A Novel Electromagnetic Bandgap (EBG) Structure and its Application for Mutual Coupling Reduction

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***Abstract*—**We present a novel Electromagnetic Bandgap (EBG) cell which is easily fabricated on standard PCB material and can be used where space is at a premium. The proposed EBG structure was designed and developed to provide two stop bands at 4.24 GHz-5 GHz and 9.2 GHz-10.2 GHz on standard FR4. The size of a 5 x 5 cells structure is 35 mm x 35 mm and provides 10 dB attenuation across the surface. We also arranged sixteen proposed electromagnetic band-gap (EBG) elements in two columns embedded between two radiating patches for suppression of the surface wave. A 10 dB suppression is observed from the result. It demonstrates an excellent performance for mutual coupling reduction.

Index Terms—**electromagnetic bandgap structure (EBG), mutual coupling reduction.**

I. Introduction

In recent years, the Electromagnetic Band Gap (EBG) property has been investigated with respect to suppression of surface waves and performance enhancement of printed antennas and circuits [1] [2]. The major characteristic of EBG structures is to exhibit bandgap feature in the suppression of surface-wave propagation. This feature can be used to reduce mutual coupling between antennas. The EBG structures are periodical cells composed of metallic or dielectric elements. The bandgap characteristics depend on the material structure such as dimensions, periodicity, and permittivity [3]. Practical applications of EBG structures have difficulties in accommodating their physical sizes, since the period of an EBG lattice has to be a half-wavelength at the stopband frequency. It is inconvenient for us to integrate with circuits and antennas. This situation has been changed because there are some advanced methods to improve compactness in EBG design, such as mushroom-like EBG structure [4] and fork-like EBG structure [5]. Those structures were called uniplanar compact EBG (UC-EBG) introduced by Yang [6] and realized with square metallic pads connected by narrow strips to form a distributed LC network mounted on a bare or grounded dielectric slab. They are not only compact in size but also easily to be fabricated in circuits.

In this paper, we present a novel EBG structure. The structure provides two stop bands and can be used for some microwave applications.

II. The Design of EBG Structure

The EBG unit cell consists of three elements; a hollow square, stubs and via. A unit cell of the EBG structure is illustrated in Fig. 1 and the photograph is shown in Fig 2. Gray parts in the figure represent the metallic periodic structure which is etched on a dielectric substrate. The patch is connected to the lower ground plane by a metal plated via.

The 5×5 EBG array has been simulated to verify EBG structure. The array is built on a 0.8mm thick substrate with the relative permittivity of 4.4 (FR4). The width of outer square (w_1) is 4 mm and inner width (w_2) is 2 mm and the lengths of the square ($l_1$and l_2) are 4 mm and 3 mm. The gap (g_2) between adjacent patches is 1 mm and the inner radius of via is 0.6 mm and outer radius is 0.4 mm. The length (w) and width (l) of stub are 1 mm and 1mm, respectively.

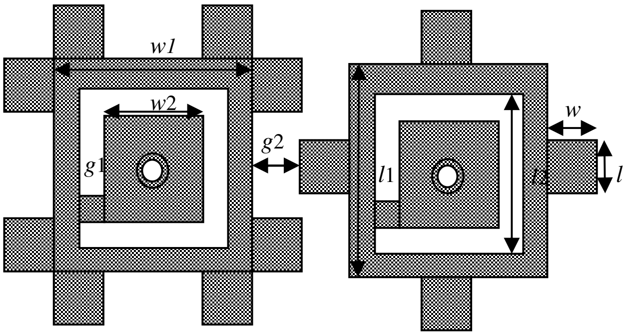


Figure 1. Schematic of the proposed EBG unit cell.

