

Using Pcb-Techniques And Dielectric Design Band Pass Filter Resonators For Ku - Band Applications

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ABSTRACT: This paper present novel design of band pass filter using dielectric resonators for various applications in ku band spectrum. It is consist of three cylindrical Resonators with simple microstrip line. This band pass filter provide greater reliability in terms of more compact, less volume , higher temperature stability and easy to use with wideband bandwidth which is vital for satellite or high data transmission involving a lot of video and data communications . Also it can be easily modified for other required band of frequency with availability of various dimensions of dielectric resonators. This band pass filter provide very good bandwidth of 1.9GHz (Pass band from 14.3GHz to 16.2GHz) in ku band. Within the whole BPF pass-band, the return loss is found better than 11dB, and the insertion loss is less than 1.5dB .

Keywords: Bandpass filter, Dielectric resonator.

INTRODUCTION

Microwave passive devices, and specially high frequency filters, are key elements in any communication system. All-metallic waveguide technology filters have been used from the first telecommunication applications to very few years ago, when filters with dielectric elements began to replace them, since this technology offers important reductions on mass and volume (about 50%) and additional thermic stability for high power applications[1]. Filters typically use pass or stop bands to modify the frequency response of a circuit by selectively transmitting or attenuating one or more frequencies within a spectrum. A microwave filter is an electromagnetic circuit that can be tuned to pass energy at a specified resonant frequency. These microwave filters are employed in numerous signalprocessing situations ranging from satellite communication systems to radar systems[13]. Microwave filters separate a communications satellite's received signal into separate bands for amplification and, after amplification, to provide channel separation for the amplified signals which are combined by a multiplexer for retransmission. The most famous filter in microwave applications is the band pass filter. Like resonant cavities, they present the resonant modes of frequency determined by the dimensions and high Q-factors. The advantages of dielectric resonators are more compact, higher temperature stability and easy to use. Moreover the ability of amenable in multi technology such as printed circuit and surface mounts technology[2]. The dielectric resonators are also usually shielded to prevent radiation as well as maintain a high-Q that required by filters and oscillators circuits . It has long been recognised that the use of high permittivity dielectric materials offer large reductions in size and weight compared to conventional waveguide filters. The term dielectric resonator (DR) first appeared in 1939, when Ritchmyer [3] of Stanford University showed that unmetallized dielectric objects in the form of toroids could function as microwave resonators. However, his theoretical investigations failed to generate significant interest and practically nothing happened . But the recent advances in material technology have made it possible to combine high

Q, good thermal stability and high dielectric constant in materials suitable for use at microwave frequencies. It is an ideal candidate for wireless application for a low design profile and wideband applications [4-5]. In this paper, a novel bandpass filter that consists of three dielectric resonators were excited with microstrip line that were used to increase the bandwidth of a bandpass filter. The idea of using the three dielectric resonators is to generate additional frequency which can merge together to produce a wideband devices, increase the transmitting power and reduce the insertion loss. The optimum coupling effect in the filter was obtained from the matching position of the resonators on the microstrip line.

FILTER DESIGN

The electromagnetic energy is coupled to the dielectric resonators by using microstrip lines as shown in Fig-1. Each resonator is positioned above microstrip line. This configuration was preferred to the direct coupling between the dielectric resonators, due to its simple design procedure.

