A New Design of Very Compact UWB Band-Stop Filter Using Coupled W-Shaped Strips

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Abstract **─** In this paper, a compact microstrip band-stop filter (BSF) with 3-18 GHz bandwidth for radar applications is proposed. The microstrip filter configuration consists of a transmission line with a pair of coupled W-shaped strips as a stub, and a ground plane. Operation frequencies of the filter can be easily controlled by changing the size of W-shaped strips. The proposed band-stop filter has a very wide bandwidth from 3 to 18 GHz that can be used in C-band (4-8 GHz), X-band (8-12 GHz) and Ku-band (12-18 GHz) applications. An excellent agreement between measured and simulated was obtained. The proposed microstrip filter fabricated on a *Rogers* RT/Duroid 5880 substrate with a relative dielectric constant of 2.2 and has a very small size of 10×15 mm^2. The proposed antenna configuration is simple, easy to fabricate and can be integrated into any radar system.

Index Terms **─** Band-stop filter, radar systems, W-shaped strip.

I. INTRODUCTION

In modern communications, one of the important parameter is isolation between channels in a given bandwidth. Filters with different configurations are essential components in communication systems and these are generally used as signal rejection for unwanted signals and simultaneously allow the wanted signals in required bands [1]. In recent times, the design of filters has become an active research area as filtering is important when used in close proximity to other circuit components, like power amplifiers in the transmitter part and low noise amplifiers in receiver part, for various RF applications [2].

Conventionally, the microwave band-stop filter (BSF) is implemented either by all shunt stubs or by series connected high-low stepped-impedance microstrip line sections. However, generally these are not easily available in microwave band due to the high impedance microstrip line and the spurious pass-bands. To remove these disadvantages, defected ground structures for microstrip lines have been presented in recent years. They have been presented in a number of different shapes for filter applications [3-5]. The DGS applied to a microstrip line causes a resonant character of the structure transmission with a resonant frequency controllable by changing the shape and size of the slot. This technique is suitable for periodic structures, and for both band-stop and band-pass filters, e.g., [6-14].

This paper work deals with design and development of a microstrip band-stop filter for radar application. In this structure, the resonant behaviors of the W-shaped strips are used here introduces transmission zeroes to the filter response and consequently improves its band-stop performance. Also, the reason for the choice of coupled W-shaped configuration is that it provides an almost constant tight coupling, which is important to generate a good frequency response. The designed filter has a small dimension of 10×15×0.635 mm^3.

II. FILTER DESIGN

The proposed microstrip filter configuration is shown in Fig. 1. This band-stop filter was designed on a Rogers RT/Duroid 5880 substrate with 0.635 mm in thickness and with a relative dielectric constant of 2.2. For the input/output connections 50-Ohm microstrip lines are used. The microstrip band-stop filter was designed on both substrate sides by opening aperture in the ground metallization under the low-impedance transmission line.

As shown in Fig. 1, a pair of W-shaped resonators

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is embedded to the microstrip transmission line. The gap between them is used as the coupling structure. The characteristic impedance of the transmission line is chosen to be 50-Ohm to obtain good stop-band matching in wideband.

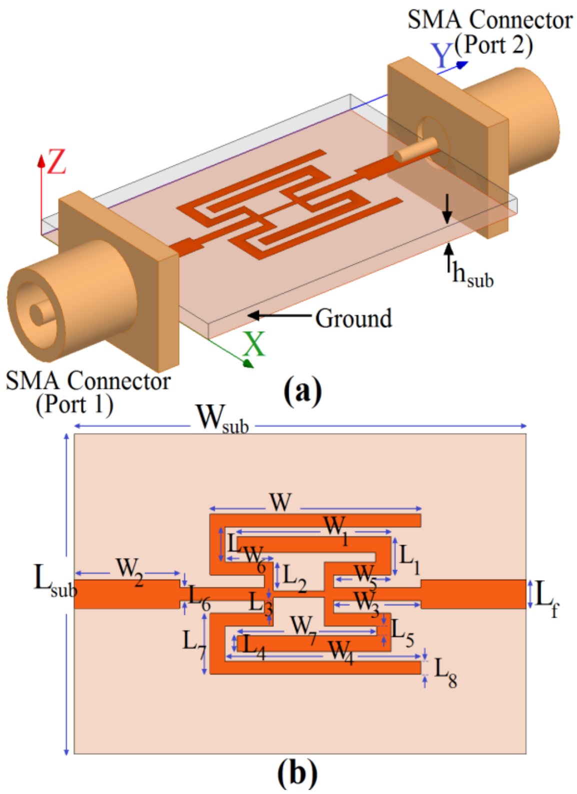

Fig. 1. Geometry of the proposed BSF: (a) side view and (b) top view.