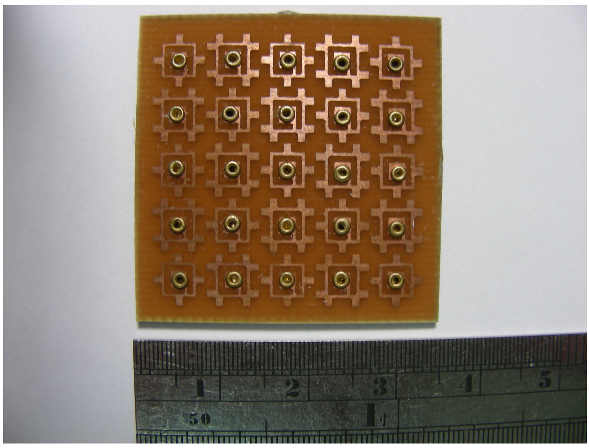
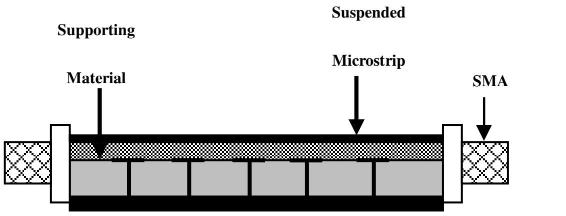


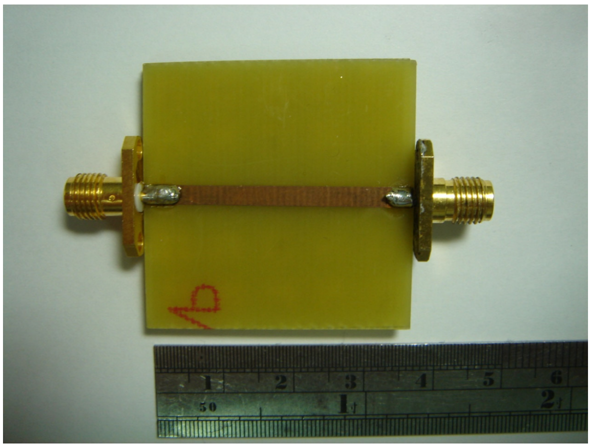
Figure 2. Photograph of the proposed EBG structure.

III. Simulated and Experimental Results

The method of suspended microstrip proposed by M. Y. Fan [7] is applied to measure the bandgap characteristic of the novel EBG structure, as shown in Fig 3. The measured EBG is embedded between the microstrip and ground plane, forming a sandwich-like structure. The suspended microstrip is soldered with subminiature A (SMA) connectors to measure the S-parameters. Comparing with the conventional coplanar microstrip method and monopole method, the suspended microstrip is a strongly coupling structure, diminishing the influence of other parasitic propagation modes, and the bandgap characteristics of the EBG are exhibited more obviously. The final simulated and measured results are shown in Fig 4. For clarity, only the transmission coefficient S_{21} is presented. The two stop bandwidths of the EBG structures are 760 MHz (4.24 GHz-5 GHz) and 1 GHz (9.2 GHz-10.2 GHz).



(a)



(b)

Figure 3. Method of suspended microstrip. (a) Sketch of the suspended microstrip structure. (b) Photograph of the proposed EBG with suspended microstrip.

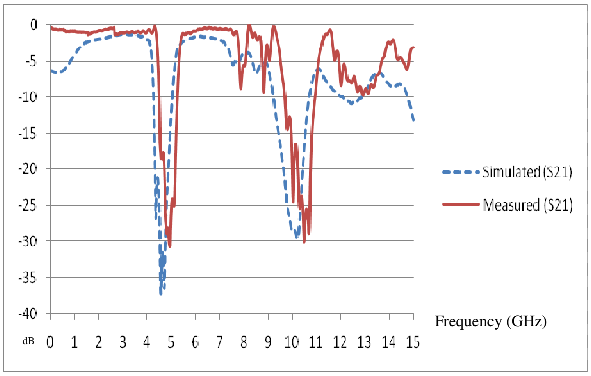


Figure 4. Simulated and measured results of proposed EBG structure.

Now, we turn to find the key parameter and underlying physics governing the EBG in this kind of periodic structure. We investigate the influences of different substrate materials of EBG structures. Hence, we use different permittivity materials to observe what goanna happened. Fig. 5 shows that when the dielectric constant decreased, the frequency band-gap position increased. This unique feature makes the proposed EBG structure more practical. Without changing the period size, one EBG structure can be used in a series of frequency band-gaps.