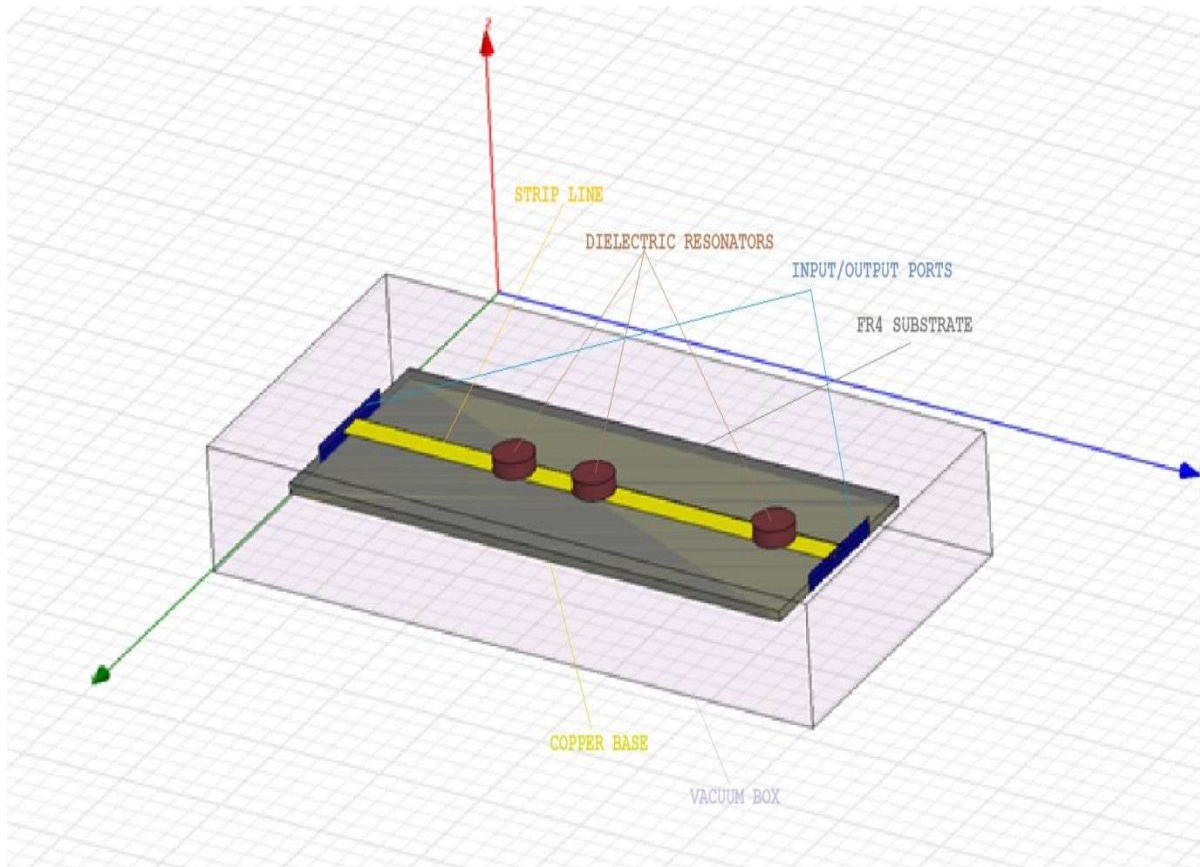


Fig 1:- HFSS Simulated Layout of proposed Bandpass filter

While the signal frequency is outside the filter passband, the input signal is reflected at the input port. For the signals with the frequency in the filter pass-band, microstrip line couples the energy from the input to dielectric resonators. Each DR will resonate for a same mode but with different frequency such that the combination response is an additional result from the single response which able to increase the overall bandwidth. Overall circuit is designed considering 15GHz central frequency. All circuits will be fabricated using a simple two-layer printed circuit board (PCB). The PCB consists of a dielectric material, usually FR4 ($\epsilon_r = 2.4$), with a thickness of 0.8mm, and two layers of Cu metal layer – base and strip. The Cu metal layers have a thickness of 0.035mm and having electrical conductivity $5.8 \times (10)^7$ S/m [9]. Three dielectric resonators are energised using microstrip line. The dimensions of stripline is taken such that its impedance is nearly 50Ω . ($Z_0 \approx 50 \Omega$). stripline width is 2.4mm and height is 0.8mm. The input and output of the board have footprints for SMA connectors which allow you to connect SMA cables. SMA stands for SubMiniature version A, a connector for coaxial cables with 50 impedance and good performance up to 18GHz. Normally we would pattern the metal layers to produce circuit but in the interest of time, the boards have been prefabricated to take on a standard form. The main formula for impedance calculation of stripline is attributed to Harold A Wheeler[10]. In order to get great coupling effect the position of the dielectric resonator is placed at odd multiple of $\lambda_g/2$ where λ_g is the guided wavelength of the dielectric medium of substrate

FR4 (dielectric constant 2.4 and loss tangent 0.002) which is easily available. The guide wavelength, λ_g is related to the free-space wavelength, λ , as shown by Eq. $\lambda_g =$

$$\frac{c}{f\sqrt{\epsilon_r \epsilon_e}} = \frac{\lambda}{\sqrt{\epsilon_r \epsilon_e}}$$

$$\epsilon_r \epsilon_e = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{\sqrt{\epsilon_r}} \left[\left(1 + \frac{12h}{w} \right)^{-1/2} \right]$$

There is an inversely proportional between size and dielectric constant. A high dielectric constant is required to reduce circuit size of a device[11]. The total length of the circuit is taken 49mm and three dielectric resonators are placed at 16.5mm, 24.5mm and 42.5mm to yield greater coupling effect. The dielectric constant of cylindrical resonator is very high (60) and resonator is 1.9mm which contributes resonant in ku band. Standard production types are cylinders with rate $h/D = 0.4$ (i.e. 40% of diameter) but custom diameters, height, temperature coefficient and tolerances can be produced in short terms [12] hence provide greater flexibility in band selection depending upon the requirements. Various effect of dimensions are analysed in further section.

