Miniaturized Planar Waveguide Filter for C-Band Applications

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Abstract - *Wireless communication is the need of world. In this era life cannot be imagined without any technology. Microstrip Filters are the essential part of the microwave system. It plays an important role in many communication applications especially wireless and mobile communications. Microstrip filters are always famous due to their easy fabrication, small size, and low cost, light weight in cellular mobile phone industry and in many integrated circuits. Many communication systems need small size filter which can easily be fit inside the body of cellular phone. In this paper it has been designed a new miniaturized planar filter for C band application is introduced. The center frequency of the proposed filter is in C band. This design mainly concentrated on compact size which is suitable for applications like Defense and Secure Communications. The realized filter has achieved the size reduction and bandwidth is improved with an excellent return loss. The dimensions of the filter including housing don't exceed 12 mm x 12 mm.*

***Key Words*: SIW-Substrate Integrated Waveguide, CPW-Coplanar Waveguide, VNA-Vector Network Analyzer, EMI, EMC.**

1. INTRODUCTION

RF/microwave filter design techniques have been subjects of active interest for several decades as RF/ microwave filters are important components in most RF/microwave applications. As we all probably know the function of a filter is to allow a certain range of frequencies to pass while to attenuate the others. Thus clearly there is a pass band and a stop band. Filters can be low-pass, high-pass, band-pass, and band reject type. By carefully defining the signal band, filters limit the system noise and reduce the potential effect of out-of-band interference essential for many Electromagnetic Interference/Electromagnetic Compatibility (EMI/EMC) applications.

With the advancement of modern wireless communication applications, the finite frequency spectrum has to accommodate additional systems and thus it is becoming increasingly congested. Hence, RF signal must be confined to the assigned spectrum ranges. As a key component to restrict signals, filters are required with stringent requirements such as high performance, low cost, compact size, and light weight. Filters are essential in separating and sorting signals in communication systems. The role of filters in communication systems is to usually transmit and receive amplitude and/or phase modulated signals through a communication channel. To get rid of or suppress spurious frequencies from being transmitted or received in radio transmitters and receivers, filters are used. Evolving applications such as wireless communication remains to challenge RF/microwave filters with even more rigid requirements like smaller size, lighter weight and lower cost with better performance. Filters used in communication and radar applications, are implemented in different kinds of transmission lines comprising strip line, rectangular waveguide, and Microstrip. Filters are also the integral part of multiplexers which are of major demand in the broadband wireless access communication systems.

2. THE EXISTING WIDEBAND SIW FILTER

Now a day's wireless communication involved in many applications like space wave communication, Radio astronomy, high-frequency microwave radio relay, microwave remote sensing, amateur radio, directed energy weapon etc… Generally wireless systems are nothing but mobile station and radar base station. In any wireless communication systems band pass filter is playing important role. Filter is used to select the frequency. BPF is a two-port network, allow some applications.

A post-wall waveguide (also known as substrate integrated waveguide (SIW) or a laminated waveguide) is a synthetic rectangular electromagnetic waveguide formed in a dielectric substrate by densely arraying metalized posts or via-holes which connect the upper and lower metal plates of the substrate. There are three layers in SIW. They are Top ground plane, Bottom ground plane and Dielectric layer. The dielectric layer is situated in between the two layers mentioned above. Metallic via array of holes is placed between these two planes.

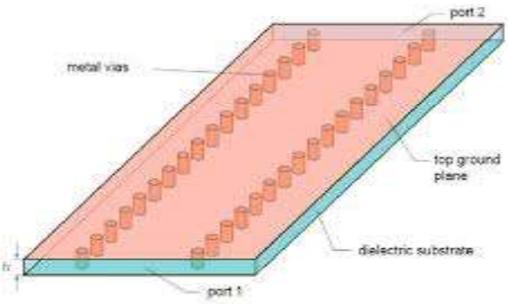

Fig. 1. SIW structure and its parameters

3. THE PROPOSED FILTER

In the previous years, wireless communication systems has developed tremendously, there was a prompt development in ultra-wideband systems, wireless internet like WiFi and Wimax, broadband personal communication systems and 3G (third generation), 4G (fourth generation) technologies. Due to this rapid development there was a need for more rigid microwave components. And now a day's satellite systems changed their path from static telecommunications systems to mobile, remote sensing and navigation applications. Microwave components play an important role in the satellite systems. Microwave components include microwave resonant components such as microwave filters, dielectric resonant antenna arrays (DRA), duplexers. Because of the rapid growth in the wireless communication area, it created more challenging requirements that enforce challenges on various novel designs, optimization and understanding of components. In microwave filters the challenges are to be faced in miniaturization, bandwidth, phase linearity, and selectivity of the filters.

