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Research Article

Design and Analysis of a Compact Wide-Band BPF using Quarter Wave Transmission Lines

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Abstract

The design of a wide band bandpass filter is described in this article, which is done by using λ/4 transmission lines and is designed at a frequency range of 12GHz. Sigma shaped BPF is simulated by using EM simulation software An-soft HFSSv13 and is a wide band BPF having a band width of 5.8GHz and FBW of 50% as the center frequency. To determine its applicability for wideband applications, the suggested filter is constructed and tested. To guarantee that it is acceptable for satellite communication applications, many characteristics such as reflection co-efficient, transmission co-efficient, bandwidth, and group delay are tested and are compared with the measured results.

Keywords: Wide band BPF, quarter wavelength transmission lines, reflection co-efficient, transmission co-efficient, satellite communication applications

1. Introduction

As the development of RF (or) microwave filters and their applications in various sectors of satellite communication and VSAT system on chip is requested, scientists focused on compact, lightweight, and broad band filters. Microstrip filters are often constructed to meet the requirements of their ideal qualities, compromises are made to improve performance [1–5]. If flexibility is the most important feature, a quarter-wavelength resonator will result in a considerably smaller design than a half-wavelength resonator, but it will require via holes, which will rise the manufacturing cost [1,2]. Folding these simple resonator structures is used to prevent via holes and that will minimize the size [3,4]. Another option is to create a stepped impedance resonator (SIR); however, With SIRs low-loss coupling is challenging. The loss characteristic values of linear tapered line resonators (LTLR) are lower than those of SIRs, they are more difficult to analyze [6]. A single resonator design with two transmission zeros (TZs) manufacture, on the other hand, is extremely favourable for achieving a small size [4,7].

Lumped element filters, on the other hand, are simple to construct and use, but they are difficult to manufacture in the microwave band. As a result, researchers are attempting to convert lumped component microwave circuits into easy-to-manufacture microstrip circuits and vice versa. The goal is to identify straight transformation techniques, such as Richard's transformation, Kuroda's identities, and impedance/admittance inverters, to conduct quick transformation procedures for microstrip filters [8]. These circuit modifications benefited and were effective with stopband filters (SBFs) and microwave low pass filters (LPFs) with simple microstrip topologies [9,10]. Microstrip dual band-bandpass filters (DB-BPFs) are rarely provided their matching lumped component circuit in the existing literature due to their complexity. A basic L-shaped microstrip construction is used to create an identical LC circuit of a double band filter in [11]. This work introduces a novel broad band BPF and its lumped component equivalent circuit. The design is built by integrating the required properties with quarter wavelength resonator transmission zero generation.

2. Filter Geometry

There are no via holes in the sigma shaped filter design to make fabrication easier, and the substrate material is FR4 with a thickness of 1.6mm, ε_r of 4.3mm, and a loss tangent of 0.0017mm. The design primarily contains two quarter wavelength microstrip transmission lines united by a semi-circular ring to create a wide band width having two transmission zeroes.

3. Filter construction and circuit equivalent

An initial BPF with two quarter wavelength microstrip transmission lines connected by a semi-circular loop with transmission zeroes is built to improve the passband isolation. For better coupling and to produce desired transmission zeroes, a quarter wavelength transmission line is employed. The suggested filter is intended to resonate at 12GHz. The properties of a suggested filter are examined using the An-soft HFSS software and the filter is fed by using two λ/4 microstrip transmission lines. The parameters for the suggested filter design are listed below in millimeters are L=6, W=13.02, R1=2, R2=1.5, W1=W2=5 and W3=1.1, R1=2, R2=1.5, W1=W2=5 and W3=1.1, R1=2, R2=1.5, W1=W2=5 and W3=1.1.

Fundamentally, a microstrip filter is configured by some microstrip components and their discontinuities to have a

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filter function fulfilling the required design. The filter components and the discontinuities have their own equivalent circuits which are represented by lumped components such as capacitor and inductor. The analysis of filter components contains the equivalent circuit such as gap or bend. For example, a gap in microstrip component as one of microstrip discontinuities can be just represented as a separation between one strip to the next strip, where the equivalent circuit for a microstrip bend is represented as the capacitors organized in a п shape. While a bend in microstrip component can be addressed by equivalent circuit contains two series inductors and a shunt capacitor associated in the middle.

