

Design of 2.5 GHz broad bandwidth microwave bandpass filter at operating frequency of 10 GHz using HFSS

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Abstract. Development of low losses, small size and broad bandwidth microwave bandpass filter operating at higher frequencies is an active area of research. This paper presents a new route used to design and simulate microwave bandpass filter using finite element modelling and realized broad bandwidth, low losses, small dimension microwave bandpass filter operating at 10 GHz frequency using return loss method. The filter circuit has been carried out using Computer Aid Design (CAD), Ansoft HFSS software and designed with four parallel couple line model and small dimension (10×10 mm²) using LaAlO₃ substrate. The response of the microwave filter circuit showed high return loss -50 dB at operating frequency at 10.4 GHz and broad bandwidth of 2.5 GHz from 9.5 to 12 GHz. The results indicate the filter design and simulation using HFSS is reliable and have the opportunity to transfer from lab potential experiments to the industry.

1. Introduction

Development of low losses and broad bandwidth microwave bandpass filter is an active area of research for selection the high-fidelity signals within the broadcast radio in radio frequency (RF) and microwave communication systems [1-3]. Microwave bandpass filter is the essential part in the microwave circuits and wireless communication systems, which is implemented to achieve a unique and accurate radiation frequency [4]. A number of reports have been published on the microwave circuits such as the antennas, filters, phase shifters, multiplexers, couplers and delay lines with high performance and low cost [5, 6]. Bandpass filters with broad bandwidth, miniaturized size, low-power consumption, and low cost are desired for microwave broadcast application [7].

Through the distribution of the microwave filter components over the entire circuits, microwave filter still occupies a lot of space. Their large dimension is due to the filter circuit distributed, which is commonly made from several resonators, which their dimensions are proportional to the guided wavelength. Hence, numerous researcher made quite efforts to develop the topology of miniaturized resonators [8]. Miniaturization of filters could be realized through change the filter geometry by replacing the 3-dimensional structure waveguide filter with 2-dimensional planar waveguide structure (i.e. microstrip line structure). Several microwave microstrip bandpass filters have been designed with surface area larger than 2 cm² [9]. However, broad bandwidth properly maintained through the coupling of two lumped elements to form the couple transmission line [10]. Many bandpass filters



have been designed using numerous types of the lumped elements such as, compact eight-pole [11], four-pole cross-coupled [12], and parallel-connected network [13]. However, all broad bandpass filters were designed with large circuit area from 225 to 5900 mm², which have been designed and simulated using different software such as, IE, EM and E6 [10-13]. Bandpass filters with small size (100 mm²), broad bandwidth and low losses, designed and simulated using HFSS software has not investigated until now.

In this work, a cascade of parallel-coupled four lines has been adopted to realize the miniaturized microwave bandpass filter of broad bandwidth, low losses and high performance, bandpass filter is designed to allow for the central frequency 10.0 GHz to pass through and attenuate other frequencies outside. The microwave filter is designed with parallel coupling line model (short strip lines) using high-frequency structural simulator (HFSS) Ansoft software [14]. This paper describes an efficient method used to design the microwave bandpass filter characteristic with broad bandwidth, high operation frequency, the detailed process has explained in this article.

2. Filter Design and Simulation

Microwave filter were designed with four parallel couple lines, which assigned as a perfect conductor and the LaAlO₃ substrate is assigned dielectric material with dielectric constant 23.5 [2]. The HFSS software has been developed to design most of kind of the microwave circuit components, it is offering an engineering task, which is able to obtain the physical dimensions of any microwave component with the specifications of high performance [15]. The data of the dimensions such as, width, height, and radius inside the command dialog windows of the software could be edited to realize the desired high-performance results. The band pass filter is consisted of dual number of the geometrical components (i.e. tape), for that it could be duplicated to create the symmetrical microwave filter. The microwave filter circuit is designed with an enclosed air body with the circuit components listed in table 3.1. The microwave bandpass filter was designed by click on the menu bar and choose the desired shape and followed by editing the characteristics of the positions and shapes in the command tab windows [16, 17]. Then by editing the data of the specific dimensions such as, width, height, and radius inside the command dialog windows of the software. The bandpass filter consists of individual number of the geometrical components that can be duplicated to create a symmetric device. The filter is designed using the coupling resonator model, which considered to be in symmetrical geometry. There are several ways to create coupling resonator between the microstrip lines, the basic principle is to design the coupled lines using two microstrip parallel end lines at least within subsection from the length of the microstrip line, which equals to the 1/4 or 1/8 of the wavelength. The coupled line of the filter has designed using four parallel tapes, which assigned as a perfect conductor.

