UDC 621.372.543

MICROWAVE FILTERS WITH VARIABLE PARAMETERS BASED ON CELLS OF METAMATERIALS

Zhivkov A., Akopian P., Galickiy I., Krylach O., Kopaniev M., Kamarali R.
National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute"
Institute of Telecommunication systems
E-mail: ilyagal26@ukr.net

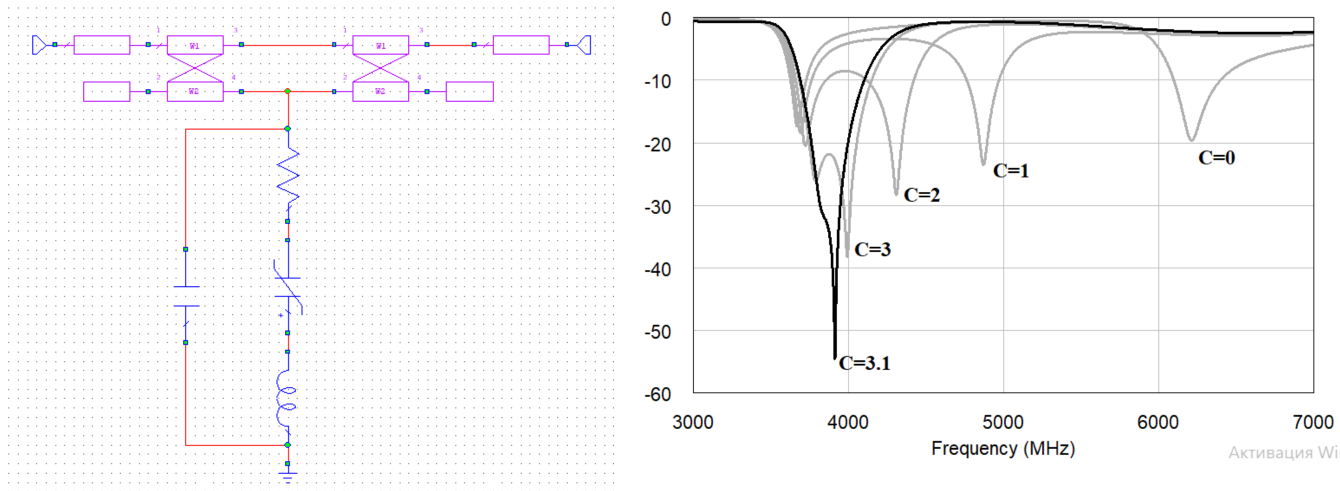
МІКРОХВИЛЬОВІ ФІЛЬТРИ ІЗ ЗМІННИМИ ПАРАМЕТРАМИ НА БАЗІ КОМІРОК МЕТАМАТЕРІАЛІВ

У доповіді розглянуті способи управління смугами пропускання і режекції мікрохвильових фільтрів на базі комірок метаматеріалів. Розглянуто особливості перебудови парних і непарних мод коливань в залежності від місця підключення варакторів. Моделювання проводилося за допомогою програмних продуктів Microwave Office.

The report considers ways to control the bandwidth and selectivity of microwave filters based on cells of metamaterials. Peculiarities of even and odd modes of oscillations depending on the place of connection of varactors are considered. The simulation was performed using Microwave Office software products.

Microwave filters with controlled characteristics are widely used in modern telecommunications technology, and numerous publications in modern literature are devoted to their study [1-7]. In [8], a design of a bandpass microstrip filter with a controllable passband was proposed, which, as it is now found out [9, 10], can be classified as "cells of a metamaterial with controllable characteristics" (control of odd mode parameters). Investigation of metamaterials with controllable characteristics and filters based on them are devoted to works [11-13].

