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APPLICATION OF SIGNAL HOUND SCALAR NETWORK ANALYZER FOR MEASUREMENT OF FILTER PARAMETERS BASED ON METAMATERIAL CELLS

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ВИКОРИСТАННЯ СКАЛЯРНОГО АНАЛІЗАТОРА КІЛ SIGNAL HOUND ДЛЯ ВИМІРЮВАННЯ ПАРАМЕТРІВ ФІЛЬТРУ НА БАЗІ КОМІРКИ МЕТАМАТЕРІАЛУ

У доповіді досліджені характеристики мікрохвильового режекторного фільтра на базі комірки метаматеріалу. Вимірювання коефіцієнта передачі фільтра з різними резонансними частотами одного з резонаторів проведені за допомогою скалярного аналізатора мереж на базі керованого генератора та аналізатора спектра компанії SIGNAL HOUND. За результатами вимірювань побудовані апроксимуючі характеристики коефіцієнта передачі фільтра та визначені відповідні їм коефіцієнти відображення, фазові характеристики та характеристики групового часу затримки. Викладена методика досліджень мікрохвильових фільтрів може бути використана як у навчальному процесі, так і в наукових цілях.

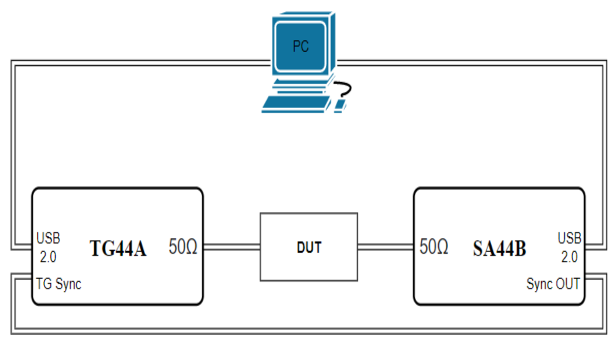
The report explores the characteristics of a microwave bandstop filter based on a metamaterial cell. Measurements of the filter transmission coefficient at various resonant frequencies of one of the resonators were carried out using a scalar network analyzer based on a controlled oscillator and a spectrum analyzer of the SIGNAL HOUND company [2,3]. Based on the measurement results, approximating characteristics of the filter transmission coefficient are constructed and the corresponding reflection coefficients, phase characteristics, and group delay characteristics are determined. The described technique for studying microwave filters can be used both in the educational process and for scientific purposes.

In the report, a microstrip bandstop filter based on a metamaterial cell (Fig.1, a) a photo of filter in the measurement process) previously proposed in [1] was experimentally studied. The filter is made on a FLAN-10 material substrate (dielectric constant ε=9.8, substrate thickness – 1 mm). For measurements of the amplitude characteristic of the filter gain $|S_{21}|$ the Signal Hound USB-SA44B spectrum analyzer [2] and the Signal Hound USB-TG44A tracking generator [3] were used (the measurement scheme is shown in Fig.1,b)). Unlike professional vector network analyzers (see, for example, [4]), Signal Hound equipment in such a configuration does not allow measurements of the phase characteristics of the objects under study.

However, as shown in [5], for filters with several parallel transmission channels of energy, which include the sample under study (it has two transmission channels of energy, one through each resonator), there is an unambiguous relationship between the transmission and reflection coefficients. Thus, if the coupling coefficients K_1 and K_2 of the first and second resonators with the transmission line are determined, it is possible, using well-known analytical expressions from [5, 6], to construct the frequency characteristics of both the reflection coefficient S_{11} and the phase characteristics of the transmission coefficient S_{21} and the corresponding group time characteristics delays (Group Delay - GD).

Figure 2 shows the measured characteristics (from 1st to 5th) of the bandstop filter gain obtained by changing the resonant frequency of the smaller resonator. Its resonant frequency is shifted “down” by pushing a thin dielectric plate onto the resonator, as described in [1].

a)



b)

Fig.1. Photo of the bandstop filter connected to the tracking generator
and spectrum analyzer (a). Measurement scheme of the bandstop filter (b).

