A New Sandwich Structure of Photonic Bandgap

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Abstract — **We propose a sandwich structure of photonic bandgap (PBG), in which a periodic pattern of square metal pads is printed in the midmost of the substrate. Neither drilling nor suspending the substrate is required, and the integrality of the ground plane is also kept. Several circuits with different location of periodic lattice are compared, and potential applying way is demonstrated.**

I. Introduction

Photonic bandgap structures [1] can forbid the transmission of microwave in certain frequencies. The original PBG structure fabrication needs painstaking work of drilling through the substrate [2], it costs a lot and time is wasted. Then comes the second method [3], which just etches periodic elements in the ground plane of microstrip line. It is cheap and convenient. Since it is etched in the ground plane, the substrate must be suspended in the shield box and the whole structure is complicated.

In this paper, we propose a sandwich structure of PBG. It quite likes the second method, but we print the periodic lattice in the midmost of the substrate instead of etch in the ground plane. It can exhibit the property of forbidden gap. The width and depth of the forbidden gap can be tuned by adjusting the location of the periodic lattice in the substrate. A simple applying way is demonstrated. This method reveals that a carefully arranged periodic lattice is certain to be a PBG structure, regardless of its shape or location. And what does interest us is that it is very simple and costs little.

II. Circuit Design

The circuit is realized through printed circuit board (PCB) technology. We use two medium board, which is 0.8mm thick with $\varepsilon r=13$, to form a 1.6mm thick substrate. The periodic lattice is printed on the top face of lower board, and buried in the midmost of the whole substrate. A 50-Ω microstrip line of such structure is shown in Fig. 1. In order to clarify the structure, we don't agglutinate the two boards in this figure.

The width of the microstrip line is 1.2mm, which is corresponding to a 50Ω line on a conventional substrate. The period of the lattice is a0=20mm, and each metal element is square pad. Its length is 10mm, and there are nine elements longitudinally along the microstrip line in this structure.

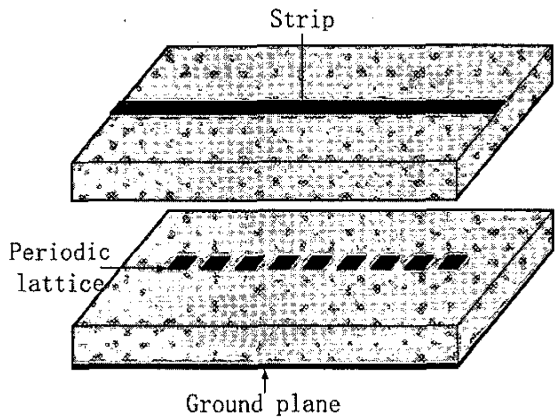

Fig. 1. Schematic of new photonic bandgap structure

III. Simulation Results

FDTD method is applied to simulate the new structure. Fig. 2 shows the simulated reflection (S11) and transmission (S21) coefficients.

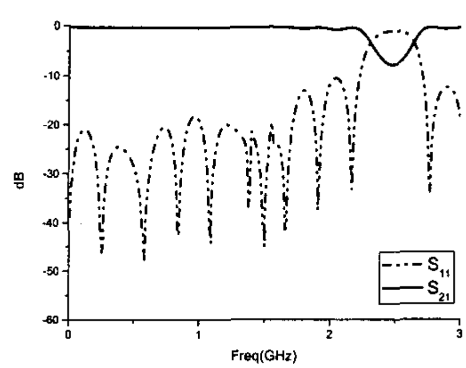

Fig. 2. Reflection and transmission coefficients of new structure

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There is an obvious forbidden gap between 2-3GHz, and the center frequency of the stopband is a function of the period. It is the property of photonic bandgap structure. And the passband loss of this structure is close to 0 dB, implying that applying this new method does not violate the matching condition nor increase the conductor loss.

Since the periodic lattice is in the middle of the substrate, the forbidden gap isn't as wide as that of usual photonic bandgap structure. But we should remember that in those structures there are more ripples and the passband loss is larger in the low frequency. And the forbidden gap width of this new structure can be tuned by adjusting the vertical location of the periodic lattice.