Table 1. The component of the designed microwave filter system.

NO.	The designed part	Assigned material
1	Air body	Vacuum
2	Feed1 (Coax outer diameter)	Vacuum
3	Feedpin1 (Coax inner diameter)	Perfect conductor
4	Substrate (LaAlO ₃)	Dielectric material
5	Ground plane	Perfect conductor
6	Resonators (2 in number)	Perfect conductor

The first part is the enclosure air body, which includes the whole filter circuits, while the rest parts designed with duplicate mode as illustrated before. The x-y coordinates center of the filter was assigned at the top center of the substrate as illustrated in figure 1. Table 2, shows the adaptive solutions in the HFSS software solution step are selected with the parameters. Table 3, shows the frequency setup details in the HFSS software and the start and stop frequency. Table 4, presents the designed part dimensions of the microwave filter circuit.

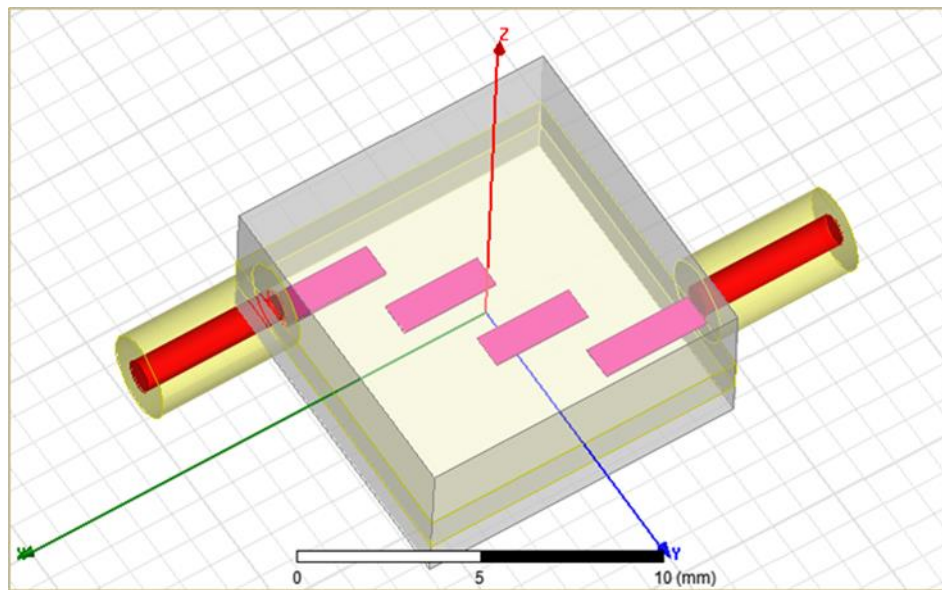


Figure 1. The image of microwave filter system from the HFSS Software.

Table 2. Adaptive solution in the HFSS software.

Sweep type	Maximum number of passes	Maximum Delta
Fast	15	0.01

Table 3. The frequency setup details in the HFSS software.

Start frequency	Stop frequency	Step Size
8.0 GHz	12.0 GHz	0.001

Table 4. The designed part dimensions of the bandpass filter.

The part	Dimension (mm ²)	Height (mm)
Feed1 (Coax Outer Diameter)	1.2 (in Radius)	4.5
Feedpin1 (Coax Inner Diameter)	0.45 (in Radius)	4.5
Substrate (LaAlO ₃)	10 × 10 (in Area)	1.0
Ground Plane	10 × 10 (in Area)	0.05
L1 Resonator	3.3 × 1.0	0.05
L2 Resonator	3.0 × 1.0	0.05

3. Results and Discussion

Figure 2, summarizes the frequency response characteristics of the simulated microwave filter by HFSS, the performance of the filter can be presented in term reflection coefficient (S11) and transmission coefficient (S12) as a function of frequency. The return loss is calculated from S11 and insertion loss from S12. The typical filter should be having high amount of return loss, lower insertion loss, broad bandwidth, good matching electrical connecting impedance and high selective frequency. Obviously, the filter has around 10.5 GHz operation frequency, the filter has broad band width of 2.5 GHz and it applicable to pass the frequencies from 9.5 GHz to 12 GHz. Furthermore, the performance

is well showed return loss more than -50 dB at the 10.5 GHz frequency and the lowest return loss -12 dB for 11.4 GHz with approximately zero insertion losses.

