A Novel 1-D Periodic Defected Ground Structure for Planar Circuits

Chul-Soo Kim, *Student Member, IEEE*, Jun-Seok Park, *Associate Memeber, IEEE*, Dal Ahn, *Member, IEEE*, and Jae-Bong Lim, *Member, IEEE*

***Abstract*—A new one-dimensional (1-D) defected ground unit lattice is proposed in order to improve the effective inductance. Increasing the effective inductance makes it easy to control the cutoff frequency characteristics. The proposed periodic defected ground structure (DGS) provides the excellent cutoff and stopband characteristics. In order to show the improved the effective inductance, three DGS circuits were fabricated with identical periodic and different dimensions. Measurements on the fabricated DGS circuits show that the cutoff and stopband center frequency characteristics depend on the physical dimension of the proposed DGS unit lattice.**

***Index Terms*—Cutoff frequency, defected ground structure (DGS), effective inductance.**

I. Introduction

THE photonic bandgap (PBG) research was done in the optical fields originally, but the photonic bandgap structures can be applied to wide frequency ranges including the microwave frequency band by properly scaled dimension. Recently, there has been an increasing interest in microwave and millimeter-wave applications of PBG [1]–[3]. A photonic bandgap structure, which has a period, has been known as providing rejection of certain frequency bands, i.e., bandgap or stopband effect [4]–[6]. However, it is difficult to use a PBG circuit for the design of the microwave or millimeter-wave components due to the difficulties in finding of its equivalent circuit and parameters. There are too many design parameters, which effect on the bandgap properties, such as the number of lattice, lattice shapes, lattice spacing, and relative volume fraction.

In this letter, the novel etched lattice shape is proposed as a defected ground structure (DGS) unit cell, which also provides the bandgap or stopband with different manner of a PBG. The proposed DGS unit lattice provides the cutoff frequency characteristic due to the effective inductance of the etched lattice. Changing the physical dimensions of the etched lattice can easily control the effective inductance. It provides the rejection of the some frequency band, which is can be called bandgap or stopband effect. This letter can explain the stopband effect of a DGS by employing the equivalent circuit of the proposed DGS unit lattice. Furthermore, we simulated the proposed DGS unit lattice with different dimensions in order to show the variation of the effective inductance. We have implemented three DGS circuits, which consist of the five unit lattices, with different physical dimension and identical period, respectively. The results are comparable with the measured data described in [4].

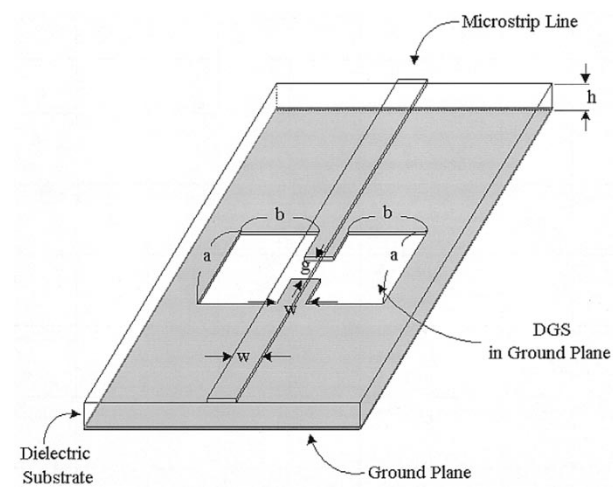

Fig. 1. Three-dimensional view of the proposed DGS unit lattice, which is etched in the ground plane of a microstrip line.

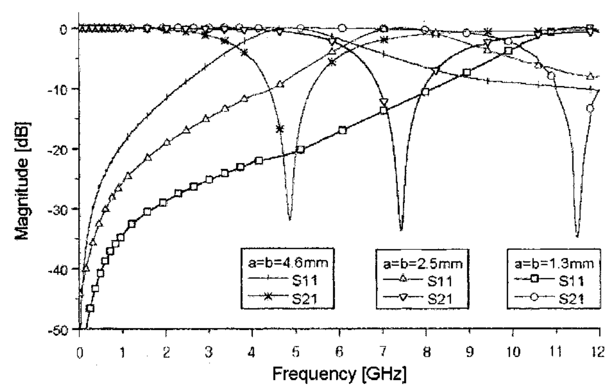

Fig. 2. Simulated S-parameters for the proposed DGS unit lattices. The gap distance g is 0.2 mm for all cases. The lattice dimension is $a = b = 1.3$ mm, $a = b = 2.5$ mm, and $a = b = 4.6$ mm, respectively.

