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Annular shape interdigital filter with increased frequency selection design

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Abstract

The design of the interdigital bandpass filter of annular shape with increased frequency selectivity due to the convergence of the input and output lines and introduction of additional lines between them is suggested. This allows the amplitude-frequency characteristic of such a filter to be formed with attenuation poles on the edges of its bandpass, which significantly increases the steepness of its slopes. A model of such four-resonator interdigital filter is made and the results of its experimental investigations are given. They showed that the developed filter can be successfully used in measuring channels to determine the frequency of signals in modern microwave equipment for communication, radar and telecommunications.

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1. Introduction

Radio-electronic systems and devices are widely used both in everyday life and in special-purpose equipment. Improving the operational characteristics of modern communication equipment, radar and telecommunications such as noise immunity, range and accuracy, stability and reliability in operation largely depends on the parameters of the used microwave bandpass filters. Such filters should have high frequency selectivity, low insertion loss, and the ability to process signals with high input power [1, 2]. Interdigital bandpass filters which have a number of well-known advantages [3, 4] are widely used in measuring channels for determining the frequency of signals in microwave equipment. Band-pass filters on counter rods, which have a number of known advantages [1, 2] are widely used in the microwave technique. Interdigital filters of typical design, having a rectangular cross-section and made on a symmetrical air-strip line with rectangular inner conductors are mainly used. Such filters have limited frequency selectivity. You can improve the frequency selectivity by increasing the number of resonators in the filters. However, firstly, this inevitably complicates the design of the filter and its settings, and secondly, the filter has finite values of the rectangularity factor, which depends on the number of resonators and the product of their own quality factor on the relative bandwidth of the filter. It is no longer possible to reduce these finite values of the rectangularity factor of the filter by increasing the number of resonators [5]. Therefore, filters of interest are those in which the increase in frequency selectivity is achieved not only by increasing the number of resonators, but also the introduction of additional reactive links: parallel between non-neighboring resonators [6, 7], directly between the input and output transmission lines [8, 9].

2. Actuality and purpose of the publication

The input-output lines are spaced a considerable distance, which increases with the number of resonators in typical designs of interdigital microwave filters. This does not significantly increase their frequency selectivity, because to organize additional reactive connections, and above all, between the input and output lines is not possible. This disadvantage is eliminated in the design of the interdigital bandpass filter of annular shape [10], which allows to increase the frequency selectivity by converging the input and output lines and the introduction of additional lines between them.

This paper presents the results of development in the S-band of the interdigital bandpass filter of annular shape with high frequency selectivity.

3. Main part

A simplified design of the developed four-resonator interdigital filter is shown in Fig. 1, and its schematic representation – in Fig. 2. The filter housing is made in the form of two similar annular gutters 1 with E-shaped cross section, which are connected butt at the edges opposite the bases of the gutters. In the middle of each gutter on the base in the same way there is a comb structure of strip resonators 2, input or output line 3, microwave connectors 5, adjusting screws 7 and fasteners, and in a small sector between the input and output line 3 and connectors 5 there

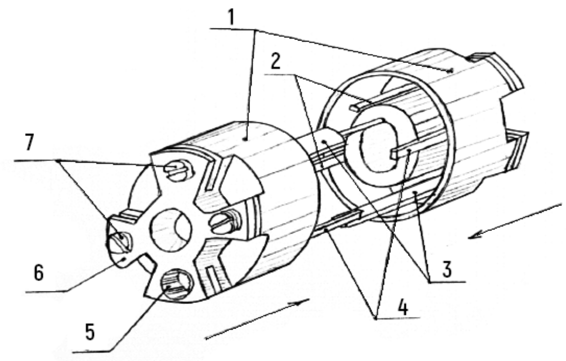

Fig. 1. *Microwave interdigital filter with high frequency selectivity.*
1 – annular gutters;
2 – strip resonators;
3 – input or output lines;
4 – additional stripe lines;
5 – microwave connectors;
6 – multi-petal inflows;
7 – adjusting screws