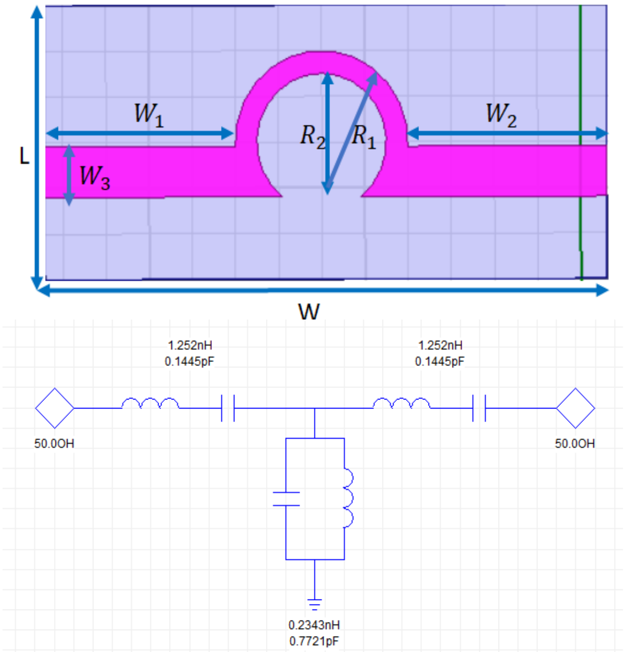

Fig. 1. Top view of the sigma shaped BPF and its circuit equivalent.

The length and breadth of the microstrip resonator, as stated by the mathematical statements given below, are L and W, respectively.

$$L=\frac{\lambda_g}{4} \quad (1)$$

where the guided wavelength is given as

$$\lambda_g=\frac{\lambda_0}{4F_r\sqrt{\varepsilon_{reff}}} \quad (2)$$

$$\varepsilon_{reff}=\frac{\varepsilon_r+1}{2}+\frac{\varepsilon_r-1}{2}\left[1+\left[\frac{12h}{w}\right]\right]^{-1/2} \quad (3)$$

h and ε_r represents the thickness and relative permittivity of the substrate.

$$\frac{w}{h}=\frac{2}{\pi}\{(B-1)-\ln(2B-1)\,\frac{\varepsilon_r-1}{2\varepsilon_r}[\ln(B-1)+0.39-(\frac{0.61}{2\varepsilon_r})]\} \quad (4)$$

Where

$$B=\frac{60\pi^2}{Z_C\sqrt{\varepsilon_r}} \quad (5)$$

To affirm the simulated results, Anritsu MS2037C combinational analyser is used to manufacture and measure the suggested BPF. Sigma shaped BPF's top and bottom views are seen in Figure 2. To generate transmission zeroes, a quarter wavelength transmission line is employed, and the semi-circular ring is constructed to achieve wide bandwidth at the necessary frequency. Return loss, transmission coefficient, and group delay are the parameters that this combinational analyser measures, and figure 3 shows the transmission coefficient measurement.

4. Results & Discussions

The constructed prototype is fabricated and tested in real time for real-time validation. The figures show a high level of agreement between the measured and simulated results. Figures 4 and 5 show the simulated and measured scattering properties of the sigma shaped filter, with some fabrication errors causing a disparity. The sigma shaped BPF having transmission co-efficient of less than 0.9dB, return loss less than 10 dB, and a maximum possible filter bandwidth of 5.8GHz, the filter's -3dB bandwidth may be achieved from 11.2GHz to 16.1GHz. The transmission coefficient is observed to be less than 3dB throughout the entire frequency ranges. Table 1 summarizes the performance metrics based on the literature, revealing that the proposed filter has a better return loss, transmission coefficient, and bandwidth.

Using the combinational analyser, the reflection co-efficient of the manufactured filter was calculated and the proposed filter resonates at 10.2GHz and 16GHz. Group delay comparison of the sigma shaped BPF is shown in Figure 6, and for the designed band of 10 to 24 GHz, the variance of reflection coefficient across frequencies is less than 10dB.