This paper presents a new procedure for the miniaturization of microwave filter realized in Microstrip technology. The new implementation proposes the elimination of metallic slots in substrate integrated waveguide (SIW). In this paper it has been designed a new miniaturized planar filter for C band application is introduced. The center frequency of the proposed filter is in C band. This design mainly concentrated on compact size which is suitable for applications like Defense and Secure Communications.

3.1 Structure of Proposed Filter

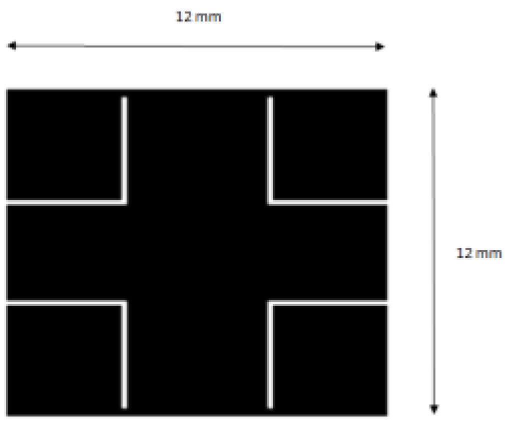

Fig. 2. Top plane of the proposed filter

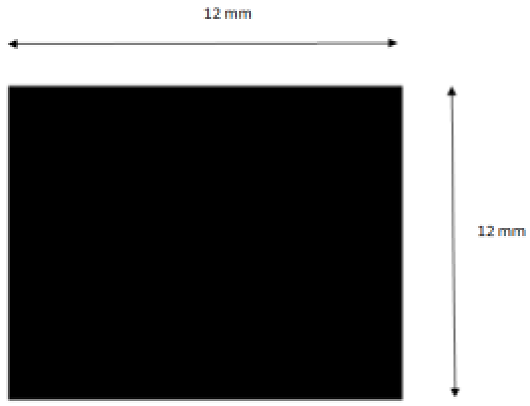

Fig. 3. Bottom plane of the proposed filter

The top and bottom planes are made up of copper plates. In between the two planes, the dielectric which I have used here is FR4 material with a dielectric constant of 4.4 with a substrate height of 1.57mm and the thickness of copper plates are 0.035mm.

In this design, coplanar waveguide (CPW) is used as transmission path to connect the ports. Let see about coplanar waveguide. A coplanar line is a structure in which all conductors supporting wave propagation are located on the same plane, i.e. generally the top of a dielectric substrate.

3.2 CPW (Coplanar Waveguide)

The coplanar waveguide is a planar transmission line. It is widely used for microwave integrated circuit design. Coplanar waveguide consists of a conductor strip at the middle and two ground planes are located on either sides of the center conductor. All these lie in the same plane. In coplanar waveguide, EM energy is concentrated within the dielectric. The leakage of the Electromagnetic energy in the air can be controlled by having substrate height (h) twice that of the width (s). The coplanar waveguide supports quasi TEM mode at low frequencies while it supports TE mode at high frequencies.

The effective dielectric constant of CPW is same as that of slot line. The characteristic impedance of a coplanar waveguide is not affected by thickness and depends on width (W) and space (S). The lowest characteristic impedance of 20 Ohm can be achieved by maximum strip width (W) and minimum slot space (S). The CPW transmission main design parameters are center conductor width (W) and spacing between ground and center conductor (S).

