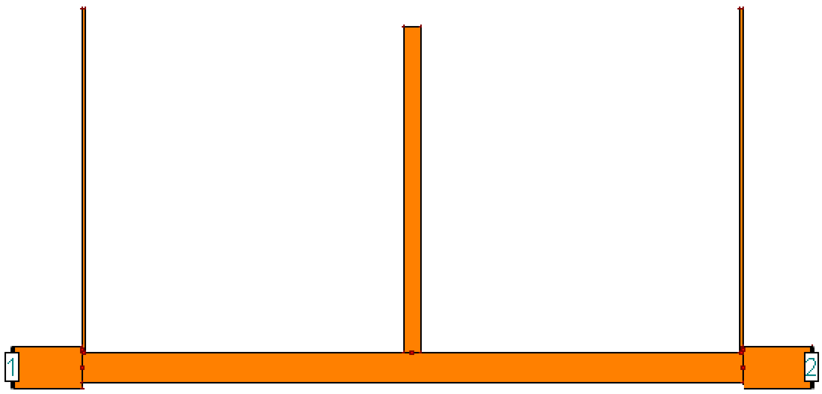


Figure 3. Fundamental Design of Second Microstrip Filter with Stubs

(3)For RT/Duroid 6006 Dielectric Substrate: This dielectric material has the following properties:
Dielectric Constant (ε_r) = 6.15, Thickness (h)=1.27 mm, Loss tangent (δ) =0.0027

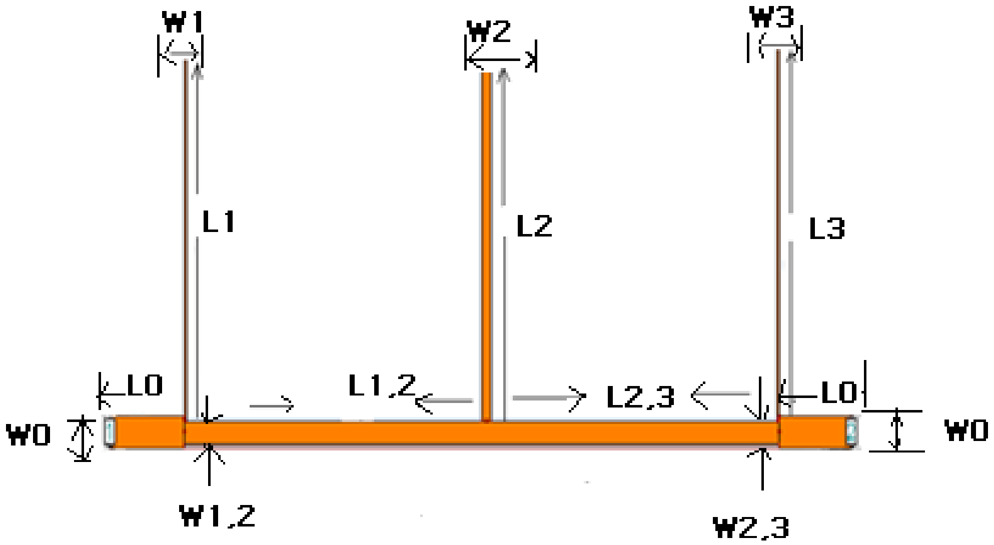


Figure 4. Fundamental Design of Third Microstrip Filter with Stubs

Table 4 illustrates the basic design parameters of microstrip band-reject filter for RT/Duroid 6006 dielectric substrate.

Table 4. Basic Design Parameters of Third Microstrip Filter

Line Impedance	Line width W(mm)	Quarter guided wavelength L=λg0/4(mm)
Z1 & Z3	W1=W3=0.13	L1=L3=21.36
Z2	W2=0.72	L2=20.52
Z1,2 &Z2,3	W1,2=W2,3=1.35	L1,2=L2,3=20.06
ZA & ZB	W0=1.87	L0=5

4. Implementation and Results

Figure 5 illustrates the frequency response of microstrip band reject filter for the dielectric material RT/Duroid 6010 LM which shows the bandwidth of the filter ranges from 1.3 to 2.3 GHz for L--band applications.