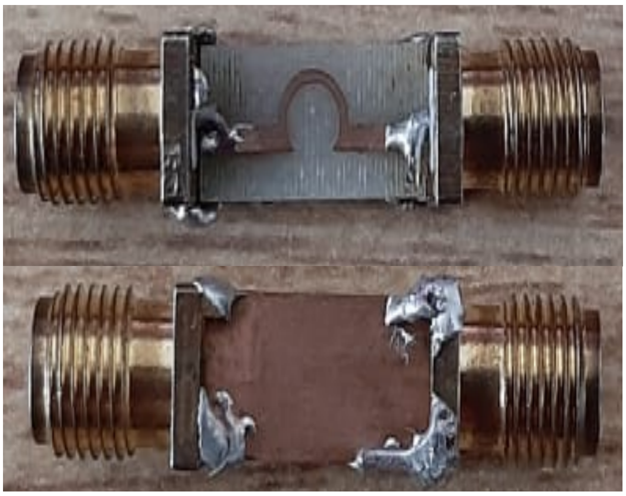

Fig. 2. Views of the fabricated sigma shaped BPF from top and bottom.

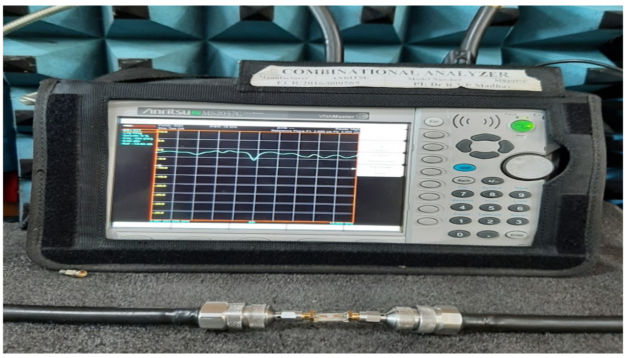

Fig. 3. Measuring the transmission Co-efficient by using Anritsu combinational analyser.

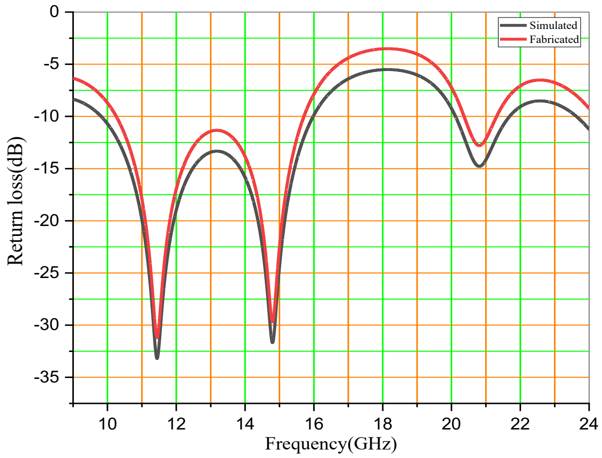

Fig. 4. Return loss comparison result of the proposed structure.

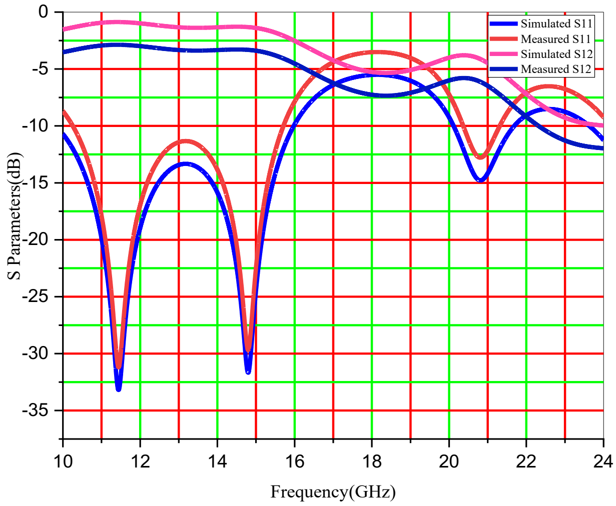

Fig. 5. S-parameters comparison of the sigma shaped BPF.

