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Waveguide triple-mode resonator

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This work examines a triple-mode waveguide resonator operating on the TM_{110} and TE_{10} modes. It is shown that this resonator has a pseudo-elliptical amplitude-frequency response (AFC). A method is described to reduce the bandwidth. The influence of the geometric dimensions of a waveguide triple-mode resonator on its frequency response has been studied.

Keywords: triple-mod resonator, attenuation pole, waveguide, iris.

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Various types of filters are used widely in modern communication systems. A unique position among them is held by waveguide filters, which are introduced into reception and transmission paths. Strict requirements are imposed in this case on passband losses, the amplitude-frequency characteristic (AFC) steepness, and weight and size parameters of waveguide filters. The use of double- and triple-mode resonators is one of the ways to fabricate more compact filters. Various dielectric inserts are often used in the design of triple-mode resonators (see, e.g., [1]). The AFC of the resonator from [1] had three attenuation poles: two located below the passband and one positioned above it. The authors of [2] have discussed a triple-mode resonator with two coupling elements; TE_{110}, TE_{101}, and TE_{011} operating modes; and coaxial ports. A triple-mode waveguide resonator with two coupling elements forming an attenuation pole above or below the passband and TE_{101}, TE_{011}, and TM_{110} operating modes was characterized in [3–5]. A triple-mode circular-waveguide resonator may have TM_{010} and two orthogonal TE_{111} operating modes [6]. This resonator forms either one or two attenuation poles above the passband. A triple-mode elliptical-waveguide resonator is also feasible [7]. It has even and odd TE_{11} and TM operating modes. Another example is a triple-mode resonator based on a circular waveguide with two longitudinal metallic conductors of a cylindrical shape that have a gap between them [8]. This resonator has even and odd TEM and TE_{11} operating modes. A triple-mode stubbed waveguide resonator with TE_{201}, TM_{110}, and TE_{011} operating modes was examined in [9]. Its AFC has one pole below the passband and one pole above it.

The longitudinal size of all the mentioned triple-mode waveguide resonators corresponds to half a wavelength. Their dimensions are reduced through the use of a dielectric in the resonator volume; naturally, this complicates the fabrication procedure. In the present study, the design of a triple-mode waveguide resonator with a considerable longitudinal size reduction is detailed.

It is known that the longitudinal size of resonators with TM operating modes with a zero third index may be reduced significantly, but their transverse size will be equal to half a wavelength. The examined triple-mode waveguide resonator is an air cavity with two transverse splits that support additional modes. Figure 1 shows a triple-mode waveguide resonator with length L, a non-split part with height B, and a split part with heights $H1$ and $H2$. The length of all three split parts is denoted as T, and the thickness of two transverse partitions is 1 mm. Leading waveguides are coupled to the triple-mode resonator by irises.

Let us examine the principle of operation of this resonator. Figure 2, a presents the electrodynamic model in the form of air cavities of a waveguide bandpass filter based on a triple-mode resonator with leading waveguides. The principal mode is TE_{10} that couples the resonator input and its output. This mode resonates in the passband; another

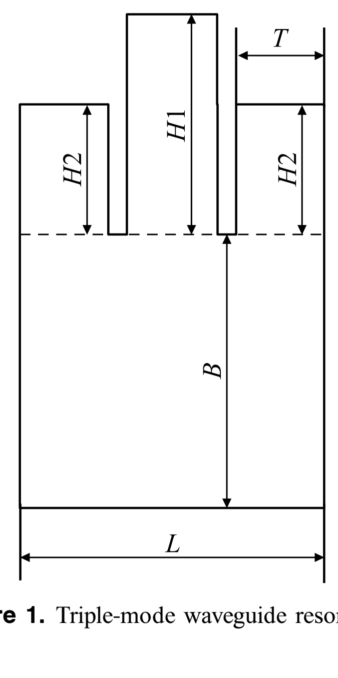

Figure 1. Triple-mode waveguide resonator.

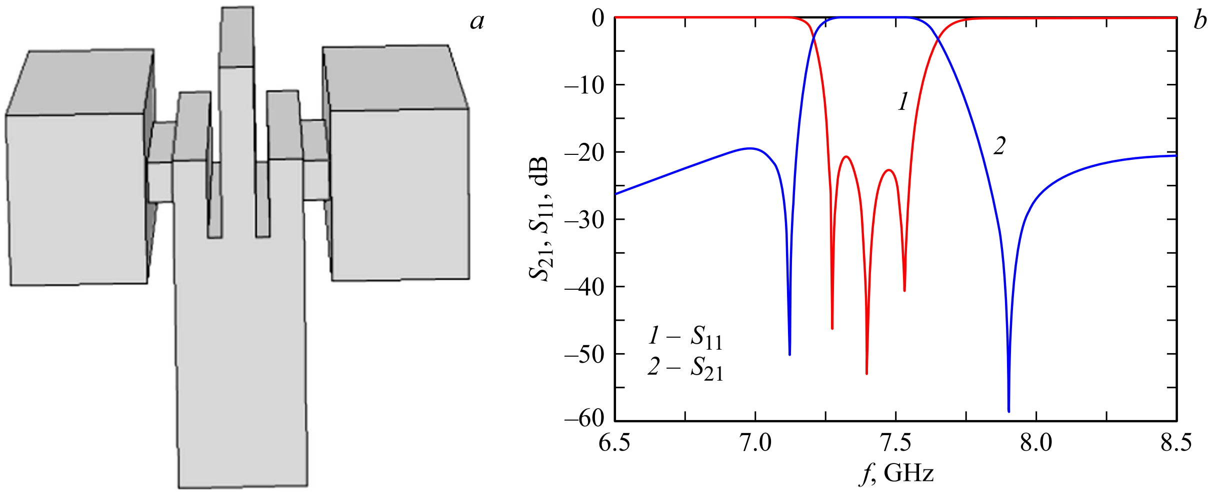

Figure 2. *a* — Electrodynamic model of a filter based on the triple-mode resonator; *b* — its frequency characteristics.

two resonances in the passband are provided by two TM_{110} modes. Figure 2, *b* shows the frequency characteristics of the filter that contain three resonances in the passband and two attenuation poles: one located below the passband and one positioned above it. As height B of the non-split resonator part increases, the lower attenuation pole shifts downward in frequency; when this height decreases, the pole moves in the opposite direction. Parameter $H1$ affects the first (lowest-frequency) resonance in the passband, and parameter $H2$ has an influence on the second and third resonances in the passband, since the resonator features longitudinal symmetry about its center. Increasing the width of the input (output) iris, one may increase the bandwidth (and vice versa).