To realize the desired capacitive and inductive values of the filter elements by the stubs of high/low impedance transmission lines, the characteristic impedance and effective dielectric constant of these transmission lines have to be determined. The resonant frequencies of the W-shaped resonators could be easily extracted using the odd-even modes analysis. In the odd excitation case, an electric wall could be added to the symmetric line of the whole structure. Thus, a quasi-quarter wavelength resonator of W-shaped trips could be extracted. In the even case, the electric wall is replaced by a magnetic wall and the resonator can be equivalent to a folded quasi half wavelength resonator.

The BSF's working frequency is dependent on the odd-mode resonant frequency, which could be modified by the pair of C-shaped strips as a microstrip-stub (L_2, L_3, W_5, and W_6). The relative working bandwidth is determined by distance of the odd-even mode frequencies, which could be easily adjusted by the size of W-shaped strips (W, W_1, L, L_1, L_5, and L_7). The matching strength is controlled by L_6, while matching balance is controlled by the bend rate Lf. The widths of the lines (W_2) have smaller impact on frequency tuning than the sizes (W_3).

Another adjustable parameter is the notch of resonator's arm (W_6). The BSF will look simpler without notches. However, without notches, the coupling between feeding line and resonator will be weakest in odd mode, whereas strongest in even mode according to the coupled line theory [15].

As shown in Fig. 2, results in unbalanced coupling or single mode in the working band. Figure 4 illustrates the reflection responses of E-shaped dual mode BSFs with different bend rates. From the curves we could find that two balanced rejection zeros is realized under proper widths of the W-shaped strips. In addition, the gap between feedline and resonator dominates the coupling in both odd-even cases. As shown in Fig. 5, it is quite sensitive. The coupling is stronger with smaller gap size. Final values of the presented band-stop filter design parameters are specified in Table 1.

Table 1: Final parameter values of the proposed band-stop filter

Parameter	W_{sub}	W_{sub}	h_{sub}	W	L_f
Value (mm)	10	15	0.635	7	0.9
Parameter	W_1	L_1	W_2	L_2	W_3
Value (mm)	5.1	1.2	3.5	0.9	2.9
Parameter	L_3	W_4	L_4	W_5	L_5
Value (mm)	0.4	6.5	0.5	1.9	0.3
Parameter	W_6	L_6	W_7	L_7	L_8
Value (mm)	1.6	0.4	4.6	1.9	0.4

III. RESULTS AND DISCUSSIONS

The proposed microstrip band-stop with various design parameters was constructed, and the experimental results of the S-parameter characteristics are presented and discussed. The simulated results are obtained using the Ansoft simulation software high-frequency structure simulator (HFSS) [16].

The structure of the various filters used for simulation studies were shown in Fig. 2. S-parameter characteristics for the microstrip filter with a pair of C-shaped strips (Fig. 2 (a)), the filter with left-side W-shaped and C-shaped strips (Fig. 2 (b)), and the proposed filter structure (Fig. 2 (c)) are compared in Fig. 3. As illustrated in Fig. 3, by using a pair of C-shaped strips as a microstrip-stub, two transmission zeroes at the upper frequencies can be achieved by converting the left-side C-shaped strip to the W-shaped structure, a new transmission zero at the low frequency is generated. Finally, with proposed structure (Fig. 2 (c)), good impedance matching for return loss/insertion (S_{11}/S_{21}) characteristics with 3-18 GHz bandwidth can be achieved [2-5].

In Fig. 4, the surface current distribution of the proposed filter is depicted. In this figure, the current distributions at four different frequencies are presented. The first lower transmission zero is at 3.8 GHz, the upper transmission zero is at 15.5 GHz and the mid-frequencies in the pass-band are at 8.3 and 10.1 GHz. In Fig. 4 (a), the current is mainly located at the left-side W-shaped strip. This implies that the lower transmission zero is mainly due to the bigger W-shaped strip. In Fig. 4 (b), the current is mainly located at transmission line. In Fig. 4 (c) and 4 (d), it can be seen that two sides of the W-shaped strips have effect on the overall performance of the filter because of acting as a half-wave resonant structure [17-19].

