ISSN 2320 - 2599
Volume 6, No. 3, May - June 2017
International Journal of Microwaves Applications
Available Online at http://www.warse.org/IJMA/static/pdf/file/ijma01632017.pdf

A Modified E-Shaped Defected Ground Structure

Shujun Yang
Department of Electrical Engineering and Computer Science
Alabama A&M University, Huntsville, AL 35810, USA

ABSTRACT

The center ground line in an E-shaped defected ground structure (DGS) is bended to form a new DGS. Simulation of the proposed DGS shows a lower resonant frequency and hence a potential size reduction effect. Extraction of effective circuit parameters shows this DGS also has the potential to increase the resonance quality factor.

Key words: DGS, resonance frequency, effective inductance, effective capacitance, quality factor.

1. INTRODUCTION

Microstrip with DGS etched in the metal ground plane has bandstop properties. Bandstop DGS structures can be divided into electromagnetic bandgap (EBG) structures and banstop resonators. EBG structures generate wide stopbands with high attenuations at the cost of large circuit sizes. Bandstop resonators generate narrow stopbands with smaller circuit sizes. DGS resonators are widely used in bandstop filters, lowpass filters, tunable resonators, amplifiers and antennas [1, 2]. The dumbbell-shaped DGS is one kind of such bandstop resonators. It has a simple structure [3], but it is not suitable for narrow band applications due to its poor resonance quality factor [4].

To overcome the problems of the dumbbell-shaped DGS, researchers have proposed T-shaped and E-shaped DGS for circuit size reduction and quality factor improvement [5, 6]. In this paper, a modified E-shaped DGS is proposed. This DGS is simulated on Sonnet Suit. Sonnet Suite is a planar 3D EM simulation software being widely used by many researchers [7]. Simulations show the proposed DGS has potentials to reduce the circuit size and to increase the quality factor.

2. E-SHAPED DEFECTED GROUND STRUCTURE

The E-shaped DGS was proposed from a T-shaped DGS for size reduction purpose [4]. Figure 1 shows the structure of a T-shaped DGS with main dimensions. This kind of DGS is based on Dumbbell-shaped DGS. In this structure, the coupling gap in the Dumbbell-shaped DGS is pushed to the edge of the etched pattern, and two long arms are attached to the center ground line to form a lengthened slot. This lengthened slot increases the distributed capacitance and decreases the resonance frequency.

The circuit substrate material is Rogers TMM10i with a relative dielectric constant of 9.8 and a loss tangent of 0.002. The thickness of the substrate is 1.27 mm. The back of the substrate is the ground plane with DGS. The width of the microstrip on the top layer is 1.20 mm, which yields a characteristic impedance of 50 Ohm.

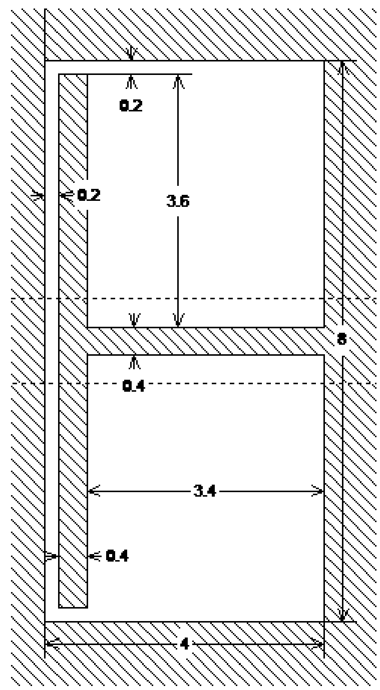

Figure 1: Layout of a T-shaped DGS with mm as the unit

The E-shaped DGS is based on the T-shaped DGS. Figure 2 shows the structure of an E-shaped DGS with additional dimensions labeled. The long slot is further extended to the edges of the structure to increase the distributed capacitance.

The T-shaped DGS and the E-shaped DGS are simulated on Sonnet Suite 14.52, and simulation results are shown in Figure 3. The resonant frequencies are 2.52 GHz and 1.94 GHz for the two DGSs. Since the E-shaped GDS has lower resonance frequency with the same circuit size, and hence it has the potential size reduction capability.

