Microstrip Rejecting Bandstop Filter

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***Abstract*—The paper is devoted to simulation, designing and fabrication of a microstrip 5-order bandstop rejecting filter. The bandstop filter uses classic schem, e.g. it consists of a microstrip through (common) line whose ends serve input and output ports. In the vicinity of the line a number of microstrip rejecting resonators locate, in our case five S-shaped resonators. They electromagnetically interact with the line, that forces signals, having frequenscies, bieng equal to the resonant ones, to reject (reflect) from a device. Dielectric substrate of the device has thickness 1.0 mm, and other sizes are 44.0×20.0 mm². The filter described in this work has shielding. In a band 1480 MHz …1499 MHz rejection exceeds 50 dB. Transmission bands at a level –2 dB are 0…1437 MHz and 1563 MHz…3000 MHz lower and upper correspondingly. Return loss in the passbands does not exceed –16 dB (VSWR≤1.4). Good agreement is observed between simulated and experimental data. Fabricated filter has small size.**

***Keywords*—microstrip, BSF, through line, resonator, rejection, stopband, substrate, shielding**

I. INTRODUCTION

Bandstop filters (BSF) are not widespread as compared, as bandpass (BPF), low pass (LPF), or high pass (HPF) filters. They mainly are needed when an interference should be suppressed with minimal distortion of spectral characteristic of a radiopath. Among the BSFs mostly used are ones of microstrip design and rejecting type. For the first time, concept of rejecting microstrip BSF was apparently formulated by H. C. Bell [1], and accordingly to the concept, a microstrip BSF structure consist of a microstrip line, whose both ends are input and output ports. This line is named through or common line. In the vicinity of the line microstrip resonators are placed, and due to an interaction between the resonators and the line signals having frequencies equal to the resonators' ones reject (reflect) from the line, and other ones go to the output port without significant attenuation. It should be noted, interaction between the line and resonators may be not only electromagnetic, but conductive too [2]. Most often L- resonators are used in rejecting type BSF [3, 4, 5].

Analyzing appropriate scientific literature, one can notice that authors pay insufficient attention to miniaturization and shielding BSFs. A number of papers suggest BSFs, where common line has inner stubs (spurs) [6,7]. They are really small sized, but work on higher frequencies and have poor performance. Refs [8,9] are examples of BSF miniaturization, which was obtained due to folding their common lines. In [10] the authors suggest to use as a BSF a 1D periodic electromagnetic bandgap structure (EBG), whose forbidden gap plays a role of BSF's stopband. Among rejecting BSFs described in a scientific literature mainly incompact and nonshielded devices are presented. Nowadays nobody needs such BSFs. In this paper we present results of simulating, designing, and fabricating a compact narrowband microstrip BSF of rejecting type.

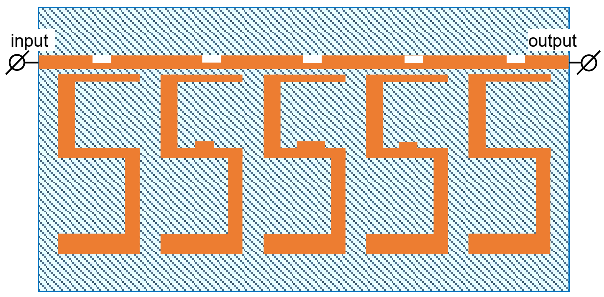

Fig. 1. Structure of a bandstop filter

II. SIMULATION AND BSF STRUCTURAL PARAMETERS

In Fig. 1 a structure of the BSF is shown. The device contains dielectric substrate, from material, having dielectric constant 10.6. Substrate thickness is 1.0 mm, and size 44×20 mm². Bottom surface of the substrate is fully metallized and serves a ground plane, on the upper surface a through line and five resonators are formed. As one can see, the resonators are S-shaped, therefore they occupy a lesser area on the substrate, as compared to L, Π, or regular resonator. Besides, such resonators weakly couple with each other, so in order to achieve narrow stopband one does not need to enlarge distance between the resonator.