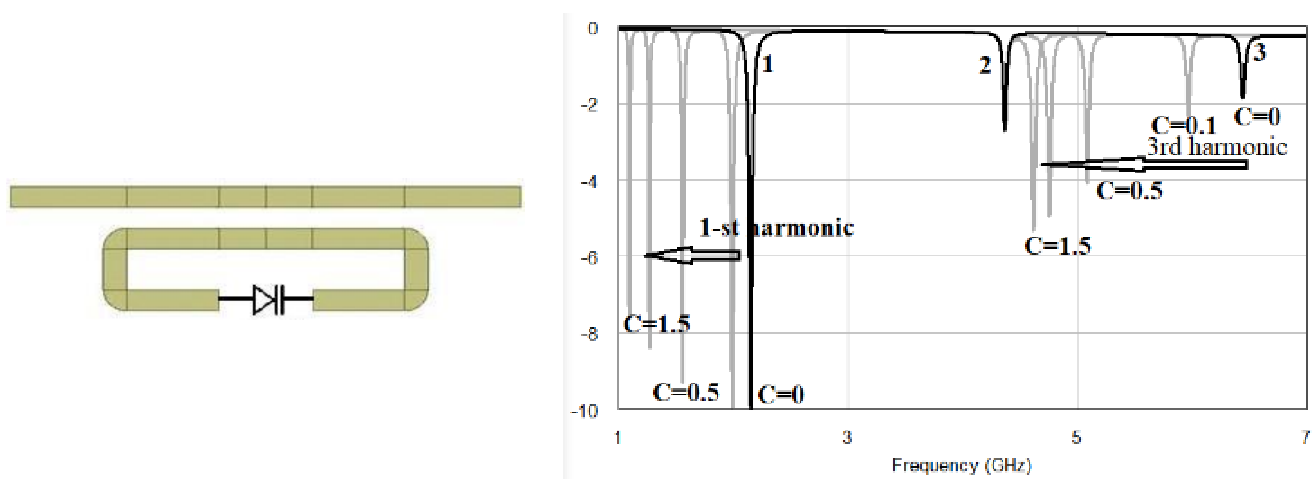
The purpose of our report is to select the optimal method for controlling the parameters of the cells of metamaterials both in band-stop and bandpass filters. Let us first of all consider the control of vibration modes of a metamaterial cell using varactors. In the microwave range, take into account that a varactor is not just a variable capacitance, but a 2-pole with its own "useful" and "parasitic" parameters [14]. In fig. 1 a) shows a model of a notch filter (AWR software environment) with a varactor connected in the middle of the microstrip resonator, and fig. 1 b) parameter S_{21} of the filter at different values of the varactor capacitance (capacitance C is indicated in the figure in pF). The most important feature of this method of turning on the varactor is that one (first, which is also odd) harmonic "remains in place", while the second harmonic is rearranged significantly and at C = 3.1 pf it approaches the first harmonic so much that the Fano resonance mode is realized.



a) b)

Fig 1. Tuning of the "even" harmonic of the microstrip resonator.

To tune the odd harmonics (first and third), we include a varactor in the gap of the microstrip resonator in Fig. 2 a). In fig. 2 b) are presented filter characteristics at different values of the varactor capacitance (capacities are indicated in the figure in pF).

