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BANDPASS MICROWAVE FILTERS ON THE BASIS OF MATERIAL CELLS

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ПОЛОСОВЫЕ МИКРОВОЛНОВЫЕ ФИЛЬТРЫ НА БАЗЕ ЯЧЕЕК МЕТАМАТЕРИАЛОВ

В докладе рассмотрены методики расчета полосовых фильтров на базе ячеек метаматериалов. Приведены рекомендации по выбору параметров фильтров для обеспечения их оптимальной избирательности за пределами полосы пропускания.

This article considers methods of calculation metamaterial cell based band-pass filters. The recommendations for the selection of filter parameters to ensure their optimal selectivity beyond the bandwidth.

The most common type of metamaterial cell used in microwave technology is the so-called Split Ring Resonator (SRR). The SRR associated with the microwave transmission line forms a band-stop filter, a embedded in the transmission line gap forms a band-pass filter [1]. Transmission and reflection coefficients of a band-pass filter based on a single SRR cell are given in [2]:

$$\mathbf{T} = \text{К}_1/(1 + \text{К}_1) - \text{К}_2/(1 + \text{К}_2)\,; \qquad (1)$$

Here К_1, К_2 – are the complex coupling coefficients of the resonators with the load, defined as:

$$\text{К}_1 = K1/[1 + j(\varepsilon + a)]\,,\quad \text{К}_2 = K2/[1 + j(\varepsilon - a)]; \qquad (2)$$

where К1, К2 - coupling coefficients of resonators with load, defined as the ratio of the eigen and loaded Q-factors of the first and second resonators, respectively [3]; ε is the generalized frequency deviation of each of the resonators with respect to the central frequency of the passband $fo = (f1 + f2) / 2$; a - a generalized detuning between the frequencies of individual resonators, defined as

$$a = 2*(f1-f2)*\sqrt{(Q1 * Q2)} / (f1 + f2) \qquad (3)$$

f1 and f2 are the resonant frequencies of the first and second resonators, Q1 and Q2 are their Q factors.

Since, generally, a metamaterial cell is located in a band-pass filter in a gap of a limited extent (for example, the filter in Fig. 1), we also take into account the final denouement between the input and output of the filter beyond the band-pass filter in the form:

$$\boldsymbol{T} = \mathbf{T} + jD \qquad (4)$$

Here, **T** is the transmission coefficient defined by formula (1), and D is the out-of-band decoupling, determined experimentally or calculated for each specific case, depending on the type of transmission line and magnitude of evanescent area.