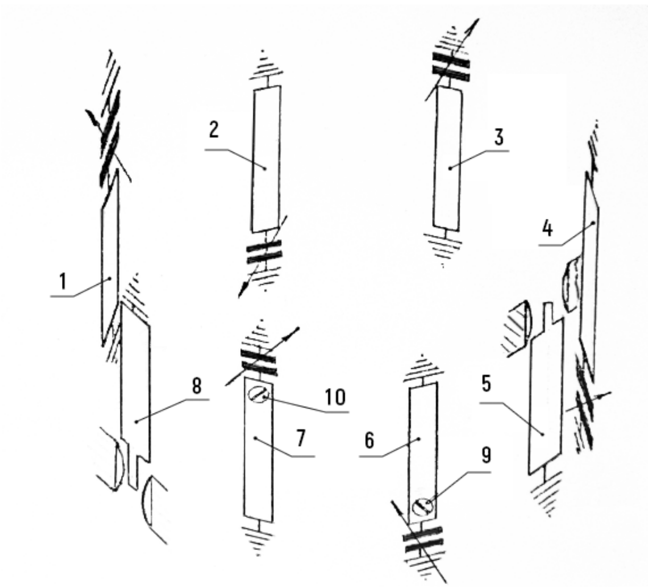

Fig. 2. *Schematic representation of a four-resonator interdigital annular shape filter.*
1-4 – strip resonators;
6, 7 – additional strip lines;
5, 8 – input or output lines;
9, 10 – adjusting screws

are additional strip lines 4, which are provided with adjusting screw 7. The annular chute end is provided with a multi-petal inflow 6 in the a Maltese cross form in the center of which is made a through hole. A threaded deformed hole in which the adjusting screw is resiliently mounted, is made in each petal in the middle of the chute, or a through cylindrical hole in which a spring clip is placed, covering the transverse groove of the contacts of the microwave connector 5.

The developed bandpass microwave filter refers to filters with direct connections and works as follows. The microwave signal is fed (removed) to the matching (non-resonant) rod at the input (output) of the filter. Strip quarter-wave resonators (rods), in which the planes of short circuit alternate, operate on TEM type waves. The main connection is made by means of edge fields between adjacent resonators (experience has shown that the assumption of complete absence of connection between non-adjacent resonators is quite acceptable for practical applications). Although the entry and exit lines are adjacent, in the absence of additional rods, the direct connection between the two matching rods according to [11] is excluded, because the minimum distance to which the latter are spaced is 2-3 times the distance between the gutter walls. In this case, the filter based on series-connected resonant structures (without additional rods) has amplitude-frequency characteristic with a monotonic change in attenuation (curve 1

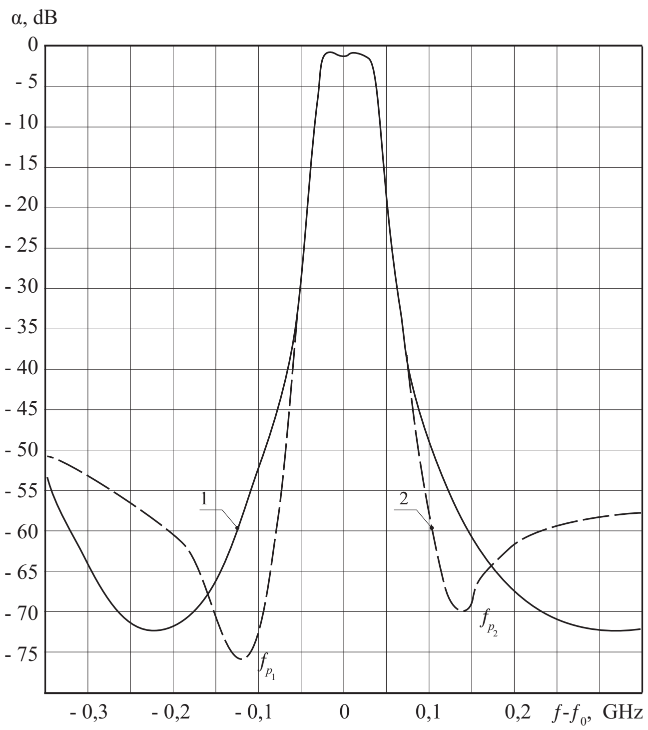

Fig. 3. *Amplitude-frequency characteristics of the filter:*
curve 1 – without additional rods;
curve 2 – with additional rods

in Fig. 3). The introduction of additional rods with adjusting screws allows to obtain an even weaker additional reactive connection between the matching rods. The signal at the output of the filter is already the sum of the signals transmitted by the main and additional connections in this case. The two attenuation poles obtained at some frequencies on either side of the filter bandpass are the result of the total output signal being close to zero at them (curve 2 in Fig. 3). The attenuation of the signal at the frequencies of the poles f_{p_1} and f_{p_2} depends on the magnitude of the additional connection, and the position of the poles also depends on the bandwidth of the filter. By changing the value of the additional connection with the adjusting screws, you can adjust the position of the poles relative to the center frequency of filter f_0.