Using the technique described in [6,7], to find the loaded Q factors of the resonators, we can approximate (the measured curves using the LabView-based program, selecting the parameters of the coupling coefficients of the resonators with the K_1 and K_2 lines, the ratio of their Q factors (parameter *b*) and the relative detuning (parameter *a*) between them (violet and blue curves in Fig.3,a and Fig.3,b), respectively, similar to curves 1 and 2 in Fig.2) and also obtain “simulated” characteristics of the reflection coefficients S_{11} (green curves in Fig.3,a and Fig.3,b), as well as phase characteristics and group delay (red and black curves in Fig. 3,a and Fig.3,b) corresponding to the gain S_{21}.

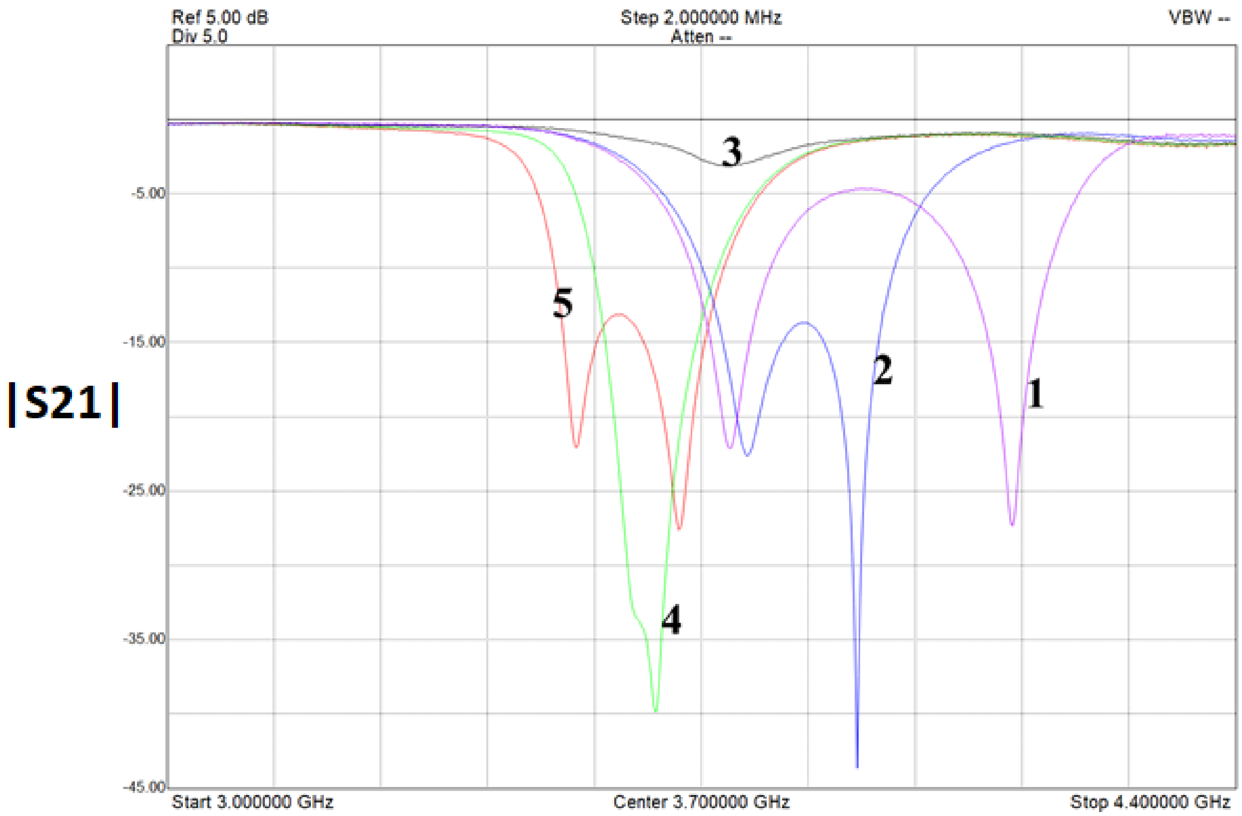
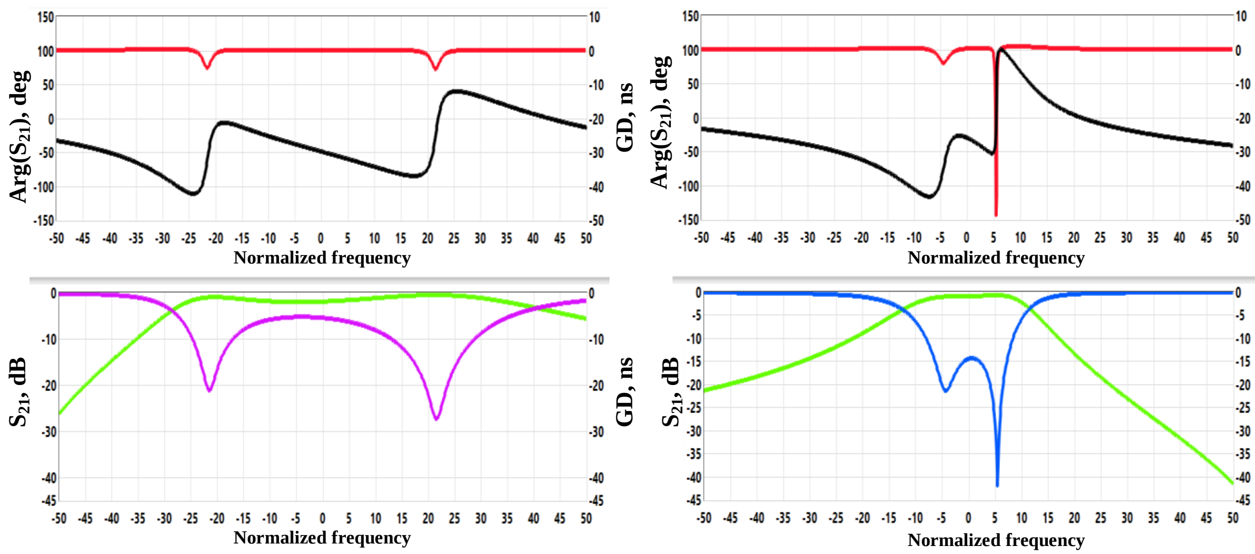


