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DESIGN OF DUAL-BAND BANDSTOP COPLANAR WAVEGUIDE FILTER USING UNIPLANAR SERIES-CONNECTED RESONATORS

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Abstract—This paper proposes a new design of coplanar waveguide dual-band bandstop filter (DBBSF) with center frequencies at 1.8 GHz and 2.8 GHz. A lumped element model of four series-connected parallel LC resonators are derived, then implemented using compact CPW resonators patterned in the center conductor. The measured and simulated responses are in good agreement which validates the design.

1. INTRODUCTION

The nonlinearity of power amplifiers (PAs) has attracted researchers worldwide to try to find solution to the problem of adjacent channel interference caused by this nonlinearity in communication systems. Several techniques have been used to linearize PAs, such as active biasing, feed forward, negative feedback, and predistortion [1]. Another technique to reduce the distortion at the output of power amplifiers is by using a low transmission loss band pass filter with sharp attenuation in the stopband. However, because the resonators of these band pass filters (BPF) resonate in the passband, they suffer from serious transmission loss due to the resistance of the resonators. They also suffer from group delay variation due to the steep phase change caused by the resonance [2].

To overcome this problem, a dual band bandstop filter (BSF), having reciprocal frequency characteristics of a BPF, may be used. To

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perform its goal of eliminating PA's distortion, the passband of the BSF should coincide with the passband of the BPF. However, as expected, the resonators in the BSF resonate in its stopband. Therefore, the loss in the passband of a BSF is less than the loss in the passband of BPF, which is required to minimize the power amplifier nonlinear distortion [2].

This paper proposes a new design of dual-band band stop filter (DBBSF) using coplanar waveguide (CPW) technology. Coplanar waveguide (CPW) enjoys several attractive features over microstrip in term of easier integration with active and passive elements and avoiding the via holes.

The design starts from the lumped element model of a Chebyshev low pass filter which is then subjected to two successive frequency transformations to yield the lumped element model of a DBBSF consisting of four series connected parallel LC resonators [2]. These LC resonators are then implemented using CPW transmission line resonators patterned in the center conductor [3].

Section 2 briefly outlines the design methodology and shows the proposed filter lumped and distributed element topologies. Section 3 provides numerical and experimental results for the scattering parameters of this filter. Section 4 discusses the results, and Section 5 provides the conclusions.

2. DESIGN EXAMPLE OF A CPW DUAL-BAND BANDSTOP FILTER

A new design of CPW dual band bandstop filter (DBBSF) with center frequencies at 1.8 and 2.8 GHz, and having a passband ripple of 0.01 dB, is presented in this section. The fractional bandwidths of the first and second bands of the DBBSF are 11.76%, and 7.4%, respectively.

The design is based on the technique developed in [2] in which a lumped element model of four series-connected parallel LC resonators is derived from the prototype of a Chebyshev low pass filter (LPF) after two successive frequency transformations [2]. Our paper then implements the DBBSF filter model using compact CPW transmission line resonators patterned in the center conductor [3].

Using the expressions developed in [2], and for the above design specifications, the values of the lumped elements of the series-connected parallel resonators of the DBBSF (see Figure 1) are shown in Table 1. For definition of these parameters refer to Figure 4 in [2].

Figure 1 shows our DBBSF implemented on Ansoft designer [4] with its lumped element values given in Table 1.

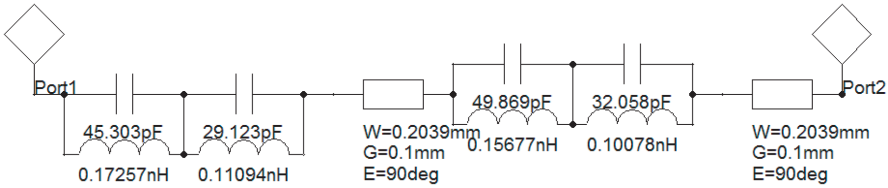


Figure 1. DBBSF using series-connected parallel-resonant circuits with its lumped elements values calculated at 1.8–2.8 GHz.