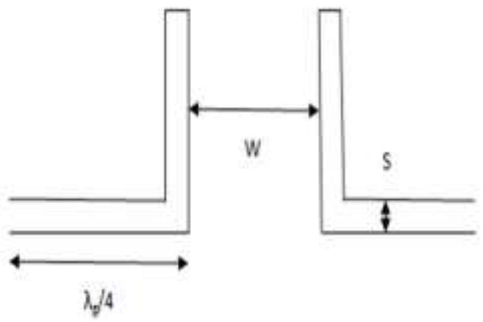

Fig. 4. CPW structure and its parameters

Where λ_g is guided wavelength,

$$\lambda_g = \frac{\lambda}{\sqrt{\varepsilon_r}}$$

3.3 Simulated Design of the Proposed Filter

The miniaturized planar waveguide filter for C-Band application is simulated using CST Microwave studio. The simulated design is shown below.

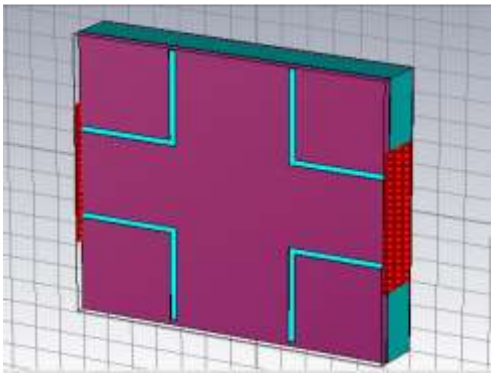

Fig. 5. Simulated structure of the proposed filter

Fig. 6. Fabricated model of the proposed filter

From the above figure, it is evident that the size of the proposed filter is very compact in size.

4. PARAMETRIC ANALYSIS FOR POSITION OF VIA

This section deals with various designs and their simulated results are shown below. In this analysis, it helps to know the compact and suitable filter for our objective.

4.1 Filter with SIW design

This is the filter which uses the substrate integrated waveguide (SIW) technology. An array of metallic via is arranged between the planes. Let see the simulated structure of the SIW filter and it is simulated using CST Microwave studio.

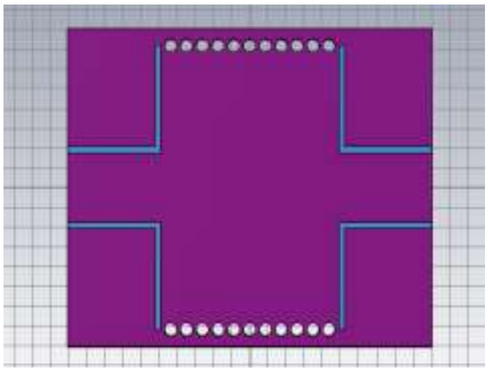

Fig. 7. Simulated design of SIW filter

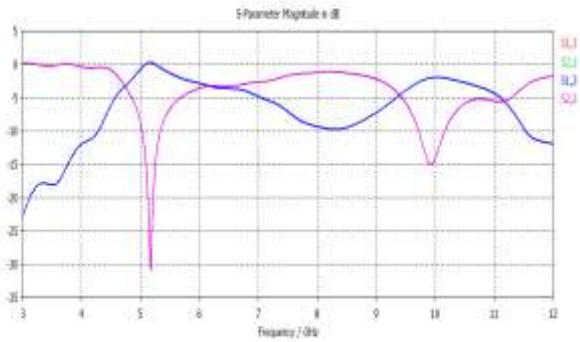

Fig. 8. Simulated S-parameters of SIW filter

The dielectric material which I have used here is FR4 and cost of the material is very cheap. The bandwidth of the filter is about 300MHz. Moreover, size of the filter that we designed is not suitable for compact size. By using this design, the size of the filter remains unchanged and the bandwidth is not improved. Additionally, it leads to some leakage losses due to the use of metallic via in between the planes.

4.2 SIW Filter with 3 via

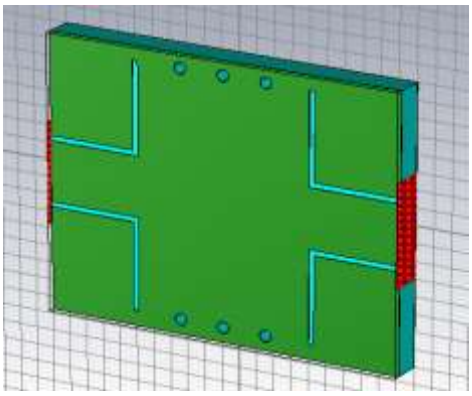

Fig. 9. Simulated design of SIW filter with 3 via

The above structure is also based on substrate integrated waveguide technology. Here, I had reduced the number of via in order to check the performance on bandwidth and size. This design is also simulated using CST Microwave studio. The dielectric material for this design is also FR4 with a same dielectric constant and height.