SIMULATION

The simulation of the band pass filter were done using Hewlett-Packards High Frequency Structural Simulator (HFSS) software. To generate an electromagnetic field

solution from which S-parameters can be computed, HFSS employs the finite element methods, in which divides the problem space is divided into thousands of smaller regions and represented the field in each sub-region (element) with a local function. In HFSS, the geometric model is automatically divided into a large number of tetrahedral, where a single tetrahedron is formed by four equilateral triangles. This collection of tetrahedral is referred to as the finite element mesh. A mesh is the basis from which a simulation begins. Initially, the structure's geometry is decomposed into meshes by iterative adding vertex points (seeding). In the case of adaptive refinement, the initial field solution is progressively refined[14]. The design was

reviewed after each simulation run and the modifications were applied to the physical parameters of the configuration until required results were achieved.

RESULTS

Filter is designed for wide band applications. Fig-2 shows simulated result of return and insertion loss in dB. The best value of insertion loss is -1.07 dB, while the maximum return loss is about -23 dB with a wideband bandwidth of 2.5GHz. It shows pass band from 14.1GHz to 16.6GHz which has insertion loss better than -1.5dB and return loss greater than 10dB.

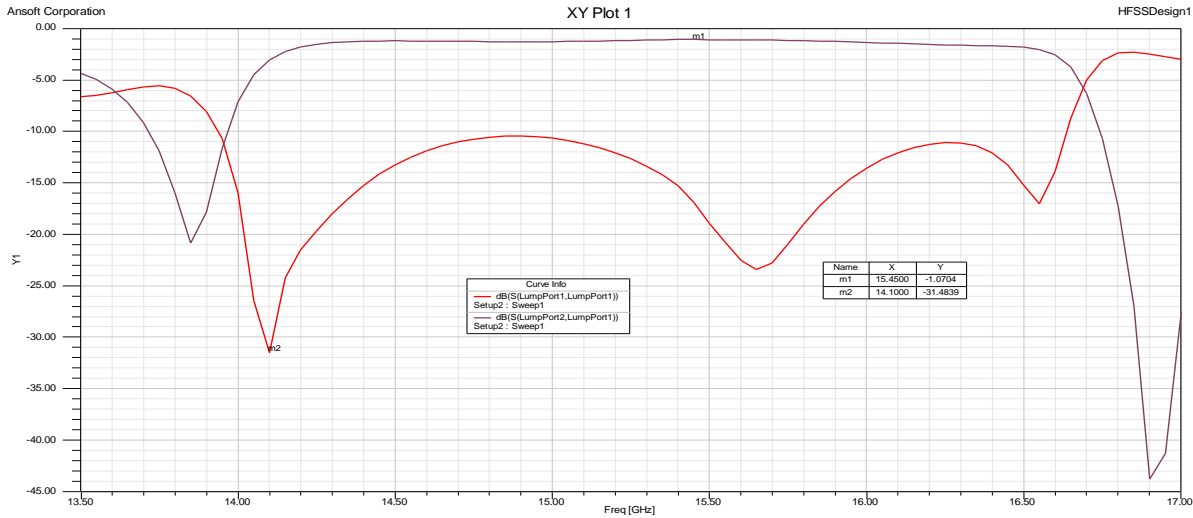


Fig 2:- Simulated Result of proposed band Pass filter having Resonator radius 1.9mm and height 1.33mm.

This band pass filter is sensitive about dimension of dielectric resonator and its place along the transmission line. The variation of radius keeping its height constant

1.33mm is illustrated by tuning its radius. This is shown in Fig-3 and Fig-4. Result shows that increase in radius lead to shifting pass band left on frequency spectrum.

