The Investigation of Microstrip Filters with Wide Stopband

S A Khodenkov
Department of Physics
Reshetnev Siberian State Aerospace University
Krasnoyarsk, Russia
hsa-sibsau@mail.ru

V A Shokirov
Laboratory of electrodynamics and microwave electronics
Kirensky Institute of Physics
Krasnoyarsk, Russia
wl-shok@mail.ru

***Abstract*—The constructions of bandpass filters with irregular quarter-wave resonators are suggested. Due to the high jump of the wave resistance in line segments the microstrip structures have extended high-frequency stopbands. Different alternatives for the location of resonators with a conductor in the form of meander on dielectric substrate were studied. In this regard the use of codirectional resonators helps to improve frequency-selective properties of microwave filters.**

***Index Terms*—Bandpass filter, meander, stopband.**

I. Introduction

While developing new frequency-selective devices of microwave range [1], the researchers traditionally try to improve the selective properties of the last ones. So, currently, the works devoted to microstrip bandpass filters are aimed at lowering the power loss in the passband with high steep slopes [2, 3] at simultaneous increase of power suppression at frequencies of stopbands [4], including extended high frequency [5]. At the same time developers also need to preserve or improve miniaturization and manufacturability of the products. All this ultimately determines the cost of microwave structures in mass production as well as their competitiveness.

At present there are several constructive approaches to a significant expansion of stopband in microstrip filters.

One of them [6] is the use in the microwave structures the irregular microstrip half-wavelength resonators grounded on the basis by segments of strip conductors (SC). But at the same time such structures are far from miniaturization.

Another constructive approach is the use of multi-conductive microstrip resonators in filters [7, 8]. The main disadvantage of such structures is high required resolution while manufacturing segments of strip conductors and clearance between them.

Therefore, in this paper we present the results of the analyses of microstrip bandpass filters on irregular quarter-wave resonators having extended high-frequency stopband.

II. Methods of Constructions' Characteristics Calculation

Amplitude-frequency characteristics (AFCs) of all above mentioned microstrip structures were calculated by means of electrodynamic numerical analysis of 3D models, which is in good agreement with the experiment, therefore theoretical study of such 2D structures can be considered reliable. Tuning the bandpass filters is done by "manual" parametric synthesis with fixed central frequency of bandwidth f_0 = 1GHz. For objective comparison of frequency-selective properties of the investigated filters the same substrate with dielectric constant $\varepsilon = 9.8$, h = 1 mm thick (material - polycor) was used in the calculations.

III. Investigation of Two-Element Filters

Topologies of strip conductors in proposed microstrip filters of the second order are shown in Fig. 1.

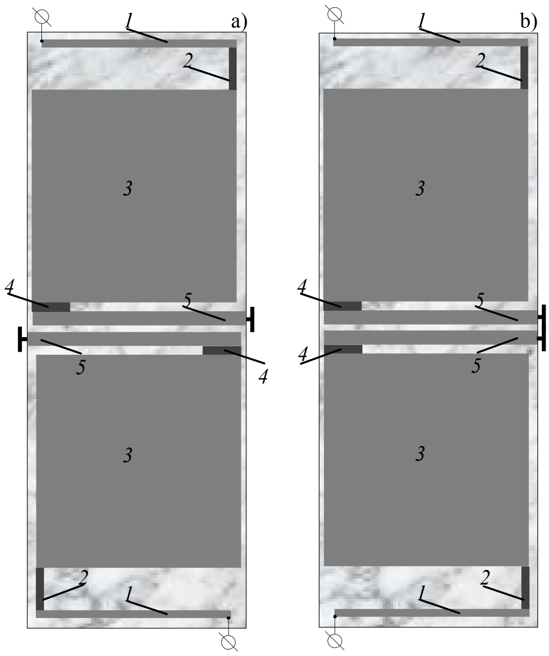

Fig. 1. Topologies of strip conductors of two-element constructions. a) – filter on the counter-directed resonators, b) – filter on codirected resonators.

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Meanwhile, strip conductors *1-5* of every single-mode resonator in both structures are in form of “irregular“ meander. In the first filter (Fig. 1a) counter-direction resonators are used, in the second (Fig 1b.) – codirectional.