IV. WIDEN FORBIDDEN GAP

In order to widen the forbidden gap, we adopt the chirp technique [4]. The structure period is adjusted by the following equation:

$$a_i = a_0 \bullet (1 + i\delta) \quad (1)$$

Fig. 3(a) and (b) show the perspective schematic of the chirped microstrip structure with δ=4% and δ=8%, respectively.

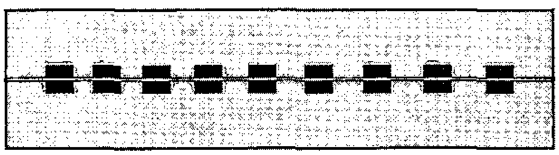

Fig. 3(a). Perspective schematic of chirped structure with δ=4%

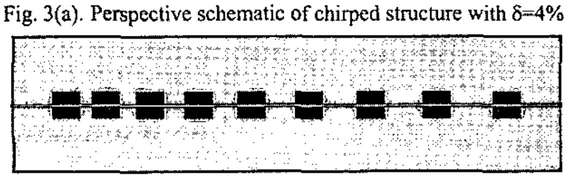

Fig. 3(b). Perspective schematic of chirped structure with δ=8%

FDTD simulations are performed for all above microstrip structures. Fig. 4 shows the simulated transmission coefficients.

As the chirp parameter δ gets larger, the bandwidth of the forbidden gap is increased, and a growing ripple appears in the stopband. These phenomena also prove that the structure fabricated by the new method is a real PBG structure. But the larger the δ parameter is, the shallower the forbidden gap is. No applications can be realized with such little attenuation, so we must try a different way.

The above structures possess the periodic lattice in the midmost of the substrate. Assuming the plane ground is zero in z-axis, the above lattice is located at z=0.8mm. We adjust its vertical location along the z-axis. Fig. 5 shows the simulated results with z=0.4, 0.8, 1.2mm.

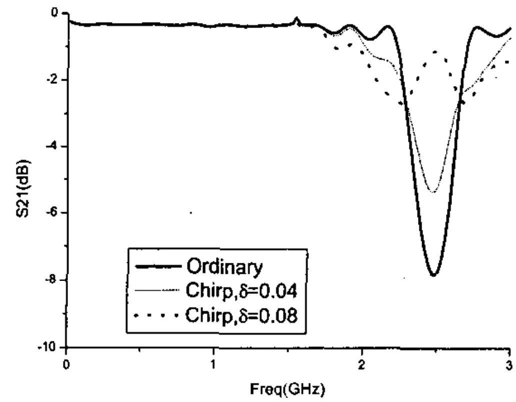

Fig. 4. Transmission coefficients of structures with different δ parameter

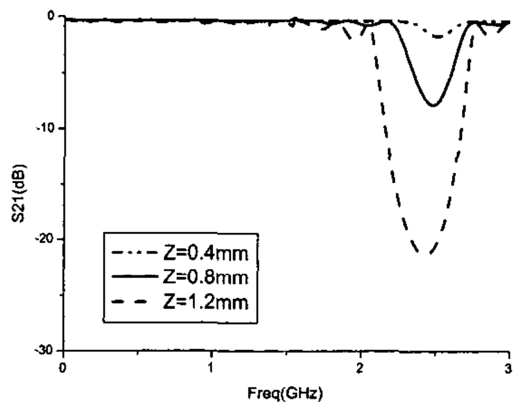

Fig. 5. Transmission coefficients of structures with different z-axis location

From Fig. 5, we can find that the shorter the distance between the periodic lattice and the top microstrip line is, the wider and deeper the forbidden gap is. Thus you can adjust the width and depth of forbidden gap of your structure only by moving the periodic lattice along the z-direction.

V. DIFFERENT MEDIUM

The two boards used in above structures are made of same medium. Supposing ε1 and ε2 are the dielectric constant of upper and lower medium respectively, we use symbol (ε1, ε2) to represent the whole structure. While above structures are represented as (13,13), Fig. 6 shows simulation results of (13,10) and (10,13) structures.