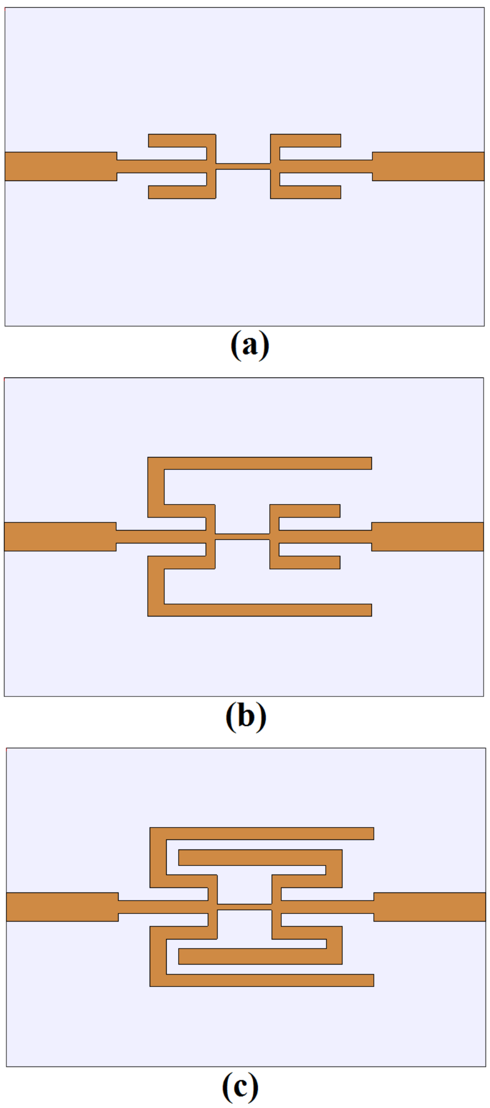

Fig. 2. (a) Microstrip filter with a pair of C-shaped strips, (b) the filter with left-side W-shaped and C-shaped strips, and (c) the proposed filter structure.

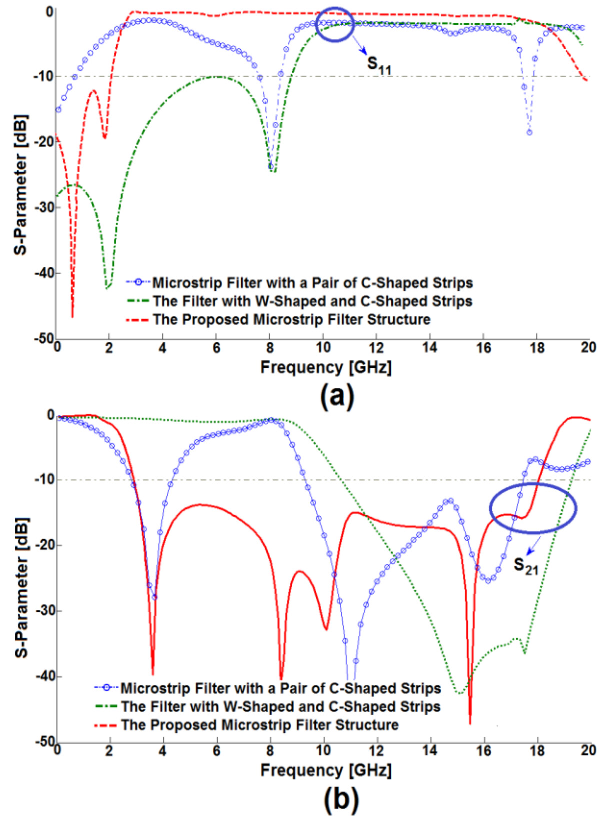

Fig. 3. Simulated S-parameter characteristics for the various structures shown in Fig. 2.

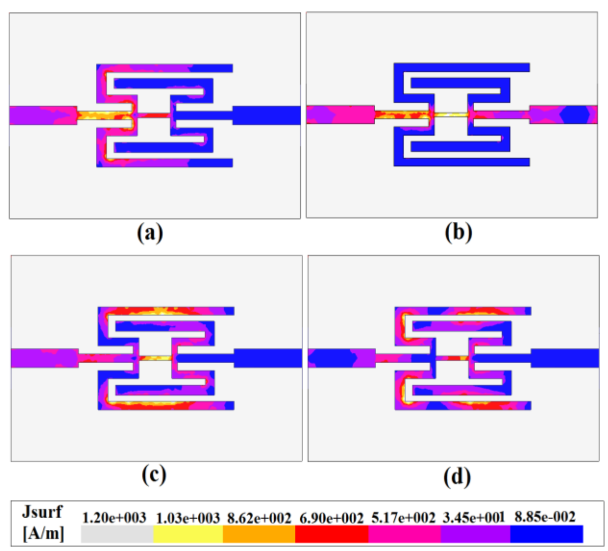

Fig. 4. Simulated surface current distribution of the proposed filter at transmission zeroes frequency: (a) 3.8 GHz, (b) 8.3 GHz, (c) 10.1 GHz, and (d) 15.5 GHz.

