ICIC Express Letters
Part B: Applications
Volume **8**, Number **2**, February **2017**
ICIC International ©2017 ISSN 2185-2766
pp. **437–441**

A NOVEL EQUIVALENT CIRCUIT FOR CIRCLE DEFECTED GROUND STRUCTURE AND ITS APPLICATION TO BANDPASS FILTER

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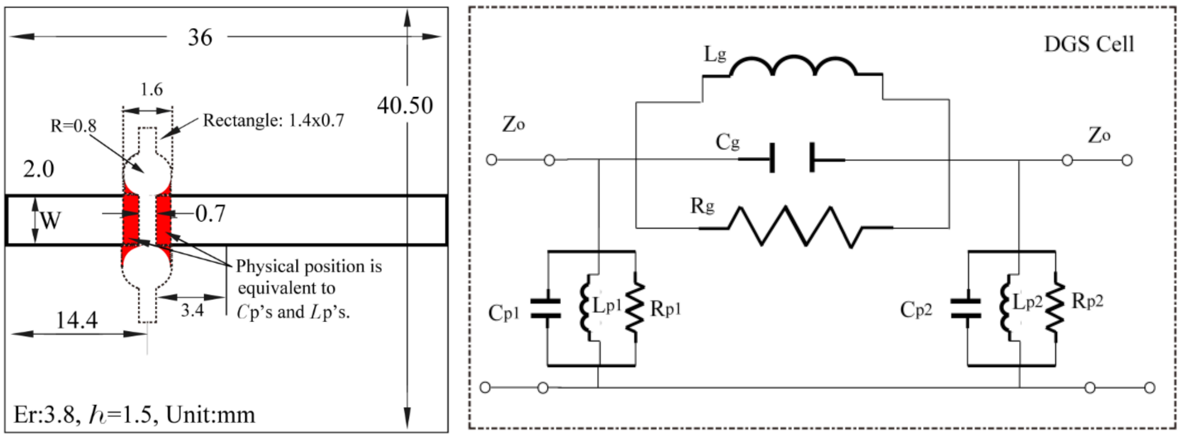
Received July 2016; accepted October 2016

Abstract. *In this paper, a dual band band-pass filter (BPF) with circle of defected ground structure (C-DGS) for wireless communications is proposed. This C-DGS is completely analyzed and its design equations are provided using transmission line theory. The novel equivalent circuit of C-DGS is employed to improve the attenuation performance in the stop band and generate a strong coupling improving the pass-band property of the I/O lines. The proposed DGS behaves as a resonant element, which allows for size compactness and high harmonic suppressions in the reject-band. The BPF with four unit cells DGS is fabricated and its measured S-parameters are shown to be in good agreement with those based on transmission line theory and EM simulation.*
Keywords: Tapped-line, Band-pass filter, Circle of defected ground structure (C-DGS)

1. **Introduction.** The conventional parallel coupled-line filter is widely used in many microwave and millimeter wave systems or subsystems. The traditional design of parallel-coupled microstrip filters suffers from the spurious response at twice the passband frequency, which causes passband response to be asymmetric, reduces the width of the upper stopband, and could greatly limit their applications. Recently, defect ground structures (DGS) etched off defected patterns from the ground planes have provided a wide rejection band in some frequency ranges [1]. DGSs with the characteristics of wide stopband and compact size are available to many circuits such as filters, power dividers, directional couplers and power amplifiers [2-4].

In general, DGS consists of narrow and wide etched shapes in the backside metallic ground plane, which changes the effective relative permittivity of substrate and increases the effective capacitance and inductance of the transmission line. It provides the rejection of some frequency bands, which can be called bandgap or stopband effect [5]. A DGS can be equivalent by three types of equivalent circuits [6]: (1) LC and LCR equivalent circuits, (2) π shaped equivalent circuit, (3) quasi-static equivalent circuit. The LC and LCR equivalent circuits are the most widely used [7].

