Designing Wideband Filters Having More Than 3-Octave Bandwidth

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Abstract— Desigining very wideband filters remains still a challenge for most of the cases even today. The suspended stripline technology is the ultimate choice for sharp filters having low insertion loss. However,**It is quite often to come across of limit circuit component values in sharp and ultra wide band filter design. When the approach with finite transmission zeros are employed resonator impedance ratios can vary in a very broad range such as 30 to1. Using a mixed technology such as microstrip together with –suspended stripline can be useful to overcome this problem. As an example in this paper, a 2 GHz Highpass filter with 30 dBc rejection at 10 % away from the corner having a passband up to 18 GHz band is designed and manufactured.** ***Key Words* — Mixed Filters, Suspended Stripline Filters, Ultra Wide Band Filters.**

I. INTRODUCTION

Some missions can have wide band operation requirements such that filtering directly after the antenna is crucial. These filters might also need to have very sharp skirts i.e. very high suppression near band edges.

The traditional filters have usually of wavelenth/4 long short circuited stubs. However those filters usually can't give sufficient suppression. On the other hand elliptical filters are mechanically unrealizable because of extreme element values of the resulting stepped stubs arising from the transmission notches (FTZ). A mixed realization containing both microstrip lines and suspended strip lines can be used. However assembly of the mechanical structure is difficult because microstrip lines have ground plane on one side, in contrast the suspended lines require ground planes on both sides of the substrate. In this work this difficulty is overcome by transferring all microstrip line grounds to the same side by using via holes placed at suitable locations on the stepped resonators. An elliptical filter is designed which works in 2-18 GHz band having 30 dBc suppression at frequencies %10 away from the band edges provided by three notches on both stopbands. The structure involves both suspended and microstrip lines. The assembly is mechanically simple.

In second part of the article a typical conventional design without finite transmission zeros is discussed. The new approach is described in third section.

II. A WIDEBAND CHEBYSHEV FILTER

Just as a reference for comparing with the targeted elliptic filter, first a Chebyshev 2-18 GHz HP filter is designed as a distributed element HP filter with quarter wavelength frequency selected as fq=11 GHz. The circuit is synthesized using FILPRO as shown in Figure 1.

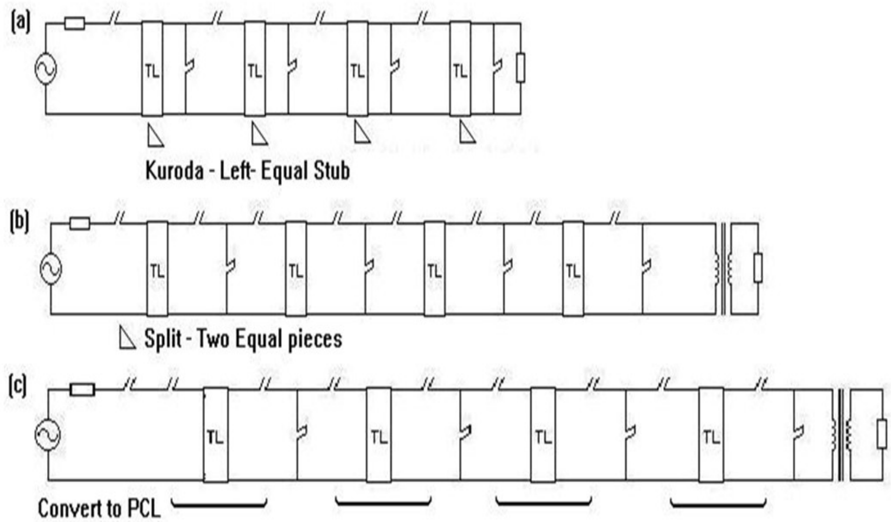


Figure 1. Synthesis steps of a 2-18 GHz Chebyshev filter.

9 attenuation poles at f=0 and 4 transmission lines (UE) are used for synthesis, leading to degree 13 HPF. The elements are extracted using the order shown in Figure 1.a. Stub-UE-Stub triplets are formed by distributing the stubs adjacent to UE's using Kuroda transformations. The triplets are then converted into parallel coupled line sections.

Impedances of the first and last stubs are around 180 ohms while those of other stubs are around 70-80 ohms. These impedances are realizable using suspended striplines.