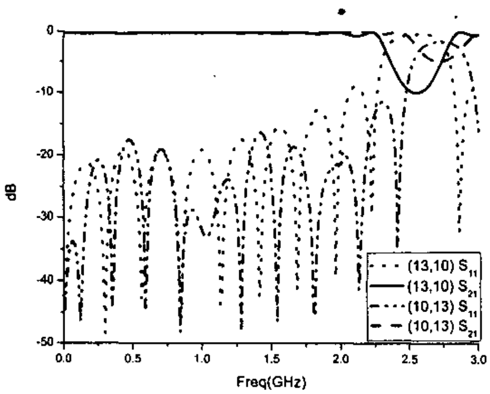

Fig. 6. Reflection and transmission coefficients of different medium substrate

From Fig. 6, we can know that the forbidden gap of (13,10) structure is wider and deeper than that of (10,13). What's more important, the center frequency of former forbidden gap is lower, which means that the (13,10) structure possesses higher equivalent dielectric constant. Then we try to change the ε2 parameter. Fig. 7 shows simulated S21 parameter.

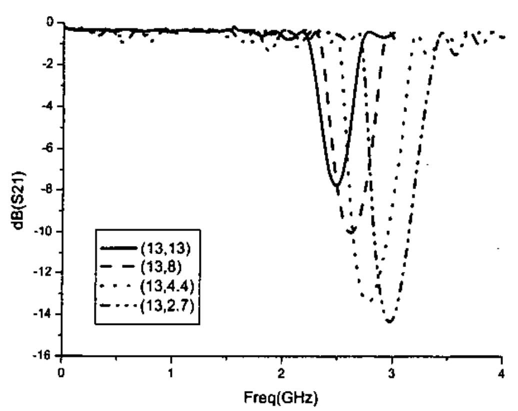

Fig. 7. Impact of different ε2 to transmission coefficients

From Fig. 7, we can find that the lower ε2 parameter is, the higher center frequency of forbidden gap is. We also can see that though the ε2 changes from 13 to 2.7, which is 4.8 times smaller, the center frequency of forbidden gap change form 2.5 to 3, which is only 1.2 times bigger. It means that the lower medium doesn't affect the PBG property as much as the upper medium.

As we know, the typical PBG structure is periodic lattice whose element is a half-wavelength long. In order to reduce its size, we must use the substrate having a high dielectric constant or try to find some miniature structure [5]. Using the method presented in this paper, we can decrease the dimension of PBG structure without changing the whole substrate. Fig. 8 outlines the method.

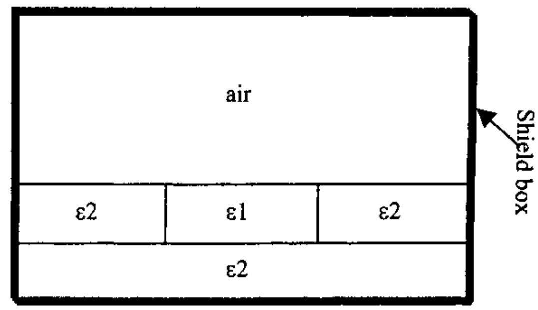

Fig. 8. Simple demonstration of new method to decrease the PBG dimension (ε1>ε2)

If one circuit design is realized in the 1.6mm thick substrate with εr=2.7, the period of its typical PBG structure should be 33mm. According to our method, the PBG period in (13,2.7) structure is only 20mm, which is less than 2/3 of the original length. Thus we get the achievement of dimension decrease.

Another advantage of such structure arrangement is that we don't have to change the whole substrate to high dielectric constant medium. Thus the loss is lower and the cost is much cheaper. In addition, all boards can be fabricated by PCB technology, and no complicated procedure is needed.

VI. CONCLUSION

In this paper, we present a new method of applying photonic bandgap structure. This new method needs neither drilling nor suspending the substrate, and also keeps the integrality of the ground plane. Another unique feature is that the width and depth of the forbidden gap of this structure can be tuned easily. If we apply this method in the circuit design, it will decrease the dimension of PBG structure. And it is very simple and costs little.

ACKNOWLEDGEMENT

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