A Novel PBG Coplanar Waveguide

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***Abstract*—A novel coplanar waveguide with photonic bandgap structure is proposed and is implemented by etching holes in the ground plane with an open connected with the gap between strip line and ground plane. Simulation and measurement results show the existence of a bandgap.**

***Index Terms*—Coplanar waveguide, FDTD, photonic bandgap (PBG).**

I. Introduction

PHOTONIC bandgap (PBG) structures are periodic structures which exhibit a bandgap within which some certain bands of electromagnetic propagation are prohibited. The concept was first introduced in optical fields [1], but has later been scaled to a wide frequency range, including microwave and millimeter-wave frequencies. Bi-dimensional and one-dimensional PBGs for microstrip lines have been proposed in recent years [2]–[6]. A periodic array of perforation in the ground plane of the microstrip line is integrated. At the resonant frequencies of the periodic structure, there exists a stopband for the transmission of microwave signals. This provides an effective method to suppress higher order harmonics in active circuits.

But most of the work has focused on PBG structures for microstrip lines; little research has been done for the coplanar waveguide (CPW). The CPW has been investigated comprehensively for applications, both in microwave integrated circuits (MICs) and monolithic microwave integrated circuits (MMICs), since its first introduction [7], [8]. Recently, A uniplanar compact PBG (UC-PBG) structure has been applied to conductor-backed coplanar waveguide (CB-CPW) [9], where the conventional ground plane is replaced by the UC-PBG structure. While, on the other hand, because the PBG structures have been integrated mostly in the ground plane, they are not fit to be supported by a metal board for mechanical purposes. In [6], a novel PBG structure is proposed to deal with this problem, while its geometric shape is complicated and not easy to compute. Another PBG-CPW structure is proposed by Yun and Chang in [10], where a pattern of rectangular apertures are etched in the ground plane just adjacent to the slot, and evident frequency bandgap has been observed. In this paper, a novel PBG structure for CPW is proposed. The principle is similar to [10], but with a different cell shape. The PBG-CPW is studied both in simulation and in experiment.

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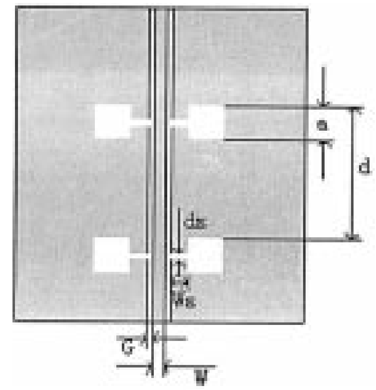

Fig. 1. Proposed PBG structure for CPW.

II. Design of PBG-CPW

The PBG structures for microstrip lines are implemented by etching holes in the ground plane following a periodic pattern. Here, the same method is adopted to design PBG-CPW using microstrip technology. Each column of rectangle holes is etched in the ground plane on both sides of strip line (Fig 1). The substrate used here is with $\varepsilon_r = 2.65$ and thickness $h = 1$ mm. The conventional CPW is designed using ESOFT software, and the physical dimension is strip width $W = 2$ mm and the gap width $G = 1$ mm, which is easier to print on the metal, corresponding to a 96.7 Ω characteristic impedance. The ground plane is 13 mm on each side. The period distance is chosen as 24 mm, and precise design is done through FDTD simulations. The etched apertures for the PBG-CPW are not simple ones, such as circular or rectangle holes. A rectangle hole is etched in the ground plane with side length a, and it is connected to the gap by a narrow transverse slot (with width Ws and height ds) (Fig. 1).

Considering the different characteristics of CPW and microstrip lines, the electromagnetic field is constrained mainly within the gap between the strip line and the ground plane, so the kind of holes totally etched within the ground plane will have little effect to the transmission characteristics of CPW. This structure is similar to the defected ground structures in [11], where the gap is related with the gap capacitance and the etched square hole is related with the shunt inductance. Thus, the equivalent circuits of the proposed etched unit lattice can be expressed as parallel LC circuit. At the same time, some other types of structures are considered, too, in the case of comparison. Square aperture alone totally within the ground plane but have different distance from the gap are simulated, just as the transverse slots alone without the square aperture. Comparison is done between these different cases by FDTD simulation. The proposed PBG structure is fabricated and measurement results are given.

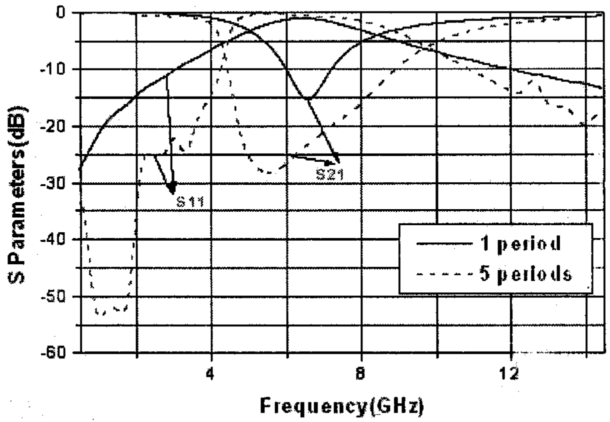

Fig. 2. Simulated S parameters of PBG-CPW with different periods.

