Progress In Electromagnetics Research Letters, Vol. 35, 99–105, 2012

COMPACT REALIZATION OF COMBLINE BANDPASS FILTER INTEGRATED WITH DEFECTED MICROSTRIP STRUCTURE BANDSTOP FILTER

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Abstract—In this paper, a microstrip combline bandpass filter (BPF) with a broad upper stopband performance is presented. The proposed filter is based on the design of a bandpass filter cascaded with a defected microstrip structure (DMS) bandstop filter. The bandstop characteristic is realized using T-shaped DMS at the external input and output coupling transformers. The measured and simulated electrical performances are in good agreement and demonstrate broad upper stopband bandwidth. The proposed filter is also compared with the characteristic of a conventionally designed filter to highlight the advantages of the proposed approach.

1. INTRODUCTION

Microwave bandpass filters (BPFs) are essential components in the development of wireless communication systems. The advanced performance of modern communication systems has imposed stringent requirements on filters including compact size, minimal insertion loss, low cost, and high selectivity. For those reasons, combline filters are good candidates [1]. Conventional bandpass filters with uniform microstrip resonators typically have a first spurious passband at a frequency around three times that of the fundamental passband center frequency [1]. This phenomenon is undesirable, especially for sensitive receivers where BPF with broad stopband is required to prevent leakage into the receiver band. In addition, combline filters usually provide Chebyshev or Butterworth characteristics with gradual rejection bands. Therefore, considerable efforts to improve the stopband performance of microstrip BPFs have been carried

Received 18 September 2012, Accepted 15 October 2012, Scheduled 16 October 2012
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out using suspended substrates with a dielectric overlay [2]. This technique increases the overall size of the RF module and may not be an option for specific configurations as in combline filters where typically chip capacitors are mounted on the top side of the substrate. Other attempts to suppress the undesired spurious passbands were by introducing geometrical perturbations to the uniform-impedance resonators in the coupling regions [3]. However, this approach provides limited stopband attenuation performance. For compact realization, defected ground structure (DGS) forming lowpass cleanup filters with wide stopband [4, 5] were utilized. Here, the DGS introduces wave leakage through the ground plane [6] and hence, high insertion loss is introduced.

In this paper, a solution to this problem is introduced by using a defected microstrip structure (DMS) bandstop filter [6, 7] which is realized by etching off specific patterns from the microstrip top side metallic plane. Such approach provides rejection of certain number of harmonics and enables realization of compact size components. Compared with DGS circuits, DMS is easily integrated with other microwave circuits, and has an effectively reduced circuit size. Furthermore, DMS structure is independent of the microstrip length (i.e., a fixed dimension DGS unit at high frequencies will behave differently when it is applied to two microstrip lines with different lengths) [6]. This property of DMS is advantageous in designing microstrip filters.

The objective of this article is to show that the proposed filter possess the desirable feature of compactness while achieving excellent upper stopband attenuation through the application of DMS on the filter's input and output feed lines.

2. FILTER IMPLEMENTATION

Figure 1(a) depicts the topology of a T-shaped DMS unit which consists of a horizontal and a vertical slot in the middle of a microstrip transmission line. Fig. 1(b) shows its equivalent lumped element circuit.

The equivalent circuit model of DGS in [5, 7] can be used to extract the equivalent circuit parameters of DMS. Thus, the inductance (L_S) and the capacitance (C_S) values of the circuit in Fig. 1(b) are given by

$$C_S = \frac{f_C}{Z_o g_1} \times \frac{1}{4\pi^2 (f_o^2 - f_C^2)} \tag{1}$$

and

$$L_S = \frac{1}{4\pi^2 f_o^2 C_S} \tag{2}$$

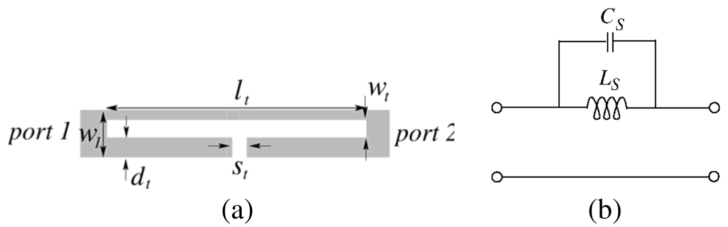

Figure 1. (a) Topology of a T-shaped DMS unit; and (b) its equivalent circuit model.

