The characteristics of the band-pass filter from the various parameters of the substrate

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Abstract. In this work, the design of a band-pass filter implemented on L-resonators is investigated. On one side of the substrate there are transmission lines responsible for the input and output of the structure. On the second side of the substrate are the resonators themselves. Studies have shown that to obtain a higher frequency band, a substrate with a high dielectric constant value is required. The thickness of the substrate affects the size of the filters. This filter is technologically easy to implement using standard methods of manufacturing printed circuit boards.

1. Introduction

Devices that provide the selection of a useful signal, are an integral part of many radio devices. High-pass filters, Low-pass filters, filter filters and band-pass filters are some of the selective devices. In this paper, one of the possible designs of a band-pass filter will be investigated. Such a filter is used when it is necessary to skip a signal in a certain frequency band, and suppress the signal outside this band. Its main characteristics are as follows: the steepness of the slopes, the quality factor, the loss in the band, etc. The design of the filter will be investigated according to frequency characteristics depending on various parameters of the substrate. Due to the location of the supply lines on one side and the resonators on the other, it was possible to ensure good filter performance with compact dimensions. For some types of microwave devices, minimizing sizes meets certain difficulties. These include nodes based circuits with distributed constants. The dimensions of these devices are rigidly tied to the wavelength of the electromagnetic field propagating in the transmission line. In this connection, it is of great interest to create bandpass filters in micro-execution, as the most demanded and difficult to implement elements.

For example, in [1-2] a compact filter is implemented on quasi-capacitance and inductance. In [3], filter designs based on spiral resonators are described. In [4], the resonator is folded in the form of a “C” symbol, and in [5] a multilayer substrate with wideband resonators with split rings is used. Filters implemented on curved resonators are described in [6–8], filters with SRR are discussed in [9–11]. A band-pass filter implemented on two sides of the substrate [12]. In [13, 14], designs of resonators based on opposing structures are described, and in [15], the design of a low-pass filter is described. However, not all of the listed devices are distinguished by simple design technology, manufacturability, compact size and high-frequency selectivity. In this paper, we study the band-pass filter on various microwave substrates.

2. Design

The band pass filter can be implemented on various microstrip resonators. The filter on L-resonators is described in [16]. On one side of the substrate are two resonators, and on the second side, supply lines are located. The location of these lines is selected on the basis of obtaining the best filter characteristics. Power lines have a characteristic impedance of 50 ohms. It is important to understand how the parameters of the substrate affect the final characteristics of the device. The scheme of such a filter is shown in Fig.1.

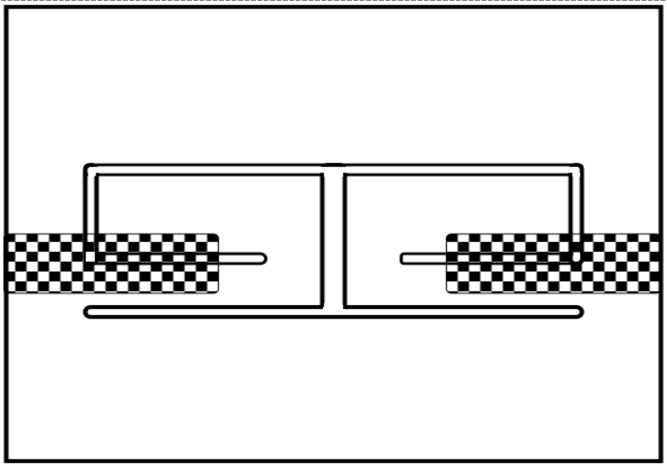

Figure 1. Topology directional coupler

3. Materials and methods

To understand the effect of dielectric constant on filter characteristics, such filters were synthesized with the same substrate parameters except dielectric constant:

– Rogers ε = 2.5;
– FR4 ε = 4.4;
– Rogers ε = 6.15.

The band of operating frequencies estimates for all structures by the same rules - 3 dB of the level of the minimum losses in the passband. Table 1 presents the characteristics of a band-pass filter with different dielectrics.