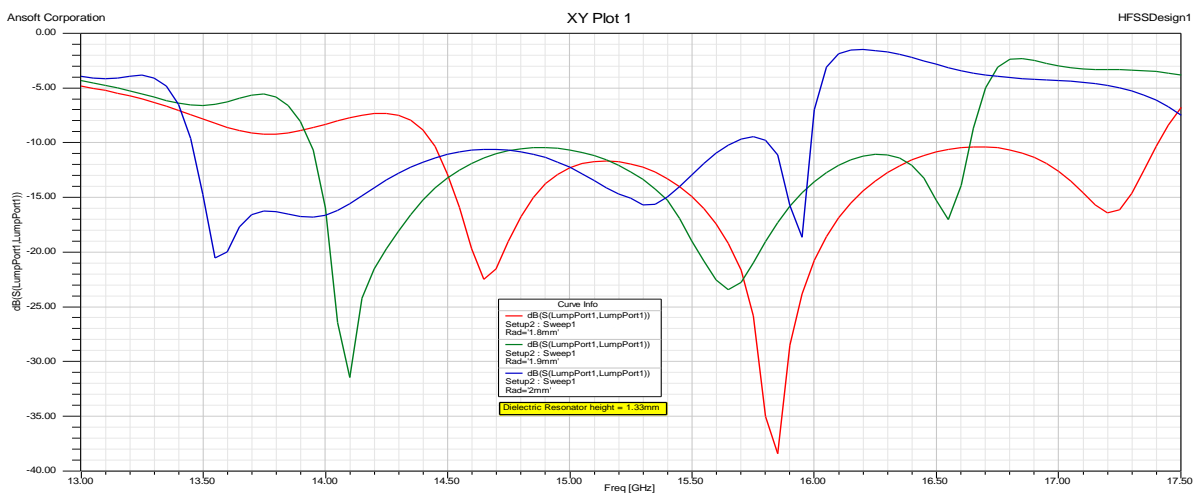


Fig-3:- Variation in Return loss due to tuning of Dielectric Resonator radius

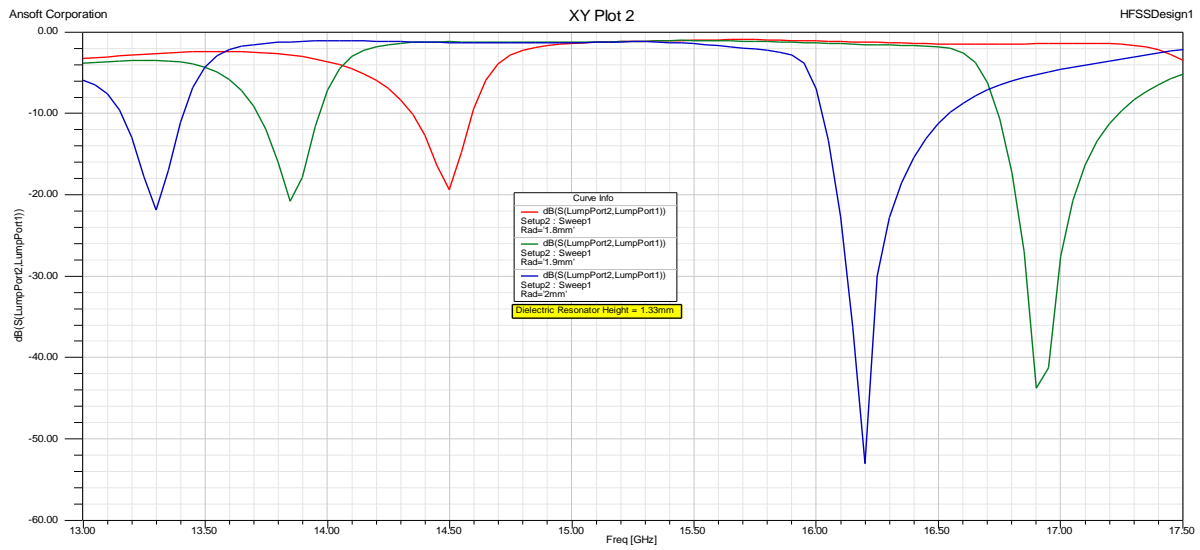


Fig-4:- Variation in Insertion loss due to tuning of Dielectric Resonator radius

Similarly we can tune dielectric resonator height to illustrate its effect keeping its radius constant 1.99mm. This is shown in Fig-5 and Fig-6. Here also result shows that increase in radius lead to shifting pass band left on frequency spectrum.