In general, the results of simulation of a filter depend on line width, line height, line coupling length, and the distance between the lines [16, 17]. As can be seen from Figure 2, the optimized filter has an operation frequency of ~10 GHz with a bandwidth of ~2.5 GHz, transmission frequencies in the 9.5 – 12 GHz range, a return loss more than -12 dB, and approximately no insertion losses. On the other hand, Kumar et al [18] recently designed microwave filter using finite modeling with 4-parallel coupled line pairs with a spacing < 1 mm apart using the HFSS software. These filters on the FR4 substrate (which is a composite material composed of flame resistant woven fiberglass cloth with an epoxy resin binder) of dielectric constant ~4.2 and thickness ~1.58 mm, gave much inferior performance (operating frequency ~2.48 GHz, bandwidth ~0.6 GHz, higher insertion loss ~2.2 dB, and low return loss ~-12 dB). On the other hand, we have undertaken an extensive optimization procedure in the present work that yielded high performance with wider bandwidth, high return loss for couple line distance >1 mm.

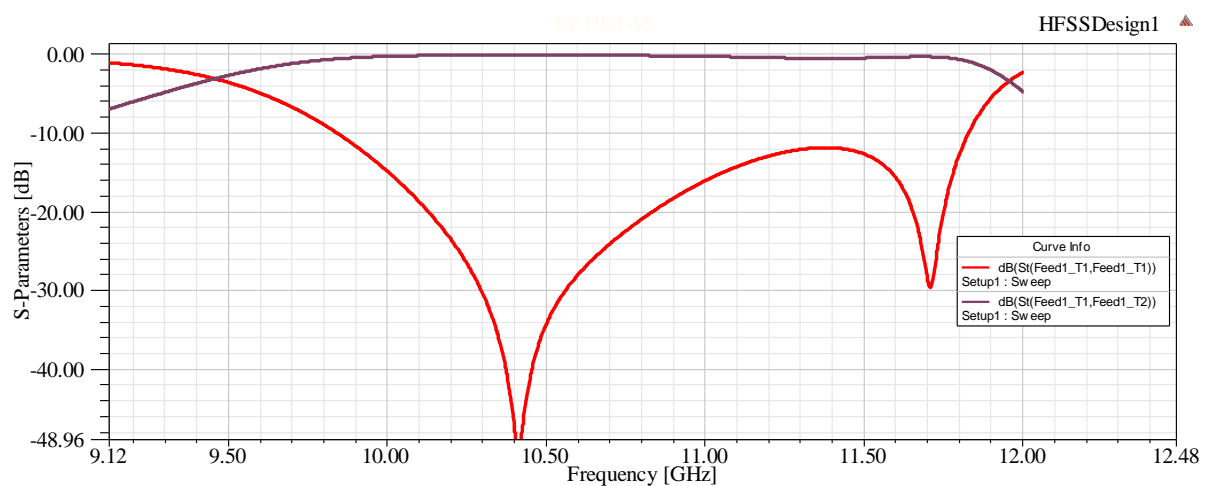


Figure 2. HFSS plot of the S-parameters versus frequency with frequency center 10.2 GHz

4. Conclusion

This work presents an innovative method used to design high return loss, wider bandwidth, and high performance miniaturized microwave filter. The filter has designed with short parallel couple line distance more than 1 mm. The microwave filter has been designed and simulated using the return loss method to find the physical dimensions of the circuit components. The microwave bandpass filter has operation frequency center at 10.5 GHz, broad bandwidth of 2.5 GHz, low return loss of -50 dB. The microwave bandpass filter is designed on the low RF losses and small area LaAlO₃ substrate. The simulation result of the designed filter has been investigated using HFSS and found it depends on the circuit physical dimensions such as, line width, line height, line coupling long, and the distance between the lines [19].

Acknowledgments

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5. References

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