The filter is manufactured on 5 mils CuFLon material as shown in Figure 2. Measurement results show better than 2:1 VSWR and insertion loss better than 2 dB in the passband (Figure 3).. Suppression at %10 away from band edges is 10. Board dimensions are 4x2 cm. As an alternative to the traditional filter designed in the previous section, 2-18 GHz HP filter is constructed as distributed element elliptic HP filter with quarter wavelength frequency, fq=11 GHz, 3 transmission zeros at DC, 4 transmisson lines and 3 notches at 1500 MHz. The schematics for this circuit is shown in Figure 4.a. Total degree of the filter is 13, just the same as the Chebyshev case. When we consider element values, we see that the even and odd mode impedances of parallel coupled sections can only be realized as broad side coupled lines, hence requiring suspended stripline technology. The notches are converted to stepped stubs. It is seen that the first step has high impedance while the second step has quite a low impedance, which implies that realization would be difficult using a single technology such as only microstrip or only suspended stripline. Therefore a compound structure is used, in which the high impedance (step-1) lines are suspended stripline sections, while the low impedance (step-2) steps are microstrip lines. It is noted for the traditional filter that return loss fails to comply with specifications. As t frequency increases, return loss degradation is obvious. Hence it becomes compulsory that the reason for degradation should be found and corrected.

The prime suspect is an old friend: the connector. The launching scheme should be optimized for the entire band. For this reason a 50 ohm transmission line was drawn and simulated with the current air gap,seal, pin radius and air above pin. When we increase the air around the pin from 20 mils to 24 mils and the distance between the top wall and pin from 32 mils to 40 mils the return loss decreases from -12 dB to -34 dB.

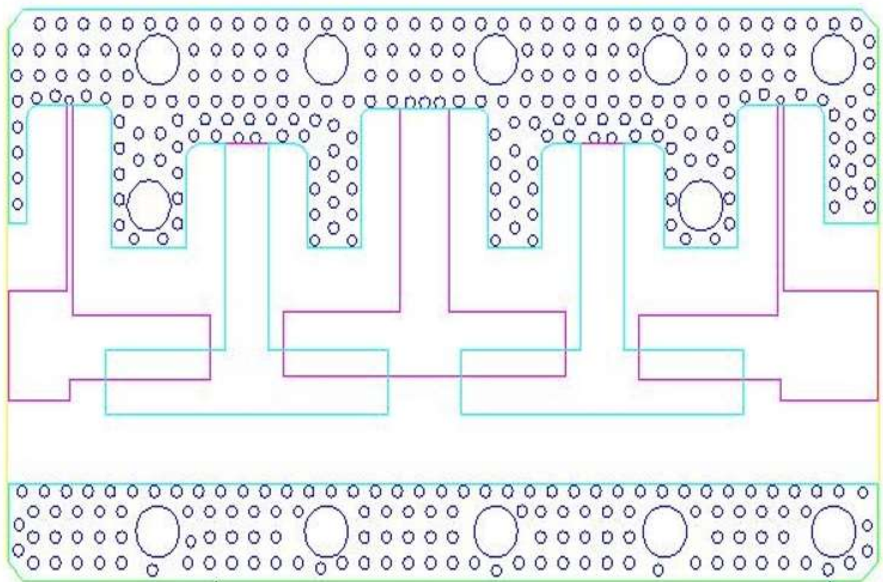


Figure 2. Layout of 2-18 GHz Chebyshev Filter.