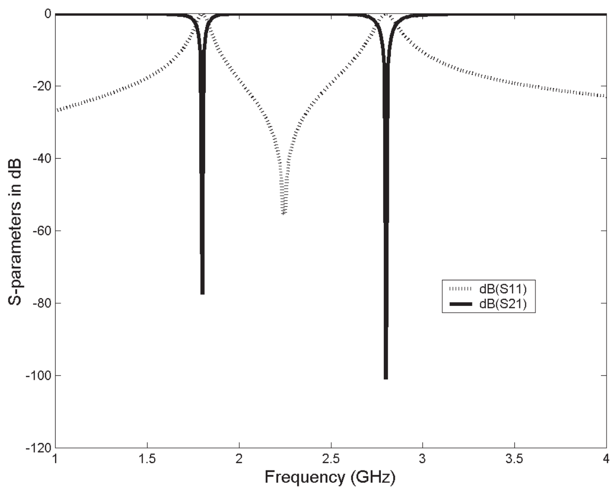


Figure 2. The simulated response of the dual-band bandstop lumped element filter of Figure 1, centered at 1.8–2.8 GHz using Ansoft designer.

Table 1. The lumped element values of the series connected parallel resonator circuit (see Figure 4 in [2]) with center band frequencies at 1.8–2.8 GHz.

$C_{a1} = 4.5303 \times 10^{-11}$ F	$L_{a1} = 1.7257 \times 10^{-10}$ H
$C_{a2} = 2.9123 \times 10^{-11}$ F	$L_{a2} = 1.1094 \times 10^{-10}$ H
$C_{b1} = 4.9869 \times 10^{-11}$ F	$L_{b1} = 1.5677 \times 10^{-10}$ H
$C_{b2} = 3.2058 \times 10^{-11}$ F	$L_{b2} = 1.0078 \times 10^{-10}$ H

Figure 2 shows the scattering parameters of the DBBSF lumped element model of Figure 1, obtained using the circuit simulator of Ansoft designer [4]. This simulator ignores the coupling between the different elements of the circuit and therefore gives an idealized response, as shown in Figure 2.

To design this filter, each parallel resonator in Figure 1 is designed separately. The exact response of each resonator is obtained using the circuit simulator of Ansoft designer software using the values of L and C (from Table 1). The CPW circuit realization of the parallel LC resonator, as proposed in [3], is simulated using IE3D [5]. Next, the IE3D built-in optimizer is used to modify the dimensions of the CPW circuit to closely fit the S-parameters of Ansoft designer.

In general, our circuit simulations have shown that S_{21} reaches low values (< -30 dB) at the resonant frequency of 1.8 GHz for the first and third resonators (from left) in Figure 1, while S_{21} reaches low values (< -30 dB) at the resonant frequency of 2.8 GHz for the second and fourth resonators. S_{11}, on the other hand, is flat across the rejection band. Therefore, we chose S_{21} as our optimization objective function in IE3D. Each resonant circuit is optimized using three optimization schemes, Powell, Genetic algorithm, and adaptive EM optimizer; and finally we chose the optimized structure that gives the closest S-parameters response to the one obtained using Ansoft designer.

From our numerical experiments we found that the Powell optimization scheme using 100 iterations gives the closest response to the lumped element response obtained from Ansoft Designer.

Figure 3 shows the configuration of our dual-band bandstop filter with center band frequencies at 1.8–2.8 GHz on alumina substrate with a relative dielectric constant of 9.5, loss tangent of 0.0004, and dielectric substrate thickness of 0.76 mm.

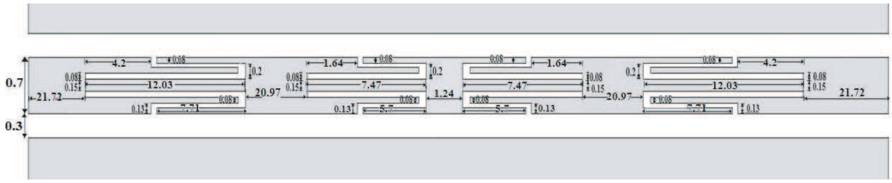


Figure 3. DBBSF layout (center bands frequencies of 1.8–2.8 GHz) with series-connected parallel LC resonators (relative dielectric constant of 9.5, loss tangent of 0.0004, and dielectric thickness of 0.76 mm).