In this paper, we first newly proposed a more accurate equivalent circuit model compared with the reported equivalent circuit of C-DGS. Furthermore, the extraction method of equivalent circuit parameters has also been derived. Demonstrating several simulations and comparisons on C-DGS circuits shows the validity of the proposed equivalent circuit model and modeling method. And then, we design a dual band coupled-line filter (2.45GHz/5.25GHz) which contains two C-DGS etching below the ground plane. The proposed filter has a small size and exhibits good performance. And the results are verified by experiments.



(a) (b)

FIGURE 1. (a) Schematic for C-DGS unit section with $R = 0.8$; (b) the newly proposed equivalent circuit

2. **Circle Defected Ground Structure.** Figure 1(a) shows the three dimensional view of the proposed dual band filter with C-DGS. It consists of two circles (radius R), two narrow connecting slot and a gaps etched areas in backside metallic ground plane. The dimension of CDGS is also shown in Figure 1(a). The mirostrip line width is chosen for 50Ω impedance offering impedance matching at both defined input and output ports. The PCboard with a relative dielectric constant of 3.8 and thickness of $h = 1.5$mm is used as the substrate of the structure. The PCboard size is 36×40.5mm^2. Figure 1(b) shows the newly proposed equivalent circuit. The proposed equivalent circuit includes the parallel inductance L_p and capacitance C_p that are due to the relatively fringing field at the discontinuity plane on metallic ground surface. Following the work of Ahn et al., we can obtain the equivalent circuit parameters L_g, C_g and R_g. By circuit and microwave theory, the equivalent circuit parameters L_p, C_p of the red section in Figure 1(a) can be expressed in the following equations:

$$\omega C_p = \frac{\cos\theta}{Z_C} \tag{1}$$

$$L_p = \frac{1}{\omega_0^2 C_p} \tag{2}$$

where θ denotes the electrical length of the shortened transmission line, ω is the angular frequency, ω_0 is the 3dB cutoff angular frequency, and Z_C is the characteristic impedance of the microstrip line. Accuracy of the extracted parameters of a circuit model is checked by comparing the response obtained from the circuit model (Agilent Advanced Design System, ADS 2009) and also from the EM-Simulator (Ansoft HFSS 11.0). The S-parameters calculated by ADS and calculated by HFSS were both shown in Figure 2. Through theoretical analysis and circuit simulation, it shows that DGS has the feature of one-pole low pass, slow wave and high characteristic impedance, which is only etched in the metal ground without additional size. These features can be used to miniaturize the circuit. So DGS is a new technique used to reduce the size of microwave planar circuits.

3. **Design of the Dual Band SIR Filter.** A coupled-line SIR bandpass filter with two C-DGS sections located on the backside metallic ground plane is designed. The C-DGS sections can be replaced with parallel resonators, which can provide cutoff frequency and attention pole. The filter is subdivided into cascaded subnetworks which shows the fabricated C-DGS with an SIR dual band filter. We applied the new C-DGS equivalent circuit to dual band SIR BPF design. In order to decrease the attenuation in the passband,