Parameters of the topology were obtained as a result of an electromagnetic simulation, using a soft *CST Studio Suite*. Their values are presented below. A length of the through line obviously is equal to the total substrate length, i.e. 44 mm. Its width initially was 1.0 mm and characteristic impedance $Z = 50$ Ohm. After connecting the resonators, characteristic impedance decreased, and the line mismatched. In order to

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restore the impedance value, firstly, the through line width was decreased to 0.7 mm, and notches of 2.8 mm×0.2 mm size were made on its edge.

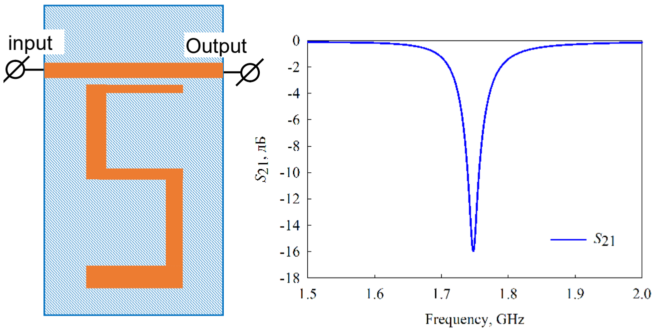

Fig. 2. Structure of one-order bandstop filter (left) and it's frequency response (right)

Each resonator has overall dimensions 8×16.7 mm^2, and is separated by 0.1 mm gap from the line. All strip conductors, forming the resonators, initially had widths 1.0 mm, which were changed during tuning. Now the widths of the horizontal conductors are 0.4 mm, 0.5 mm, and 1.2 mm. The top conductors are narrowed in order to strength couplings between the line and the resonators. But this has led to a rise in resonators' frequencies. In order to compensate this effect, the middle conductor of each resonator was narrowed, and the lower one, on the contrary, widen. Distances between the resonators are 0.5 mm. For accurate tuning of the stopband, frequencies of three middle resonators were raised using three patches, having sizes 1.8 mm×0.3 mm, 4.2 mm×0.3 mm, and 1.8 mm×0.3 mm. Distance between through line and substrate's edge is 1.4 mm. For shielding the substrate is placed into a conducting housing having inner sizes 44.0 mm×9.0 mm×7.0 mm. Thus a distance between substrate and shielding cover is 6.0 mm. It should be note, if a device is simulated without proper shielding, its frequency response can differ significantly from the required one after fabricating.

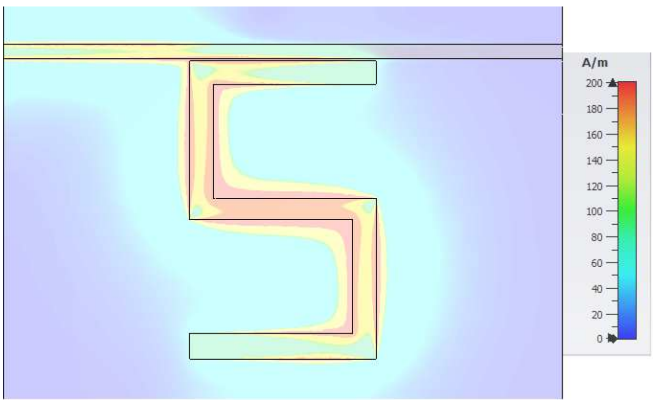

Fig. 3. Distribution of H-field in one-order bandstop filter at a resonant frequency of S-shaped resonator (1752 MHz)

Design of the BSF was carried out with a help of *CST Studio* project in the next manner. Firstly 50-Ohm line is formed. Then resonator of selected configuration, for example S-shaped, is placed in the vicinity of the line, and one can name it «first-order BSF» Fig. 2, left. A frequency response of the BSF has sharp notch (Fig. 2, right). Its position corresponds to the resonant frequency of the resonator, which is equal to 1752 MHz. In Fig. 3 a distribution of H-field in one-order band-stop filter at a resonant frequency of the resonator is shown. As we can see, antinode of microwave current is located in central part of resonator. Thus S-shaped resonator interacts with the through line using microwave electric filed.

Varying structural parameters of the resonator, we shift notch's and resonator's frequency to the given one. After that, we add one by one required number of the resonators in the structure, four in our case, and varying structural parameters try to achieve specified parameters of the response. Thus five-order BSF having center frequency of the stopband 1.5 GHz was designed.