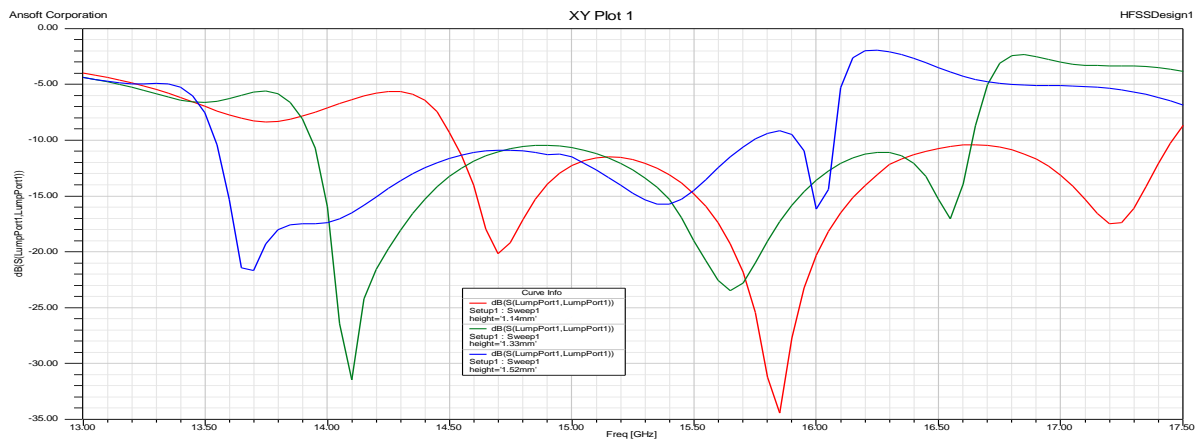


Fig-5:- Variation in Return loss due to tuning of Dielectric Resonator height

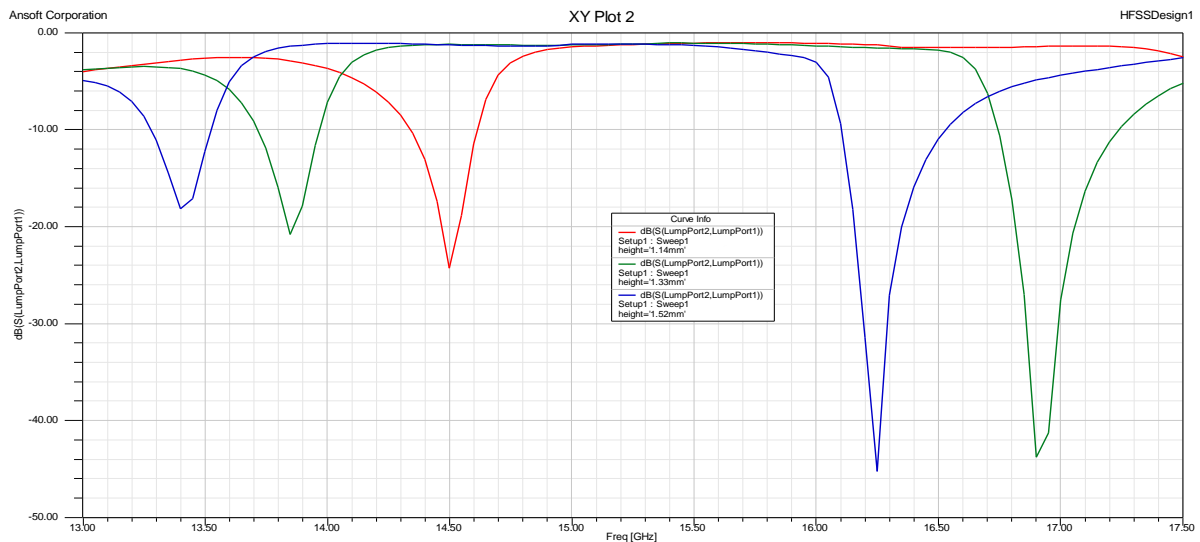


Fig-6:- Variation in Insertion loss due to tuning of Dielectric Resonator height

we have placed dielectric resonator at odd multiple of $g/2$ (where g is the guided wavelength of the dielectric medium), hence if we change its position on strip line such a way that, change in position is even multiple of $g/2$, ie integral multiple of g , then it should must have same pass band response provided the change in position does not creates mutual coupling effect between that of resonators. Fig-7 to Fig-12 shows various simulated results verifying the above theory. In each case pass band is all most same

with only variation in peak values. In these plots, green colour curves refer to our selected value of the corresponding parameter for our proposed band pass filter. Again , it is a advantage in terms of error tolerance if the error in position of dielectric resonator is sufficient to place it near to g length multiple or error is very very less compared to its radius. This makes it robust in fabrication point of view.