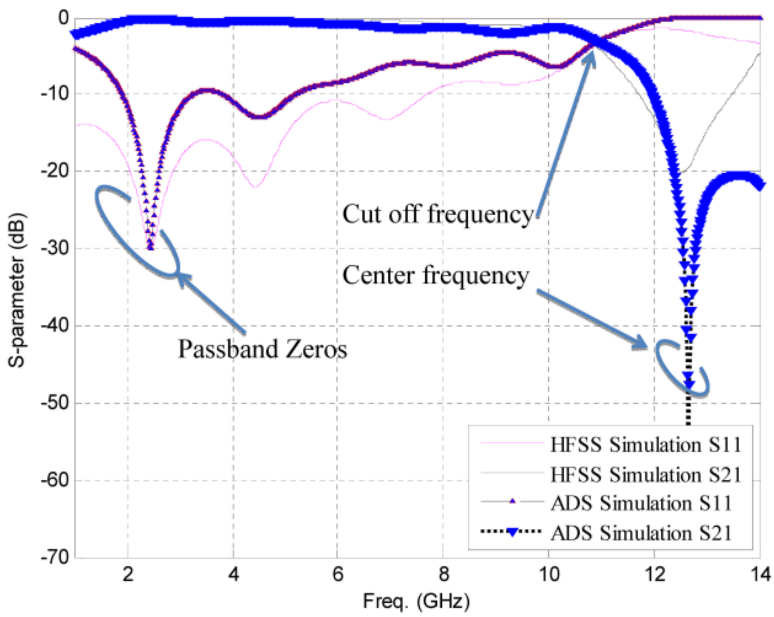


FIGURE 2. S-parameters comparison of HFSS and ADS simulation results

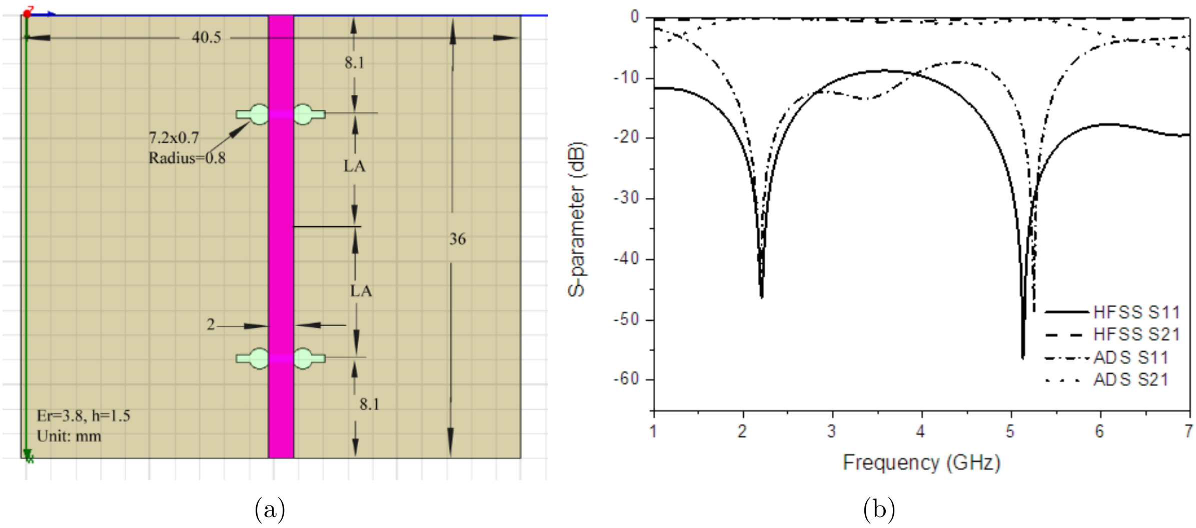


FIGURE 3. (a) Schematic view of two C-DGS's units; (b) HFSS and ADS simulation

we adjust the distance (L_A) of two C-DGS units to get an optimum response in 2.45GHz and 5.25GHz as shown Figure 3(a) and Figure 3(b).

The filters were fabricated on a PCboard substrate with relative permittivity of 3.8 as shown in Figure 4 and Figure 5. The EM solver HFSS is used for simulation and fine-tuning. The simulations of SIR dual band filters with C-DGS are shown in Figure 6(a). Furthermore, Figure 6(b) shows its measured results by Agilent E5071B vector network analyzer. For the dual band filter with C-DGS, the first passband with a center frequency of 2.45GHz has 1.6dB of insertion loss and approximately 30dB of return loss. The second passband with a center frequency of 5.25GHz has 3.4dB of insertion loss and approximately 16dB return loss. Measurement shows good agreement with simulations on the optimized C-DGS and dual band SIR PBF which operate dual frequencies 2.45GHz and 5.25GHz for use in WLAN application.