From free ends of the meander (segment SC *1*) input and output ports of the filter 50 Ω are situated. On the opposite side of the meander the segment of strip conductor *5* is connected with the ground. Due to such grounding the resonators in the proposed bandpass filters are quarter-wave, and the studied constructions on their base are characterized by miniaturization.

It is obvious (Fig. 2), that bandpass filter with a relative bandwidth ~ 44% of each resonator is formed only by one lowest oscillation mode. The transition to multi-mode operation of every resonator increases construction miniaturization [3], but significantly reduces the length of high-frequency stopband realized by a large jump in wave resistance of line segments.

It is worth noting that the second filter realized on collinear resonators, differs from the first one, by higher frequency-selective properties, the extension of high-frequency stopband and more power suppression in its frequencies in particular.

Here are construction parameters for both investigated filters given in mm^2: *1* – 7.90×0.15, *2* – 1.80×0.20, *3* – 8.70×8.30, *4* – 1.50×0.30. The clearance between adjacent segments SC *5* and *5* - 0.10 mm. In filter on counter-directed resonators segment *5* – 8.6 × 0.55 mm^2, resonators’ conductors are horizontally apart from each other by 0.2 mm. In filter realized in codirected resonators, segment *5* – 8.60 × 0.65 mm^2.

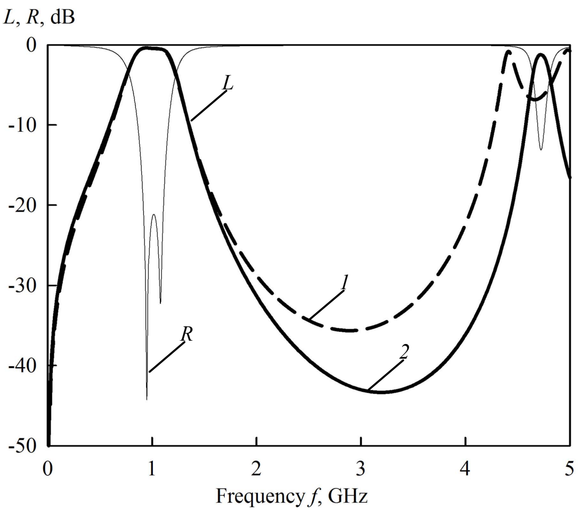

Fig. 2. Amplitude-frequency characteristics of two-element filters. *L* – direct losses for power passing, *R* – reverse loss of power return, *1* – filter on counter-directed resonators, 2 – filter on codirected resonators.

IV. Investigation of Four-Element Filters

Adding a pair of quarter-wave resonators to original two-element structures on counter-directed or codirected resonators is accompanied by an increase of filters order up to four. It is obvious that combining the arrangement of four resonators on the substrate makes it possible to realize larger number of filters that differ in frequency-selective properties. However, it is important to note that in this case, for electromagnetic quarter-wave resonators matching one with another and marginal ones also with 50 Ω microwave path it is necessary to “pull“ marginal and central segments of strip meander conductors for all four resonators along the *x*-axis.

There are four basic options for resonators location on the substrate, let us consider each of them in details.

In the first alternative, the bandpass filter is realized on counter-directed resonators (Fig. 3).

