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METAMATERIAL PROPERTIES OF MICROSTRIP RECTANGULAR RESONATORS.

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МЕТАМАТЕРІАЛЬНІ ВЛАСТИВОСТІ ПРЯМОКУТНИХ МІКРОСТРІЧКОВИХ РЕЗОНАТОРІВ

У доповіді розглянуто метаматеріальні властивості мікросмужкових резонаторів прямокутної форми, зумовлені інтерференцією парних та непарних типів коливань і які проявляються у вигляді аномальних фазових та часових характеристик. Проведено дослідження таких резонаторів у режекторному фільтрі та дільнику потужності.

The report examines the metamaterial properties of rectangular strip resonators, which are caused by the interference of even and odd types of oscillations and manifest themselves in the form of anomalous phase and time characteristics. A study of such resonators in a bandstop filter and power divider was carried out.

In [1], microstrip rectangular resonators and their use for creating bandpass directional zone filters are considered. Previously, such resonators were widely used in the form of waveguide structures [2, 3]. When replacing waveguide resonator structures with microstrip ones, one should take into account the fact that in the region of microstrip lines there are even and odd mode with different wave parameters [4].

Let's consider the use of a rectangular microstrip resonator in the form of a notch filter (Fig. 1 a, b)). Depending on the aspect ratio of the resonator (length and width) with the same perimeter, the filter transmission coefficient can take the form of an anomalously steep resonant characteristic of the Fano resonance type (green curve in the lower graph of Fig. 1 c) [5], or in the form of a double-humped curve (blue curve in the bottom graph of Fig. 1 d). In the top graph of Fig. 1 a) shows the phase (dashed curves) and time (GD - solid curves) curves of the S21 transmission coefficients (green and blue curves) with a very slight change (0.01 mm) in the gap between the resonator and the line when “jumping” through the Fano resonance - transition from the region anomalous into the region of normal phase characteristics [6]. It can be seen that the phase characteristic of S21 near the Fano resonance can have both a normal and anomalous character, therefore its frequency derivative, GD, can have both positive and negative values in the resonance region.

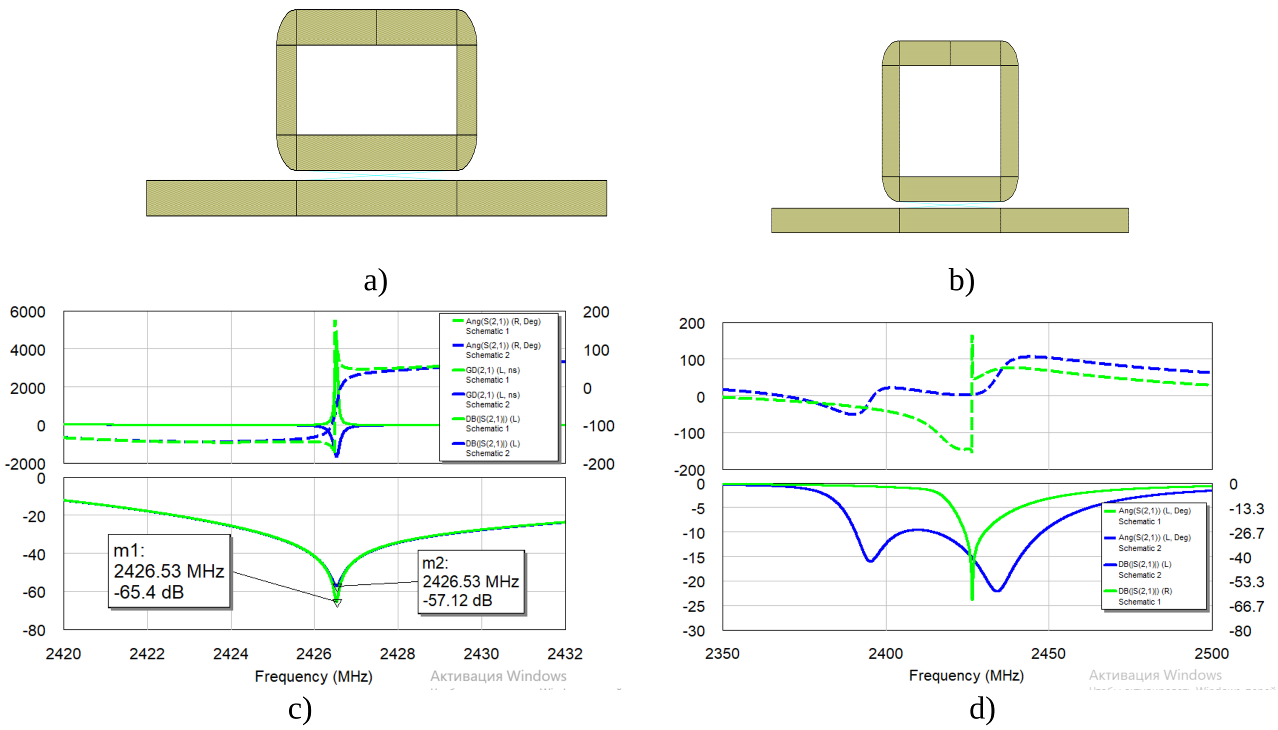
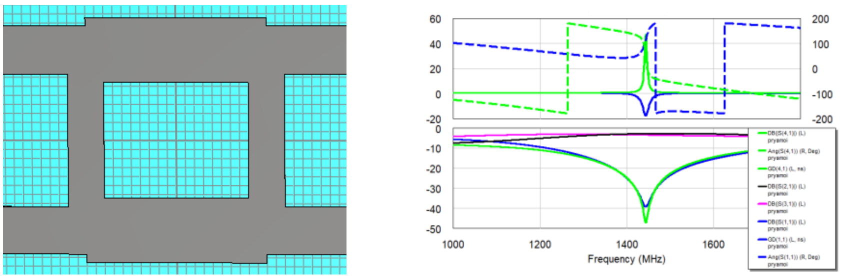


