Abstract: A microstrip transmission line incorporating one dimensional photonic bandgap (PBG) structure is proposed. It consists of a periodic array of perforations on the microstrip line itself. No drilling through the substrate or etching on the ground plate is required. We have studied the rectangular continuous and Split ring type PBGs. By splitting the ring it is possible to obtain higher rejection bandwidth. FDTD and MOM based simulations show that the proposed PBG exhibits slow-wave and wide stopband characteristics.

I. INTRODUCTION

Over the last ten years, there has been a lot of attention focused on periodic dielectric structures, sometimes called Photonic bandgap (PBG) that exhibit the property to forbid the propagation of electromagnetic waves for certain frequency bands[1].

Microstrip transmission lines incorporate a photonic bandgap structure exhibit slow-wave characteristics which can be exploited to reduce the dimension of the microstrip structure. The PBG can be in the form of a periodic array of dielectric inclusions with a dielectric constant different from that of host dielectric substrate or a periodic array of perforations in the ground plane of the microstrip line.

While various configurations have been proposed in the literature, only the planner etched PBG configurations have attracted much interest due to their ease of fabrication and integration with other circuits. The passband of a PBG structure is used as a slow-wave medium that is useful for compact design. The stopband is used to suppress the surface wave and spurious transmission.

PBG structures for Microstrip lines had been proposed in last few years [2] where periodic patterns were etched in the ground plane of microstrip lines. Many microwave circuits based on this structure, such as filter, resonator and antennas, were also proposed [3-4]. But when such PBG ground plate is mounted on metal base, PBG effect disappears. Proposed structure can avoid such shortcoming by maintaining integrality of the ground plane. Instead of latticing PBG cells on the ground plane of the microstrip structure, we place on the signal line as proposed earlier in the paper [5]. We have proposed the rectangular continuous and Split ring type PBGs in this paper.

II. THEORY

The center frequency of the stop band of a PBG which satisfies Bragg’s condition is calculated approximately with the expression: \( \beta a = \pi \), where \( a \) is the period of the PBG pattern and \( \beta = (2\pi f_0/c) \sqrt{\varepsilon_r} \), where \( f_0 \) is the stopband center frequency, \( \varepsilon_r \) is effective dielectric constant of the substrate, and \( c \) is the speed of light in free space. Using the above expression, the period for any stopband frequency can be determined.

In the following structure, the narrow lines at both side of the perforation result in an increase of series inductance. In contrast the two edges of the perforation across the width of the microstrip line result an increase of shunt capacitance. According to transmission line theory, the propagation constant of a line without loss is \( \beta = \sqrt{LC} \) where \( C \) and \( L \) are the distributed shunt capacitance and series inductance per unit length. Therefore the propagation constant can be increased i.e., a slower wave, by increasing \( L \) and \( C \).

III. DESIGN OF PBG STRUCTURE

Two designs are investigated with PTFE substrate having dielectric constant 2.5 and thickness 1.6 mm The width of the 50 ohm microstrip line is 4 mm.

Design 1:
The microstrip line consisting of five number of periodic slots with lattice period 8.0 mm as shown as Fig.1. Each cell is rectangular shape ring having inner width is 1.6 mm and outer width is 3.2 mm. The filling factor, defined as the volumetric ratio of one PBG element to one unit cell, has been chosen to be 0.5. The outer arm length of PBG element is 4.0 mm.
Design 2:
The microstrip line consisting of five number of periodic slots with same lattice period as shown in Fig. 2. Each cell is rectangular shaped split ring having gap width is 0.4 mm. The other parameters like inner width, outer width, filling factor and outer arm length are same as Design 1.

IV. SIMULATION

Finite Difference Time Domain (FDTD) [6] simulations are performed for the above microstrip structures. The FDTD code used in this work is based on the standard Yee cell geometry and the values of the electric and magnetic fields are calculated in consecutive time steps.

The software is developed in house, coded with ‘C’. The incident, reflected, and transmitted signals were obtained from time domain simulations and transformed to frequency domain by MATLAB Fast Fourier Transform function to calculate S-parameters.

In the discretization of the structures, $\Delta x = 0.400 \text{ mm}$, $\Delta y = 0.400 \text{ mm}$ and $\Delta z = 0.266 \text{ mm}$ are considered. The FDTD volume considered is of 62 X 170 X 20 cells and PML-ABC [6] is applied. In order to maintain the courant condition, the time step ($\Delta t$) = 0.443 ps is chosen. A Gaussian pulse of spread $T = 48.0 \text{ ns}$ and a delay of 150 ns has been considered as the excitation source. 3000 numbers of time-iterations are taken to obtain the steady state response.

V. RESULTS

Design 1:
Simulated results for transmission coefficient ($S_{21}$) and reflection coefficient ($S_{11}$) for rectangular ring PBG are shown in the Fig. 3. The stopband is centered at 11.5 GHz. The 20 dB rejection bandwidth is 2.4 GHz with 27 dB maximum attenuation. Observing the passband ripple, there are four poles from the five elements.

Design 2:
As shown in Fig. 4, the stopband is centered at 10 GHz. The 20 dB rejection bandwidth 5.5 GHz with 80 dB maximum attenuation. Observing the passband ripple, there are four poles from the five elements.

The same structure of Design 2 has also been simulated by well known MOM based IE3D microwave software and our result is confirming to that as shown in Fig. 5.
If we compare the stopband characteristic of design-2 for same set of parameters with design 1, it is observed stopband have higher rejection bandwidth and higher maximum attenuation with minimum change of center frequency.

As shown in Fig. 6, if we change the gap width from 0.4 mm to 0.8 mm and 1.2 mm, it is observed that the center frequency shifted by 0.5 GHz in both cases but rejection bandwidth remains unchanged. So fine tuning of center frequency can be done by changing gap width.

We observe that undesired pass band ripple increases with increase of filling factor and get optimum result with filling factor 0.5. It is also observed that smaller the width of the PBG cell, less the maximum attenuation of the stop band.

VI. APPLICATION

The proposed PBG structure requires only partial etching in the signal line, which is compatible with monolithic circuit technology. It can be utilized to design different microstrip structures, like, Transmission lines, wideband filter, branch-line coupler, microstrip line-fed patch antenna, microstrip spiral inductor etc.

VII. CONCLUSION

The behavior of split ring PBG structures for microstrip lines was studied and compared the result with continuous rectangular ring. It is observed that the stop band center frequency is independent of cell size and depends on lattice period. The split on the ring produce higher rejection bandwidth. The stop band characteristic can be tuned by changing the gap width. In this design the passband ripple is significantly less. Finally the structure is simple, easy to fabricate and can be installed in metal shielded box without any performance loss.

REFERENCES