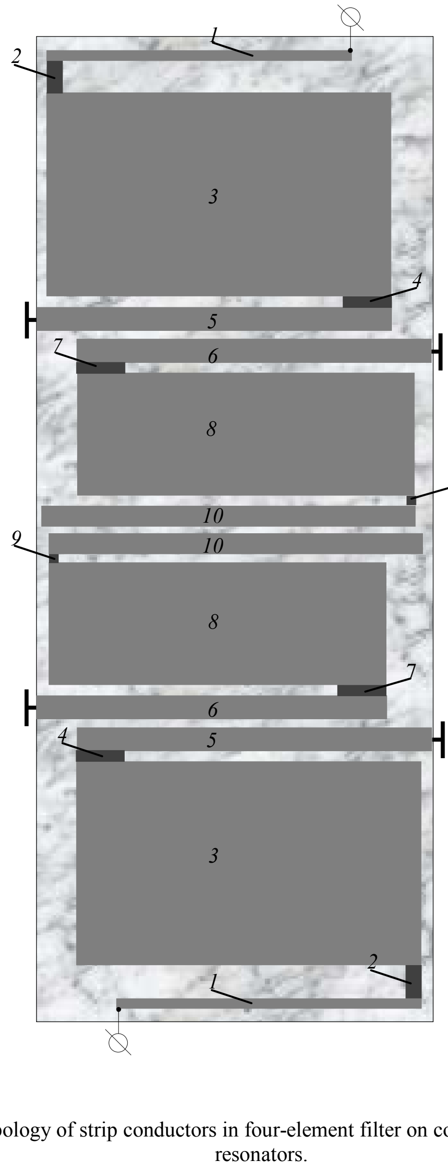

Fig. 3. Topology of strip conductors in four-element filter on counter-directed resonators.

The construction parameters of the filter are given in mm^2: *1* – 8.80×0.20, *2* – 1.05×0.40, *3* – 10.30×6.30, *4* – 1.40×0.30, *5* – 10.60×0.75, *6* – 10.40×0.75, *7*– 1.30×0.30, *8* – 10.10×3.85, *9*– 0.25×0.20, *10* – 11.20×0.55. The clearance between segments SC *5* and *6* – 0.10 mm, between *10* and *10* – 0.05 mm. Strip conductors segments *6*, *7* and *8* are 1.30 mm offset from the substrate marginal.

In the second alternative filter of the 4-th order internal resonators are also arranged opposite-directed and codirectionally one to another in reference to external resonators (Fig. 4).

Its construction parameters are given in mm^2: *1* – 8.80×0.20, *2* – 1.05×0.40, *3* – 10.30×6.30, *4* – 1.20×0.30, *5* – 10.60×0.75, *6* – 10.60×0.75, *7*– 1.40×0.30, *8* – 10.30×3.85, *9*– 0.25×0.20, *10* – 11.80×0.55.

The clearance between segments SC *5* and *6* – 0.10 mm, between *10* and *10* – 0.05 mm.Adjacent segments SC *10* are horizontally offset from each other by 0.10 mm.

In the third alternative of four-element filter realization, all resonators in it are codirectional (Fig. 5).

Here are the parameters of microwave construction in mm^2: *1* – 9.90×0.20, *2* – 1.10×0.50, *3* – 11.20×6.20, *4* – 1.40×0.30, *5* – 11.60×1.20, *6* – 11.60×1.15, *7*– 1.40×0.25, *8* – 11.00×3.85, *9*– 0.25×0.10, *10* – 12.20×0.55. The clearance between segments SC *5* and *6* – 0.10 mm, between *10* and *10* – 0.05 mm.

Finally, in the fourth alternative, in contrast to the previous third one, internal and external resonators are opposite-directed on construction substrate (Fig. 6).

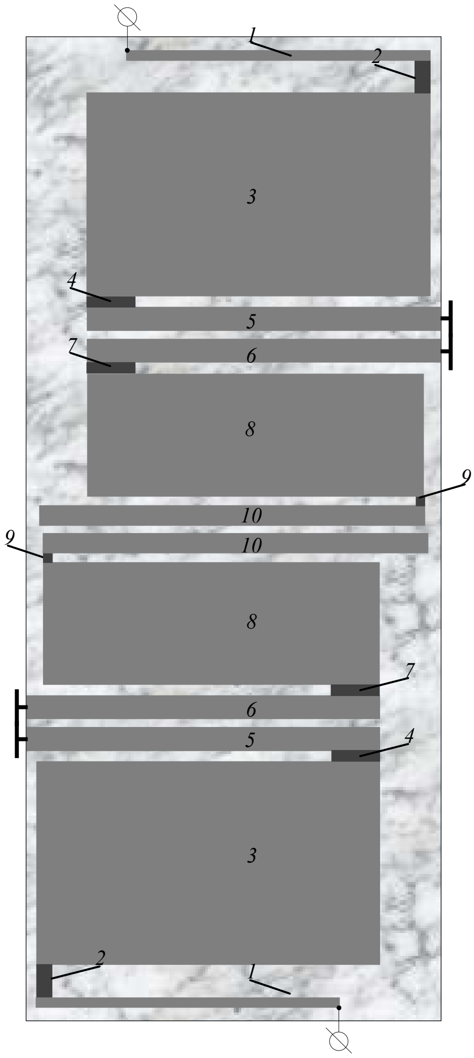

Fig. 4. Topology of strip conductors in four-element filter on internal counter-directed resonators.