Fig. 1. a) and b) – rectangular resonators with the same perimeter and different ratios of length and width; c) – d) – amplitude (lower graphs), frequency and time (upper graphs) characteristics of resonators with different ratios of length and width.

In Fig. 1 d) shows the amplitude (lower graph) and frequency characteristics (upper graph) of the notch filter transmission coefficients for different ratios of the side lengths of the resonators (with the same perimeter). The characteristics presented in green correspond to a degenerate oscillation (Fano resonance, structure in Fig. 1 a), blue curves demonstrate the “removal of degeneracy” mode (structure in Fig. 1 b). As you can see, a notch filter based on a microstrip rectangular resonator can provide both very high attenuation in a narrow frequency range and slightly less attenuation in a relatively large frequency range, since its characteristic actually corresponds to the characteristic of a two-resonator filter (each type of oscillation corresponds to one “resonator”).

Microstrip rectangular structures are also widely used in the form of a quadrature hybrid coupler, for example, to form circular polarization in microwave antennas and rectennas [7]. In this embodiment, when the microstrip structure is directly connected to the transmission line, it can be considered as a “tightly coupled” resonator.

To ensure a phase shift of 90° between the second and third outputs (the condition for the formation of circular polarization), dividing the input power in half, the rectangle must have the shape of a square (Fig. 2 a). In Fig. 2 b) the amplitude (lower graph), phase (dashed curves) and time (solid curves) characteristics (upper graph) of the quadrature hybrid coupler are presented, which demonstrate its “metamaterial” properties.



a) b)

Fig. 2. a) microstrip quadrature hybrid coupler; b) amplitude (lower graph), time (solid curves) and frequency (dotted curves) on the upper graph, green curves - S41 characteristics, blue curves - S11.

The transmission coefficients S41 (green curve) and reflection coefficients S11 (blue curve) are resonant in nature (Fano resonance type interference). This is confirmed by their phase and time characteristics, and S41 is characterized by an anomalous phase characteristic and, as a consequence, a positive GD value.

Conclusion. The unique resonant characteristics of rectangular microstrip resonators, similar to the Fano resonance in metamaterial cells, are caused by interference phenomena in these structures and therefore, under certain parameters, can demonstrate characteristics inherent in metamaterial cells - anomalous dispersion and large positive GD values.

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