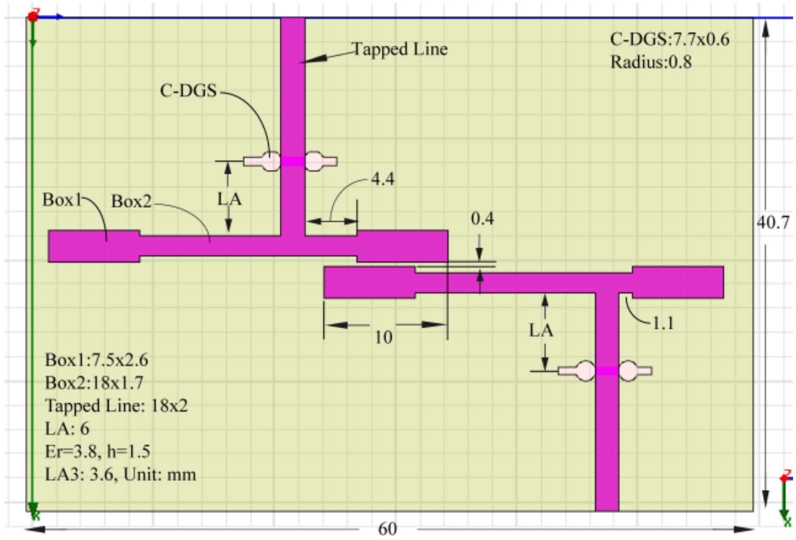
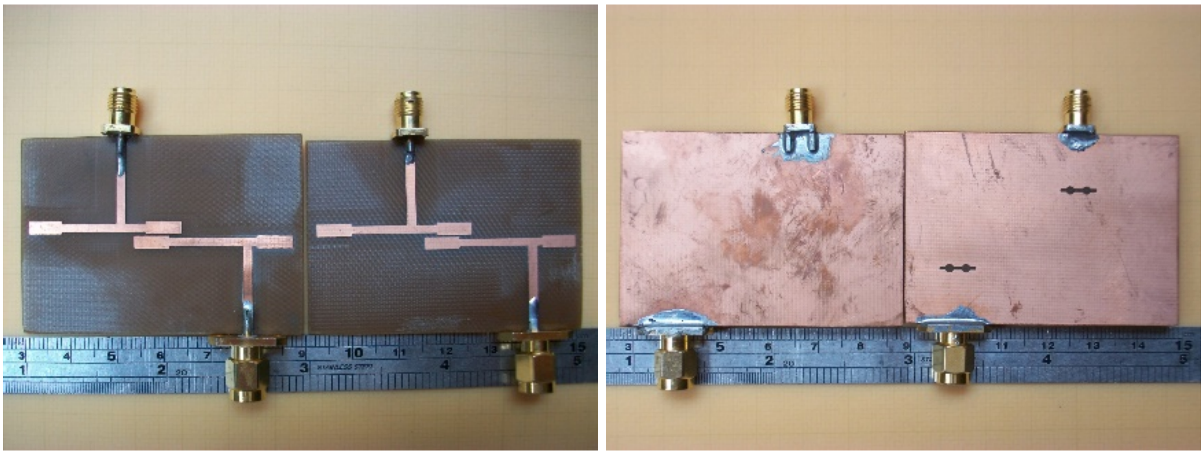
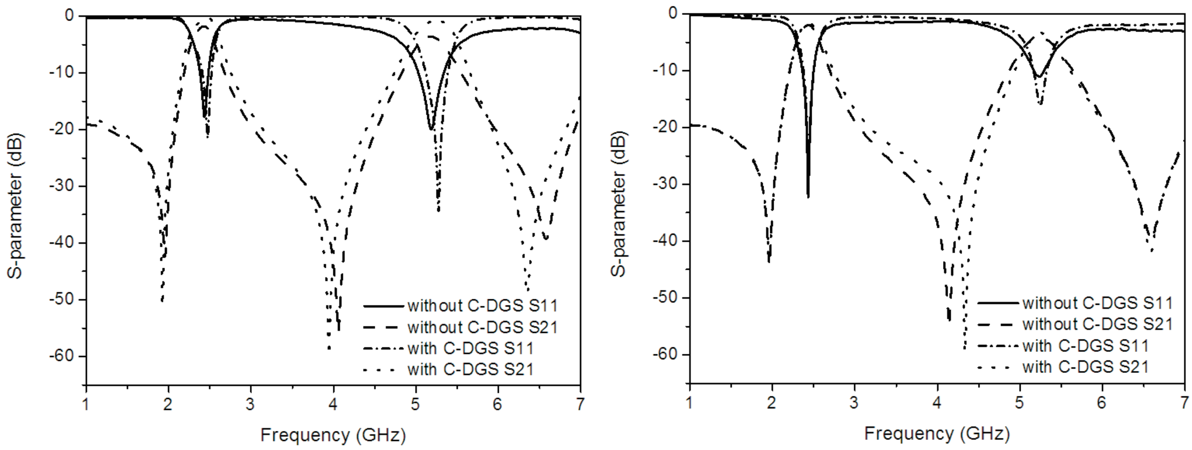