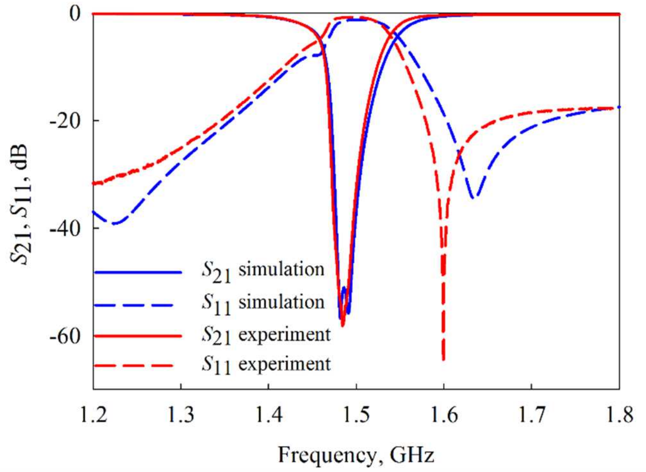

Fig. 4. Frequency response of the five-order bandstop filter

In Fig. 4 the BSF simulated frequency response is presented: insertion loss (S_{21}) is shown by solid blue line, return loss (S_{11}) is shown by dashed blue line. As one can see, rejection in a band 1480 MHz…1499 MHz exceeds 50 dB that corresponds to the best results published earlier. The stopband width is 21.5 MHz at a level –40 dB, or 1.44%, and 29 MHz at a level – 30 dB, or 1.94%. Transmission bands at a level –2 dB are 0…1437 MHz and 1563 MHz…3000 MHz in lower and upper band, correspondingly. Return loss does not exceed – 16 dB in these bands.

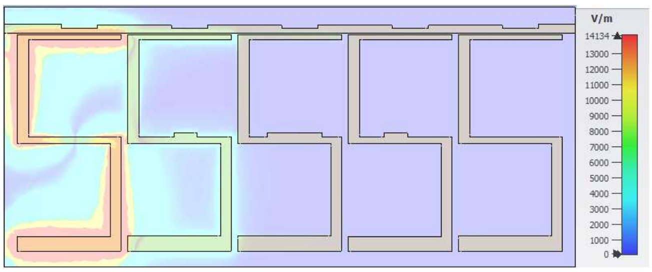

Fig. 5. Distribution of E-field in five-order bandstop filter at a central frequency of the stopband (1489 MHz)

In Fig. 5 distribution of E-field in five-order band-stop filter at a central frequency of a stop band is shown. As one can see, on output part of through line E-field is absent, that confirms a fact of rejecting a signal on this frequency.

III. Experiment

In order to verify simulated results, an experimental BSF was designed and fabricated. Its photograph is presented in Fig. 6. The substrate from polycor (polycrystalline corundum, ε=9.5…11.0), thickness 1.0 mm is mounted in a measuring housing from brass, whose inner sizes are 44 mm×20 mm×7 mm. The ports are connected with SMA type connectors.

The frequency response measurements were carried out with a help of Vector Network Analyzer ZVA50 (Rohde&Schwartz), and their results are presented in Fig. 4 by) red curves. Good agreement between simulated and measured data is seen, and this fact confirms an effectiveness of the method used in designing the BSF. In Fig.7 the BSF's frequency response in wide band is shown.

Fig. 6. Photograph of fabricated BSF

In designing a BSF, some circumstances should be taken into account. Rejection depth depends on a value of coupling between a through line and resonators: the more coupling, the more depth. Also the depth depends on a number of resonators: the more the number, the more the depth. If a coupling between resonators is not small, an ability appears to obtain more wide stopbands.

