A Novel Photonic Bandgap Structure for Low-Pass Filter of Wide Stopband

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***Abstract*—In this letter, a novel photonic bandgap (PBG) structure is proposed for increasing the stopband of a low-pass filter without the increasing circit size for applications in microstrip circuits. The proposed structure is connected in parallel two periodic structures which have different center frequency of the stopband. The wide stopband is achieved by two periodic structures of two different stopbands. We also show the performance improvement of microstrip patch antenna by etching of the proposed structure in ground plane.**

***Index Terms*—LPF, microstrip antenna, PBG, wide stopband.**

I. Introduction

FILTERING is one of the most important parts of microwave circuit systems. Filters can be implemented with shunt stubs or stepped-impedance lines in a microstrip circuit, but these techniques require large circuit layout size and provide a narrow band and a spurious passband in stopband. Photonic bandgap (PBG) structures have been considered as an alternate to solve these problems in microwave circuit applications. PBG structures have been studied in the optical region and have been started to apply in microwave and millimeter-wave circuits recently. (A PBG structure is a periodic structure where electromagnetic waves of some frequency bands cannot be propagated [1].) Many researchers have proposed and demonstrated several PBG structures for microstrip circuits application with filtering characteristics [2]–[4]. Several authors have focused on achieving compact design and wide frequency stopband [5]. For example, Kelly [6] has proposed a serial connection of several different PBG structures for wide rejection frequency bandwidth, but this required large size and had a limitation in microstrip circuits applications in compact sizes.

In this letter, we introduce a novel PBG structure for wide stopband of low-pass filter without increasing size of PBG structure. To achieve periodic structure, a circular, square, or rectangular has been used as unit lattice in the used method of PBG implementation, but we used two new lattices to build up two PBG structures which have different stopbands. This builds up two different stopbands, and it results in a wide stopband with good performance. Because it is achieved with a parallel connection of two different PBG structures, this structure has the wide stopband characteristic without an increment in size. The microstrip patch antenna with the proposed PBG structure in

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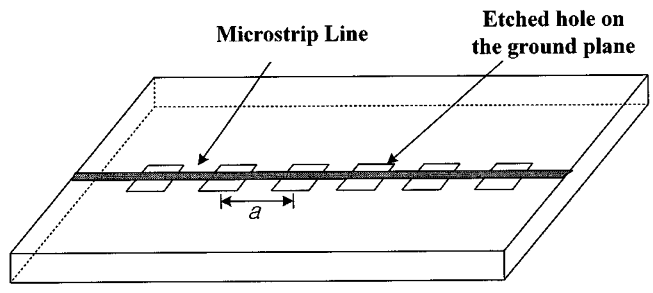

Fig. 1. 1-D PBG structure with etched square hole in ground plane.

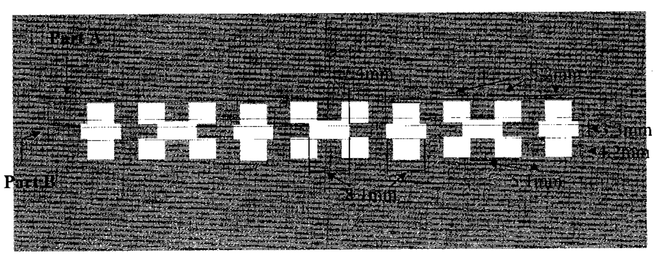

Fig. 2. The proposed PBG structure for constructing wide stopband.

ground plane was demonstrated experimentally to suppress the harmonic components and improve bandwidth performance.

II. PBG Structure with Wide Stopband

The classical filters with PBG structures can be achieved in microstrip technology with the periodic pattern in the ground plane and the conductor microstrip line having a width of 50 Ω on the top plane by etching, as shown in Fig. 1. The center frequency of stopband is determined by the distance a between the center of lattices. The reflected frequency in periodic structure should satisfy the Bragg condition to accomplish the stopband around the reflected frequency [7]. From the Bragg condition, we can get the period a of a half of guided wavelength at center frequency of the stopband at f_0 to construct stopband around f_0.