Table 1. Comparison of filters with different dielectric constant

Dielectric constant	Area, mm^2	Transmission coefficient dB	Bandwidth, MHz
2.5	2130	-2.5	85
4.4	1940	-3	84
6.15	1800	-2.2	85

Based on the data presented in Table 1, it can be seen that the dielectric constant affects the dimensions of the filter and its transmission coefficient. The next stage of the research is the analysis of the influence of the substrate thickness on the filter characteristics. So filters were synthesized for the substrate thickness of 1, 1.5 and 2 mm. The results obtained from the design of such filters are presented in Table 2.

Table 2. Comparison of filters with different dielectric constant

Dielectric constant	Area, mm^2	Transmission coefficient dB	Bandwidth, MHz
1	2130	-3	84
1,5	2190	-3.05	87
2	2230	-3.2	83

4. Results

Based on the data presented in Table 1, it can be seen that the thickness of the substrate affects the dimensions of the filter, its loss and bandwidth. The most effective combination of dielectric constant and substrate thickness is 1 mm and 6.15. The topology of the filter obtained in the Ansys HFSS program is shown in Figure 2,3. Due to the location of the supply lines on one side of the substrate, and micropolicy resonators on the other side - allows you to save filter area.

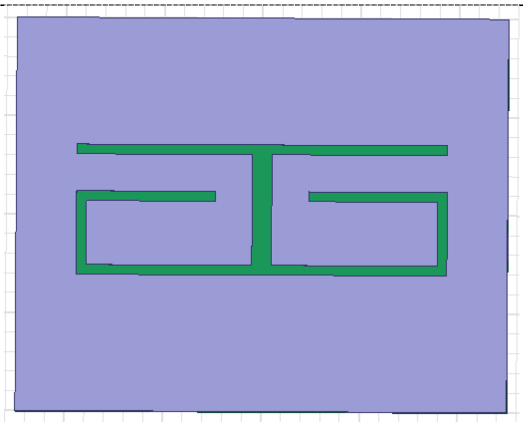

Figure 2. Configuration of resonator on the top side of substrate

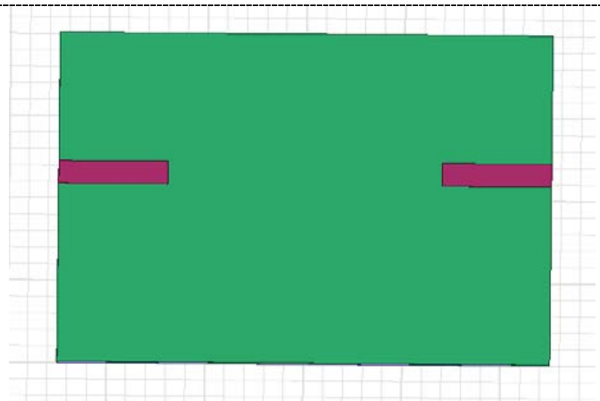

Figure 3. Configuration of microstrip lines on the bottom side of substrate

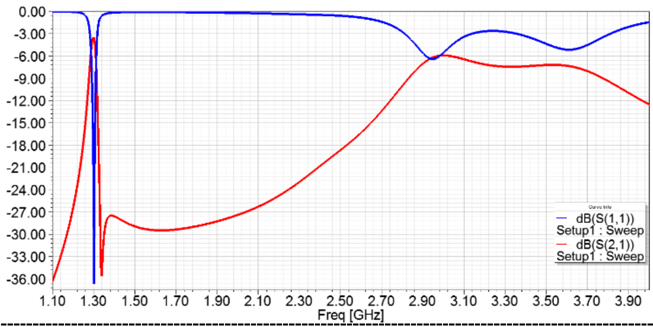

Figure 4. Amplitude-frequency response

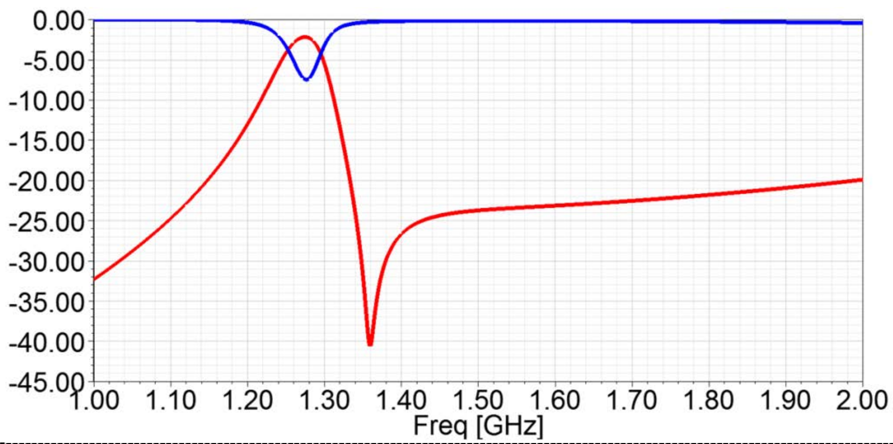

Figure 5. Amplitude-frequency response

From Figure 4 it can be seen that the center frequency of the filter is 1280 MHz, and the bandwidth, estimated at -3 dB of minimum loss, is 85 MHz. The minimum loss at the center frequency is -2.2 dB. Coordination parameter S11 has a value below -8 dB within the transmission band. The filter area is 1800 mm^2.

Analysis of the effect of the substrate parameters showed advantages and disadvantages depending on the selected material. This information may allow you to select the necessary material for your tasks.
Proposed filter has the following principle of operation - a signal arriving at one of the inputs begins to interact electromagnetically with resonators on the opposite side and is filtered by a frequency-selective structure. This structure consists of two identical resonators. Then the signal goes to the output of the filter.