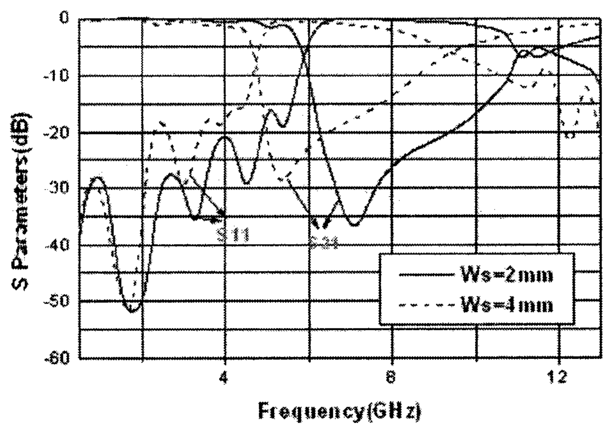

Fig. 3. Simulated S parameters of PBG-CPW with different slot width.

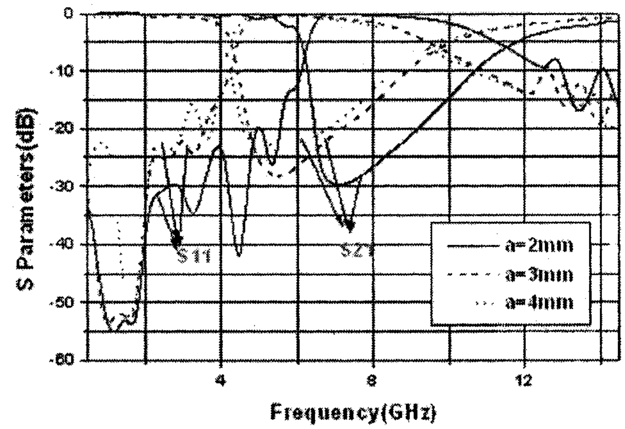

Fig. 4. Simulated S parameters of PBG-CPW with different square aperture size.

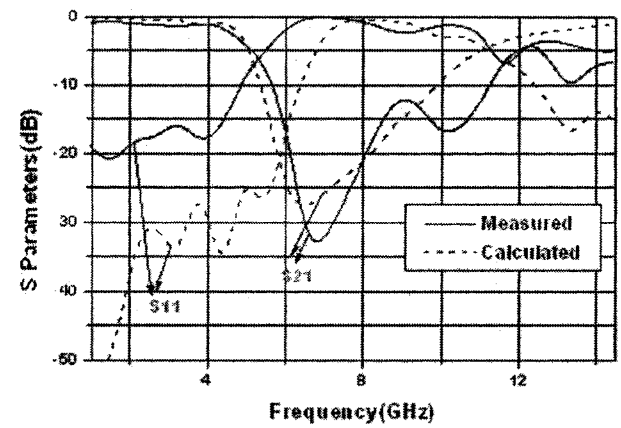

Fig. 5. Comparison of measured and simulated S parameters of PBG-CPW.

III. Simulation and Measurements Results

A simulation program based on FDTD method has been executed to obtain the exact scales of the lattice. PML absorbing boundary conditions are applied, and the thin dielectric layer is modeled. The case of different periods is simulated, with slot width $Ws = 3$ mm, and $ds = 3$ mmt. Transmission coefficients are given in Fig. 2. It can be seen that the bandgap is not very good when adopting one cell only, so a periodic pattern is necessary to construct PBG structures. Next the proposed PBG lattice is simulated with different slots width Ws or different square holes dimension a. The simulation results are given in Figs. 3 and 4. Fig. 3 shows the transmission coefficients of varied slot width Ws, while keeping $a = 3$ mm. For small slot width, the cutoff frequency is higher. For the large slot width, the cutoff frequency becomes lower. This is due to the variation of the gap capacitance with the width of the slot. Fig. 4 shows the transmission coefficients of the lattice with varied square aperture size, while keeping the slot width constant. The square aperture sizes are $a = 2$ mm, 3 mm, and 4 mm respectively. For small square area, the cutoff frequency is very high. As the etched area increases, the cutoff frequency becomes lower. The stopband width and depth are related to the etched area, too. With large square area, the stopband is wide but not so deep as the small square area. The reason for this is probably due to the strong resonant characteristic of the etched lattice. Moreover, the center frequency of stopband for the proposed PBG structures is best determined by the resonant of each lattice cell, which is different from [2] and [3]. One of this kind of PBG-CPW is fabricated, with $a = 3$ mm, $Ws = 3$ mm, $ds = 1$ mm, (Fig. 4). The measured transmission coefficients are plot together with the simulated results in Fig. 5. Agreements can be seen between the measured and simulated results, considering the error of fabricated art and the loss of the substrate.

IV. Conclusion

We proposed the etched lattice to construct a two-dimensional PBG coplanar waveguide. The proposed structure provides a frequency stopband for the CPW. The FDTD method has been applied to determine the characteristics. The stopband characteristic can be controlled by changing the lattice dimensions. The structure is easy to design and fabricate, and will be valuable for MMIC and antennas applications.

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