We proposed to fabricate two different PBG structures in parallel on the ground plane to construct two stopband single microstrip plane. The substrate used has a dielectric constant of 3.2 with a thickness of 0.76 mm. The conductor strip on top plane has a width of 1.83 mm, corresponding to a 50-Ω line for conventional microstrip. On the ground plane, a parallel PBG with bandstop filters, which have the center frequency of 6 and 9 GHz in the rejection band, was fabricated. For achieving bandstop filters at 6 and 9 GHz, the period a of 15.5 and 10.3 mm

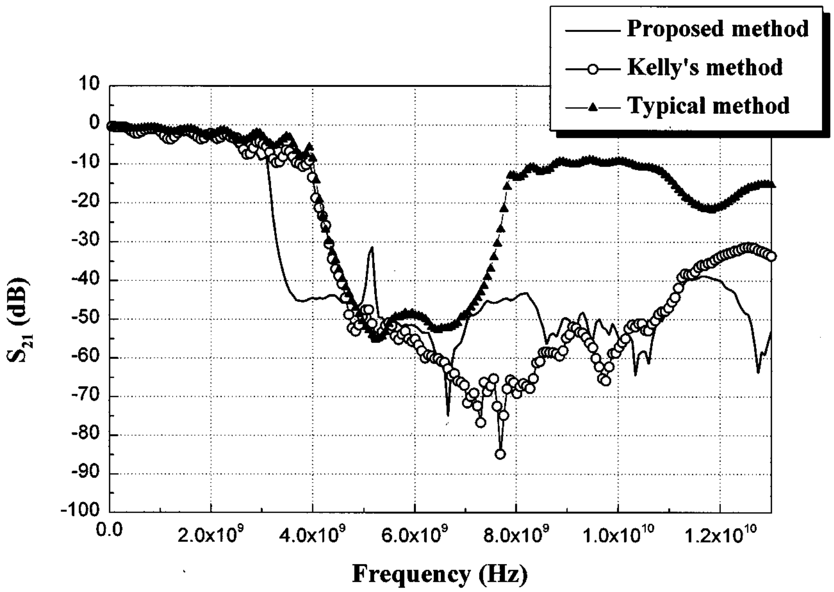

Fig. 3. The measured S-parameters of the proposed PBG structure, Kelly's method, and the typical structure for LPF in microstrip plane.

were selected. To implement these two stopbands on the single plane effectively, a novel structure was used as shown Fig. 2. Part A is constructed with the period of 15.5 mm and part B has the period of 10.3 mm for acheiving the rejection bands around 6 and 9 GHz. The proposed method in this letter does not require additional size increment when compared with Kelly's method [6], which achieves wide rejection band by serial connection of several different PBG structures.

Fig. 3 shows the measured S-parameters of the proposed PBG structure, Kelly's method, and the typical PBG structure of 6 GHz for LPF in the microstrip plane. The solid curve is the result of the proposed structure which has seven lattices of 15.5-mm period (6 GHz) and ten lattices of 10.3-mm period (9 GHz) in parallel, as shown in Fig. 2. The dot curve is the result of Kelly's method, which is constructed from a serial connection of two different PBG structures of seven lattices of 15.5-mm period and ten lattices of 10.3-mm period. So, the proposed method can reduce required circuit size by half of Kelly's method. As shown in Fig. 3, the proposed PBG structure has wider stopband than the typical PBG structure, and its performance is similar to Kelly's method. In addition, we can expect the probability of radiation in the proposed structure is a little, because the S_{11} value is about -0.9-dB in stopband, which means the reflection is very big in stopband.

III. Application in Microstrip Antenna

In the active array antenna system, the patch antenna operates not only as a radiator, but also as a resonator for integrated oscillator. The harmonic components of the antenna could be serious problem in this system. To solve this problem, PBG structure application was presented [2] and [8].