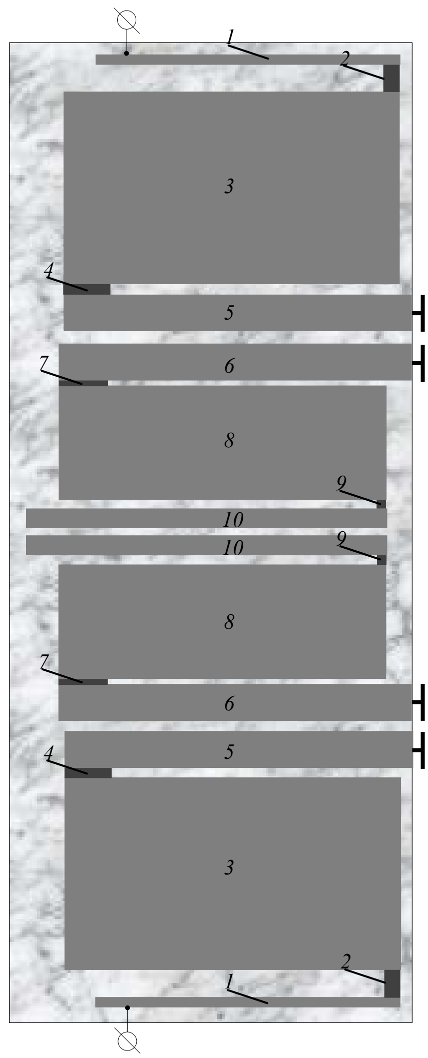

Fig. 5. Topology of strip conductors in four-element filter on codirected resonators.

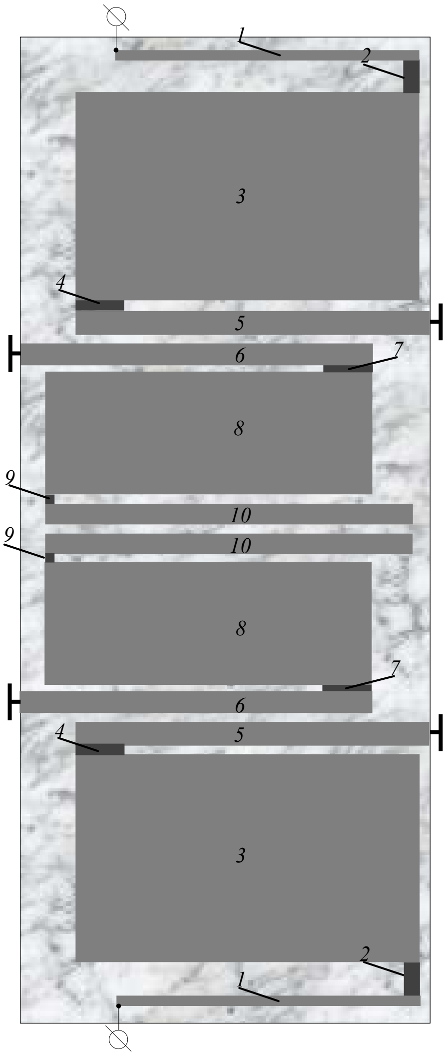

Fig. 6. Topology of strip conductors in four-element filter on internal codirected resonators.