FIGURE 4. Top view of the investigated defected ground structure



(a) (b)

FIGURE 5. Photograph of the SIR bandpass filter with/without C-DGS: (a) top view, (b) bottom view



(a) (b)

FIGURE 6. (a) Simulations on the designed SIR BPF with and without C-DGS; (b) measurement on the designed SIR BPF with and without C-DGS

4. **Conclusion.** In this paper, an SIR band pass filter has been designed by using tapped-line coupled with a defect in the ground plane. The improved equivalent circuit parameters extraction method for dumbbell-shape DGS is proposed. By adjusting the size of C-DGS, two measured resonance frequency at 2.45GHz and 5.25GHz are obtained. The filter is compact and can be easily fabricated. The designed filter is a good candidate for modern wireless communication systems such as WLAN Bluetooth applications. It suggests the possibility that future research may benefit from designing C-DGS structures with a slot antenna design, combined with microwave ceramic materials for extended design flexibility.

Acknowledgments. This work was supported by the I-Shou University under grant ISU-105-01-01B.

REFERENCES

[1] J. S. Park et al., A design of the novel coupled-line bandpass filter using defected ground structure with wide stopband performance, *IEEE Trans. Microwave Theory & Tech.*, vol.50, no.9, pp.2037-2043, 2002.
[2] W. Wu et al., Design of a compact filter-antenna using DGS structure for modern wireless communication systems, *Microwave, Antenna, Propagation and EMC Technologies for Wireless Communications (MAPE)*, pp.355-358, 2013.
[3] J. Yang, C. Gu and W. Wu, Design of novel compact coupled microstrip power divider with harmonic suppression, *IEEE Microwave and Wireless Components Letters*, vol.18, no.9, pp.572-574, 2008.
[4] F. Yang, J. Lees, H. Choi, H. Yu and P. J. Tasker, Continuous class BJ power amplifier with DGS output matching, *IEEE MTT-S International Microwave Symposium (IMS2014)*, pp.1-4, 2014.
[5] N. C. Karmakar, S. M. Roy and I. Balbin, Quasi-static modeling of defected ground structure, *IEEE Trans. Microwave Theory & Tech.*, vol.54, no.5, pp.2160-2168, 2006.
[6] S. M. Roy, N. C. Karmakar and I. Balbin, Dumbbell shaped defected ground structure, *International Journal of RF and Microwave Computer-Aided Engineering*, vol.17, no.2, pp.210-224, 2007.
[7] C. S. Kim, J. S. Park, D. Ahn et al., A novel 1-D periodic defected ground structure for planar circuits, *IEEE Microwave and Guided Wave Letters*, vol.10, no.4, pp.131-133, 2000.
[8] L. H. Weng et al., An overview on defencted ground structure, *Progress in Electromagnetics Research B*, vol.7, pp.173-189, 2008.
[9] F. Zhang et al., Design of UWB low pass filter using a novel defected ground structure, *Microwave and Optical Technology Letters*, vol.48, pp.1805-1807, 2006.