Due to the increase in the amplitude of electromagnetic excitations in the microstrip resonator at the frequencies of coupled oscillations, the signal is transmitted with small losses in the passband, and then, through electromagnetic interaction, is transmitted to the second port. At other frequencies, the signal is strongly reflected from the input port.

5. Conclusion

In this paper, a compact directional coupler has been developed, the dimensions of which are reduced using compact structures. These structures have a smaller length, due to which the area of the structure has smaller dimensions. Due to the fact that the characteristics of structures and segments coincide at the center frequency, a workable structure is obtained. The area of such a coupler at the center frequency of 2000 MHz is 341 mm^2, which is 45.2% less than the area of the coupler on standard quarter-wave segments. Reducing the operating frequency band by only 4%. This approach can be used for other designs.

References

[1] Yang T, Tamura M and Itoh T 2010 *IEEE Trans. Microw. TheoryTech.* **58** 390-402
[2] Zhu J and Feng Z 2006 *IEEE Microw. Wireless Compon.Lett.* **16** 672-674
[3] Letavin D A 2018 *International Conference of Young Specialists on Micro/Nanotechnologies and Electron Devices* **EDM 2018** 199-202
[4] Hung C Y, Weng M H, Lan S W and Huang C Y 2012 *Electromagnetic Waves and Applications.* **26** 12-23
[5] Vegesna S and Saed M 2012 *IEEE Microw. Wireless Compon.Lett.* **37** 81-102
[6] Letavin D A 2018 *International Conference of Young Specialists on Micro/Nanotechnologies and Electron Devices* **EDM 2018** 189-191
[7] Letavin D A *2017 25th Telecommunications Forum.* **TELFOR 2017** 1-3
[8] Letavin D A *2017 International Conference on Industrial Engineering, Applications and Manufacturing.* **ICIEAM 2017** 199-201
[9] Jia Q L, Jun Y J and Li J L *2013 International Conference on Communications, Circuits and Systems.* **ICCCAS 2013** 425-427
[10] Rathore V, Awasthi S and Biswas A *2014 44th European Microwave Conference.* ***EUMC*** **2014** 949-952
[11] Panda A K, Sahu K S and Mishra R K 2012 5th International Conference on Computers and Devices for Communication. **CODEC 2012** 1-4
[12] Letavin D A *2017 International Conference of Young Specialists on Micro/Nanotechnologies and Electron Devices* **EDM 2017** 105-107
[13] Horestani A K, Duran-Sindreu M, Naqui J, Fumeaux C and Martin F *2014 IEEE Antennas and Wireless Propagation Letters.* **13** 1349-1352
[14] Belyaev B A, Serzhantov A M, Balva Y F, Leksikov A A and Galeev R G *2014 Pis'ma v Zhurnal Tekhnicheskoi Fiziki.* **41** 504-507
[15] Letavin D A *2018 International Conference of Young Specialists on Micro/Nanotechnologies and Electron Devices* **EDM 2017** 192-194
[16] Khiem N K, Nikolay S K, Vuong L Q and Hung L Q *2018 IEEE East-West Design & Test Symposium.* **EWDTS 2018** 508-511