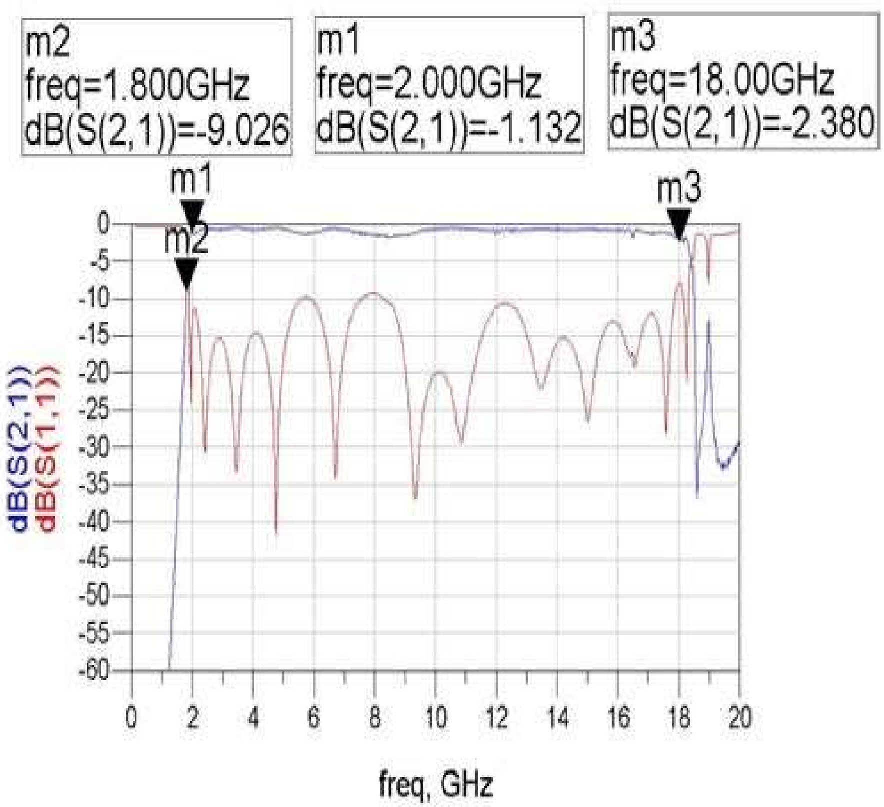
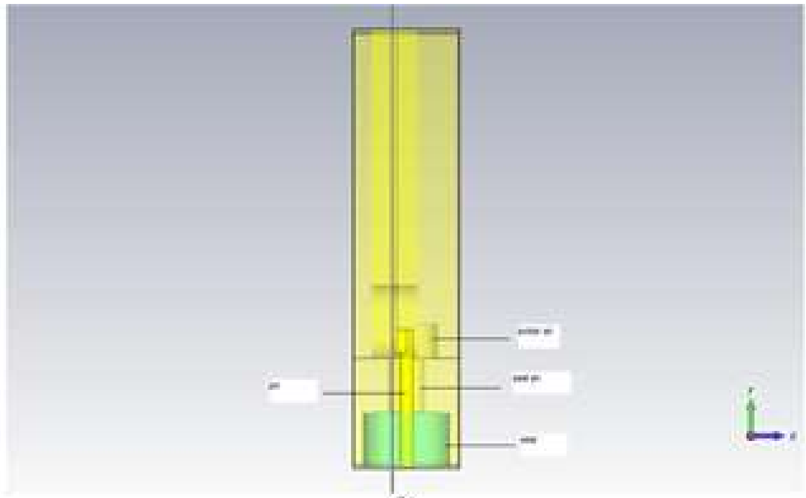


Figure 3. 2-18 GHz Chebyshev Filter measured response.



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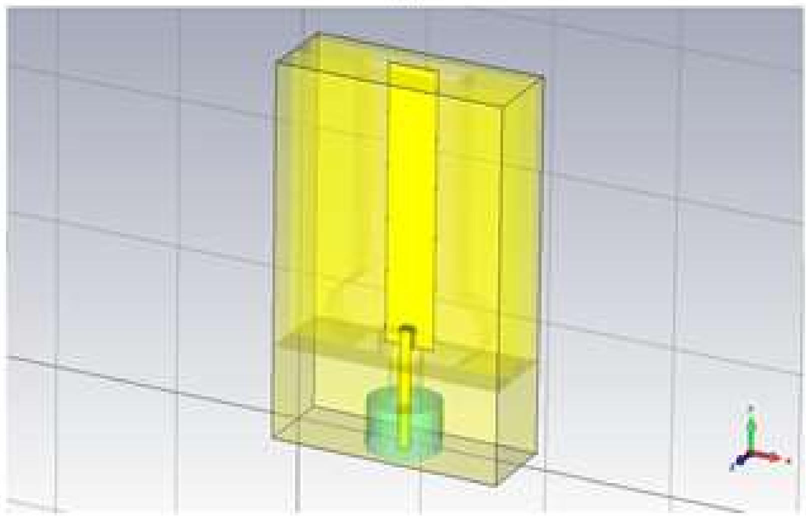
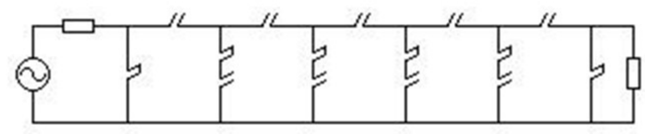


Figure 4. Launching of the connector

III. WIDEBAND ELLIPTIC FILTER

The design steps will not e given as detailed as given in chapter 2. A Hp filter at 14 GHz with the specifications below is designed in FILPRO. Band edge frequency: 14 GHz, Cut off frequency: 26 GHz , Passband ripple: 0.01 dB, rejection at 13 GHz: 60 dBc. The filter will be in the form of Generalized Chebyshev-3 as given in Figure 4.1a. The open circuits are replaced by series LC resonators. Inductors in the resonators are splitted into two equal pieces and they are replaced by transmission lines as given in Figure 4.1.b. The resultant circuit is shown in Figure 4.1c. the series open,short circuit in the parallel arm is transformed into step resonators, then inductors are replaced by transmission lines and the circuit is translated into ADS. The optimized circuit in ADS and its response is given in Figures 4.1a and 4.1.b respectively.

