Bandpass filter based on microplane resonators

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Abstract. A band-pass filter based on microstrip resonators is proposed and analyzed. The resonators and the filter itself are made on a Rogers 3003 substrate. The filter design itself consists of two resonators on one side of the substrate, and power lines located under the resonators on the opposite side of the substrate. The filter is planned to be manufactured using standard photolithography methods. To demonstrate the capabilities of the proposed design, the filter was designed and tested from the obtained frequency characteristics. So the filter operates at a center frequency of 1 GHz, its bandwidth is 168 MHz, and the gain is -3 dB. In this case, the area of the device is 250 mm².

1. Introduction
Telecommunication systems are actively developing, which has led to stricter requirements for electromagnetic environments - this is radio interference from operating systems with close operating frequencies. In order to reduce the influence of interference, it is necessary to use frequency filtering of this interference. Therefore, one of the important areas of microwave technology is the research, development and production of frequency-selective device modules. Frequency selective devices are an integral part of any communication system. At the same time, with the increasing complexity of communication systems, the requirements for the electrical and weight and size parameters of frequency selection devices are constantly becoming more stringent.

A bandpass (or simply - bandpass) filter can be made in the form of a series connection of two filters - low pass (LPF) and high pass (HPF), the characteristics of which are selected so that there is an overlapping section. The frequency band in which the signal passes from input to output without attenuation is called the passband, and the frequency band in which, on the contrary, the signal undergoes significant attenuation is called the stop band. Thus, the filter allows you to select only the required frequency range from the entire spectrum.

Today's filter designs are very diverse in terms of design. The filters use lumped elements from inductance and capacitance, distributed elements, resonators and more. It all depends on the task and the requirements for the filter. In this work, a band-pass filter based on microstrip resonators is designed and investigated. Such resonators are made on a dielectric substrate and make it possible to obtain small dimensions and cost of the filter. In addition, these filter topologies are simple in design, allowing standard PCB manufacturing methods to be used. A number of existing works related to microwave bandpass filters were considered. In [1], a band-pass filter with two operating frequencies and assembled on coupled transmission lines is proposed. The work [2] describes an original microstrip bandpass filter based on capacitively coupled resonators. In work [3, 4, 5] a filter based on LC resonators is assembled. In [6] filter design on the Substrate Integrated Waveguide (SIW). In work
using defected stepped impedance resonator (DSIR) and microstrip stepped impedance resonator (MSIR) to obtain a bandpass filter design [7]. The hairpin filter was investigated in [8, 9], and in [10] the filter was obtained on the basis of a ring resonator with interdigital structures. In [11], a bandpass filter was assembled using low and high pass filters. Filters on spiral resonators were proposed in [12, 13]. Using microstrip sections on one side and ring resonators in the screen, a filter was obtained in [14]. Filters on coupled lines and quarter-wave sections were investigated in [15, 16, 17, 18, 19, 20], in [21] a three-section resonator with a step change in the wave impedance of lines, a filter obtained on lines bent into a meander [22], in [23, 24, 25], reconfigurable bandpass filters are presented, in [26], in [27] using transformed radial stubs (TRS), in [28, 29, 30], open ring resonators are used. In [31], the filter consists of a hexagonal ring with connected stubs, which made it possible to ensure the operation of the device at two frequencies. Work [32] is devoted to a band-pass filter based on parallel-coupled resonators; in [33], a patch filter is proposed. In our work, we investigated a band-pass filter based on microstrip resonators.

2. Design of a Band-pass filter

Today in the literature and textbooks you can find band-pass filters, whose designs are known to everyone - a filter on coupled lines, a hairpin filter, and others. Consider a couple of standard 1 GHz bandpass filter designs assembled on a Rogers substrate. In fig. 1 shows the topology of the BPF obtained on the coupled transmission lines. The filter characteristics are shown in Fig. 2.

![Figure 1. Design directional coupler](image)

![Figure 2. S-parameters from frequency](image)

The filter area is $235.4 \times 11.2 = 2336.5$ mm$^2$, the minimum bandwidth is -0.55 dB. The 3 dB bandwidth from the minimum value is 243 MHz. In fig. 3 shows the topology of a hairpin PPF. The filter characteristics are shown in Fig. 4.
The filter area is $45.3 \times 33.6 = 1522.1$ mm$^2$, the minimum bandwidth in the bandwidth is -0.55 dB. The 3 dB bandwidth from the minimum value is 140 MHz.

However, their designs at low frequencies can have an impressive area, which can adversely affect their use. Therefore, the work considered the design of a filter assembled on a Rogers substrate, consisting of microstrip resonators located on one side of the substrate and supply segments on the other side. The filter has a central operating bandwidth of 1 GHz. Figure 5 shows a variant of a microstrip resonator.
By installing two such resonators on one side of the substrate and adjusting the position of the supply segments and the dimensions of the resonators, it was possible to tune the filter to the desired center frequency. In fig. 6 shows the resulting filter based on the proposed resonators. The developed design has small dimensions and demonstrates good frequency-selective properties. The filter characteristics are shown in Fig. 7.

![Design filter](image1)

**Figure 6. Design filter**

![S-parameters from frequency](image2)

**Figure 7. S-parameters from frequency**

The filter area is 50 x 50 = 250 mm$^2$, the minimum bandwidth in the bandwidth is -0.65 dB. The 3 dB bandwidth from the minimum is 168 MHz. For comparison with typical designs, the data were summarized in Table 1. At a frequency of 2.276 GHz, the second resonance with a coefficient. Transmission 0.8 dB.

| Design        | Area, mm$^2$ | Center frequency, GHz | Bandwidth, MHz |
|---------------|--------------|-----------------------|----------------|
| Edge coupled  | 2336.5       | 1                     | 243            |
| Hairpin       | 1522.1       | 1                     | 140            |
| Proposed option | 250          | 1.05                  | 168            |

The results show that the proposed filter has a smaller area than the others, and it is also narrow-band. Consider a filter option with an additional resonator. In Fig. 8 shows the resulting filter, and Fig. 9 shows the filter characteristics.
The filter area is $50 \times 50 = 250\, \text{mm}^2$, the minimum bandwidth is -0.74 dB. The 3 dB bandwidth from the minimum value is 150 MHz.

### 3. Conclusion
In this work, the authors proposed a design of a bandpass filter based on microstrip resonators. The proposed filter operates at a center frequency of 1 GHz and has a relative bandwidth of 16.8%. The well-known Rogers material acts as a substrate. The filter area is 250 mm$^2$. Such a filter has a smaller size in comparison with the typical BPF options proposed in the textbooks.

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