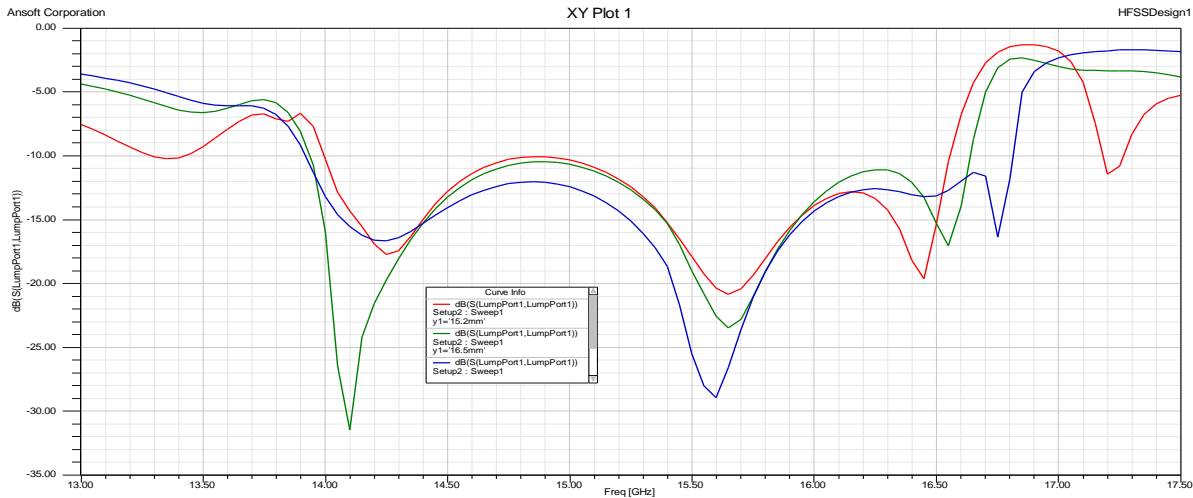


Fig-7:- Variation in Return loss due to change in the place of First Dielectric resonator along Y – axis.

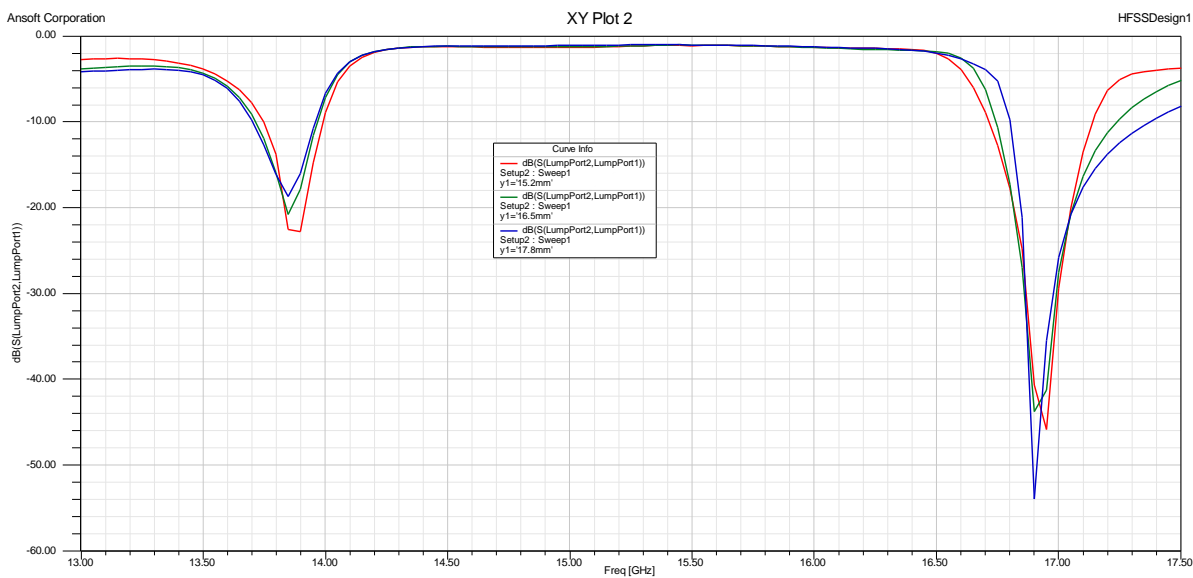


Fig-8:- Variation in Insertion loss due to change the place of First Dielectric resonator along Y – axis.

