A New Uniplanar Compact Photonic-bandgap (UC-PBG) Structure in Transmission Line

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Abstract— Recently, the photonic band-gap (PBG) structure has received much interest in microwave and millimeter-wave domain. Applications of PBG in transmission line, microwave components and antennas have been studied and discussed. Especially the compact PBG structure consisting of small metal pads has been demonstrated to improve the performance of microwave circuits and antenna performance.

In this paper, a new uniplanar compact photonic-bandgap (UC-PBG) structure was presented. The proposed PBG structure unit has a two dimensional structure of a rectangle box with two branches intersecting at center. Then this identical unit was connected as a periodical structure. The periodical structure acting as the ground plane of the microstrip transmission line was studied. The transmission line model with the proposed UC-PBG structure ground (TL-UC-PBG) was then studied. An equivalent circuit model of this TL-UC-PBG was suggested to analyze the characteristics of the transmission line with PBG ground. From our study, it was found that this structure has a nice character of low-pass filter. At high-frequency, it showed a broad stop-band.The proposed TL-UC-PBG structure could be used in compact microwave circuit.

1. INTRODUCTION

Recently, there has been great interest in the application of the structure of the photonic bandgap (PBG) which was developed from optical regime, especially in the microwave devices [1–3]. Such as the application of microstrip antennas, resonant cavities, filters and so on.

Typical PBG structure has periodical elements etched in the conducting plane in a PCB board as the ground plane of microstrip devices. The PCB structure and the microstrip structure constitute the left-handed structure (LH). The LH material was first studied by Vselago in 1960s [1]. A planar slab of material with a negative refractive index (NRI) focusing rays of light emanating from the source to the other side of the slab. After that, the effect of the slab on the image quality has been studied. Eleftheriades el al. [4] proposed the equivalent circuit model of the LH transmission line with the concept of L-C components. The distributed circuit model of the LH transmission line unit was constructed of a series connected capacitor and shunt connected inductor exhibiting a negative refractive index.

In [5], the LH structure was implemented in a two dimensional periodic elements with split ring resonators and long wire strips to model the behaviors of magnetic and electric dipoles respectively. Extended studied was then carried out on various similar structures with the effective electromagnetic parameters were retrieved experimentally and numerically combining the LH structure with the transmission line. Besides, three dimensional LH structure was introduced in [6] with conducting vias connecting ground and metal pads.

In this paper, a new uniplanar compact photonic bandgap (PBG) structure was designed and studied. The construction of the paper was as following. The structure of the proposed UC-PBG structure would be introduced in the first part with the equivalent circuit model presented to analyze the structure. In the second part, the characteristics of the transmission line with the PBG structure would be shown; the effect of the parameters on the TL-UC-PBG model would be discussed. In the third part, the conclusion and future work would be presented.

2. DESIGN AND DISCUSSION

The structure of the proposed PBG structure was shown in Fig. 1. The units were etched on the surface of a PCB periodically in two-dimension. Each of the unit was constructed four parts. The patch at the center was surrounded with a rectangular ring which could also a circular ring. Small parasitic patches were around the patch and the ring. Each of the unit was connected to the neighboring units by four arms which intersect at the center. The patch and the ring introduced the series inductance in the structure, the parasitic patches together with the ring made the series capacitance and the gap between the elements introduced the shunt capacitance.

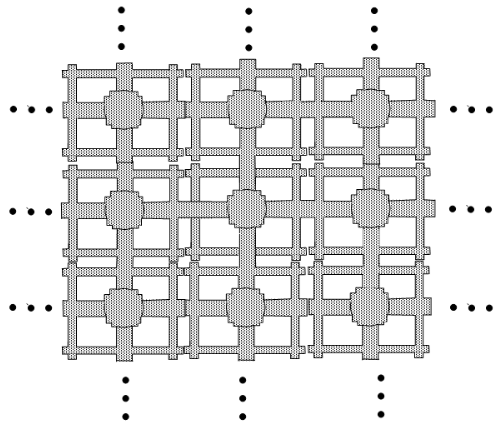

Figure 1: Schematic of the proposed PBG structure.