(a)



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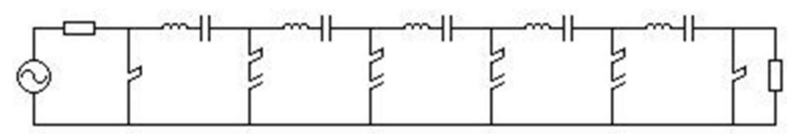

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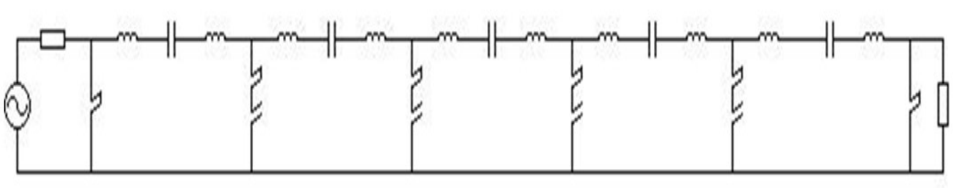
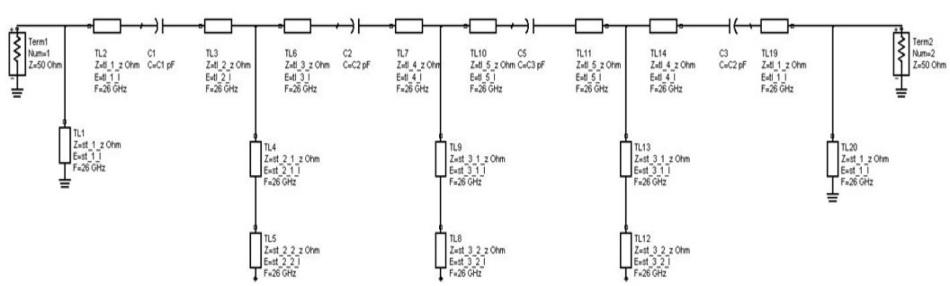




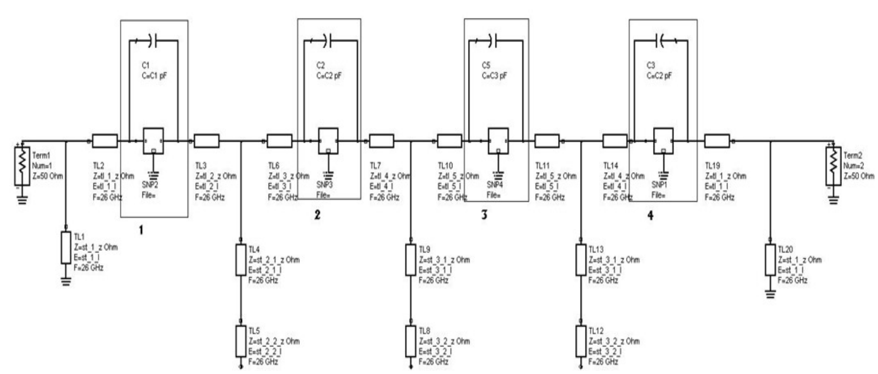
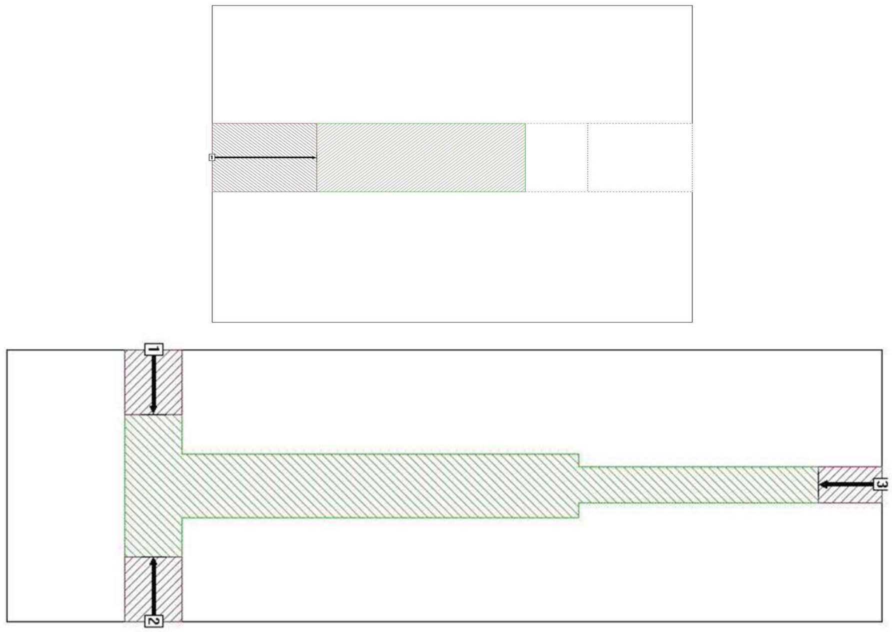