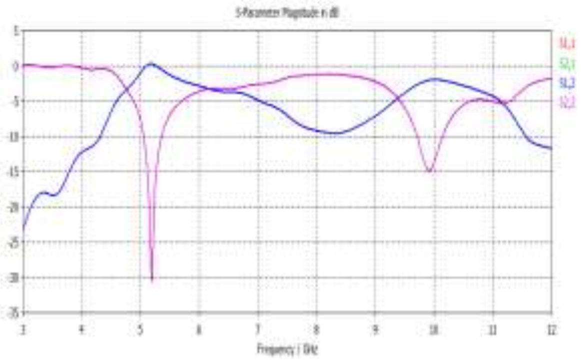

Fig. 10. Simulated S-parameters of SIW filter with 3 via

The bandwidth of the filter is again calculated about 300MHz. Hence, the size of the filter that we designed is not suitable for compact size. By using this design, the size of the filter remains unchanged and the bandwidth is not improved. The leakage losses due to the use of metallic via in between the planes are again stagnated.

4.3 SIW Filter with 2 via

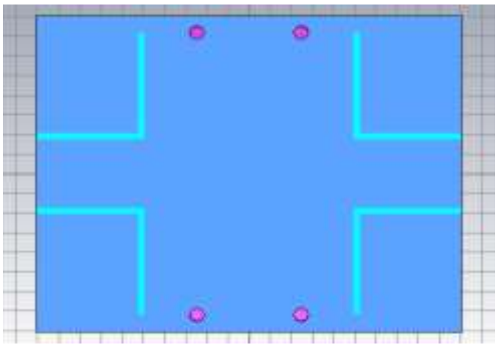

Fig. 11. Simulated design of SIW filter with 2 via

Here, the above figure depicts the SIW filter. In this filter design, I have used only 2 via.

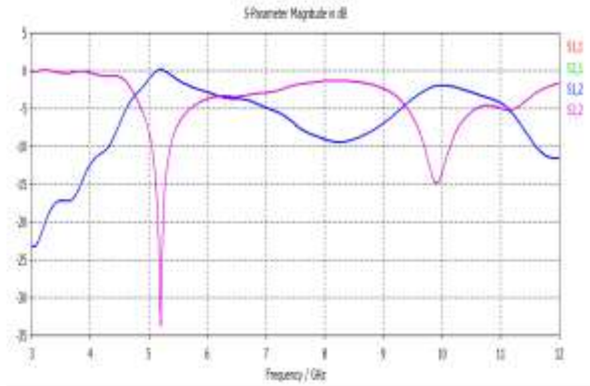

Fig. 12. Simulated S-parameters of SIW filter with 2 via

The bandwidth is again found to be 300MHz. It remains unchanged.

4.4 Proposed Filter

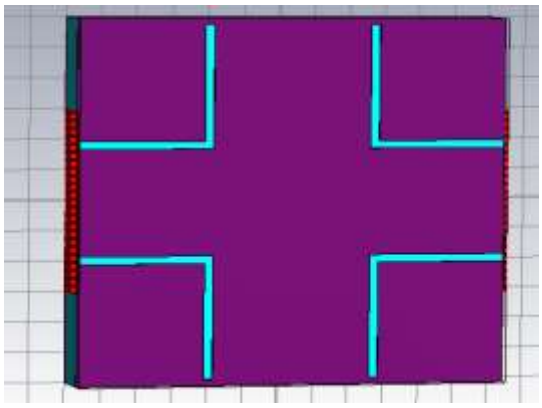

Fig. 13. Simulated design of proposed filter

Finally, I have designed a filter which replaces the metallic via with planar structure of ground planes and dielectric. This filter design presents a new procedure for the miniaturization of microwave filter realized in Microstrip technology. The new implementation proposes the elimination of metallic slots in substrate integrated waveguide (SIW). This miniaturized planar filter has attained the center frequency in C band. This design mainly concentrated on compact size which is suitable for applications like Defense and Secure Communications.