Fig. 2. Amplitude characteristic of the bandstop filter transmitter coefficient S_{21}: curve 1 is the original version, the resonators are initially detuned in frequency; curve 2 is the Fano resonance; curve 3 is the regime close to the “transparency window” (the oscillation frequencies of the resonators are the same), curve 4 is the regime close to the Fano resonance, but it is visible the beginning of the "removal of degeneracy"; curve 5 is the resonant frequency of the "short" resonator is lower than the resonant frequency of the "long" resonator.

Note that in the region of the Fano resonance (anomalously high attenuation and a narrow resonance characteristic around the frequency f = 3.9 GHz), as expected [6], the phase response of the filter has a very steep slope, which, in turn, leads to large values of GD. The dependency between a sharp change in phase and amplitude is known in the theory of circuits and is described in sufficient detail in [8] - “the change in attenuation caused by losses will be proportional to the “delay time”.

Conclusion. Thus, using the capabilities of a simple and relatively inexpensive measuring complex based on Signal Hound equipment, on the one hand, and the properties of filters based on metamaterial cells, on the other hand, it is possible to simulate the parameters of such structures that cannot be measured, that is, to obtain their phase characteristics and GD.



a) b)

Fig.3. Modeled curves under study: a) Transmission coefficient S_{21}, which corresponds to curve 1 in Fig.2, K_1=8, K_2=20, a=50, b=1; b) Transmission coefficient S_{21}, which corresponds to curve 2 in Fig.2, K_1=8, K_2=18, a=17, b=3

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