Figure 4.1. Circuit synthesis of the elliptic filter



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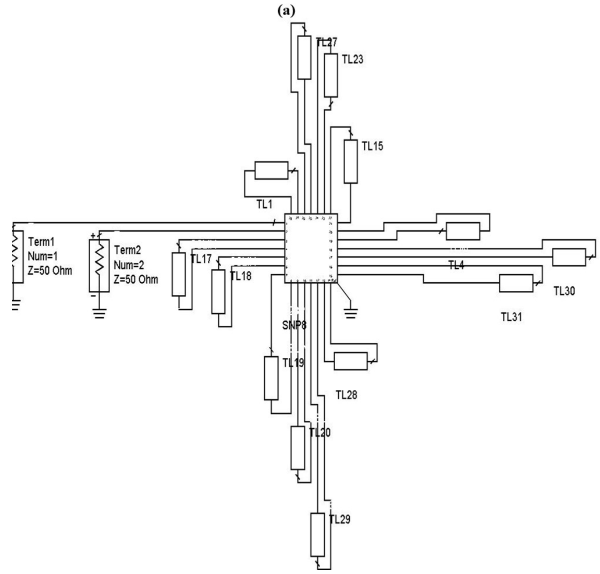

Figure 4.3 Replacing circuit elements of the elliptic filter.

EM modeling will proceed as follows:

First the capacitors are replaced by broadside coupled lines. The capacitors to be replaced are shown in Figure 4.1.c Notice that the width of coupled lines should be chosen as the same width as the transmission lines that were used to replace inductors. It should be kept in mind that the higher the impedance of the transmission line the better the less is the degradation of the response, however there is a trade-off. The higher the impedance of the transmission line the narrower the physical line would be. As the transmission line gets narrower, broadside coupled line to replace the capacitor will be longer. This limits the upper frequency of the approximation. As a result it can be deduced that the width of the transmission line should be thin enough to replace the inductors, but wide enough to replace the capacitor.

Another possibility is to use very thin line to replace inductors and very thick broadside coupled lines to replace capacitors, but this time reflections from T-junctions forms by thin and thick lines connected together will cause extra reflections which would in return degrade the return loss of the structure.

An additional problem occurs in assembly: As parallel coupled line sections are broad side coupled lines, notch sections must also be located on the opposite sides of the substrate. That is, every second section in stepped stub resonators need to be of microstrip form, which in turn demands to be placed on the housing, on alternate sides (top and bottom) which is not possible. This problem is overcome by transferring the low impedance parts to the other side of the suspended substrate using via holes as shown in Figure 5. Thus, two of the stepped stubs which realize notches are placed at back face of the board. This way all of the tuning screws are on front face and module thickness is 3mm less.