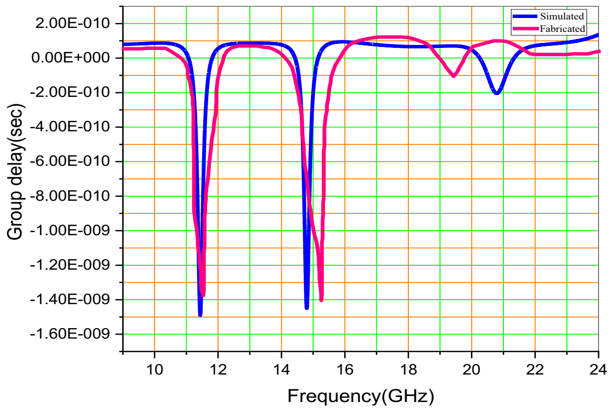

Fig. 6. Group delay comparison of the sigma shaped BPF.

Group delay is generally used to derive the time domain properties of any microstrip BPF, and the comparison of the group delay plot for sigma shaped BPF is shown in Figure 6 With a deviation of 0.2 ns, the group delay of the suggested filter is maximally flat. The delay induced by the filter is therefore consistent across the operating range, resulting in minimal signal distortion. Figure 7 indicates the sigma shaped BPF's electric field distribution and it is observed that the electric field is concentrated at the ends of the resonator.

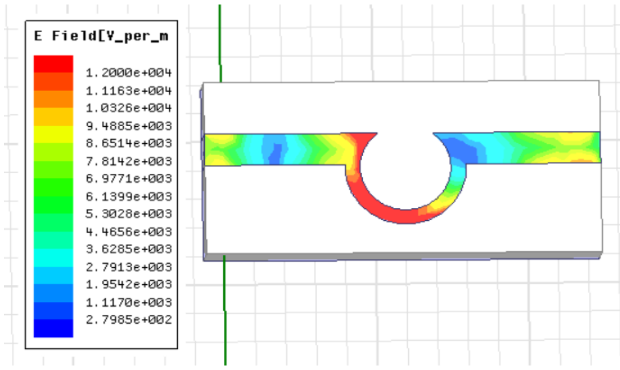

Fig. 7. Sigma shaped BPF's electric field distribution.

Table 1. Comparison of contemporary work with other literary works.

Design Proposed by	Substrate	Reflection Co-efficient	Group delay	Area (mm^2)	Center Frequency
[2]	Rogers RT/duroid	-14dB	-------	5x13	13.3GHz
[3]	GaAs	-15dB	---------	1.09x0.97	13.5GHz
[5]	FR4	-16dB	0.5ns	11.12x8	14GHz
[11]	Rogers RT/duroid	-14dB	-------	5x13	13.3GHz
[12]	GaAs	-15dB	---------	1.09x0.97	13.5GHz
[13]	FR4	-16dB	0.5ns	11.12x8	14GHz
[14]	FR4	-11dB	---------	25x25	10GHZ
Proposed Filter	FR4	-35dB	0.2ns	6x13.02	10.2GHz 16GHz

5. Conclusion

It's critical to create a microwave filter that makes effective and efficient use of the spectrum while preserving a wide bandwidth. A new design using microstrip quarter wavelength transmission lines has been created to produce a larger bandwidth bandpass filter. The proposed filter's design approach and attributes, such as its small size and wide bandwidth, are better suited to today's multiband and multistranded systems. The proposed filter has a 5.8GHz bandwidth and operates between 10.2GHz and 16GHz, making it perfect for satellite communication and VSAT systems on chip.