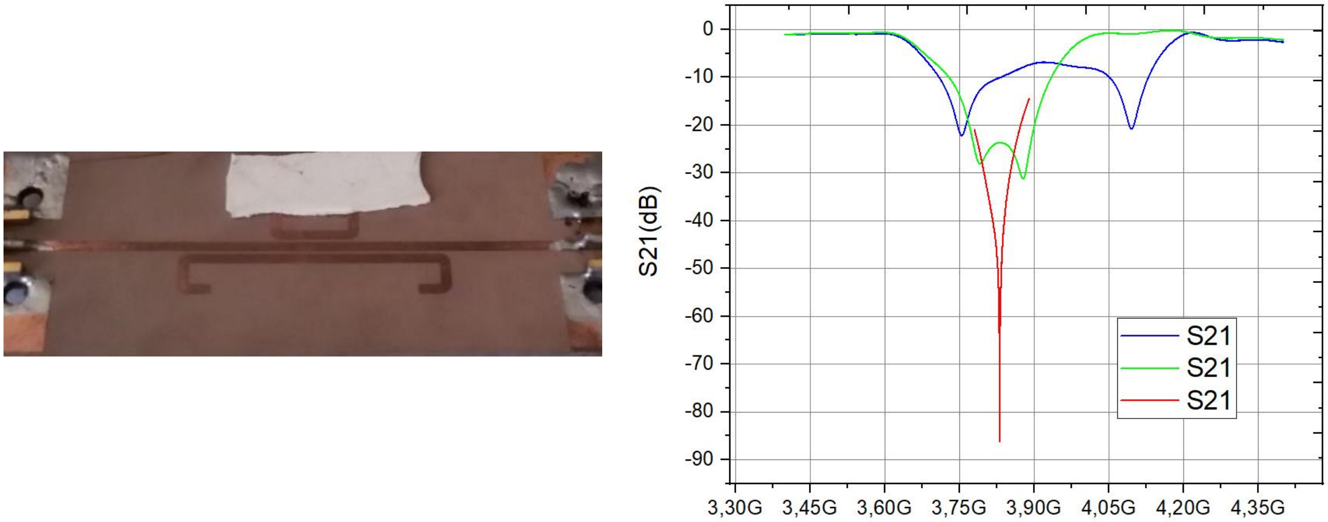


a) b)

Fig. 2. Tuning of "odd" harmonics of a microstrip resonator.

We observe, as expected, the rearrangement of the "odd" 1st and 3rd harmonics, the second harmonic ("even") does not change with this method of switching on the varactor.

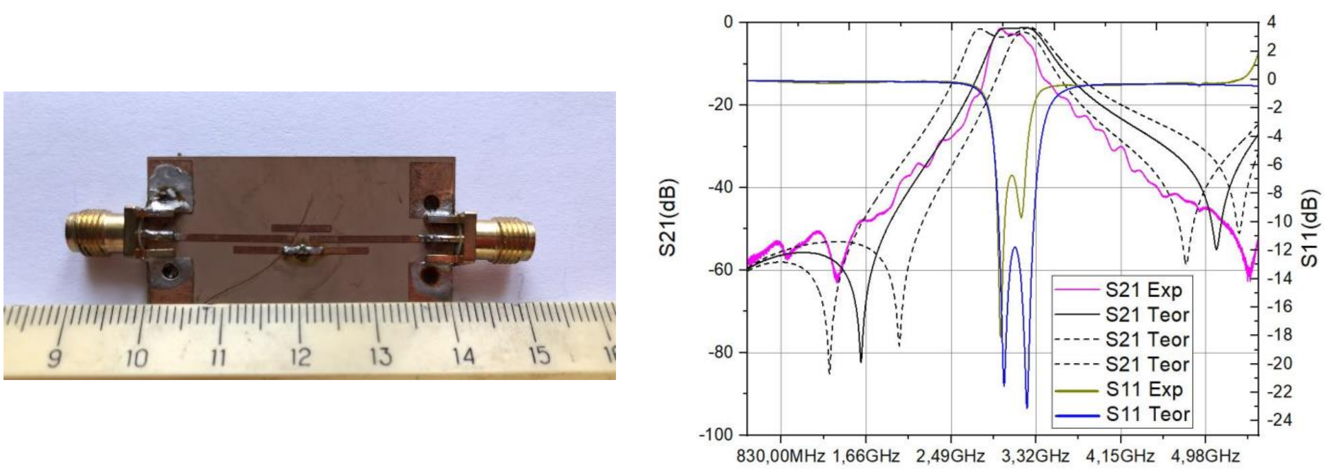
Other methods of tuning the frequency of microstrip resonators are also known. In the process of fine tuning the band-stop filters to obtain anomalously high levels of attenuation (Fano resonance) and group delay (GD), we used a dielectric plate with a permittivity not exceeding the permittivity of the substrate (Fig.3a). The more the plate “covers” the resonator, the lower its resonant frequency. Approaching the resonant frequency of the short resonator ("odd" mod) to the resonant frequency of the long resonator (even mod), we also achieve the Fano resonance, as shown in Fig. 3.b).



a) b)

Fig. 3. Tuning the "cell of the metamaterial" using a dielectric plate.

Let us note one more way of influencing the characteristics of filters based on metamaterial cells of some elements of its design. If, in the bandpass filter investigated in [15], we change the real thickness of the wire, which provides a short circuit of the “long” resonator, that is, in fact, its parasitic inductance, then it is possible to quite effectively regulate its bandwidth and the position of the damping poles, as demonstrated in fig. 4. The dotted line shows the theoretical curves of the transmission coefficient S21 (the diameter of the wire providing the short circuit varies from about 5 to 2 mm), the "theoretical" solid lines for S21 and S11 (the wire diameter is 1 mm) are in good agreement with the experimental results.



a) b)

Fig. 4. Layout of a band-pass microstrip filter (Fig. A) [15] and its characteristics
for different parameters of the parasitic inductance of the short-circuit wire.