4. Experimental results

The model of such four-resonator interdigital bandpas filter is made and was experimentally investigated. Hyperboloid connectors are installed in the filter [12]. The filter has the following characteristics: the bandpass at the level of 3 dB is equal to $\Delta f \approx 60$ MHz; insertion loss α_0, is not more than 1,5 dB; the range of operating frequencies in which it is possible to adjust the frequency response of filter is about 350 MHz; signal attenuation during detuning from the center frequency of filter f_0 by ± 60 MHz is 35 dB; the filter decoupling, which is determined by direct signal leakage through the coupling elements, is not less than 50 dB; VSWR $\leq 1,7$; volume $v \approx 34$ cm^3; weight $m \approx 170$ g.

It should be noted that the organization of additional reactive communication between the input-output lines, increasing the local selectivity, leads to a slight deterioration of the filter decoupling (see Fig. 3).

Let us determine the quality index (QI) of the developed filter using the well-known quality criterion for band-pass filters of any type, which is given in [13]. The expression for QI has the following form:

$$\mathrm{QI} = \frac{10}{\lambda}\left[\frac{\alpha_0(\Delta f / f_0)\upsilon}{(\alpha_r / 20)^2}(\log\frac{\Delta f_r}{\Delta f})^2\right], \quad (1)$$

Where,

α_0, dB – level of the minimum insertion loss in the bandpass;

Δf – bandwidth at the level 3 dB;

Δf_r – bandwidth at the level of rejection α_r;

$\Delta f / f_0$ – relative bandwidth, %;

$\Delta f_r / \Delta f$ – squareness factor (SF);

υ, cm³ – physical volume of the filter;

λ, cm – working wavelength.

Theoretical and experimental studies of many filters on sections of transmission lines of various types have shown that for canonical filters $\text{QI} = 3,0 - 3,5$ with high-quality manufacturing. A similar annular shape filter, without additional strip lines between the input and output, is established to have a quality index of 3,5 in [10]. For the developed filter, from expression (1) when substituting the above parameters, the following quality indexes were obtained: $\text{QI}_1 = 3,14$ for $\text{SF}_1 = 1,83$ at the level $\alpha_r = 30$ dB; $\text{QI}_2 = 2,88$ for $\text{SF}_2 = 2,17$ at the level $\alpha_r = 40$ dB; $\text{QI}_3 = 2,58$ for $\text{SF}_3 = 2,50$ at the level $\alpha_r = 50$ dB. The average quality index is $\text{QI} = 2,87$.

The filter was experimentally investigated by means of a complex transmission coefficient meter R4-38, which has improved measurement accuracy for devices of its group due to the use of microprocessor technology. This makes it possible to obtain acceptable uncertainties of filter attenuation measurement in the range of its transmission coefficient modulus measurement (0 ... – 80) dB. Thus, the standard uncertainty does not exceed ± 1.1 dB (taking into account that, as a rule, single measurements are made, the error limits of which are determined during verification or are specified in the metrological documentation for the device [14]). The expanded measurement uncertainty of the filter attenuation at a confidence level of 0,95 and coverage factor $k = 2$ (taking into account the assumption of the normal distribution law of the measurement result) does not exceed ± 2,2 dB.

5. Conclusions

1. The design of the interdigital bandpass filter of annular shape with increased frequency selectivity due to the convergence of the input and output lines and introduction of additional lines between them was developed.

2. The results of experimental investigations of the designed filter are presented, which have established the presence of two attenuation poles on its amplitude-frequency characteristic allows significantly increase the steepness of its slopes.

3. It was determined that the introduction of additional strip lines between the input and output of an interdigital bandpass annular shape filter improved its quality index from 3,5 to 2,87.

4. The developed filter can be used in measuring channels for determining the frequency in modern microwave equipment for communication, radar and telecommunications, as it surpasses the known types of interdigital bandpass filters in terms of its electrical and design-technological indices.

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