To find the properties of the PBG structure acting as the ground plane of the transmission line, the model shown in Fig. 2 was studied. The proposed PBG structure was etched on one side of the PCB board with the microstrip line on the other side which constructed the LH transmission line model. When this LH transmission line worked at the stop-band, the qusi-TEM transmission mode would be stopped, so that a deep stop band would be appeared as shown in Fig. 3. In this figure, the curve of the S_{21} was given. At the frequency near to 3 GHz, a stop-band was showed. It was also shown in Fig. 4. The phase also made it obvious that the Braag frequency of our structure is near 3 GHz. Fig. 5 showed the comparison of the group delay between the LH transmission line and the traditional transmission line having conducting ground plane. From this figure, it was showed

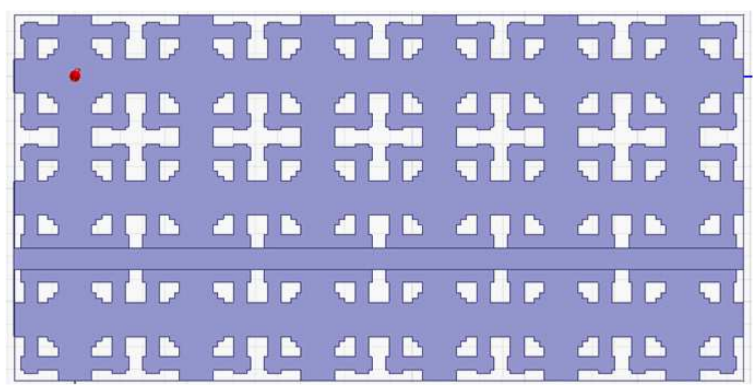

Figure 2: Transmission Line with PBG structure as the ground plane.

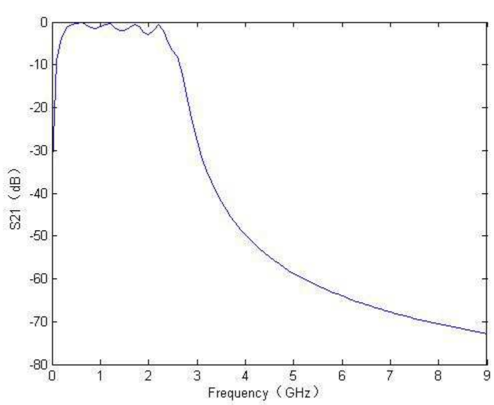

Figure 3: S_{21} of the transmission line with PBG structure as the ground plane.

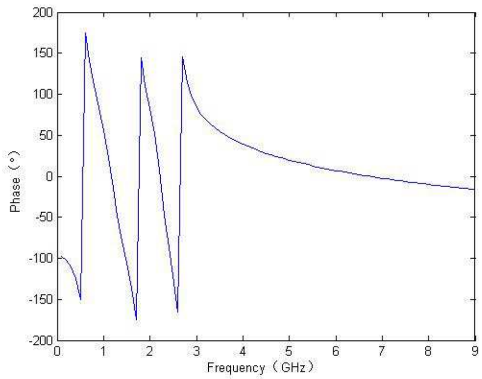

Figure 4: Phase delay of the transmission line with PBG structure as the ground plane.

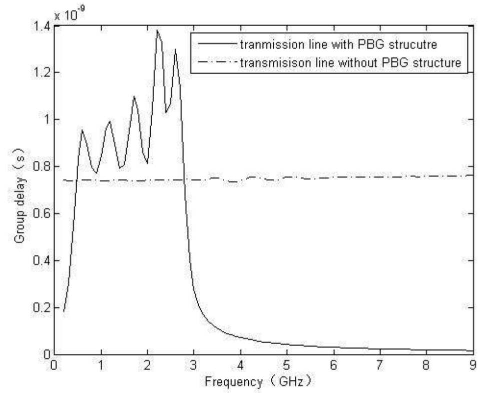

Figure 5: Comparison of the group delay between the transmission line with PBG structure and without PBG structure.

that a slowing factor of 1.5 achieved.

3. CONCLUSION

In this paper, a new uniplanar band-gap structure was proposed. Its application in LH transmission line was studied and discussed. The comparison between the proposed transmission line structure and the traditional RH transmission line was shown. The result showed the proposed structure had the characteristics of slow wave.

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