DESIGN BROAD BANDWIDTH MICROWAVE BANDPASS FILTER OF 10 GHZ OPERATING FREQUENCY USING HFSS

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Abstract: Microwave bandpass filter is the essential part in microwave circuits and wireless communication systems. This paper presents a new designing and simulation of broad bandwidth, low losses microwave bandpass filter operating at 10 GHz frequency using return loss method. The designing and simulation of the circuit has been carried out using Computer Aid Design (CAD) Ansoft HFSS software purchase from Ansys. The microwave filter circuit has designed with a parallel coupled line having a small dimension (10 × 10 mm^2) of $LaAlO_3$ substrate. The microwave circuit showed a high return loss -20 dB, broad bandwidth of 1.5 GHz, and operating frequency at 10 GHz. The results indicate the filter design and simulation using HFSS is reliable and have the opportunity to transfer from lab potential experiments to industry.

Keywords: Broad bandwidth, HFSS, Microwave Filter, Parallel couple line.

I. INTRODUCTION

Compressive loads Microwave filter still occupies a lot of space through of a distribution of the entire circuits. The large dimension is required to distribute the filter circuit stems from the fact that it is commonly made of several resonators, which their dimensions are similar to the guided wavelength. Hence, numerous researcher made many efforts to develop the topology of miniaturized resonators [1]. Miniaturization of filter could realize through the change of filter geometry from the 3-dimensional structure waveguide filter to the 2-dimensional planar waveguide structure (i.e. microstrip line structure). Several microwave microstrip bandpass filters were designed with surface area greater than 2-centimetre square, which were designed with various microstrip lines for example parallel edge lines, strip line, pole, parallel edge, network, compact loops, linear phase etc.) [2]. One of most common design to realize the high performance and miniaturized microwave circuits such as bandpass filter of a broad bandwidth and lower losses is to use of the cascade design, which is named as parallel coupled strip lines.

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 [3-5]. A number of reported 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 [6, 7]. Bandpass filters with broad bandwidth, miniaturized size, low-power consumption, easy to fabricate and low cost are desired for microwave broadcast application [8]. The above requirements make a lumped element (strip lines) desirable for high-performance bandpass filters for high frequency applications.

However, broad bandwidth achieved through coupling two lumped elements to form coupled transmission line bandpass filters to have smaller Quality factors (Qf) in comparison with narrow bandpass filters [9]. Many bandpass filters are designed with several types of lumped elements, such as Four-pole cross-coupled [10], compact eight-pole [11] and parallel-connected network [12]. Microwave bandpass filters were designed and simulated with parallel coupled poles, coupled line edge, compact connected and not connected network. Most of the bandpass filters were designed onto MgO and LaAlO3 substrates. Chung, Dong-chul (2000) [13] have designed bandpass filter onto MgO substrate with dimension of 30 mm^2 and center of frequency is 16.6 GHz with narrow bandwidth of 1 GHz. However, all the broad bandpass filters were designed on $LaAlO_3$ substrate have been designed with large area between 225 to 5898 mm^2. Most of these filters have been designed and simulated with different software such as IE, EM and E6. The results of these bandpass filters showed that the bandwidth is in between 10 MHz and 3.6 GHz. Bandpass filters with small size (100 mm^2), broad bandwidth and low losses which designed and simulated using HFSS software have not investigated until now. This paper describes an efficient method used to design a microwave bandpass filter of broad bandwidth, high operation frequency using Computer Aid Design (CAD). The microwave bandpass filter is designed via high-frequency structural simulator (HFSS) Ansoft software. HFSS is an industrial standard software used widely for simulating three-dimension (3-D) microwave passive circuit developed by Ansys [14]. It is offering the art of an engineering task, which is used to create and simulate all the microwave circuits for the desired frequency. A cascade of parallel-coupled four lines have been adopted to realize the microwave planar filter. The microwave filter presents a broad bandwidth 1.5

GHz, center frequency at 10 GHz and low losses, detailed process has explained in this article.

II. FILTER DESIGN AND SIMULATION

Microwave bandpass filter was designed with a broad bandwidth to allow for the frequencies of high data rate to pass through the interval region of 1.5 GHz and stop the attenuated other frequencies outside of the central frequency 10 GHz. The filter is designed by 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 to design the coupled line filters 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 a wavelength. The coupled line of the filter has designed using four tapes parallel, which assigned as a perfect conductor. The microwave filter is designed on ($10×10×0.5$ mm^3) $LaAlO_3$ substrate, which assigned as a dielectric material with a high dielectric constant of 23.5 [4]. The microwave filter was designed with a symmetrical geometry using duplicate mode, it was created by Freehand drawing and it's followed by editing their characteristics from the command tab windows. The data on the specific dimensions such as width, high, and radius inside the command dialog window of the software were edited toward the optimization. However, the bandpass filter consists of dual number of the geometric components that can be duplicated to create a symmetric system successfully. Microwave bandpass filter is designed with an enclosed air body and other geometric elements as illustrated in Table 1.