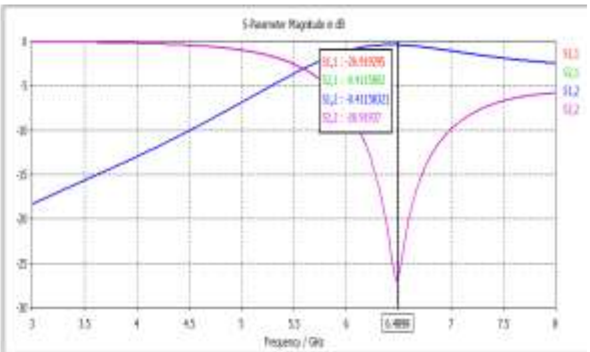

Fig. 14. Simulated S-parameters of proposed filter

Maximum resonance peak occurs around at 6.4GHz, at this frequency S11 is -26.9dB and transmission coefficient S21 is below -1dB. The bandwidth is calculated around 900MHz. And the size of the filter is 12 mm x 12 mm. My objective of miniaturization has achieved in this last model of filter design.

5. EXPERIMENTAL RESULTS

This miniaturized planar waveguide filter is designed by using FR4 substrate with a dielectric constant of 4.4, a loss tangent of 0.025 and height of the substrate h is 1.57mm. Top and bottom of the substrate coated with pure copper metal plates with thickness is 0.035mm. Here operating frequency is 6.4 GHz which is suitable for the applications like satellite communication, weather radar systems, defense, Wi-Fi and ISM band applications.

The simulations results are shown below for the proposed filter structure. Graph show frequency versus reflection coefficient (S11) and transmission coefficient (S21).

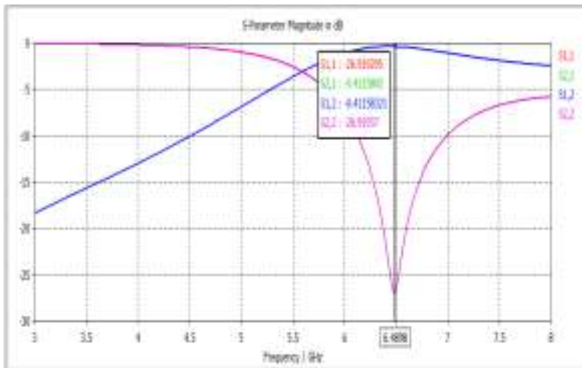

Fig. 15. Simulated S-parameters of miniaturized planar waveguide filter

In the simulation results, Bandwidth is calculated on reflection coefficient curve -10dB is taken as reference. From the graph -10dB line touches S11 curve at first and second points as we can notice that in the above figure. A first point f1 touch at 6.1GHz and a second point f2 touch at 7GHz. Bandwidth is calculated as f2-f1=900MHz. Maximum resonance peak occurs around at 6.4GHz, at this frequency S11 is -26.954dB and transmission coefficient S21 is below -1dB. In this simulation VSWR is below 1.5.

The fabricated design is then measured using Vector Network Analyzer (VNA) is shown below. Here operating frequency is 6.35 GHz. Maximum resonance peak occurs around at 6.35GHz, at this frequency S11 is -23.60dB.

Fig. 16. Photograph of VNA Result

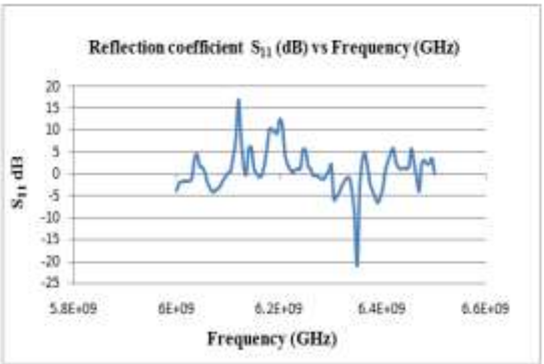

Fig. 17. Measured S_{11} value through VNA

6. CONCLUSION

Throughout this paper, the planning and implementation of miniaturized planar wave guide filter for C-Band application are incontestable. The measured response of the ultimate filter structure has shown moderately sensible characteristics with relation to its bandwidth and return loss. Meanwhile, compact size and efficient implementation on typical Microstrip technology are maintained.

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