3. EXPERIMENTAL AND EM SIMULATION RESULTS

The DBBSF of Figure 3 was fabricated using typical IC fabrication techniques on a CoorsTek ADS-96R alumina substrate. The substrate has a dielectric constant of 9.5, a loss tangent of 0.0004, and a thickness of 0.76 mm. A Vesco E-Beam evaporator was used to deposit 4 μm of Au on the substrate and photolithography and an etch-back process were preformed to define the filter pattern. SMA connectors were soldered onto the CPW feed lines to facilitate the measurement. The filter was characterized on Agilent's PNA E8364B Series Network Analyzer and a HP 85052B 3.5 mm calibration kit was used to calibrate the system to the SMA connectors. A photograph of the measured filter is shown in Figure 4.

4. DISCUSSION OF RESULTS

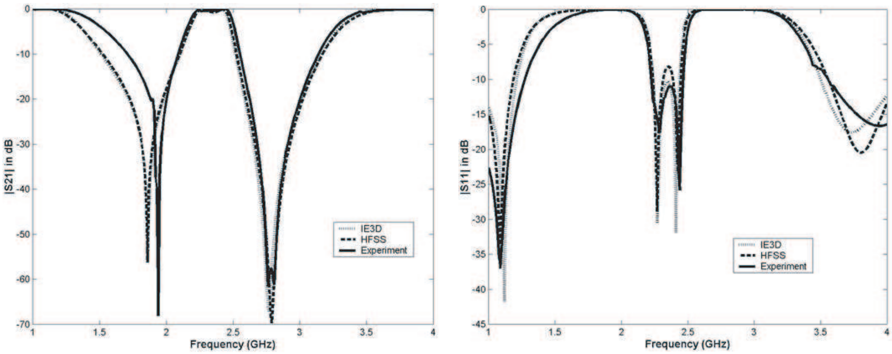
Figures 5(a), (b) show the simulated characteristics of the filter, using IE3D [5] and HFSS [6], as compared to the measured response. Very good agreement is obtained between simulations and measurement. The shift in the resonant frequency of the experimental results in Figure 5 around 1.8 GHz may be due to measurement tolerances. It can be seen that there are two transmissions zeroes at around 1.8 and 2.8 GHz with high attenuation rates close to passband of the filter.

(a) (b)

Figure 4. Photograph of the measured CPW DBBSF. (a) Top overall view. (b) Detailed (expanded) view.

Table 2. The characteristics of the DBBS filter shown in Figure 3 obtained from IE3D response in Figure 5.

band / criteria	The first band centered at 1.8 GHz	The second band centered at 2.8 GHz
Return loss	0.02 dB	0.028 dB
Insertion loss	55 dB	60 dB
Q-factor	2.09	3.2
3-dB bandwidth	860 MHz	865 MHz



(a) (b)

Figure 5. Simulated and measured responses of the dual-band bandstop filter centered at 1.8–2.8 GHz. (a) $|S_{21}|$, (b) $|S_{11}|$ in dB.

Table 2 shows the characteristics of the filter obtained from the EM simulations. We believe that the difference in the response between the lumped element model (Figure 1) and the distributed one (Figure 3) is due to the discontinuity effects, coupling effects, conductor losses, dielectric losses and radiation losses.

5. CONCLUSIONS

This paper presents a new design of dual band-bandstop filter using CPW technology. This design uses series-connected parallel LC resonators patterned in the center conductor of CPW. A complete design procedure is presented, and the simulations obtained using IE3D and HFSS show very good agreement with measurement. They also show a good bandpass response with sharp attenuation besides the passband which validates our utilization of the series-connected parallel LC resonators in realizing this kind of filters.

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