NO.	The designed part	Assigned material
1	Air body	Vacuum
2	Feed1(Coax outer diameter)	Vacuum
3	Feedpin1 (Coax inner diameter)	Perfect conductor
4	Resonators (2in number)	Perfect conductor

Table1: The component of the designed microwave filter system

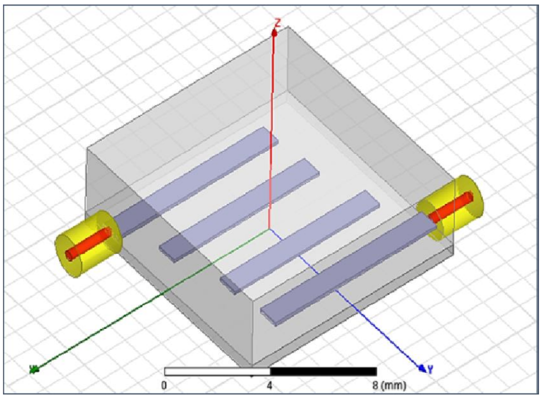

Fig.1. The image of microwave filter system from the HFSS Software

The first part (i.e. Air Body) is the enclosure body which contains the filter system while the rest parts, it will have the duplicate state as illustrated before. The center of x-y coordinates is assigned at the top center of the substrate as illustrated in Fig. 1.

The adaptive solutions in the HFSS software solution step are selected with the parameters as shown in Table 2.

Sweep type	Maximum number of passes	Maximum Delta
Fast	15	0.01

Table 2: Adaptive solution

The frequency setup was linear and the start and stop frequency is shown in Table 3. The designed part dimensions of the coupled lines and coax feed of the microwave filter are described in Table 4.

Start frequency	Stop frequency	Step Size
8.0 GHz	12.0 GHz	0.001

Table 3: Frequency details

Designed part	Dimension (mm)	Thickness (mm)
Feed1(Coax outer diameter)	0.8 (in radius)	2.0
Feedpin1 (Coax inner diameter)	0.2 (in radius)	2.0
L1 Resonator	8.0 × 0.9 (mm^2)	0.15
L2 Resonator	7.2 × 0.9 (mm^2)	0.15

Table4: Designed part dimensions of filter

III. RESULTS AND DISCUSSION

The performance of the designed filter can be summarized in terms of the broad bandwidth, high return and lower insertion losses for the selected frequency. To avoid any interference with the typical filter described by the high amount of return loss, lower insertion loss, broad bandwidth, good matching electrical connecting impedance and high selective frequency. Fig. 2, presents the results of the designed and simulated device using HFSS software. The simulation results display the response between the scattered S-parameters (S_{11} and S_{12}) and the frequency. Clearly, the filter operation frequency around 10 GHz achieves nearly 1.5 GHz bandwidth and it's applicable to pass the frequencies from 9.5 GHz to 10.9 GHz. Furthermore, the performance is well shown more than -20 dB return loss with approximately zero insertion losses. The bandpass filter was designed with broad bandwidth with the quality factor of 6.5, however, all the broadband filters having a lower quality factor, and the narrow band filters have a high-quality factor. All narrow bandpass filters having high quality-factor, in contrast, the broad bandpass filters having low quality-factor and more of data rates (wide band) the narrowband; increase data strength (low loss). It depends on the application, the narrowband filter is more secure since it only allows less frequency, but for the communication system, narrowband is preferred due to the data rate factor. 4G and LTE are using higher data rate for communication [15]. The term 4G mean the fourth generation, which related to the data technology of cellular phone networks. LTE abbreviated for Long Term Evolution, which means the modern technology can use the high-speed data by smartphones.

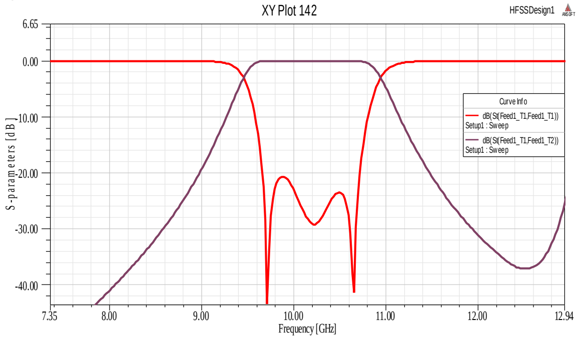

Fig.2. HFSS plot of the S-parameters versus frequency with frequency center 10.2 GHz.

On the other hand, microwave filter has been designed with 4-parallel coupled line pairs at the operating frequency 2.48 GHz, bandwidth 0.6 GHz, using FR4 substrate 4.2 dielectric constant and thickness of 1.58 mm. The filter has been simulated using HFSS software, the values of insertion Loss are less than 2.2 dB and the return loss -2.5 dB. It was found the increase in orders of the filters can improve the selectivity of frequency, while the dimensions, return loss and insertion loss so on increased [16, 17].