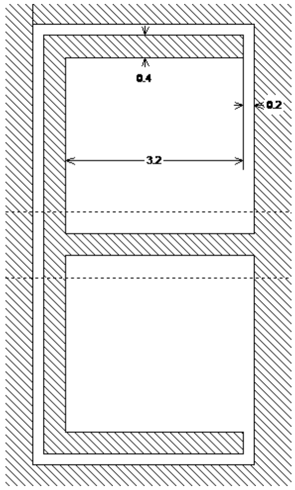

Figure 2: Layout of an E-shaped DGS with additional dimensions

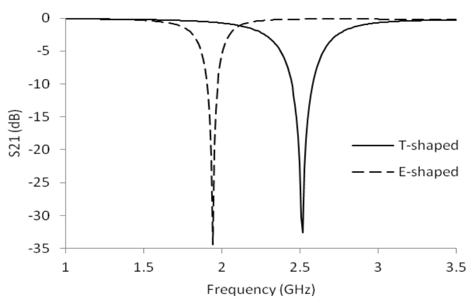

Figure 3: Simulation results of the T-shaped and E-shaped DGSs

3. PROPOSED DEFECTED GROUND STRUCTURE

To further decrease the resonance frequency of the E-shaped DGS, a modified E-shaped DGS is proposed here. This DGS structure is shown in Figure 4 with new dimensions labeled. The center ground line is bended and extended. This DGS is also simulated on Sonnet Suite 14.52, and simulation results are shown in Figure 5. The resonance frequency is at 1.59 GHz, which is lower than that of the E-shaped DGS. Hence the proposed DGS can decrease the circuit size further.

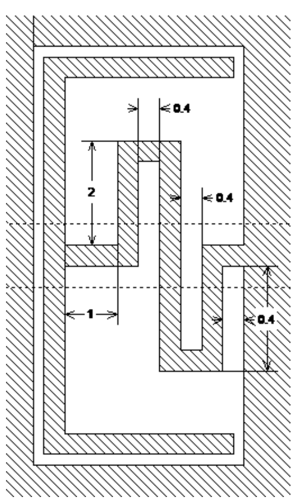

Figure 4: Proposed DGS with additional dimensions labeled

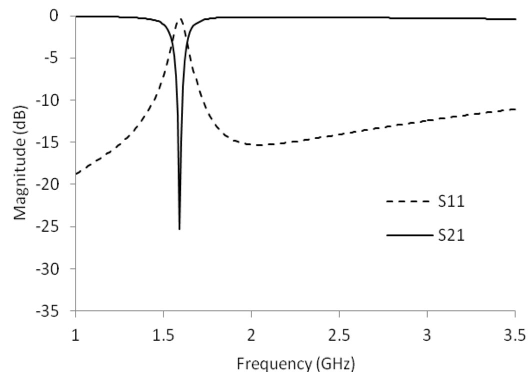

Figure 5: Simulation results of the proposed DGS

The effective LC parameters of the three DGSs are extracted as [6]:

$$C = \frac{\omega_c}{2Z_0\left(\omega_0^2 - \omega_c^2\right)} \quad (1)$$

$$L = \frac{1}{\omega_0^2 C} \quad (2)$$

where ω_c and ω_0 are the cutoff frequency and the center frequency, and Z_0 is the characteristic impedance of the transmission line on the top layer. The results are summarized in Table 1. From T-shaped DGS to E-shaped DGS, the effective capacitance increases from 3.62 pF to 7.02 pF as expected. From the E-shaped DGS to proposed DGS, the effective inductance decreases from 0.958 nH to 0.510 nH, and the effective capacitance increases from 7.02 pF to 19.6 pF dramatically. The bended center ground line increases the effective capacitance and decreases the effective inductance. This capacitance effect of the center ground line should come from coupling between the neighboring vertical ground lines. Since proposed DGS increases the effective capacitance and decreases the effective inductance, it has the potential to increase the resonance quality factor, which is proportional to $\sqrt{C/L}$ [6].

Table 1: Effective inductances and capacitances for three DGSs

DGS	Inductance (nH)	Capacitance (pF)	Resonant frequency (GHz)
T-shaped	1.1	3.62	2.52
E-shaped	0.958	7.02	1.94
Proposed	0.51	**19.6**	1.59

4. SUMMARY

The center ground line of the E-shaped DGS is bended and extended to form a novel DGS. The proposed DGS is simulated on Sonnet Suite. Simulations show the lower resonance frequency and hence the potential effect on size reduction. Since the proposed DGS increases the effective capacitance and decreases the effective inductance, it also has the potential to increase the resonance quality factor.

ACKNOWLEDGEMENT

The author would like to thank Dr. Montgomery, Dr. Scott, Dr. Heidary and Mr. Pryor for their assistance. This work was mainly supported by USA NSF through a grant 1255441.

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