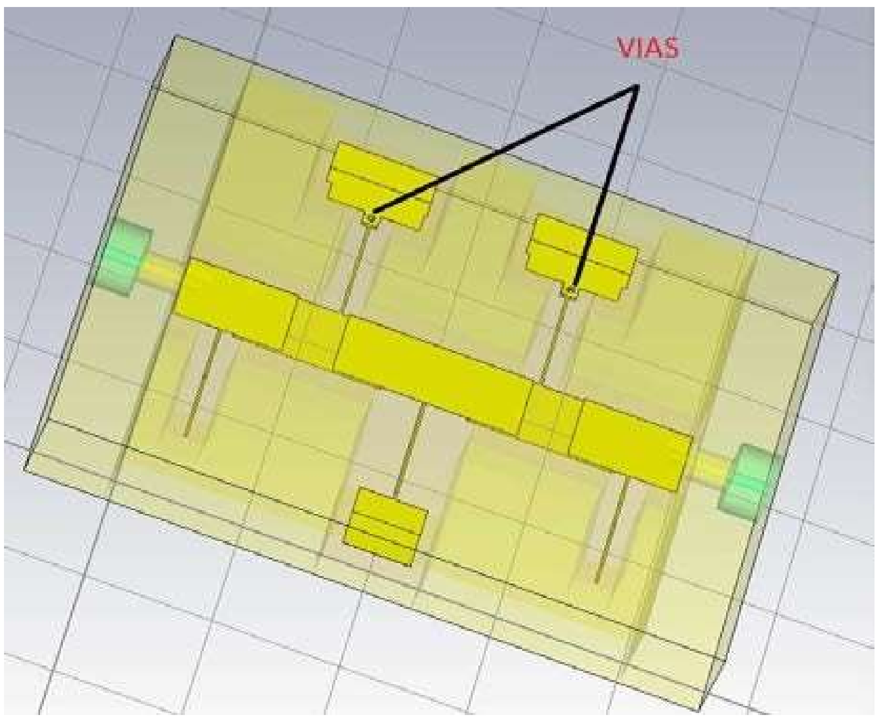

Figure 5. CST Layout of the elliptic filter

Filter is simulated in a 3-D simulator and response in Figure 6 is obtained. It is observed that return loss is better than 16 dB in full band, insertion loss at band edge frequency is around 1 dB and suppression at %10 further than the band edge is better than 27 dBc. The circuit is produced on 5 mils RTD 6002 material. The measured response of the final module of Figure9 is shown in Figure 7. Return loss is better than 14 dB in the whole band and insertion loss is less than 2 dB at band edges. The suppression at 10% away from band edges is better than 30 dBc. Board dimensions of the filter are 2x2 cm and module dimensions are 2.7cm x 2.2 cm (Figs. 8 and 9). It is seen that elliptic filter is superior in both mechanical dimensions and electrical performance compared to the Chebyshev filter. The spurs beyond 18

GHz can be eliminated by appending a simple LPF. Comparison of 3-D simulation results with measured results shows that higher performance is possible. One of the reasons for the difference between the return losses of the simulation measured results may be due to bonding the microstrip regions to the mechanical box with standard epoxy. Since the applied epoxy thickness can be higher or lower than the expected one, the distance between the board and ground could be changed and performance is affected. One solution for this problem can be using epoxy film. Another source of error may be the tolerances imposed by the PCB process which limits the performance of the structure. Micromachining (dielectric membranes) can be used for this filter enabling tighter tolerances and lower cost for mass-production.