To supress the harmonic components and improve the bandwidth performance, the proposed PBG structure was constructed in the ground plane of the microstrip patch antenna which resonates at frequency of 1.9 GHz, as shown in Fig. 4.

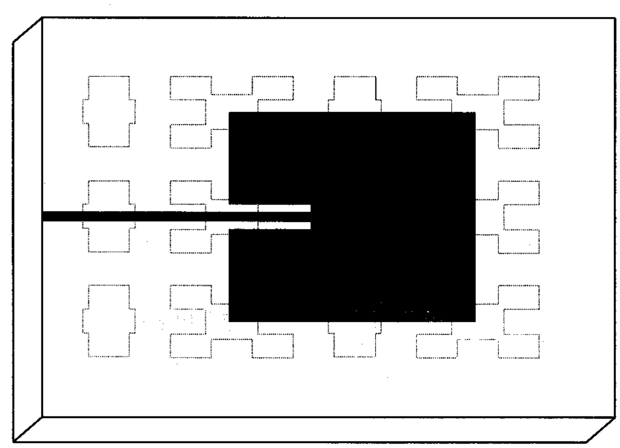

Fig. 4. Microstrip antenna with the proposed PBG structure in ground plane.

Fig. 5 shows the measured S_{11} of the microstrip antenna with proposed PBG structure. The harmonic components are almost perfectly suppressed in the PBG antennas with square lattice and with proposed lattice and has better performance in return loss and bandwidth, while the typical microstrip antenna has harmonic components, as shown Fig. 5. The PBG antenna, which has proposed structure, has better return loss level and bandwidth performance than one of the square PBG lattice and normal microstrip antenna with same patch size as shown Fig 2. But the resonant frequencies of PBG antennas were slightly shifted. So, the shift of resonant frequency should be considered in design of PBG antenna for enhancement of antenna performance.

IV. Conclusions

We proposed a novel PBG structure for wide stopband low-pass filter with a new periodic lattices and demonstrated

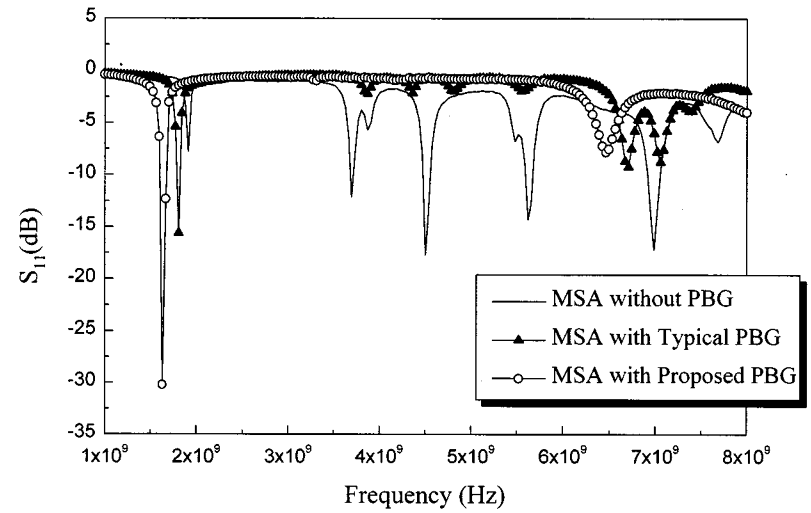

Fig. 5. Measured S_{11} graph of the microstrip antennas with proposed PBG structure, with typical PBG structure and without PBG structure in ground plane.

the PBG microstrip antenna with the proposed novel PBG structure. The proposed PBG structure has very wide stopband without any increasing circuit size. The demonstrated antenna has improvement in the return loss level and the bandwidth. It is also expected that the proposed structure can be applied in various microstrip circuits to improve their performance by removing harmonic components using the characteristics of wide stopband.

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