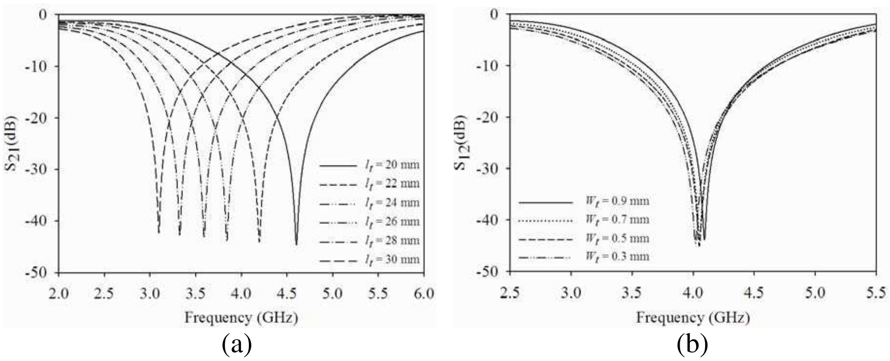

Figure 2. Simulated transmission coefficient (S_{21}) versus frequency by varying: (a) the DMS length (l_t); and (b) the DMS width (w_t).

where f_o is the resonance frequency of the parallel LC resonator represented by the attenuation pole location in Fig. 2, f_C the cutoff frequency, Z_o characteristic impedance of the microstrip line, and g_1 is given by the prototype value of the maximally flat-type low-pass filter.

Figure 3 shows the structure of a 2nd order microstrip combline filter integrated with two DMS units in a $50\,\Omega$ system. The proposed filter exhibits a Chebyshev characteristic to achieve high selectivity while maintaining low in-band insertion loss. External couplings consist of same sided transformers [8], which look like extra resonators at each end of the filter but without affecting the insertion loss function. This feed topology allows additional resonator lengths compared with direct tapping and is advantageous, especially at high frequencies where physical dimensions are small. Using step changes in the microstrip line impedance (i.e., the right-angle bend in the microstrip line between the $50\,\Omega$ line and the same sided transformer) can cause degradation in circuit performance. This is due to the introduced parasitic reactances which lead to spurious couplings, input

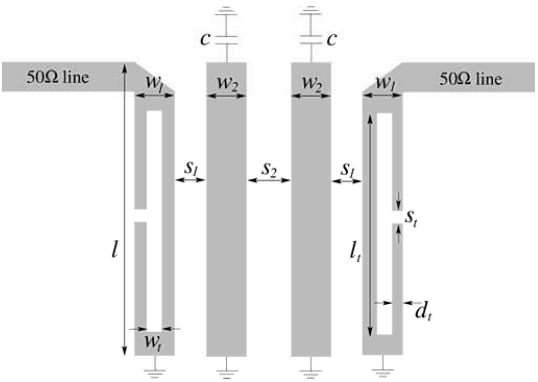

Figure 3. 2D layout of the integrated combline BPF with DMS bandstop filter.

and output mismatch, or an increase of the insertion loss level due to the undesirable radiation effects [9]. One way to minimize this phenomenon is by compensating the discontinuity through a mitred bend conductor as depicted in Fig. 3.

3. RESULTS AND DISCUSSIONS

Full-wave EM simulations have been carried out with the aid of ANSYS-HFSS† for demonstrating the DMS unit operation. An example of a single-pole DMS bandstop filter (Fig. 1(a)) was evaluated at 4 GHz. The structure is supported by a 0.8128 mm thick Roger's‡ (RO4003C) substrate with a dielectric constant of 3.55, a loss tangent of 0.0027, and a copper cladding thickness of 17 µm. The microstrip line and the input/output ports have 50 Ω characteristic impedances. From Fig. 2(a), it can be seen that for a given rejected center frequency, the bandwidth is a function of the slot width (W_t). Fig. 2(b) shows the variation of the S-parameter transmission coefficient (S_{21}) with frequency for different slot lengths (l_t). As anticipated, increasing the slot length leads to a negative shift in the resonant frequency. The proposed integrated BPF with DMS bandstop filters was designed using the substrate parameters provided in the previous DMS example and simulated leading to the following optimal dimensions: $C = 4.1\,\text{pF}$, $l = 16.8\,\text{mm}$, $W_1 = 3.2\,\text{mm}$, $W_2 = 2.26\,\text{mm}$, $S_1 = 0.29\,\text{mm}$, $S_2 = 4\,\text{mm}$, $W_t = 1.1$, $S_t = 0.5\,\text{mm}$, $l_t = 10.3\,\text{mm}$, $d_t = 0.5\,\text{mm}$. The simulated

† ANSYS High Frequency Structure Simulator (HFSS), ver. 13.0, 2011.

