Analysis and Circuit Modeling Method for Defected Microstrip Structure in Planar Transmission Lines

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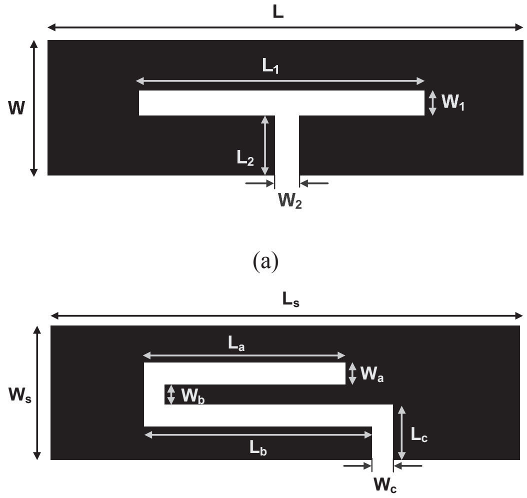
***Abstract*—In this paper a new G-type defected microstrip structure (DMS) is proposed and its frequency response characteristics are analyzed. It also presents a novel method to extract circuit model for modified planar DMS transmission line which exhibits the dual-bandstop characteristics in the frequency response. The proposed equivalent circuit consists of lumped elements that easily extracted from the full-wave electromagnetic (EM) simulations. It is simple and accurate circuit modeling of proposed DMS over a broad bandwidth. The proposed modeling method was verified by a good agreement between simulation and measurements results.**

***Index Terms* — Circuit modeling, defected microstrip structure (DMS), multi-stop bands characteristics.**

I. Introduction

In recent years, there has been a growing interest for studying planar microstrip structures combined with perturbation or modified ground structure such as defected ground structure (DGS), photonic bandgap (PBG). The DGS is realized by etching the specific patterns such as dumb-bell shape, spiral shape and so on in the ground plane which provides the band rejection frequency characteristics due to change in equivalent inductance and capacitance of transmission line. Both DGS and PBG have been very effectively used to improve the performances of various microwave circuits such as power amplifiers, filters, antennas and so on [1]-[5].

On the basis of DGS, the modified planar transmission line with the DMS is proposed which can be realized by etching T-type slot on the signal pattern of microstrip line. The slot on microstrip line disturbs current distribution on strip and presents the stopband characteristics in the frequency response. As like DGS, the DMS also has been applied to improve performances of microwave circuits such as harmonic termination networks in power amplifier [6], filters [7] [8], antennas [9] etc. Novel types of compact filtering devices can also be designed based on periodic or non periodic DMS [10].



(b)

Fig. 1 Structure of defected microstrip structure (a) conventional T-type, and (b) proposed G-type.

However, a direct optimum design of DMS array using full-wave EM simulation is really a time-consuming process. In this case, the optimization based on an equivalent circuit of the device is highly desirable. To solve this problem, the key issue to obtain a simple and accurate model of unit cells of DMS. A lumped element circuit model has been reported to model transmission line with DMS [11]. However, the reported model provides the equivalent circuit of DMS with only single bandgap characteristics. On other hand, very limited research on its equivalent circuit model has been studied.

In this paper, a new G-type DMS is proposed. The proposed DMS is analyzed in detail. Moreover, a more general circuit model that is able to represent dual-bandgap characteristics of DMS in planar transmission is demonstrated.

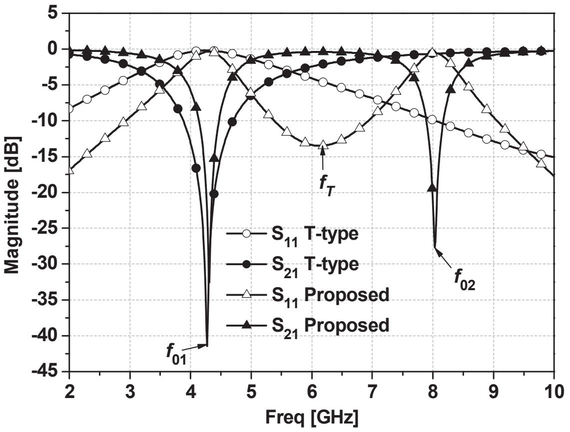


Fig. 2. Simulated frequency response characteristics of conventional T-type and proposed structure.

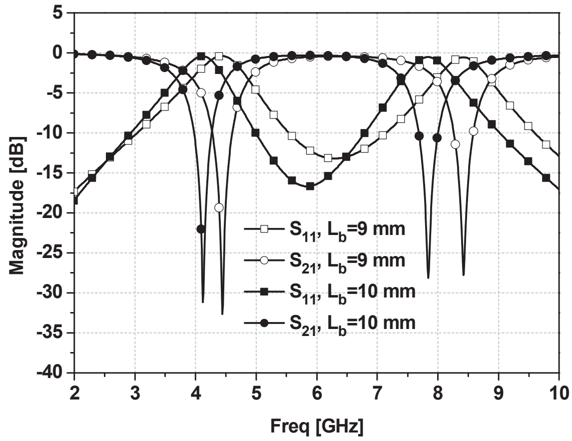


Fig. 3. Simulated frequency response of proposed structure for different lengths of L_b.

