PATCH ANTENNA WITH ELECTROMAGNETIC BANDGAP (EBG) SHIELD AND SURFACE WAVE DISTRIBUTION OVER THE EBG

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1. Introduction

Electromagnetic bandgap (EBG) material or photonic bandgap (PBG) crystals are artificially fabricated to forbid the propagation or transmission of the electromagnetic waves within a particular frequency band, or bandgap [1]. Because of such unique and useful characteristics not obtainable from ordinary metal plates, varieties of applications have been demonstrated for waveguides and antennas over the broad frequency range that includes microwave and millimeter-wave [2].

When used with patch antennas, the EBG technology could effectively improve the antenna performance [3]-[4]. By placing the EBG shield structure around or under a microstrip patch, the front-to-backward radiation ratio of the antenna is drastically enhanced. This improvement on the radiation patterns comes from the fact that the EBG can suppress the surface wave transmission.

In this paper, we measured the distribution of the surface wave on the EBG. A specially designed micro current probe was used to detect the H-field strength of the radiated microwave. By scanning the probe over the EBG board and measuring H-field, we succeeded in visualizing the surface wave distribution at the various frequencies. These results clearly explain the improvement in radiation patterns of our proposed antenna that an EBG reflective shield is attached under the microstrip patch [5].

2. Design and Experimental Setups

[EBG Structure]

Figure 1 shows the structure of the EBG antenna. This antenna consists of a regular microstrip patch and an EBG reflective shield. The patch, being stacked on the shield, is fed by a coaxial feed through a hole at the center of the shield. Figure 2 shows the detailed structure of the EBG. This EBG is composed of hexagonal patches proposed by D. Sievenpiper et al [1]. We used FR-4 for the dielectric.

The resonance frequency of the EBG is designed to be from 3.8 to 5.1GHz. Figure 3 plots the frequency response of the designed and measured reflection phase. Generally, the phase rotates 180 to –180 degrees around the bandgap, and the frequency whose phase is within 90 to –90 degrees is defined as a bandgap. The measured data, calculated from S11 at the EBG surface, shows similar response with the design.

Figure 4 shows the measured TM surface wave transmission and the test setup. The surface wave profile is evaluated by measuring the vector transmission coefficient between the transmitting horn antenna and micro current probe that detect H-field near the EBG surface. From this figure, we found the surface wave propagation is suppressed inside the bandgap.

[Beam Pattern of Antenna]

In this experiment, we measured the radiation beam patterns in three different frequencies. We fabricated three microstrip antennas that resonate at 3.0, 4.4 and 5.8GHz, respectively. These patches are made of the 0.8mm-thick Teflon substrate with ε_r=2.6. The substrate size is 50mm x 50mm. By combining these patches with the same EBG shield, we build the EBG antennas and measured their beam patterns. The shield size is 210mm x 210mm.

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[Surface Wave Distribution]

Figure 5 illustrates the measurement setup for the surface wave distribution. The TM surface wave was exited by using a horn antenna at the edge of the EBG substrate. The micro current probe, supported by the 3-D scanner, detects the H-field of the microwave. This probe operates up to 6.0GHz. The field strength can be easily measured by connecting both the horn antenna and the current probe to the vector network analyzer (VNA). The measured S21 contains the strength and phase information of the microwave at the probe. The minimum distance between probe and EBG is 0.5mm in this experiment.

3. Experimental Result

Figure 6 plots the measured beam patterns at the E-plane of the hybrid EBG patch antennas. And table 1 lists the front-to-backward (F/B) radiation ratio. This ratio is defined by dividing the strength toward 0 degree by the maximum strength among 180±60 degrees. As a reference, we also measured the antenna with metal shield. The size of metal shield is the same as the EBG shield; 210mm x 210mm.

From fig. 6, we found that for frequencies outside of the bandgap, 3.0GHz and 5.8GHz, metal shield and EBG shield shows the comparable beam patterns. F/B ratios are also comparable between metal and EBG. On the contrary, at the middle of the bandgap, 4.4GHz, the EBG shield, suppressing the backward radiation, sharpens the beam. The F/B ratio is drastically improved by changing the metal shield into EBG. From this measurement, we confirm the performance of the EBG reflective shield.