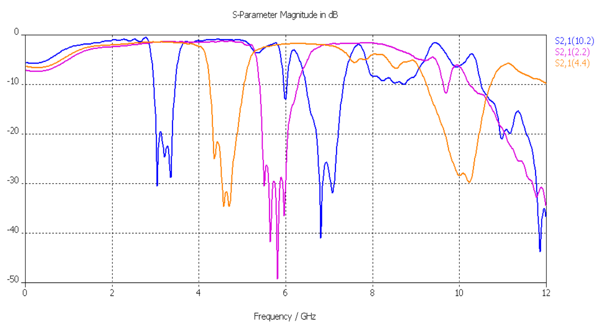


Figure 5. Comparison of simulated results of EBG structure with different substrate materials (εr=2.2, 4.4, and 10.2).

IV. Reduction of Mutual Coupling Between Two Patch Antennas

Recently, terminals for wireless communication with multimode have become more and more popular. There will be more than one wireless communication module integrated on one terminal, so we must take measures to increase the isolation between the antennas on different wireless communication modules. Because EBG structures have effects of surface wave suppression, using it for increasing the isolation between antennas has become a hot area. In this paper, we use the novel dual-stopband compact EBG structure to reduce the mutual coupling.

The schematic was shown in Fig. 6. The patch antennas are designed to resonate around 4.7 GHz and 9.8 GHz. The proposed EBG structures have two stop bands from 4.2 GHz~5 GHz and 9.2 GHz~10.7 GHz. Hence, when the EBG are properly designed, the pronounced surface waves are suppressed, and result in a low mutual coupling.

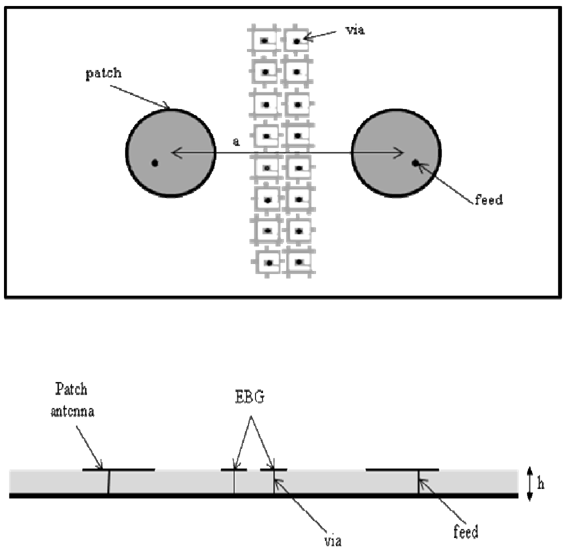


Figure 6. Patch antennas separated by the double cross EBG structure for a low mutual coupling.

The simulated results are shown in Fig. 7. For the antennas without the EBG structure, the mutual coupling at 4.7 GHz and 9.8 GHz are -22 dB and -18 dB. In comparison, the mutual couplings of the antennas with the EBG structure are only -33 dB and -27 dB at the respective frequencies. An approximately 10 dB reduction of mutual coupling is achieved at the resonant frequency of 4.7 GHz and 9.8 GHz. From this experimental demonstration, it can be concluded that the EBG structure can be utilized to reduce the antenna mutual coupling between array elements.

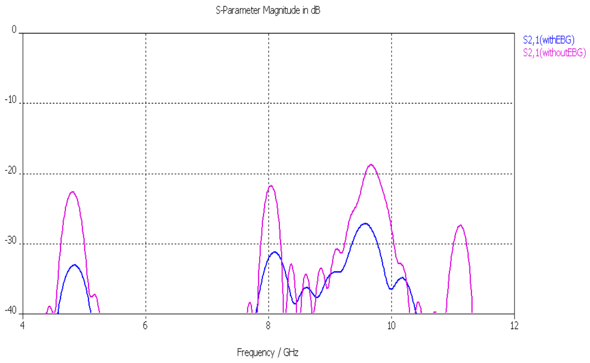


Figure 7. Simulated results of patch antennas with and without the EBG structure.

V. Conclusion

In this paper, we proposed a novel EBG structure. The structure was designed and developed to provide two stop bands. Two patch antennas with the EBG structure had been implemented. It demonstrates that the EBG reduce the strong mutual coupling caused by the thick substrate without sacrificing the compact size or bandwidth of the antenna elements. This mutual coupling reduction technique can be used in various antenna array applications.

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