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ATTENUATION POLES IN MICROWAVE THREE-RESONATOR BANDPASS FILTERS

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ПОЛЮСИ ЗАГАСАННЯ В МІКРОХВИЛЬОВИХ ТРИРЕЗОНАТОРНИХ СМУГОВИХ ФІЛЬТРАХ

У доповіді розглянуто трирезонаторні мікрохвильові фільтри з полюсами загасання. Досліджено різні механізми формування полюсів загасання, запропоновано моделі таких фільтрів на базі мостових чотириполюсників. Аналіз проведено з використанням універсальних фізичних понять – власних, навантажених та зовнішніх добротностей резонаторів та їх взаємних розлаштувань.

In the paper three-resonator microwave filters with attenuation poles are considered. Different mechanisms of formation of attenuation poles are investigated and models of such filters on the basis of bridge quadrupoles are proposed. The analysis is carried out with use of universal physical notions - natural, loaded and external quality factors of resonators and their mutual detuning.

The history of the appearance of works in which microwave filters with attenuation poles were studied is described in detail in [1]. The most common are filters with so-called elliptical characteristics, in which the attenuation poles are formed due to additional connections between cross-coupling resonators [2-4]. However, as shown in [5], this is not the only possible way to form attenuation poles. Another possible way is to use parallel communication channels with resonators of different quality factors. Previously, similar structures were used in 4-pole lattices with lumped-element resonators. Since, as is known [7], bridge filters are more versatile structures than ladder ones, they can be used for modeling an arbitrarily complex combination of resonators that form a particular filter.

In the general case, when using inductive or capacitive couplings between resonators, the number of poles of the n-resonator filter can be equal to n-1 [4]. To demonstrate what has been said, on Fig. 1. a) and b) the characteristics and on Fig. 1. c) and d) the topologies of the three-resonator filters considered in [8] are presented.

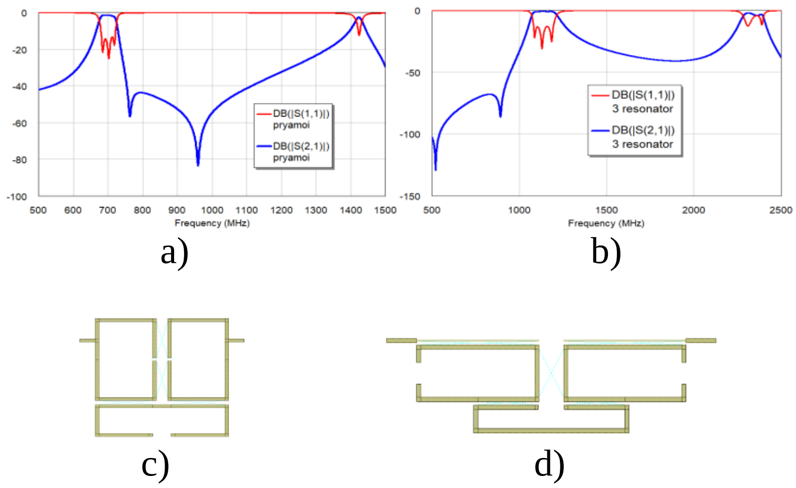


Fig. 1.
a), b) The characteristics of the three-resonator filters.
c), d) topologies of the three-resonator filters.

The attenuation poles in a the three-resonator filters can also be located on opposite sides of the passband.

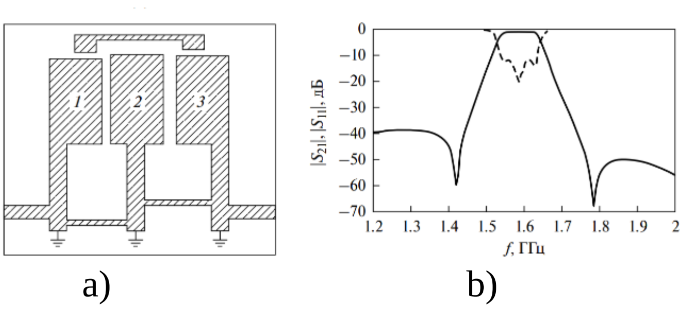


Fig. 2. a) Topology of a microstrip filter with additional coupling between the input and output resonators. Fig. 2 b) transmission coefficients S21 and reflection coefficients S11 of said filter [2].

As in [5] two-resonator filters and three-resonator filters can also be considered in terms of own and loaded Q-factors, coupling coefficients and mutual detunings, which for series and parallel resonators are defined as [9]:

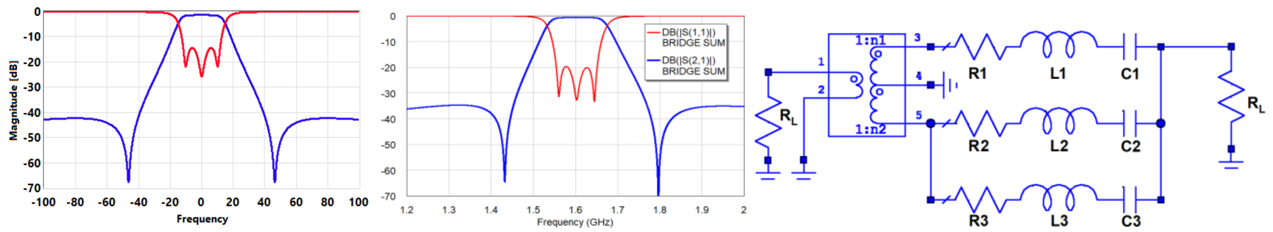
$$K_i = Q_{0i}/Q_{ei} \tag{1}$$

$$Q_{os} = \omega_0 \cdot L/R_s = 1/\omega_0 \cdot R_s \cdot C \tag{2}$$

$$Q_{op} = R_p/\omega_0 \cdot L = \omega_0 \cdot R_p \cdot C \tag{3}$$

Where Q_{0i} unloaded Q-factor of “i” resonators, Q_{ei} – external Q-factor of “i” resonators, R_p и R_s – the loss resistance of the parallel and series resonators.

Fig. 3 a) shows the characteristics of a three-resonator filter that modeling the filter of Fig. 2 a) in terms of coupling coefficients and generalized detuning. Next modeling parameters were used $K_1 = K_3 = 5, K_2 = 10, b_1 = b_3 = 1.1, a_1 = -a_3 = 14, a_2 = 0$, b_i corresponds to relative quality factor and a_i to detuning - see formulas from [5]. As can be seen, the characteristics of Fig. 2 b) and 3 a) are quite coincide.



a) b) c)

Fig. 3. a) The characteristics of a three-resonator filter,
b) characteristics lattice 4-pole, c) Schematic of a three-resonator filter.

Knowing the coupling coefficients, relative Q-factors and detuning's, it is easy to execute the transition to the bridge circuit of the three-resonator filter Fig. 3c, which has similar characteristics Fig. 3b. The modeling was carried out using the AWR software package. (academic licenses were acquired via Cadence Academic Network of university). R_L - external load resistor. At the same time, it was taken into account that during the transition from an unbalanced bridge circuit to a circuit with a transformer with a midpoint in Fig. 3 c) taking into account the transformation of the resistances of the arms [6], the following relations must be fulfilled:

$$K_s = 2 \cdot R_L / R_S \tag{4}$$

$$K_P = R_P / 2 \cdot R_L \tag{5}$$

Small discrepancies in the characteristics of the filters in Fig. 2 and 3 are caused only by the fact that the authors did not set themselves the problem of exact approximation, but only wanted to demonstrate the possibilities of designing microwave filters with attenuation poles using a 4-pole lattice.

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