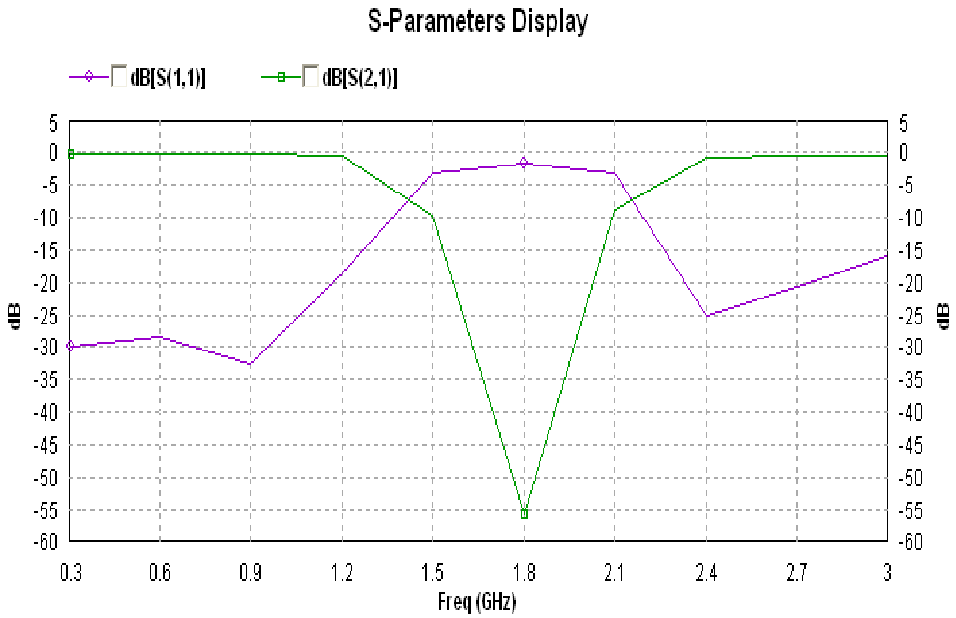


Figure 6. IE3D EM Simulated Performance of the First Microstrip Band-Reject Filter for RT/Duroid 6010 LM Dielectric Substrate

Performance of the filter is measured in terms of return- loss and insertion-loss which is measured in the form of S- parameters (S_{11}, S_{21}). Figure 7 shows the frequency response of microstrip band reject filter for the dielectric material FR4 Substrate, which shows the bandwidth of the filter, ranges from 1.25 to 2.35 GHz for mobile communication. It has very low return loss and high insertion loss as compared to previous design.

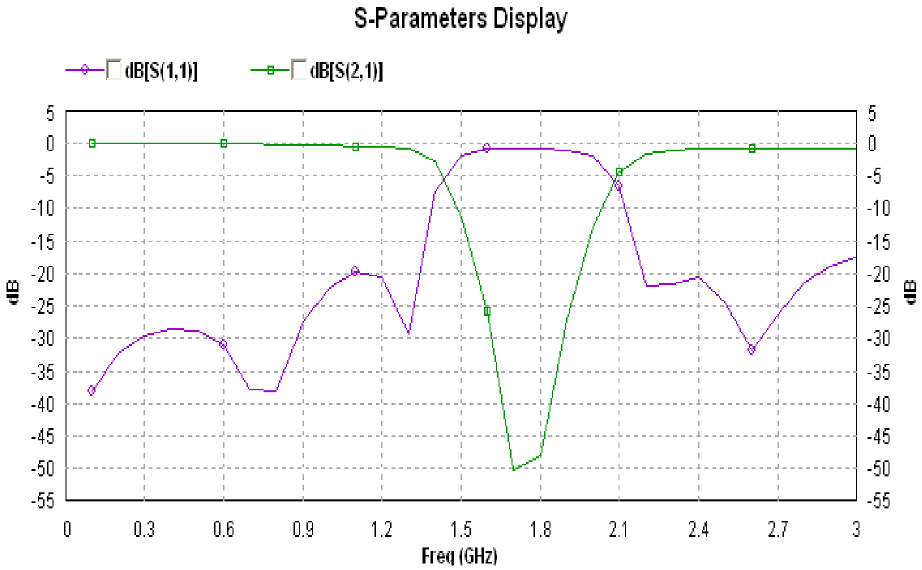


Figure 7. IE3D EM Simulated Performance of the Second Microstrip Band-Reject Filter for Glass Epoxy FR4 Dielectric Substrate