References

1. Richtarsic. M. and Thornaton. J. “Characterization and Optimization of LTCC for High Density Large Area MCM's,” International conference on Multichip Modules and High-Density Packaging, 1998, 92-97.
2. Q. Yang, X. Xiong, Y. Wu, L. Wang and H. Xiao, "Design of microstrip tapped-hairpin dual-band pass filter for Ku-band application," 2010 International Conference on Microwave and Millimeter Wave Technology, Chengdu, 2010, pp. 772-774, doi: 10.1109/ICMMT.2010.5525064.
3. J. Sheen, Y. Cheng and W. Liu, "Ku-band Bandpass Filter Design with Compact Size and Broad Stopband by pHEMT Process," 2019 Photonics & Electromagnetics Research Symposium - Spring (PIERS-Spring), Rome, Italy, 2019, pp. 1022-1026, doi: 10.1109/PIERS-Spring46901.2019.9017867.
4. H. Miyake, S. Kitazawa, T. Ishizaki, T. Yamada and Y. Nagatomi, “A miniaturized monolithic dual band filter using ceramic lamination technique for dual mode portable telephones,” IEEE MTT-S Int. Microw. Symp. Dig. vol. 2, 1997, pp.789-792.
5. C. S. Panda, R. Nayak and S. K. Behera, "Design and analysis of a compact Substrate Integrated Waveguide bandpass filter for Ku band applications," 2016 Online International Conference on Green Engineering and Technologies (IC-GET), Coimbatore, 2016, pp. 1-5, doi: 10.1109/GET.2016.7916694.
6. J. T. Kuo and H. S. Cheng. "Design of quasielliptical function filters with a dual-passband response," IEEE Microw. Wireless Compon. Lett., vol.14, no. 10, 2004, pp. 472-474.
7. M. Makimoto and S. Yamashita, "Bandpass filters using parallel coupled strip line Steeped impedance Resonator," IEEE Trans. Microwave Theory Tech., vol. 28, 1980, pp. 1413-1417.
8. Sulaiman1, M. F. Ain1, S. I. S. Hassan. "Design of Hairpin Band Pass Filters for K-Band Application," 2008 IEEE international rf and microwave conference proceedings.
9. Yingjie Di, Peter Gardner, Peter S. Hall. "Multiple-Coupled Microstrip Hairpin-Resonator Filter," IEEE microwave and wireless components letters, vol. 13, no. 12, December 2003.
10. Chen-Kang Hsu, Hsin-Han Tung. “Microstrip Cross-Coupled Interdigital Hairpin Bandpass Filter,” Microwave Conference, 2008. APMC 2008. Asia-Pacific16-20 Dec. 2008 Page(s):1-4.
11. Q. Yang, X. Xiong, Y. Wu, L. Wang and H. Xiao, "Design of microstrip tapped-hairpin dual-band pass filter for Ku-band application," 2010 International Conference on Microwave and Millimeter Wave Technology, Chengdu, (2010), pp. 772-774.
12. J. Sheen, Y. Cheng and W. Liu, "Ku-band Bandpass Filter Design with Compact Size and Broad Stopband by pHEMT Process," 2019 Photonics & Electromagnetics Research Symposium - Spring (PIERS-Spring), Rome, Italy, (2019), pp. 1022-1026.
13. C. S. Panda, R. Nayak and S. K. Behera, "Design and analysis of a compact Substrate Integrated Waveguide bandpass filter for Ku band applications," 2016 Online International Conference on Green Engineering and Technologies (IC-GET), Coimbatore, (2016), pp. 1-5.
14. P. Sridharan and Sreeja B.S., "Design and analysis of 1–10GHz band selected bandpass filter with broad tunable range," 2014 International Conference on Communication and Signal Processing, Melmaruvathur, (2014), pp. 303-306.
15. Q. Yang, X. Xiong, Y. Wu, L. Wang and H. Xiao, "Design of microstrip tapped-hairpin dual-band pass filter for Ku-band application," 2010 International Conference on Microwave and Millimeter Wave Technology, Chengdu, (2010), pp. 772-774.
16. J. Sheen, Y. Cheng and W. Liu, "Ku-band Bandpass Filter Design with Compact Size and Broad Stopband by pHEMT Process," 2019 Photonics & Electromagnetics Research Symposium - Spring (PIERS-Spring), Rome, Italy, (2019), pp. 1022-1026.
17. C. S. Panda, R. Nayak and S. K. Behera, "Design and analysis of a compact Substrate Integrated Waveguide bandpass filter for Ku band applications," 2016 Online International Conference on Green Engineering and Technologies (IC-GET), Coimbatore, (2016), pp. 1-5.
18. P. Sridharan and Sreeja B.S., "Design and analysis of 1–10GHz band selected bandpass filter with broad tunable range," 2014 International Conference on Communication and Signal Processing, Melmaruvathur, (2014), pp. 303-306.
19. Ge Zhiqiang, “A downsized and integrated C-band transceiver for VSAT,” IEEE Microwave and Optoelectronics conference, 1995, 33-36.
20. Hong Jia-sheng, Lancaster M J. “Microstrip filters for RF/microwave applications”, New York: John Wiley & Sons.
21. Hayati, M., Noori, L., and Adinehvand, A, “Compact dual-band band-pass filter using open loop resonator for multimode WLANs”, Electron. Lett., 2012, 48, (10), pp. 573–574.