ISSN 0735-2727, Radioelectronics and Communications Systems, 2017, Vol. 60, No. 2, pp. 88–98. © Allerton Press, Inc., 2017.
Original Russian Text © A.V. Zakharov, M.Ye. Ilchenko, L.S. Pinchuk, 2017, published in Izvestiya Vysshikh Uchebnykh Zavedenii, Radioelektronika, 2017, Vol. 60, No. 2, pp. 107–120.

Thin Stripline Bandpass Filters for the Centimeter Band

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Received in final form December 10, 2016

Abstract—This article considers the design of thin stripline (1 mm) bandpass filters in the centimeter band, which contain dielectrics with different relative permittivity ε_r. This includes the choice of the resonators, the dielectric material, the preliminary assessment of resonators' unloaded quality factors and taking into account the features of the frequency response curve of the filter. It was found, that the passband width of the thin comb filters with $\lambda/4$ resonators and array-type filters with $\lambda/2$ resonators cannot exceed 6% for any values of ε_r and the length of resonators of at least 2 mm. The array-type filters with resonators of half-wave type and with alternating signs of the coupling factors between resonators were proposed. Under certain additional conditions, the attenuation poles appear in such filters, resulting in improved selectivity. The results of computer modelling of the frequency response curve of thin filters of cm band are presented. They are compared to the frequency response of other filters. The data obtained from computer modelling showed good correspondence with the experimental data.

DOI: 10.3103/S0735272717020030

INTRODUCTION

The passband filters are the core part of the radiotechnical equipment in the superhigh frequency (SHF) range [1,2]. Compact filters are the most popular. Such filters include the surface-acoustic-wave filter (SAW filter) [3], the filters using dielectric coaxial resonators [2], the mono?block ceramic filters with a number of resonance holes [4]. The high-tech companies in the world produce large quantities of these filters. Microstrip filters also deserve the attention [5–7]. The sizes of the microstrip filters can be quite compact if the thickness of the dielectric substrate is h, and the metal patch is above the ground plane at the distance of $h \ldots 2h$ [6].

Filters commonly have frequency limitations. For example, the operating frequency range of the SAW filters is limited by 2.7 GHz [8]. Therefore, they cannot be used in the centimeter frequency band. The other mentioned filters, such as filters using dielectric coaxial resonators and mono-block ceramic filters, use the microwave ceramics with the high value of relative permittivity ε_r. Thus, they are only used in the lower frequency part of the centimeter band up to 6 GHz inclusive [9].

The microstrip filters can use the insulative substrate of different values of $\varepsilon_r = 2$–100. This allows to use such filters in the entire centimeter band. The bandpass filters on symmetric striplines (stripline filters) [2] can also use dielectrics with different values of ε_r and can be used in the frequency range from 3 to 30 GHz. The stripline resonators have higher unloaded quality factor Q_u compared to the microstrip resonators [10]. The stripline design does not require additional shielding. These are some advantages of the stripline filters over the microstrip ones.

The filter design is based on the knowledge about coupling factors between the resonators and the ability to control them. The research works about the coupling coefficients of the stripline quarter-wave [11] and half-wave [12] resonators, which are placed in parallel without the mutual displacement, have allowed to create the prototypes of the compact stripline comb and array-type filters. According to the results, the values of K increase as the relative permittivity of the strip lines ε_r and their thickness b increase. The results were obtained in the decimeter frequency band, which is limited by 3 GHz.

The use of the thin stripline designs in the centimeter band holds a great practical interest, which corresponds to the general trend of the miniaturization of the microwave filters. Which coupling factors will be between the thin stripline resonators in the centimeter frequency band at different values of ε_r? What should be the characteristics of the bandpass filter for values of K, if they are high enough for the filter