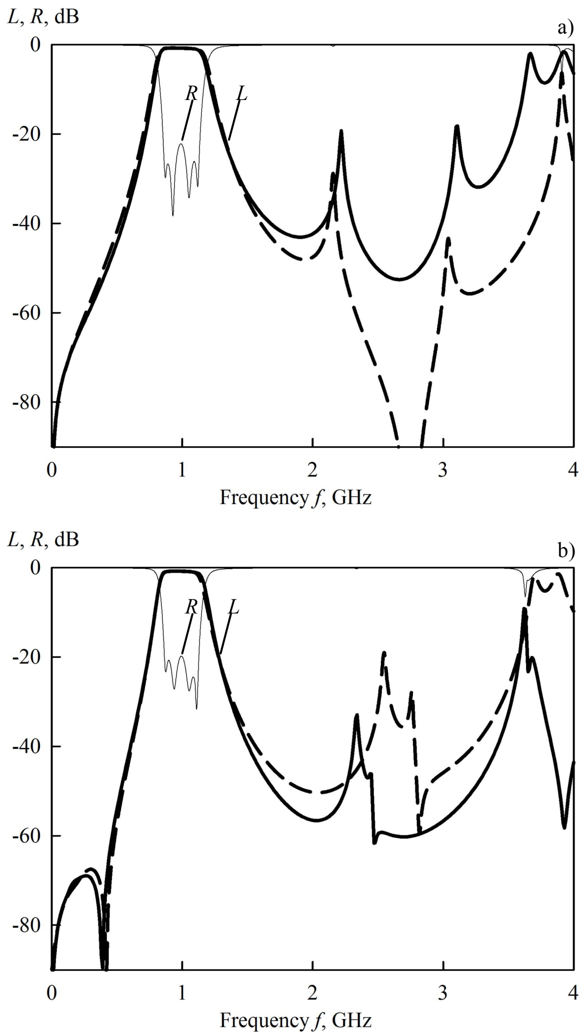

Fig. 7. AFCs of four-element filters realized in internal counter-directed (a) or codirected (b) resonators. a) solid lines – all resonators in the construction are counter-directed, dashed lines – external and internal resonators are coderectional. b) solid lines – all resonators in the construction are codirected, dashed lines – external and internal resonators are counter-derectional.

Construction parameters of this synthesized filter are given in mm^2: *1* – 9.00×0.20, *2* – 1.05×0.40, *3* – 10.40×6.30, *4* – 1.50×0.30, *5* – 10.70×0.75, *6* – 10.70×0.75, *7*– 1.40×0.30, *8* – 10.00×3.85, *9*– 0.25×0.20, *10* – 11.00×0.60. The clearance between segments SC *5* and *6* – 0.10 mm, between *10* and *10* – 0.05 mm. Adjacent segments of the conductors *5* and *6* are horizontally offset from each other by 1.70 mm.

Amplitude-frequency characteristics of all four constructions are shown in Fig. 7. While tuning the bandpass filters of the 4-th order electromagnetic connection between internal resonators is to be strong, and the clearance between the conductors of these resonators should be narrow. Taking into account the limited resolution of lacquer engraving ~ 0.05 mm, the minimum clearance between the conductors while modelling four constructions was equal to this value. Therefore, the bandwidth of the developed filters varies from 33% to 39%.

Minimum loss in bandpass of microwave filters does not exceed 0.8 dB.

It can be seen (Fig. 7a) that enlarged high-frequency stopbands are observed in the first two given filters of the 4-th order of AFCs. Moreover, in the second construction there is strong power suppression at high frequencies stopband with width ~ $2.4f_0$, measured at -30 dB.

As it is known from in Fig. 7b, in the third and fourth four-element filters at AFCs near the low frequency slope of passband there is attenuation pole that increases the steepness of passband slope significantly. Power suppression at frequencies of high-frequency stopband is stronger in the third construction.

Thus all of the presented bandpass filter constructions realized with the use of only codirected quarter-wave resonators with strip conductors in the form of “irregular“ meander have higher frequency selective properties.

V. Conclusions

Consequently, six microstrip bandpass filters of the 2-nd and the 4-th orders, realized on the basis of quarter-wave resonator with strip conductors in the form of “irregular“ meander were investigated. Codirectional and counter-directional resonators’ location on the substrate relative to each other was used. It was found out that filters of collinear resonators have higher frequency-selective properties.

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