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Band-pass Hairpin Filter Using C-shaped DGS With Wide-band Rejection

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***Abstract*—A band-pass hairpin filter is proposed that is combined with two C-shaped defected ground structures (DGSs) to provide a wide rejection band. The top layer of the structure consists of a hairpin filter of 5th order, and the bottom layer has DGSs that introduce low-pass filtering. The proposed hybrid circuit has 5 dB of insertion loss and 13 dB of return loss at its center frequency of 1.98 GHz.**

Keywords—Band-pass filter, defected ground structure, hairpin filter, wide-band rejection.

I. Introduction

Wireless telecommunications systems expanded and evolved in recent years, with new technologies emerging rapidly. RF/microwave filters are essential components in transmitting systems and receivers. Their function is to allow the passage of the signal in a certain band, and to attenuate in other, unwanted bands. In the current telecommunication scenario, where a high number of systems are interconnected, filters with low-losses, low-cost, ease of fabrication and rejection of spurious responses are increasingly required [1, 2].

This paper presents a band-pass hairpin filter, e.g. [3], using a C-shaped geometry as defected ground structure (DGS) that provides a wide rejection band. The design aspects of the hybrid filter are described.

II. Filter Design

The numerical characterization of all filter components was performed using Ansys HFSS. All structures are designed on a FR-4 dielectric substrate with dielectric constant of 4.4, thickness of 1.5 mm, and loss tangent of 0.02.

A. Hairpin Filter

The passive band-pass filter is a device that passes signals within a certain frequency range and attenuates frequencies outside of that range. Planar filters can have different geometric shapes and are widely used in RF/microwave applications. The hairpin filter is a compact structure and consists of parallel coupling of half-wavelength-based U-shaped resonators (Fig. 1, left). Feeding is provided by using a 50-Ω microstrip-line with width W_0. The dimensions of this filter are L = 21 mm, s = 1 mm, W = 1.5 mm, W_0 = 2.8 mm and W_1 = 2 mm. Fig. 2 shows its frequency response where a lower cutoff frequency at 1.83 GHz, upper cutoff frequency at 2.19 GHz, and the center frequency at 1.98 GHz are observed. At the center frequency, the transmission coefficient, $|S_{21}|$, is -5 dB and the reflection, $|S_{11}|$, is -24 dB. Note that the dimensions of this filter account for the limitations in the fabrication process and, hence, affects its frequency response.

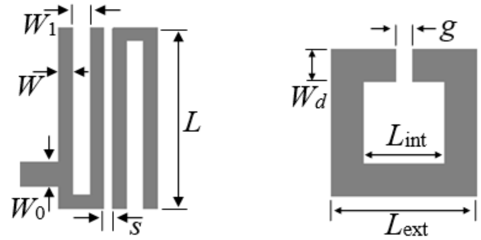

Fig. 1. Design parameters of hairpin filter (left) and C-shaped DGS (right).

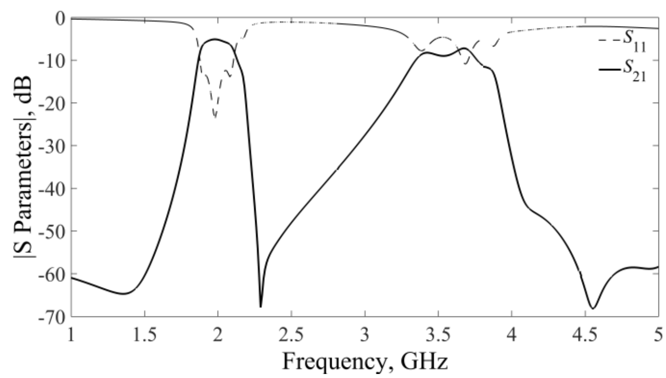

Fig. 2. Simulated results for hairpin filter.

B. C-shaped DGS

In order to attenuate the second passband in Fig. 2, i.e. to provide a wide-band rejection, slots or defect structures can be added on the ground plane to modify the filter's current distribution, thus producing variations in capacitance and inductance along the line [4]. A DGS behaves as a parallel LC circuit in the ground plane that, at its resonance, takes energy out of the top microstrip line and thus can provide attenuation in the second passband, leading to wide-band rejection when combined with the original filter. Fig. 1 (right) shows the parameters of the C-shaped geometry used as a DGS stop-band filter. The dimensions of the DGS are g = 1 mm, L_{ext} = 9 mm, L_{int} = 7 mm and W_d = 2 mm. Fig. 3 presents the quasi-stopband response, with a lower cutoff frequency of 2.97 GHz and attenuation up to 3.38 GHz. The best insertion loss is 2 dB with a return loss of 31 dB.

C. Hybrid Filter

The proposed hybrid filter, illustrated in Fig. 4, combines the hairpin band-pass filter located in the top metalization layer with two C-shaped DGSs in the bottom layer. We use two C-shaped DGSs, where each one is positioned at the input and output microstrip lines so that their distance can be adjusted for a better selectivity performance.