TABLE I. PERFORMANCE COMPARISON OF BANDSTOP FILTERS

Refs.	Operating frequency	Rejection band	Shielded device	Size ($\lambda_g\times\lambda_g$)
2	1.01 GHz	36% ($\|S_{21}\|$<20 dB)	not	0.42×0.31
3	2.00 GHz	10% ($\|S_{21}\|$<40 dB)	not	0.67×0.27
4	2.45 GHz	3.2% ($\|S_{21}\|$<38 dB)	not	1.73×0.68
5	2.57 GHz	13.6% ($\|S_{21}\|$<42 dB)	not	2.48×0.66
9	3.01 GHz	14.0% ($\|S_{21}\|$<50 dB)	not	0.54×0.42
This work	1.48 GHz	1.35% ($\|S_{21}\|$<50 dB)	yes	0.56×0.25

Concerning to comparison between our filter and ones described earlier, a correct comparison may be done only with BSF, described in [3]. This filter has the same scheme, practically the same center frequency of the stopband, the same order (5), the same substrate thickness and its dielectric constant. The difference is in rejecting resonators used: in [3] they are L-shaped. Besides, BSF from [3] is not shielded. Its substrate has area 1073 mm^2, whereas it is 880 mm^2 in our case, in spite of the fact, the resonators in our BSF are half-wavelength, whereas, in [3] they are quarter-wavelength. As a rule, at the rest equal conditions, developers prefer half-wavelength devices, because they are easier in fabrication and production.

In order to highlight advantages of the proposed filter, a performance comparison between it and other published ones is listed in Table I. As we can see, the filter considered in this work is one of the most compact and has shielding.

From the formal point of view, filters described in [8] and [9] are more compact in comparison with the one presented here, but they have center frequencies of stopbands 3.7 GHz and 3.6 GHz correspondingly, and were they designed for 1.5 GHz, their sizes will increase twice.

It should be noted, in structures having folded common line, it is very difficult to heighten a filter order.

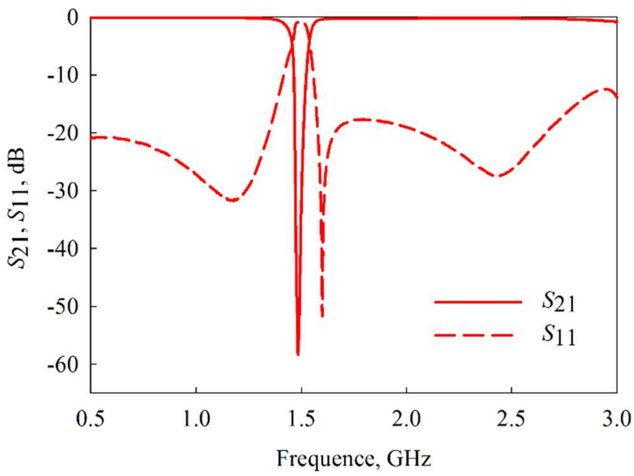

Fig.7 Measured frequency response of five-order bandstop filter in a wideband

Investigating S-resonator, we have established an interesting fact: an interaction between such resonators has anomalous behavior in varying a distance between them. In other words, when we are increasing the distance, for example, from 0.10 mm, the interaction begins drop, achieving a local minimum at the distance 0.55 mm. The further increasing leads to a smooth rising of the interaction, and when the distance becomes qual to about 3 mm, the interaction value achieves flat maximum. Then only decreasing of the value is observed.

Such an amusing behavior of interaction vs a distance between resonators is due to a competition between inductive and capacitive interactions between resonatos, which can be described with a help of frequency-dependent coupling coefficients. See, for example, [11,12].

CONCLUSION

A microstrip 5-order bandstop rejecting filter is simulated, designed and fabricated. The filter uses classic schem [3], e.g. it consists of a microstrip through (common) line whose ends serve input and output ports. In a vicinity of the line five S-shaped microstrip rejecting resonators are located. The resonators electromagnetically interact with the line. Dielectric substrate of the device has thickness 1.0 mm, and other sizes 44.0×20.0 mm^2. In a band 1480 MHz …1499 MHz rejection exceeds 50 dB Transmission bands at a level –2 dB are 0…1437 MHz and 1563 MHz…3000 MHz lower and upper correspondingly. Return loss in the passbands does not exceed –16 dB (VSWR≤1.4).

Nowadays Printed Circuits Board (PCB) technology intensively penetrates in an area of microstrip filters [13]. This technology is very promising for application to BSF. That will allow more compact and cheap BSF, adopted to surface mount device technology, to replace BSFs on discrete surfaces.

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