The examined filter based on an aluminum triple-mode resonator has a passband of 7.28–7.55 GHz, passband losses of 0.18 dB, and $S_{11} < -20$ dB. The frequencies of attenuation poles are 7.116 and 7.898 GHz; i.e., the low-frequency AFC slope is steeper. The parasitic resonance above the passband is located at a frequency of 11.1 GHz. The resonator dimensions are as follows: the heights of split parts are $H1 = 12.55$ mm and $H2 = 5.8$ mm, length $L = 9.5$ mm, the width is 28.5 mm, and the non-split part height is $B = 18.85$ mm. Thus, the overall resonator height is 31.4 mm. The dimensions of input irises are as follows: the iris thickness (length) is 2 mm, the window width is 16.5 mm, and the height is 3 mm. The intrinsic Q-factor of the resonator is 2200.

It should be noted that the range of bandwidth adjustment achieved by varying the window width of input irises is limited. Inductive irises in the form of air cavities, which weaken the coupling between TM modes, are introduced into the non-split resonator part (see Fig. 3, *a*) in order to narrow down the bandwidth significantly.

The frequency characteristics of the waveguide band-pass filter based on a triple-mode aluminum resonator with weaker coupling between neighboring TM modes are presented in Fig. 3, *b*. This filter has a pass-band of 7.28–7.4 GHz, passband losses of 0.45 dB, and $S_{11} < -19$ dB. The frequencies of attenuation poles are 7.052 and 7.57 GHz. The parasitic passband above the pass-band originates at a frequency of 11.2 GHz. The suppression level below the passband to a frequency of 7.11 GHz is at least 37 dB, and the suppression level above the passband is at least 30 dB within the 7.54–9.3 GHz frequency range. The resonator dimensions are as follows: the heights of split parts are $H1 = 15.4$ mm and $H2 = 10.5$ mm, length $L = 9.5$ mm, the width is 28.5 mm, and the non-split part height is $B = 16.35$ mm. Thus, the overall resonator height is 31.75 mm. The dimensions of input irises are as follows: the iris thickness (length) is 2 mm, the window width is 15.6 mm, and the height is 3 mm. The irises within the triple-mode resonator have the following dimensions: the iris thickness (length) is 1 mm, the window width is 14 mm, and the height is 16.35 mm. The intrinsic Q-factor of the resonator is 2000.

In order to suppress losses (i.e., raise the intrinsic Q-factor of the triple-mode waveguide resonator), one needs to increase dimension T. The height will decrease in the process, and an accompanying increase in resonator width will provide an additional enhancement of the intrinsic Q-factor.

Thus, the feasibility of a triple-mode waveguide resonator was demonstrated. The influence of various parameters of this resonator on its frequency characteristics was examined. A method for narrowing down the bandwidth of a filter by weakening the coupling between TM_{110} modes was demonstrated.

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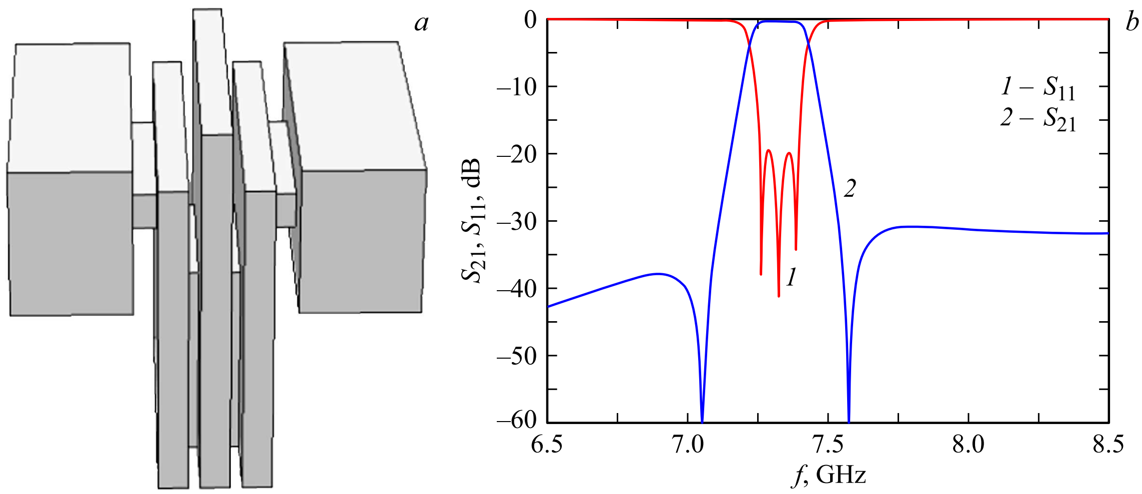

Figure 3. *a* — Electrodynamic model of a filter based on the triple-mode resonator with weaker coupling between TM_{110} modes; *b* — its frequency characteristics.

Conflict of interest

The author declares that he has no conflict of interest.

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