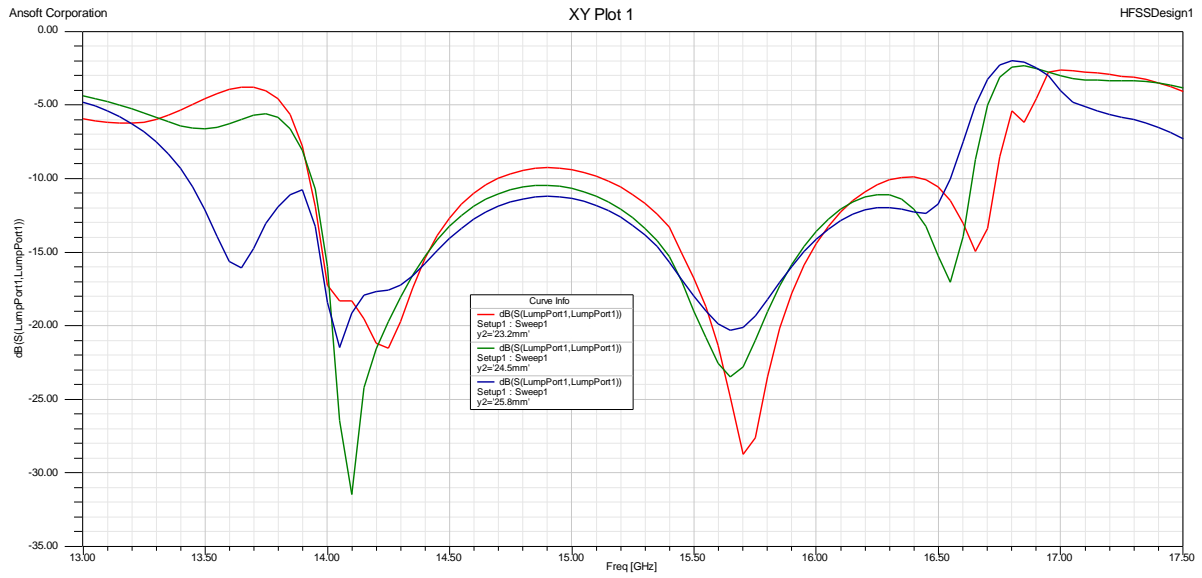


Fig-9:- Variation in Return loss due to change in the place of Second Dielectric resonator along Y – axis.

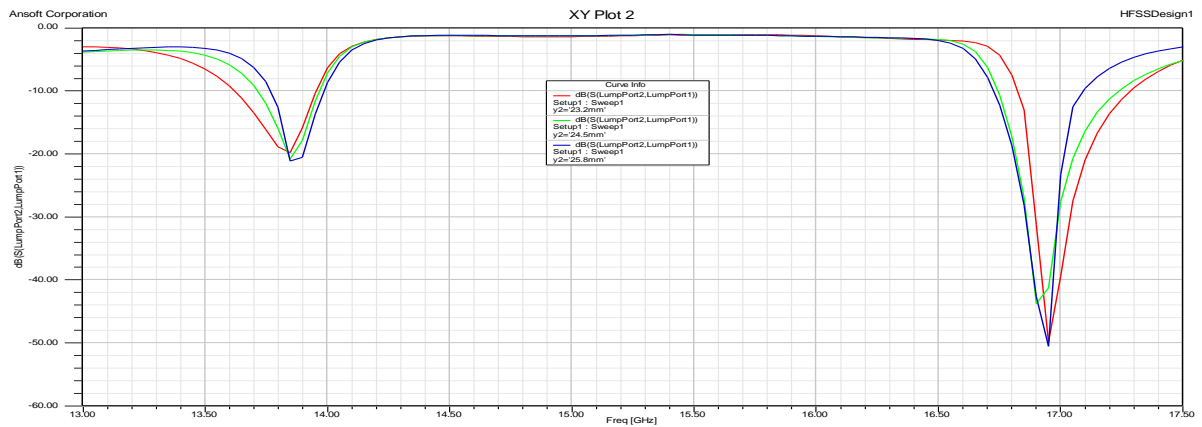


Fig-10:- Variation in Insertion loss due to change in the place of Second Dielectric resonator along Y – axis .