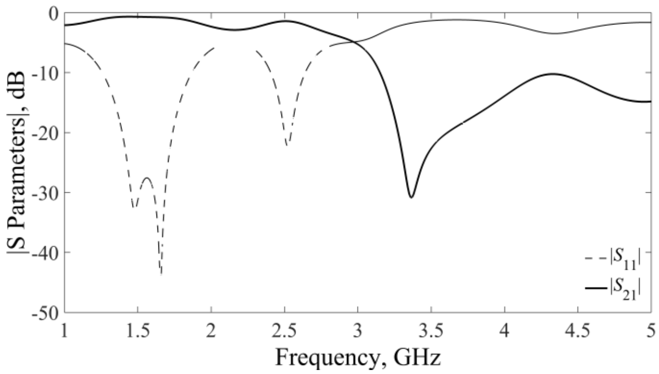

Fig. 3. Simulated results for C-shaped DGS.

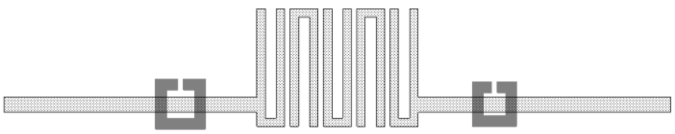

Fig. 4. Hybrid circuit configuration.

III. Results

To validate the simulated results, the proposed hybrid filter was prototyped as shown in Fig. 5. The top view shows the hairpin filter, and the C-shaped DGSs are in the bottom layer. The experimental characterization was carried out using a two-port Agilent N5230A vector network analyzer. The measured results of reflection and transmission parameters are compared with simulated ones and are observed to be in good agreement.

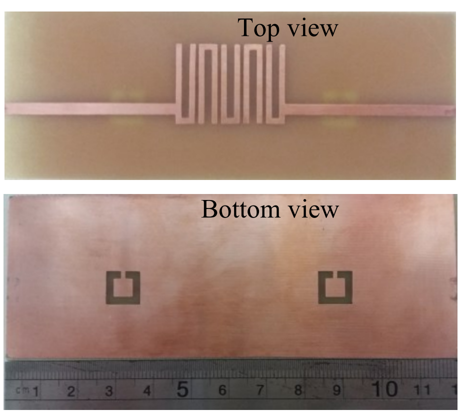

Fig. 5. Hybrid filter prototype.

The hybrid circuit has a passband response from 1.85 to 2.22 GHz. Fig. 6 shows the reflection coefficient, which presents a center frequency at 1.98 GHz with -13 dB reflection according to measured result. Fig. 7 displays the transmission coefficient with -5 dB at the center frequency. Based on these results, a wide rejection band is observed that is obtained by the use of C-shaped DGSs to attenuate the undesired second band in Fig. 2 band.

IV. Conclusion

A hybrid circuit filter, consisting of a combination of band-pass hairpin filter and C-shaped DGSs, is designed for wide-band rejection. This band-pass filter operates from 1.85 GHz to 2.22 GHz with a center frequency of 1.98 GHz. The C-shaped DGSs were placed on the ground plane under the input/output microstrip lines of the hairpin filter. The second passband from the hairpin filter was successfully attenuated though the use of the DGSs. The numerical and experimental results demonstrate good agreement and confirm that a wide rejection band is achieved up to 5GHz.

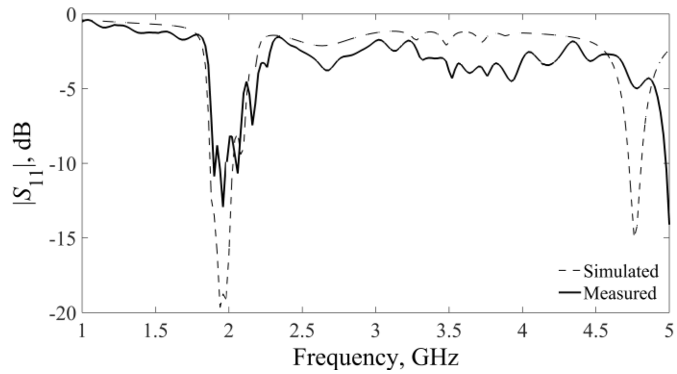

Fig. 6. Comparison between simulated and mesured results of return loss for hybrid filter.

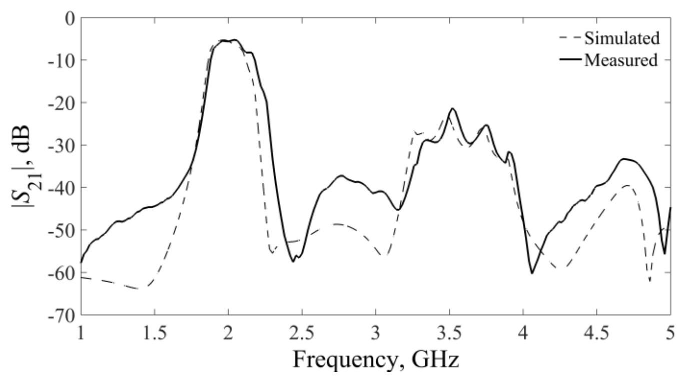

Fig. 7. Comparison between simulated and mesured results of insertion loss for hybrid filter.

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