II. DGS Unit Cell Configuration

Fig. 1 shows the proposed etched lattice for the DGS circuit, which is located on the ground metallic plane. The line width is chosen for the characteristic impedance of 50 Ω-microstrip line. Three DGS unit circuits without any period were simulated with the different dimension. In order to investigate only the variations of the series inductance, the etched gap, which is related

Manuscript received December 17, 1999; revised February 10, 2000.

C.-S. Kim, J.-S. Park, and D. Ahn are with the Department of Electrical and Electronic Engineering, Soonchunhyang University, Chungnam 336-745, Korea.

J.-B. Lim is with the Department of Electronics, Kookmin University, Seoul, Korea.

Publisher Item Identifier S 1051-8207(00)04027-7.

TABLE I
EXTRACTED EQUIVALENT CIRCUIT PARAMETERS FOR THE PROPOSED UNIT DGS SECTION. THE GAP DISTANCE g IS 0.2 mm FOR ALL CASES

	DGS dimensions		
	$a = b = 1.3$mm	$a = b = 2.5$mm	$a = b = 4.6$mm
Inductance (nH)	0.3675	0.865945	1.97725
Capacitance (pF)	0.51222	0.52845	0.537947
Cutoff Frequency (GHz)	10.15	6.085	3.62
Attenuation pole Location (GHz)	11.6	7.44	4.88

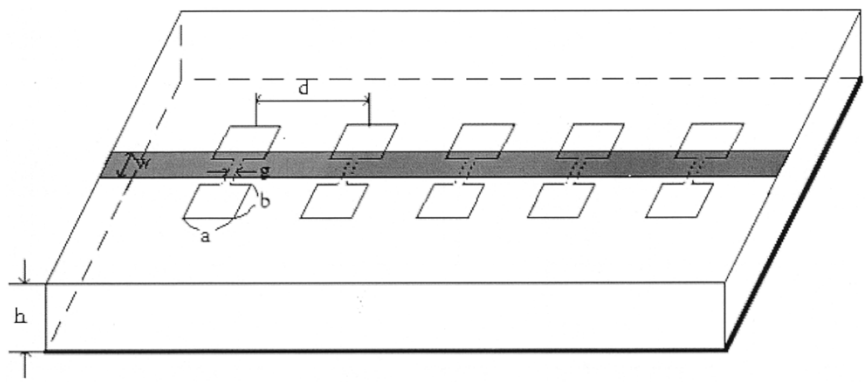

Fig. 3. Three-dimensional view of the proposed DGS structure with one-dimensional period.

with the gap capacitance, was kept constant to 0.2 mm for all three cases and the etched square area was varied. The simulation results are shown in Fig. 2. From Fig. 2, it can be seen that employing the proposed etched lattice increases the series inductance to the microstrip line. This effective series inductance introduces the cutoff characteristic at a certain frequency. As the etched area of the unit lattice is increased the effective series inductance increases, and increasing the series inductance gives rise to a lower cutoff frequency, as seen in Fig. 2. There are attenuation poles in simulation results on the etched unit lattices. These attenuation poles can be explained by parallel capacitance with the series inductance. This capacitance depends on the etched gap below the conductor line, which is noted as g in Fig. 1. Thus, the equivalent circuit of the proposed etched unit lattice can be expressed as parallel LC circuit. The capacitance values are identical for all cases due to the identical gap distance. As the series inductance is increased the resonance frequency of the equivalent parallel LC circuit, which is the attenuation pole locations and the cutoff frequency becomes lower. Simulation results seen in Fig. 2 pertinently show the variation of the effective inductance for the proposed lattice cells. Table I presents the extracted equivalent circuit parameters for simulated unit DGS sections. The equivalent circuit and extraction of circuit parameters for proposed DGS circuit is detailed in [7].