Figure 8 illustrates the frequency versus return/ insertion loss response of microstrip band-reject filter for the dielectric material RT/Duroid 6006 Substrate which shows the bandwidth of the filter ranges from 1.4 to 2.2 GHz for narrowband application. It also has very low return loss and high insertion loss as compared to previous design.

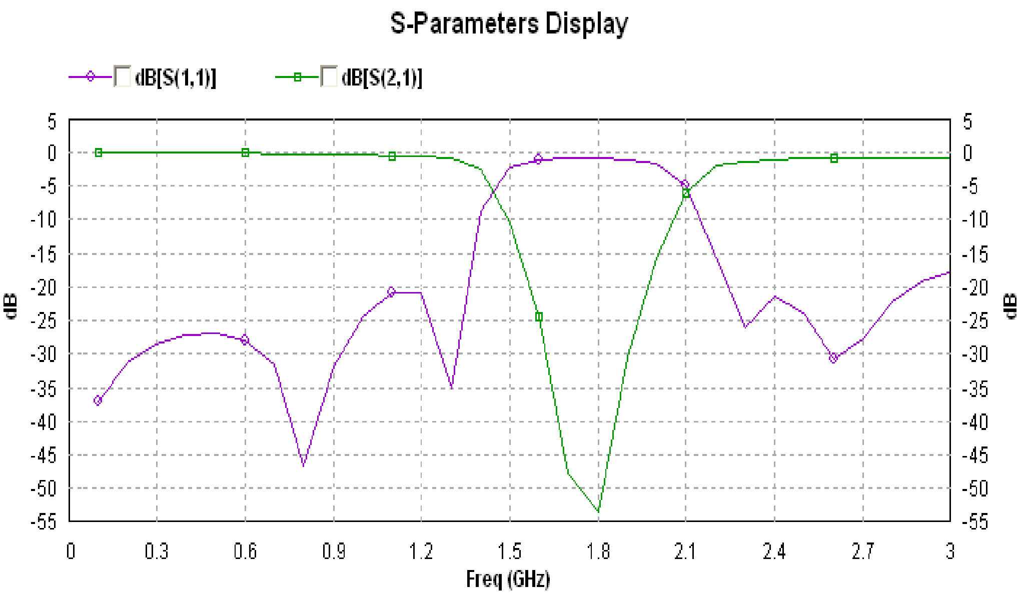


Figure 8. IE3D EM Simulated Performance of the Second Microstrip Band-Reject Filter for RT/Duroid 6006 Dielectric Substrate

Table 3 represents the performance comparison of microstrip filter in terms of return and insertion loss for various dielectric substrates.

Table 5. Performance Comparison of Microstrip Filter for different Substrate

Material/Substrate	Return loss in dB	Insertion Loss in dB	Bandwidth
RT/Duroid 6010 LM	-1.663 dB	-55.73 dB	1.3 to 2.3 GHz
Glass EpoxyFR4	-0.8384 dB	-47.95 dB	1.25 to 2.35 GHz
RT/Duroid 6006	-0.9926 dB	-53.41 dB	1.4 to 2.2 GHz

It is obvious from table 5, that most suitable substrate for the designing of microstrip band-reject filter is RT/Duroid 6006 which provides wide bandwidth and improved insertion and return loss with compact structure as compared to other substrates.

5. Conclusion

In this paper three types of dielectric substrates are used for the performance and design comparison of Microstrip band-reject filters which is used for L-band applications. Scattering parameters are calculated from the simulated performance of the filter in terms of insertion and return loss. It is concluded that RT/Duroid 6006 is the best dielectric substrate for obtaining good bandwidth, better performance and compact size as compared to other two substrates.

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