References

1. A. R. Brown and G. M. Rebeiz, A Varactor-Tuned RF Filter Ieee Transactions On Microwave Theory And Techniques, vol. 48, no. 7, July 2000 DOI: 10.1109/22.848501.
2. H. Lee and S. Yun, Microwave Planar Varactor Tuned Bandpass Filters: Historical Overview Ieice Transactions on Electronics 2006/12/01 vol.E89-C, no.12 pp.1806-1813 DOI:10.1093/ietele/e89-c.12.1806.
3. C. Musoll-Anguiano, I. Llamas-Garro, Z. Brito-Brito, L. Pradell and A. Corona-Chavez, Fully Adaptable Band-Stop Filter Using Varactor Diodes Microwave And Optical Technology Letters, vol. 52, no. 3, March 2010 DOI: 10.1002/mop.24969.
4. W. Tang and J. Hong, Varactor-Tuned Dual-Mode Bandpass Filters September 2010 IEEE Transactions on Microwave Theory and Techniques 58(8):2213 – 2219 doi:10.1109/tmtt.2010.2052958.
5. A. V. Zakharov and M. Ye. Ilchenko, Varicap-Tuned Narrowband Filters with Extended Rejection Band Based on U-shaped Microstrip Resonators Radioelectronics and Communications Systems, 2017, vol. 60, no. 9, pp. 383–392. © Allerton Press, Inc., 2017 DOI: https://doi.org/10.3103/S0735272717090011.
6. Alexander Zakharov et al.: Varactor-Tuned Microstrip Bandpass Filter with Loop Hairpin and Combline Resonators IEEE Transactions on Circuits and Systems II: Express Briefs (Volume: 66, Issue: 6, June 2019) DOI: 10.1109/TCSII.2018.2873227.
7. B. Pal and S. Dwari, Harmonic Suppressed Tunable Bandpass Filter Using Varactor-Tuned Stub-Loaded Resonator, IETE Journal of Research, 2019, DOI: 10.1080/03772063.2019.1700176 USSR Inventor's Certificate 1518837.
8. M. Ilchenko, A. Zhivkov, A. Zazerin, Metamaterial Cells Equivalent Circuit, Degenerated Oscillation and Electromagnetically Induced Transparency 2018 International Conference on Information and Telecommunication Technologies and Radio Electronics (UkrMiCo) September 10-14, 2018, Odessa, Ukraine DOI: 10.1109/UkrMiCo43733.2018.9047596.
9. M. E. Ilchenko, A. P. Zhivkov, Bridge Equivalent Circuits for Microwave Filters and Fano Resonance. in: Advances in Information and Communication Technologies. Springer, 2019, pp. 278-298.
10. A. Genc and R. Baktur, A Tunable Bandpass Filter Based On Varactor Loaded Split-Ring Resonators Microwave And Optical Technology Letters, vol. 51, no. 10, October 2009 https://doi.org/10.1002/mop.24641.
11. T. Nesimoglu and C. Sabah, A Tunable Metamaterial Resonator Using Varactor Diodes to Facilitate the Design of Reconfigurable Microwave Circuits Ieee Transactions On Circuits And Systems—II: Express Briefs, vol. 63, no. 1, January 2016 DOI: 10.1109/tcsii.2015.2503058.
12. M. Maasch, Tunable Microwave Metamaterial Structures Springer, 2016, DOI 10.1007/978-3-319-28179-7.
13. G. H. Stauffer, Finding the Lumped Element Varactor Diode Model. November 2003 High Frequency Electronics.
14. M. Ilchenko et al: Attenuation Poles In Band-Pass Filters With Even End Odd Modes. Proceedings of the International Scientific and Technical Conference "Prospects for Telecommunications", [S.l.], May. 2020. ISSN 2664-3057 online. DOI: http://conferenc.its.kpi.ua/proc/article/view/201713.