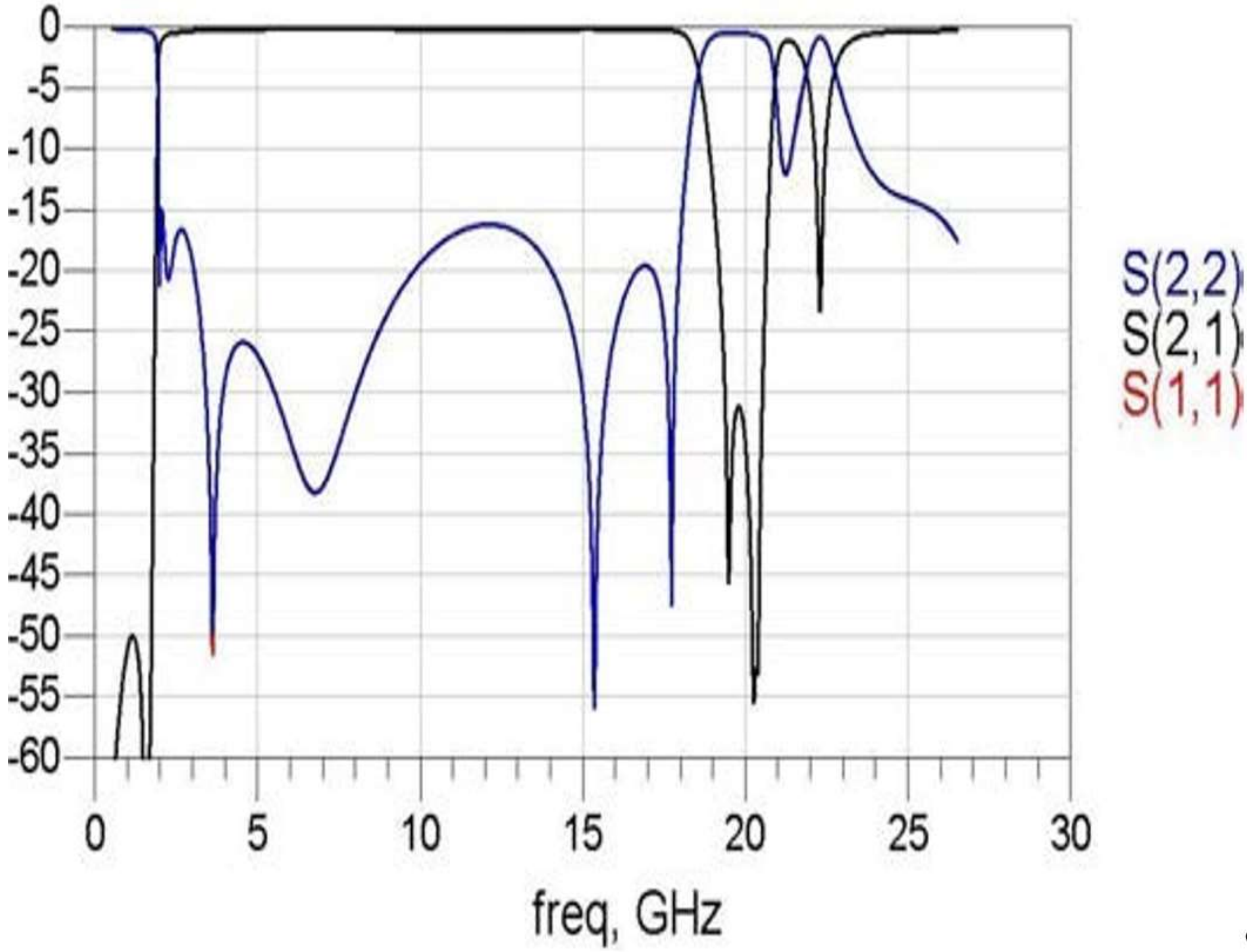

Figure 6. 3D EM simulation result

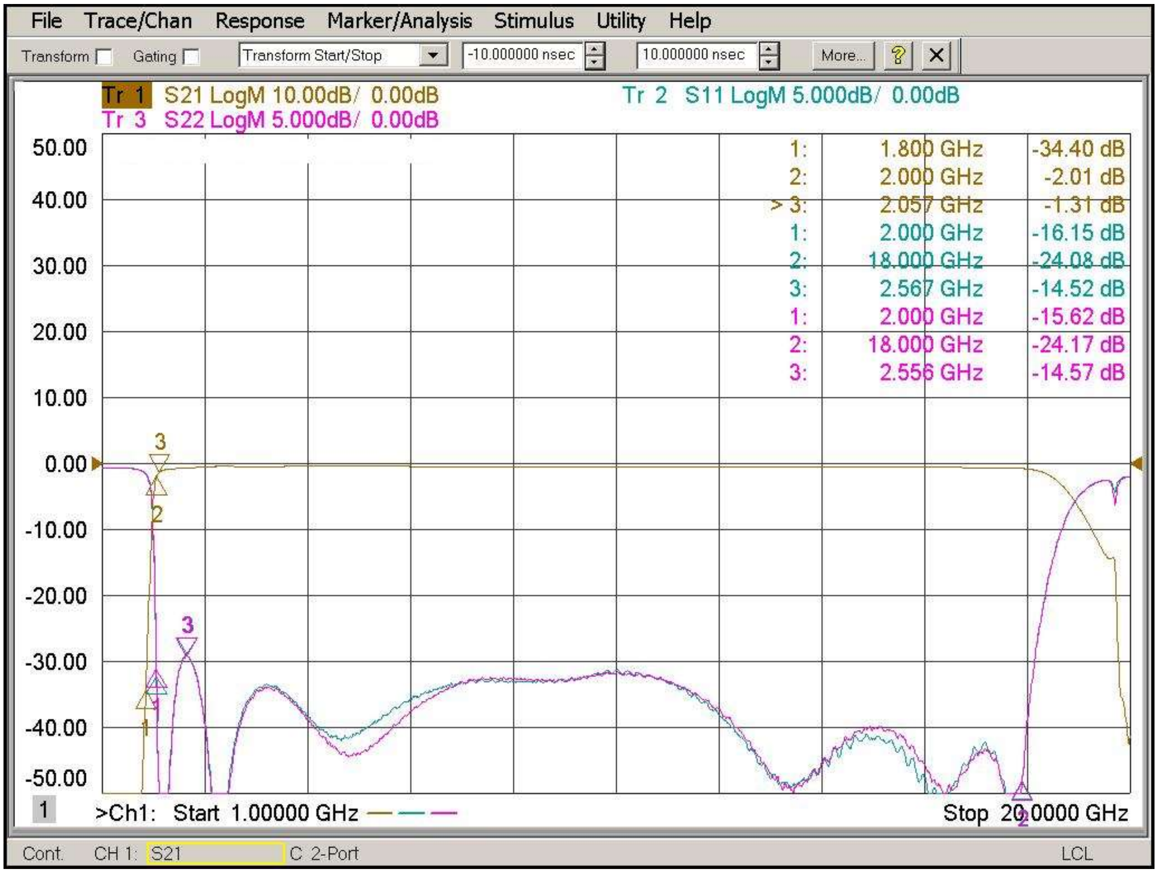

Figure 7 Measured response of the elliptic filter.

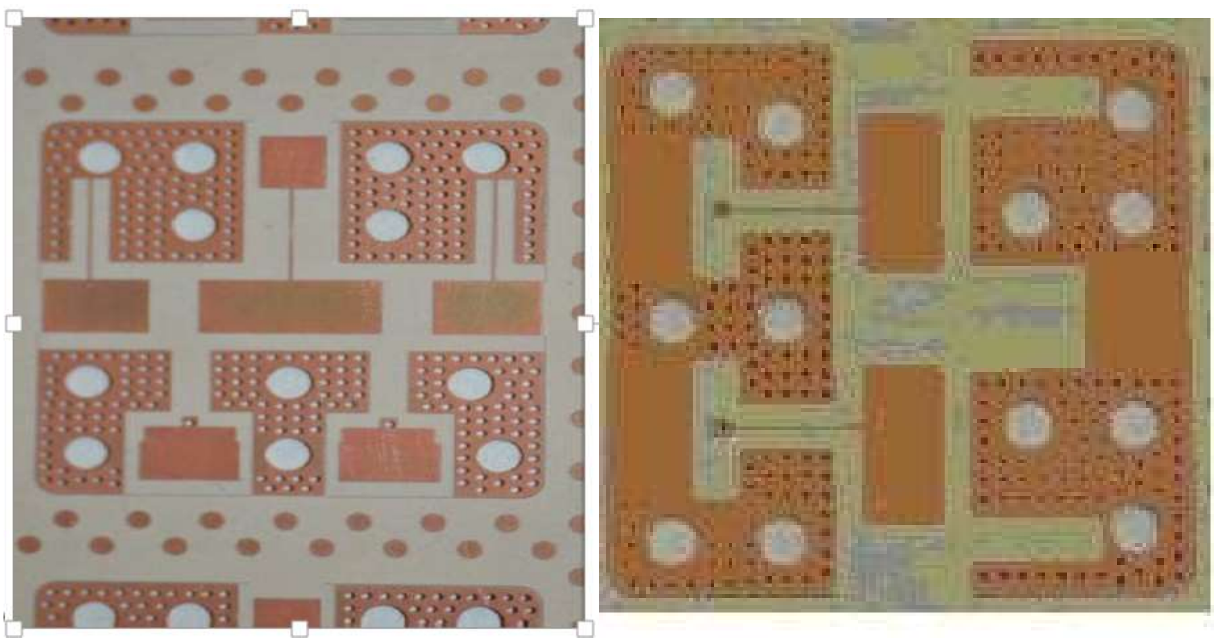
Figure 8. Manufactured Filter Board (front-back)

Figure 9. Manufactured Filter Module

IV. CONCLUSION

In this work a 2-18 GHz high pass filter is designed and manufactured. Traditionally way these filters are designed using conventional Chebyshev filters. In this work both Chebyshev and elliptic filters are designed and compared. The elliptical function is realized using the microstrip line- suspended stripline combination and all of the stubs are realized on the same face of the board by using vias on stepped stubs. This way the whole circuit is made suitable for production. It is seen that elliptic filter is superior in both mechanical dimensions and electrical performance compared to the Chebyshev filter.

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