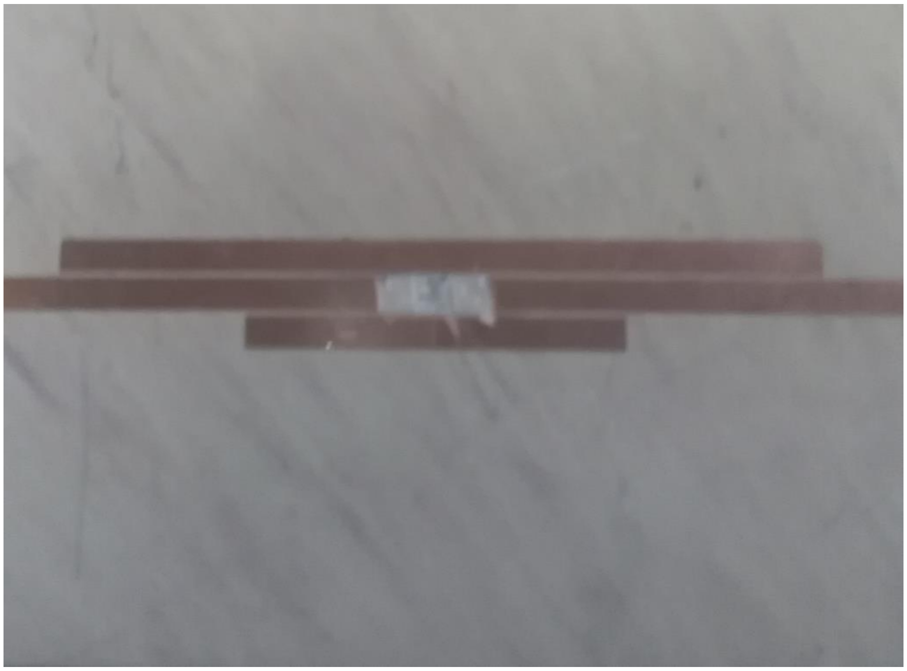
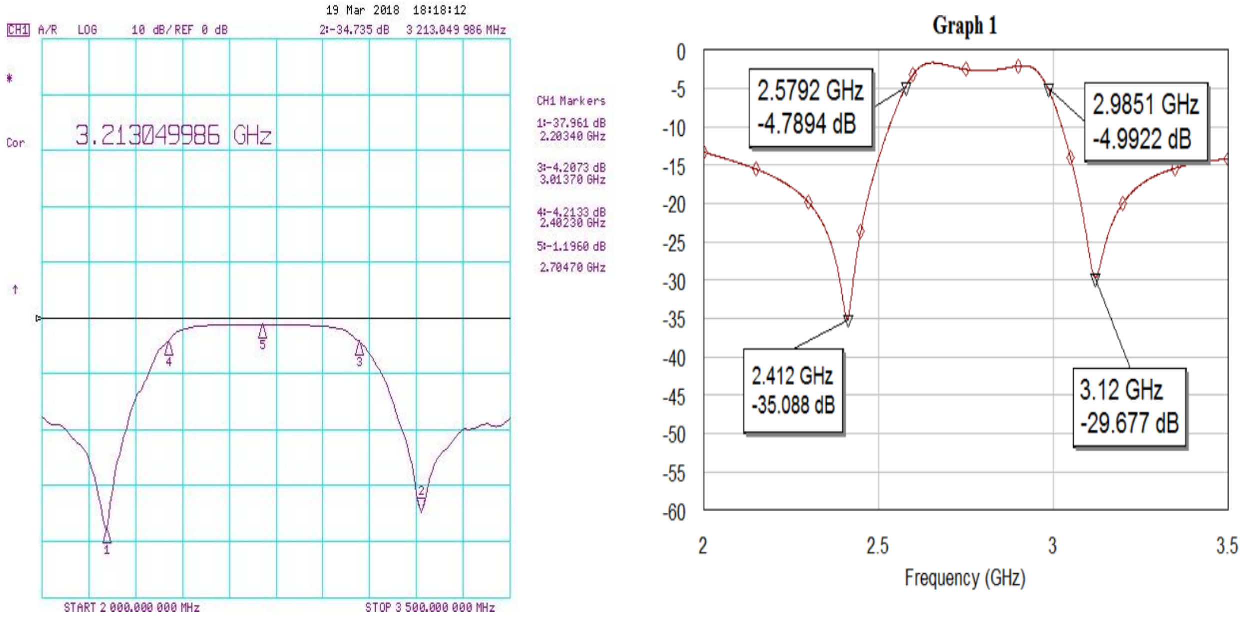


Fig. 1. Band-pass filter with "half-wave" and "wave" resonators connected in parallel

Note that by changing the resonant frequency of one of the resonators (which is equivalent to changing the generalized detuning "a" in formula 2), we are able to control the bandwidth of the filter.

The relations 1-4 given above can be used to construct the characteristics of a band-pass filter based on a metamaterial cell in an analytical form.

Simulation of the band-pass filter in Fig. 1 was made using the Microwave Office program. The simulation results are shown in Fig. 2



a) b)

Fig. 2 a) the experimental characteristic of the band-pass filter in Fig. 1;
b) the characteristic of the filter in Fig. 1, calculated using the Microwave Office program.

A good coincidence of the calculated and measured characteristics of the filter indicates the correctness of the chosen model.

References

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