II. Characteristics of Proposed Defected Microstrip Structure

Schematic view of a conventional T-type DMS is shown in Fig. 1 (a). The configuration of DMS is described by a slit height L_2 and a width W_2 perpendicular to strip, and a slot length L_1 and the width W_1 along the strip. In general, the slot gap provides capacitive effects while a narrow microstrip line exhibits inductive effect. Thus, giving desirable frequency operation and effects on frequency response such as bandstop characteristics, increase in slow-factor, etc. Furthermore, a new proposed G-type DMS is shown in Fig. 1(b) whose physical parameters are shown figure. To compare the performances of conventional and proposed DMS, a substrate material with dielectric constant (ε_r) of 2.2 and height of 31 mils of RT/Duroid 5880 of Rogers Corporation is used. The parameters of DMS are $W=W_s=2.7$, $L=L_s=30$, $L_1= 17.6$, $W_1=0.4$, $W_2=W_C=0.3$, $L_2=1$, $L_a=8.6$, $L_b=9$, $L_c=0.8$, $W_a= 0.4$, and $W_b=0.3$ mm, respectively.

The simulation was done using HFSS v.11 of Ansoft and the frequency response characteristics is shown in Fig. 2.

Table I
Frequency response values for different values of L_b

	L_b=9 mm	L_b=10 mm
f_{01} (GHz)	4.44	4.12
f_{02} (GHz)	8.42	7.84
f_T (GHz)	6.31	5.84
Δ_{3dB_f01} (GHz)	0.99	0.85
Δ_{3dB_f02} (GHz)	0.97	0.95

As can be seen from Fig. 2, the conventional structure has single resonant frequency characteristic while the new proposed structure has a dual-resonant characteristic.

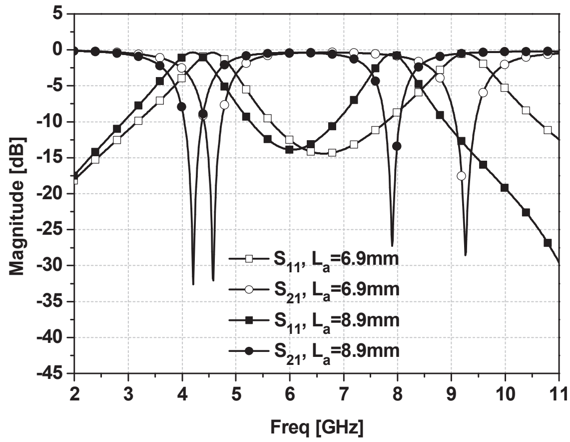


Fig. 4. Simulated frequency response of proposed structure for different lengths of L_a.

Table II
Frequency response values for different values of L_a

	L_a=6.9 mm	L_a=8.9 mm
f_{01} (GHz)	4.57	4.30
f_{02} (GHz)	9.26	8.03
f_T (GHz)	6.65	6.06
Δ_{3dB_f01} (GHz)	0.97	0.98
Δ_{3dB_f02} (GHz)	1.13	0.85

To analyze the new proposed structure deeply, the effect of structural parameters, the unit size L_b, and L_a are analyzed in detail keeping other parameters same as above. Fig. 3 shows simulated frequency response characteristics as a function of unit size L_b.

In Fig. 4, the simulated frequency response characteristics as the function of unit size L_a are plotted. The effect of structure parameters are summarized in Table I and Table II and concluded as.

1. As the unit size L_b increased, the first resonant frequency is shifted down slowly where as the second resonant frequency shifted faster toward to lower frequencies.
2. Similarly, as the unit size L_a increased, the first resonant and second resonant frequencies moves toward the lower frequencies.

III. Circuit Model

Fig. 2 shows the typical frequency response of proposed DMS where f_{01} and f_{02} are the first and second resonant frequencies, respectively and f_T denotes a transit frequency. Considering dual-bandstop characteristics of the new G-type DMS, the proposed circuit model is shown in Fig. 5. Thus, a unit cell G-type DMS is modeled by two LC resonators *i.e.* L_{ps1} and C_{ps1}, L_{ps2}, and C_{ps2}, in interconnection with T-network consisting of C_p, L_{s1} and L_{s2}. The T-network is essential to represent the interaction between two resonators. Below the transit frequency f_T, the first resonator dominates the frequency characteristics whereas the second resonator is dominant for the frequency above the f_T.

The following data are required to extract lumped elements of the proposed circuit model and can be easily found from the EM simulations: f_{o1}, f_{02}, f_T, $_{3dB\text{-}fo1}$ (the 3-dB bandwidth at f_{o1}), $_{3dB\text{-}fo2}$ (the 3-dB bandwidth at f_{o2}), X_{11}, X_{22}, and X_{21}, which are the imaginary parts of three Z-parameters at f_T. The elements values of LC-parallel resonators can be derived from transmission parameter, i.e. S_{21} of individual two-port resonator network when S_{21} is expressed in terms of the admittance of resonator, which is given as.