The simulated VSWR curves with different values are plotted in Fig. 7. As shown in Fig. 5, when the interior widths of the W-shaped strips increase from 6.3 and 4.7 mm to 7.7 and 5.3 mm respectively, the lower stop-band frequency is increases from 1.7 GHz to 3.6 GHz and also the upper stop-band frequency is increased from 14 GHz to 19 GHz. From these results, we can conclude that the stop-band operation is controllable by changing the size of the embedded W-shaped strips. As illustrated in Fig. 5, the microstrip filter with W=7.7 mm and W_1=5.3 mm has a coefficient and wider stop-band bandwidth.

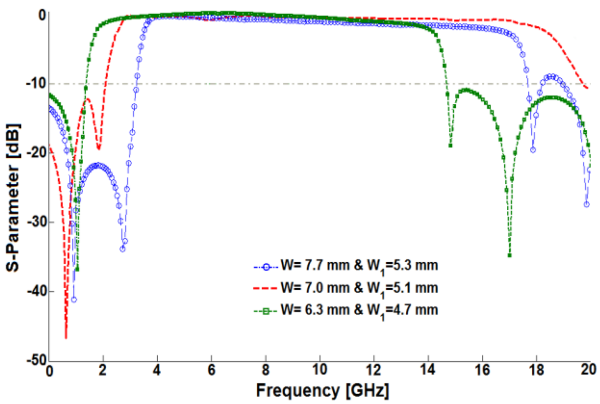

Fig. 5. Simulated and measured insertion and return loss characteristics of the filter.

The proposed filter with final design as shown in Fig. 6, was fabricated and tested that has a good insertion loss (S_{11}) and return loss (S_{21}) are introduced to the filter response from 2.82 to 18.05 GHz. Figure 7 shows the simulated and measured insertion and return loss of the filter. As shown in Fig. 7, a flat insertion and return losses are introduced to the filter response. Consequently, a very wide band-stop characteristic was achieved.

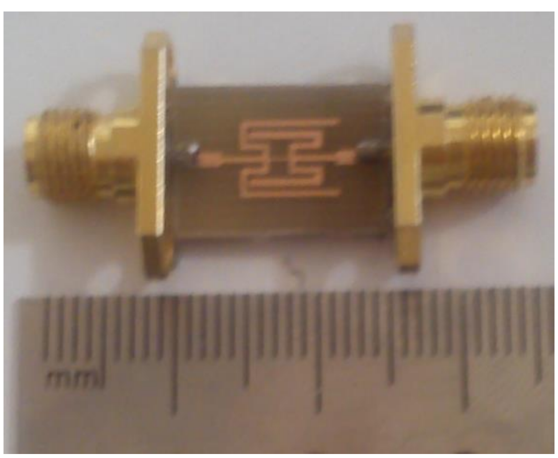

Fig. 6. Photograph of the fabricated microstrip filter.

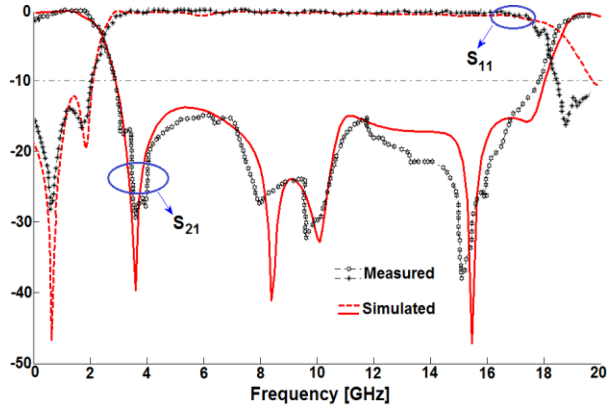

Fig. 7. Simulated and measured return and insertion loss (S_{11}/S_{21}) characteristics of the filter.

IV. CONCLUSION

In this paper, a novel design of band-stop microstrip filter that covers frequency bandwidth of 3-18 GHz has been presented. Configuration of the presented filter consists of a transmission line with a pair of coupled W-shaped strips .The measured results have shown that the fabricated filter has a band-stop characteristic that extends from 2.082 to 18.05 GHz, with an insertion loss (S_{21}) which is larger than 20 dB and a return loss ($S_{11)}$ which is less than 0.5 dB at the center of the band-stop frequency range. The proposed filters are promising for use in radar wireless technologies for UWB communications due to their simple structure, compact size, and excellent performance.