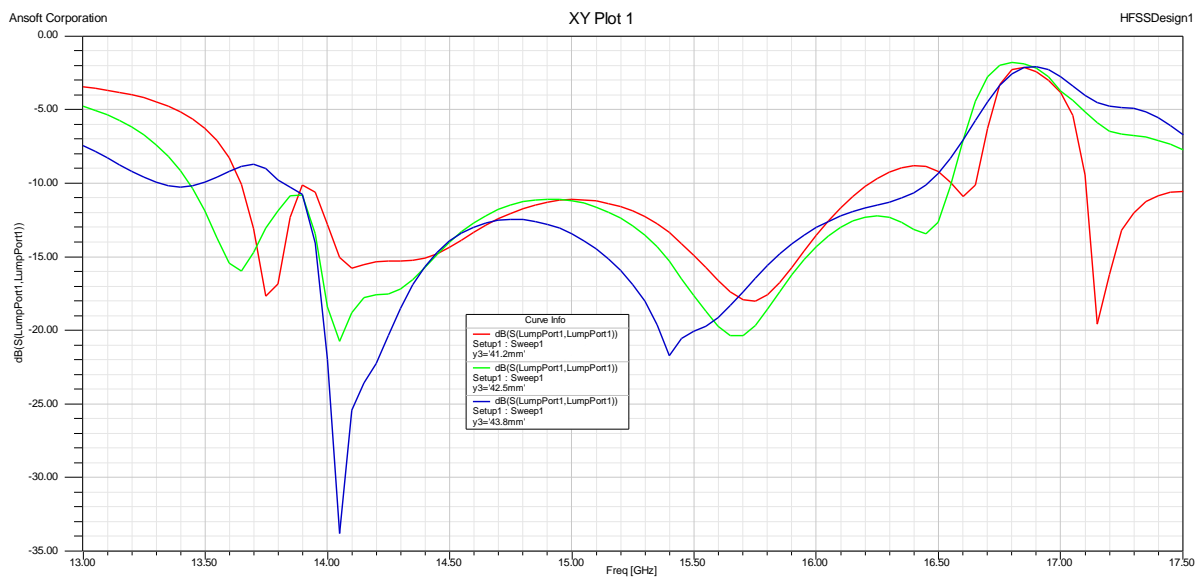


Fig-11:- Variation in Return loss due to change in the place of Third Dielectric resonator along Y – axis

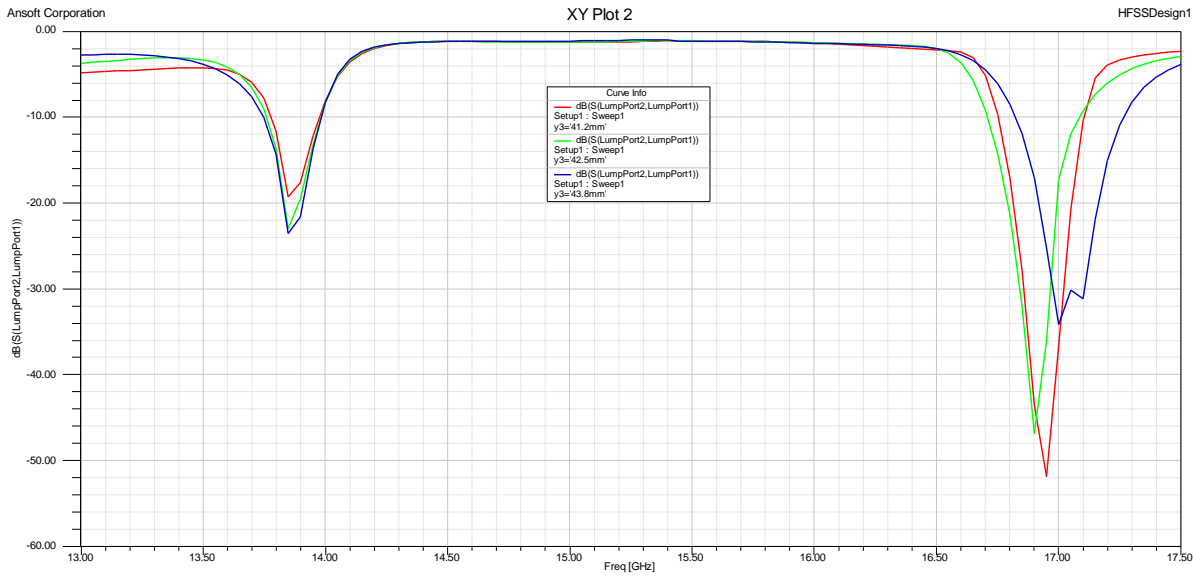


Fig-12:- Variation in Insertion loss due to change in the place of Third Dielectric resonator along Y – axis .

CONCLUSION

A band pass filter was designed to operate at central frequency of 15 GHz which can be used for various ku-band applications which requires wide bandwidth and reliability in terms of more compact design, less volume , higher temperature stability, easy to modify and etc. Various simulation results were obtained with variation in parameter such as dielectric resonator dimensions and its position along transmission line.

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