III. MEASUREMENTS AND RESULTS

The proposed DGS circuit, which is composed of the five-etched lattices, is shown in Fig. 3. In this letter, we try to compare the measurement results with those of the circular lattice cases, which are described in [4]. Three DGS circuits for measurements have been fabricated using TACONIC CER-10 with 62-mil thick (1.5748 mm) and dielectric constant ε_r of 10. The period d was kept constant to 5 mm for all three circuits. The etched rectangular area was varied with keeping the square shape. In order to compare the stopband effect of the proposed DGS circuit with previous results, the etched square area was chosen by corresponding to etched circle areas described in [4]. A line width of 1.46 mm was used, corresponding to 50-Ω line for conventional microstrip line.

Measured results for three fabricated DGS circuits are shown in Fig. 4(a)–(c). For smaller square area the cutoff frequency is very high. As the etched area is increased the cutoff frequency becomes lower. Based on previous research, the measured results with constant number of periods show that depth and bandwidth of the stopband depend on the circle radius. In general, the stopband center frequency is a function of the period of the structure. However, the measurements on the proposed DGS circuit show that cutoff frequency and stopband characteristic depend on the etched square dimensions. The period of the proposed DGS defect affects slightly on the stopband center frequency compared with its dimension. The depth and bandwidth of the stopband for the proposed DGS circuit are inclined to depend on the number of period. The etched square area, which determines the effective inductance, characterizes the cutoff and stopband frequency characteristics of the newly proposed DGS structure. The center frequency of stopband for the proposed DGS structure is determined by the resonance frequency of each etched lattice cell. Thus, the cutoff and stopband characteristics for the proposed DGS structure can be easily estimated. Radiation loss could be occurred in some frequency range due to the etched defected area in ground plane. However, addition of