CONCLUSIONS

1. This work presents a modern design method results for high performance wider bandwidth, high return loss, the simulated filter results with a parallel couple line distance more than 1 mm. The microwave filter circuit has been designed and simulated and find the physical dimensions of the parallel couple lines using low return losses method. The designed microwave bandpass filter result with the operation center frequency at 10 GHz, broad bandwidth of 1.5 GHz, low return loss of -20 dB.
2. The microwave bandpass filter is designed on low losses, small area of $LaAlO_3$ (10 × 10 mm2) substrate. From the literature, the simulation results of any designed filter depend on several parameters related to the lines such as, line width, line height, line coupling long, and the distance between the lines [18]. In this paper, broad bandwidth microwave bandpass filter has been designed and simulated using Ansoft HFSS software. cases, the initial cracks were initiated at the edge/corner of the square specimens.

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REFERENCES

[1] J. S. Lee, "Microwave resonator filters for advanced wireless systems," University of Michigan, 2009.
[2] J. Marimuthu, "Design of Microwave Bandpass Filter with Novel Parallel Coupled Grooved Microstrip Structure," Master's Thesis, unpublished dissertation, Universiti Technologi Malaysia, 2004.
[3] M. Nisenoff, "Microwave superconductivity part 1: History, properties and early applications," in Microwave Symposium Digest (MTT), 2011 IEEE MTT-S International, 2011, pp. 1-4.
[4] R. R. Mansour, "Microwave superconductivity," Microwave Theory and Techniques, IEEE Transactions on, vol. 50, pp. 750-759, 2002.
[5] J. Ribadeneira-Ramírez, G. Martínez, D. Gomez-Barquero, and N. Cardona, "Interference analysis between digital terrestrial television (DTT) and 4G LTE mobile networks in the digital dividend bands," IEEE Transactions on Broadcasting, vol. 62, pp. 24-34, 2016.
[6] N. Newman and W. G. Lyons, "High-temperature superconducting microwave devices: fundamental issues in materials, physics, and engineering," Journal of Superconductivity, vol. 6, pp. 119-160, 1993.
[7] R. Weigel, A. Valenzuela, and P. Russer, "YBCO superconducting microwave components," Applied Superconductivity, vol. 1, pp. 1595-1604, 1993.
[8] A. Liu, A. Yu, and Q. Zhang, "Broad-band band-pass and band-stop filters with sharp cut-off frequencies based on series CPW stubs," in Microwave Symposium Digest, 2006. IEEE MTT-S International, 2006, pp. 353-356.
[9] J. Bonache, I. Gil, J. Garcıa-Garcıa, and F. Martın, "Compact microstrip band-pass filters based on semi-lumped resonators," IET Microwaves, Antennas & Propagation, vol. 1, pp. 932-936, 2007.
[10] L. Wang, C.-H. Hsieh, and C.-C. Chang, "Cross-coupled narrow-band filter for the frequency range of 2.1 GHz using YBCO resonators with artificial magnetic pinning lattices," IEEE transactions on applied superconductivity, vol. 15, pp. 1040-1043, 2005.
[11] D. Bai, J. Du, T. Zhang, and Y. He, "A compact high temperature superconducting bandpass filter for integration with a Josephson mixer," Journal of Applied Physics, vol. 114, p. 133906, 2013.
[12] T. Zhang, K. Yang, H. Zhu, L. Zhou, M. Jiang, W. Dang, et al., "Miniaturized HTS linear phase filter based on neighboring CQ units sharing resonators," Superconductor Science and Technology, vol. 28, p. 105012, 2015.
[13] D.-C. Chung, "HTS bandpass filters using parallel coupled microstrip-stepped impedance resonator," Physica C: Superconductivity, vol. 341, pp. 2659-2660, 2000.
[14] A. Toossi, H. Moghadas, M. Daneshmand, and D. Sameoto, "Bonding PMMA microfluidics using commercial microwave ovens," Journal of Micromechanics and Microengineering, vol. 25, p. 085008, 2015.
[15] A. Ghosh, T. A. Thomas, M. C. Cudak, R. Ratasuk, P. Moorut, F. W. Vook, et al., "Millimeter-wave enhanced local area systems: A high-data-rate approach for future wireless networks," IEEE Journal on Selected Areas in Communications, vol. 32, pp. 1152-1163, 2014.

[16] T. Zhang, J. Du, Y. J. Guo, and X. Sun, "A compact HTS bandpass microstrip filter with novel coupling structure for on-chip integration," Physica C: Superconductivity, vol. 495, pp. 69-73, 2013.
[17] L. SUN, "DUAL-MODE DUAL-BAND MICROSTRIP BANDPASS FILTER," 2011.
[18] M. Flanner, "Microwave Filter Design: Coupled Line Filter," 2011.

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