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REFERENCES

[1] J. A. Kong, *Electromagnetic Wave Theory*, EMW Publishing, Cambridge, 2000.
[2] K. L. Finch and N. G. Alexopoulos, "Shunt posts in microstrip transmission lines," *IEEE Trans. Microwave Theory Tech.*, vol. MMT.-38, pp. 1585-1594, 1990.
[3] D. S. La, Y. H. Lu, S. Y. Sun, N. Liu, and J. L. Zhang, "A novel compact band stop filter using defected microstrip structure," *Microw. Opt. Technol. Lett.*, vol. 53, pp. 433-435, Feb. 2011.
[4] X.-H. Wang, B.-Z. Wang, H. Zhang, and K. J. Chen, "A tunable band-stop resonator based on a compact slotted ground structure," *IEEE Trans Microwave Theory Tech.*, vol. 55, pp. 1912-1918, 2007.
[5] W. D. Yan and R. R. Mansour, "Compact tunable

bandstop filter integrated with large deflected actuators," *IEEE MTT-S International Microwave Symposium*, Honolulu, HI, pp. 1611-1614, 2007.

[6] R. Habibi, Ch. Ghobadi, J. Nourinia, M. Ojaroudi, and N. Ojaroudi, "Very compact broad band-stop filter using periodic L-shaped stubs based on self-complementary structure for X-band application," *Electron. Lett.*, vol. 48, no. 23, pp. 1483-1484, 2012.

[7] L. H. Weng, Y. C. Guo, X. W. Shi, and X. Q. Chen, "An overview on defected ground structure," *Progress In Electromagnetics Research* B, vol. 7, pp. 173-189, 2008.

[8] M Ojaroudi and N. Ojaroudi, "Microstrip low-pass filters by using novel defected ground structure slot with a pair of protruded T-shaped strips inside the slot," *Advanced Electromagnetic Symp., (AES)*, 2012.

[9] N. Ojaroudi, M. Ojaroudi, and R. Habibi, "Design and implementation of very compact band-stop filter with petal-shaped stub for radar applications," *Microw. Opt. Technol. Lett.*, vol. 55, pp. 1130-1132, 2013.

[10] N. Ojaroudi, H. Ojaroudi, and Y. Ojaroudi, "Very low profile ultra-wideband microstrip band-stop filter," *Microw. Opt. Technol. Lett.*, vol. 56, pp. 709-711, 2014.

[11] N. Ojaroudi, Y. Ojaroudi, and S. Ojaroudi, "Novel design of UWB band-stop filter (BSF) based on Koch fractal structures," *Applied Computational Electromagnetics Society (ACES) Journal*, vol. 30, no. 1, pp. 576-581, 2015.

[12] M. Pourbagher, N. Ojaroudi, Ch. Ghobadi, and J. Nourinia, "A novel design of compact board band-stop filter for use in X-band transceivers," *Applied Computational Electromagnetics Society (ACES) Journal*, vol. 30, no. 4, pp. 423-427, 2015.

[13] S. Ojaroudi, Y. Ojaroudi, and N. Ojaroudi, "Compact planar microstrip-fed printed antenna with double band-filtering for UWB application," *Applied Computational Electromagnetics Society (ACES) Journal*, vol. 30, no. 4, pp. 457-462, 2015.

[14] N. Ojaroudi, "Novel design of low-profile microstrip band-stop filter (BSF) with Koch fractal RSLRs," *22nd Telecommunications Forum, TELFOR 2014*, Belgrade, Serbia, Nov. 25-27, 2014.

[15] N. Ojaroudi, "Application of protruded Γ-shaped strips at the feed-line of UWB microstrip antenna to create dual notched bands," *International Journal of Wireless Communications, Networking and Mobile Computing*, vol. 1, no. 1, pp. 8-13, 2014.

[16] Ansoft High Frequency Structure Simulator (HFSS), ver. 13, Ansoft Corporation, Pittsburgh, PA, 2010.

[17] N. Ojaroudi, "A modified compact microstrip-fed slot antenna with desired WLAN band-notched characteristic," *American Journal of Computation, Communication and Control*, vol. 1, no. 3, pp. 56-60, 2014.

[18] N. Ojaroudi, "An UWB microstrip antenna with dual band-stop performance using a meander-line resonator," *22nd International Conference on Software, Telecommunications and Computer Networks (SoftCOM)*, Split, Croatia, 2014.

[19] N. Ojaroudi, "A new design of Koch fractal slot antenna for ultra-wideband applications," *21st Telecommunications Forum, TELFOR 2013*, Belgrade, Serbia, Nov. 27-28, 2013.