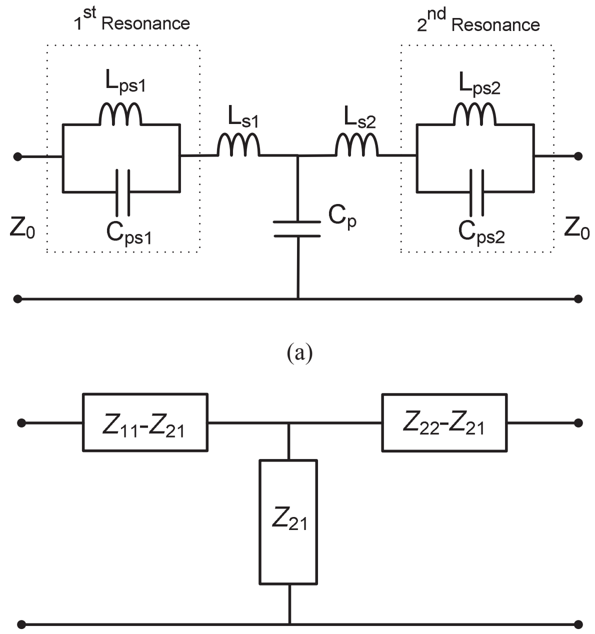
$$C_{psi} = \frac{1}{4\pi Z_0 \Delta_{3dB\_f_{0i}}} \quad \text{for } i = 1,2 \tag{1}$$

$$L_{psi} = \frac{1}{(2\pi f_{0i})^2 C_{psi}} \quad \text{for } i = 1,2 \tag{2}$$

Where Z_0 is characteristic impedance of the network port. The remaining parameters of circuit model can be found by matching Z-parameters of the two ports T-network of Fig. 5 (a) and (b), which is given as.

$$C_p = -\frac{1}{2\pi f_T X_{21}} \tag{3}$$

$$L_{si} = \frac{X_{ii} - X_{21}}{2\pi f_T} + \frac{L_{psi}}{\left(\frac{f_T}{f_{0i}}\right)^2 - 1} \quad \text{for } i = 1,2 \tag{4}$$



(a)

(b)

Fig. 5. (a) Proposed equivalent circuit model of DMS, and (b) Z-parameters of T-network.

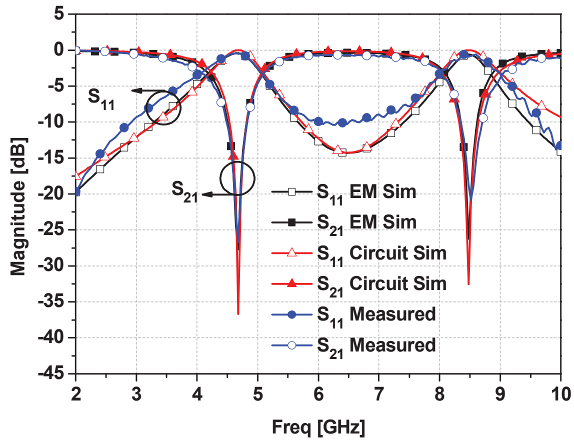


Fig. 6. Simulation and Measurement results.

IV. Modeling Results

To show the validity of proposed circuit model, new DMS is simulated with following physical parameters: L_a=7.9, L_b=8.6, L_c=0.8, L_s=30, W_a=0.4, W_b=0.3, W_c=0.3, and W_s=2.7 mm, respectively. The characteristic impedance at reference planes are 50 . The circuit parameter extracted from EM simulations are C_{ps1}=1.7299 pF, L_{ps1}=0.6685 nH, C_{ps2}=1.9894 pF, L_{sp2}=0.1771 nH, C_p=0.136 pF, L_{s1}=-0.0845 nH, and L_{s2}=0.4945 nH, respectively. Note that negative value of L_{s1} is perfectly allowed for the circuit modeling.

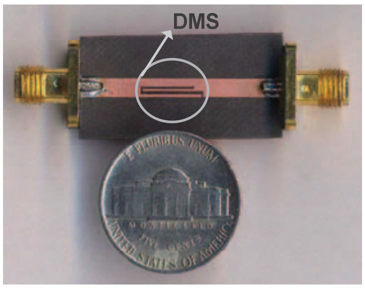


Fig. 7. The photograph of the fabricated defected microstrip structure transmission line.

This is similar to a lumped element inverter with negative elements in which physically may be observed by the adjacent reactance components [12].

The comparison between circuit modeled, full-wave EM simulated and measured results is shown in Fig. 6. Excellent agreement between them can be observed. The photograph of fabricated modified transmission line with DMS is shown in Fig. 7.

V. Conclusion

In this paper, a new type defected microstrip structure has been proposed. Its bandstop characteristics are discussed and can be adjusted by changing the dimension of defected microstrip structure. A circuit model of modified planar transmission line with new type defected microstrip structure which exhibit dual-bandstop characteristics have been proposed and verified by measurement results. It is simple and accurate modeling over broad-band and its element values can easily be extracted from full-wave EM simulation. It is expected that proposed defected microstrip structure will be applicable for designing dual-band microwave components such as dual-band rejection filters and so on.

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