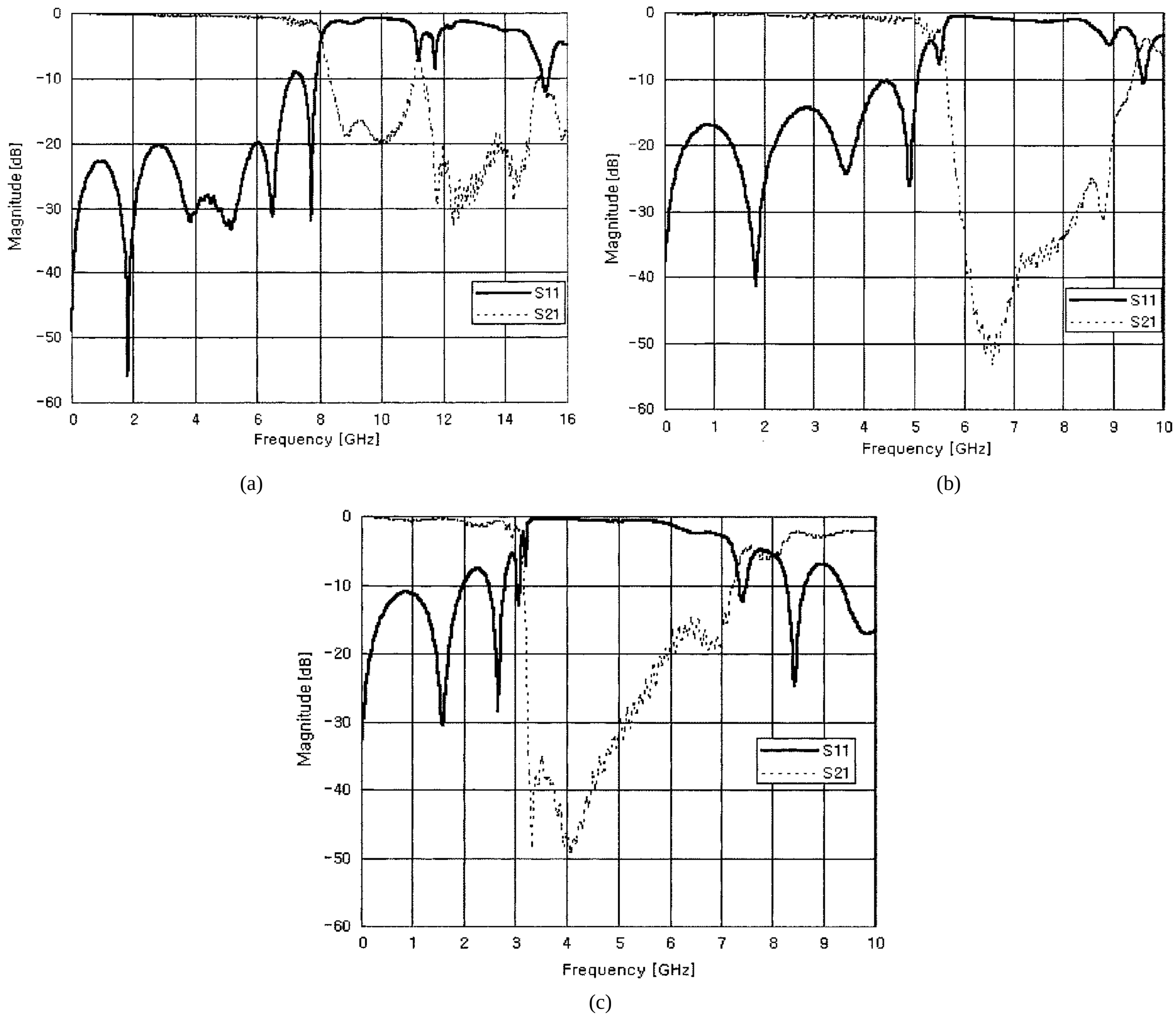

Fig. 4. Measured S-parameters for the fabricated DGS circuits. The lattice dimension is (a) $a = b = 1.3$ mm, (b) $a = b = 2.5$ mm, and (c) $a = b = 4.6$ mm.

the reflected and transmitted power in the first propagation frequency band shows very low radiation level from the ground plane compared with a reported PBG circuits.

IV. Conclusion

We proposed the novel etched lattice shape for the one-dimensional (1-D) DGS structure. The proposed DGS structure provides the cutoff frequency characteristic due to the effective inductance of the unit lattice, which is etched on microstrip ground plane. The proposed DGS structure is easier to control the cutoff and stopband characteristics by changing the dimensions and to fabricate. And it is much easier than circular periodic cases to analyze proposed periodic structure with finite-difference time-domain (FDTD). It is possible for the newly proposed PBG structure to apply to coplanar waveguide (CPW) and strip line for MMIC applications.

References

[1] T. J. Ellis and G. M. Rebeiz, “MM-wave tapered slot antennas on micromashined photonic bandgap dielectrics,” *IEEE MTT-S Int. Microwave Symp. Dig.*, pp. 1157–1160, June 1996.

[2] V. Radisic, Y. Qian, and T. Itoh, “Broadband power amplifier using dielectric photonic bandgap structure,” *IEEE Microwave Guide Wave Lett.*, vol. 8, pp. 13–14, Jan. 1998.

[3] M. P. Kesler, J. G. Maloney, and B. L. Shirley, “Antenna design with the use of photonic bandgap material as all dielectric planar reflectors,” *Microw. Opt. Tech. Lett.*, vol. 11, no. 4, pp. 169–174, Mar. 1996.

[4] V. Radisic, Y. Qian, R. Coccioli, and T. Itoh, “Novel 2-D photonic bandgap structure for microstrip lines,” *IEEE Microwave Guided Wave Lett.*, vol. 8, no. 2, pp. 69–71, Feb. 1998.

[5] Y. Qian, V. Radisic, and T. Itoh, “Simulation and experiment of photonic bandgap structures for microstrip circuits,” *Proc. APMC’97*, pp. 585–588, Dec. 1997.

[6] D. Maystre, “Electromagnetic study of photonic band gaps,” *Pure Appl. Opt.*, vol. 3, no. 6, pp. 975–993, Nov. 1994.

[7] J. L. Park, C. S. Kim, J. Kim, J. S. Park, Y. Qian, D. Ahn, and T. Itoh, “Modeling of a photonic bandgap and its application for the low-pass filter design,” *Proc. APMC’99*, pp. 331–334, Dec. 1999.