REFERENCES

1. G. Matthaei, E. M. T. Jones, L. Young, *Microwave Filters, Impedance-Matching Networks, and Coupling Structures* (Artech House, 1980).
2. M. Makimoto, S. Yamashita, *Microwave Resonators and Filters for Wireless Communication. Theory, Design and Application* (Springer, 2001), DOI: 10.1007/978-3-662-04325-7.
3. D. Morgan, E. G. S. Paige, *Surface Acoustic Wave Filters: With Applications to Electronic Communications and Signal Processing* (Academic Press, 2010), ISBN: 978-0-12-372537-0.
4. A. Fukasawa, "Analysis and composition of a new microwave filter configuration with inhomogeneous dielectric medium," *IEEE Trans. Microwave Theory Tech*. **30**, No. 9, 1367 (1982), DOI: 10.1109/TMTT.1982.1131262.
5. J.-S. Hong, *Microstrip Filters for RF / Microwave Application*, 2nd ed. (Wiley, N.Y., 2011).
6. A. V. Zakharov, S. A. Rozenko, N. A. Zakharova, "Microstrip bandpass filters on substrates with high permittivities," *J. Commun. Technol. Electron.* **57**, No. 3, 342 (2012), DOI: 10.1134/S1064226912020143.
7. A. V. Zakharov, M. Y. Ilchenko, "A new approach to designing varicap-tuned filters," *J. Commun. Technol. Electron*. **55**, No. 12, 1424 (2010), DOI: 10.1134/S1064226910120156.
8. http://www.nxp.com.
9. http://www.murata.com.
10. A. L. Feldstein (ed.), *Reference about Elements of Stripline Engineering* [in Russian] (Svyaz', Moscow, 1979).
11. A. V. Zakharov, M. Ye. Ilchenko, L. S. Pinchuk, "Coupling coefficient of quarter-wave resonators as a function of parameters of comb stripline filters," *Radioelectron. Commun. Syst*. **58**, No. 6, 284 (2015), DOI: 10.3103/S0735272715060060.

12. A. V. Zakharov, M. E. Ilchenko, “Pseudocombline bandpass filters based on half-wave resonators manufactured from sections of balanced striplines,” *J. Commun. Technol. Electron*. **60**, No. 7, 801 (2015), DOI: 10.1134/S1064226915060182.
13. V. I. Wolman (ed.), *Calculation and Design of Microwave Stripline Devices Reference* [in Russian] (Radio i Svyaz’, Moscow, 1982).
14. https://www.rogerscorp.com.
15. A. V. Zakharov, M. Ye. Ilchenko, V. Ya. Karnauh, L. S. Pinchuk, “Stripline bandpass filters with step-impedance resonators,” *Radioelectron. Commun. Syst*. **54**, No. 3, 163 (2011), DOI: 10.3103/S0735272711030071.
16. A. V. Zakharov, “Stripline combline filters on substrates designed on high-permittivity ceramic materials,” *J. Commun. Technol. Electron.* **58**, No. 3, 265 (2013), DOI: 10.1134/S1064226913030145.
17. Gerhard Megla, *Dezimeterwellentechnik. Theorie und Technik der Dezimeterschaltungen* [in German] (Leipzig Fachbuchverl., 1955).
18. Y.-M. Chen, S.-F. Chang, C.-C. Chang, T.-J. Hong, W.-C. Lo, “A compact step-impedance combline filter with symmetric insertion-loss response and wide stopband range,” in: *Proc. of IEEE MTT-S Int. Microwave Symp. Dig.*, 11–16 Jun. 2006, San Francisco, CA (IEEE, 2006), pp. 1209–1212, DOI: 10.1109/MWSYM.2006.249427.
19. A. V. Zakharov, M. Ye. Ilchenko, L. S. Pinchuk, “Coupling coefficients of step-impedance resonators in stripeline band-pass filters of array type,” *Radioelectron. Commun. Syst*. **57**, No. 5, 217 (2014), DOI: 10.3103/S0735272714050045.
20. J.-S. Hong, M. J. Lancaster, “Design of highly selective microstrip bandpass filters with a single pair of attenuation poles at finite frequencies,” *IEEE Trans. Microwave Theory Tech*. **48**, No. 7, 1098 (2000), DOI: 10.1109/22.848492.
21. http://www.ctscorp.com.