‡ http://www.rogerscorporation.com.

electrical performance without DMS units (i.e., conventional combline BPF response) is shown in Fig. 4(a). Fig. 4(b) shows the simulated performance with DMS and improved upper stopband superimposed with its measured performance. Both the evaluated and measured responses exhibit a passband center frequency at 1 GHz with a 2% fractional bandwidth as depicted in Fig. 4(c). It is clear that the width of the upper stopband has been widened in comparison to that of Fig. 4(a) by virtue of the DMS bandstop filter. A photograph of the fabricated combline BPF integrated with DMS bandstop filters is shown in Fig. 5.

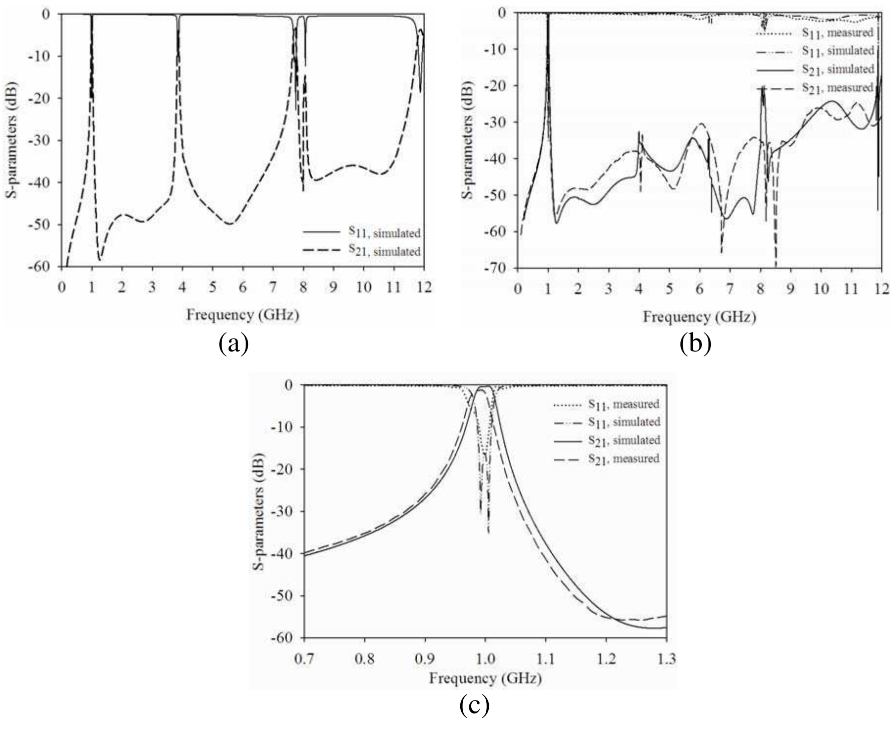

Figure 4. Electrical performance of the 2nd order combline BPF: (a) simulated performance without DMS; (b) measured and simulated performances with DMS; and (c) measured and simulated responses at a different frequency range.

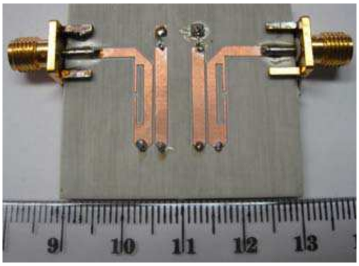

Figure 5. Photograph of the fabricated filter.

4. CONCLUSION

Harmonics suppression of a microstrip combline bandpass filter cascaded with T-shaped DMS bandstop filters has been introduced. The proposed filter is comprised of two combline resonators with two same sided external coupling transformers while the bandstop filter generated using T-shaped microstrip pattern etched within the bandpass filter's feed line area. The proposed filter has a passband center frequency of 1 GHz and a fractional bandwidth of 2%. The presented approach is validated by simulation and measurement that shows an excellent upper stopband improvement from 1 to 12 GHz with an average attenuation level of about 35 dB.

ACKNOWLEDGMENT

This work was supported by the National Science Foundation (NSF) in the form of the NSF Engineering Design and Innovation grant (No. 1000744).

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