Figure 7 shows the measured surface wave distribution over the EBG. The frequencies are identical with the beam pattern measurement. At each frequency, horizontal and vertical scanning maps are visualized. On the maps, we plot the surface wave distribution by calculating the following value.

$$S_{xyz} = \mathrm{Re}(S_{21} \cdot e^{j\omega_c t})$$

where S_{21} is a measured scattering parameter at the each point, ω_c is frequency and t is a time. On fig. 7, we set t=0 and drew the maps by plotting S_{xyz} at the individual positions.

From fig. 7, we can easily find out that at the 3.0GHz and 5.8GHz, below and above the frequency bandgap, the surface wave propagates over the EBG. But at the 4.4GHz, inside the bandgap, surface wave is suppressed effectively. By eliminating the propagation of the surface wave, the edge re-radiation will be also prevented and the beam will be sharpened. These surface wave profiles agree with our measured beam patterns shown on fig. 6.

4. Conclusion

We demonstrated the hybrid EBG antenna that the reflective EBG shield is attached under the microstrip patch. Inside the bandgap, the EBG shield suppressed the undesired backward radiation and improved F/B radiation ratio of the antenna. And we measured surface wave distribution over the EBG by using micro current probe. From the measured data, we visualized the distribution maps. These maps gave us the evidence that the EBG really suppresses the surface wave propagation. We conclude that this suppression effect is the main reason why the EBG shield improves the F/B ratio.

References

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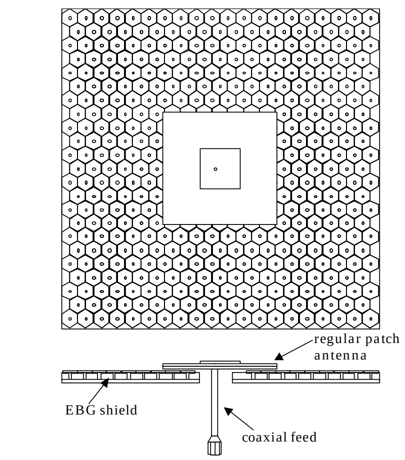


Fig.1 Configuration of the hybrid patch antenna with external EBG shield.

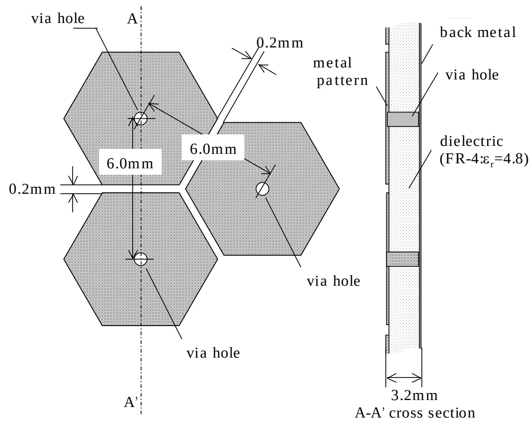


Fig.2 Detailed structure of EBG.

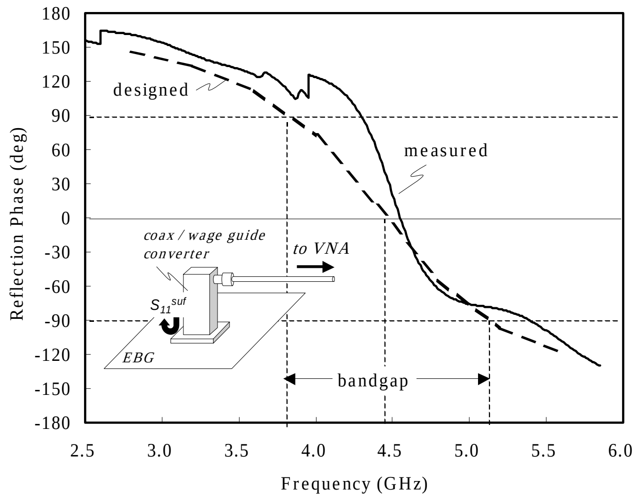


Fig.3 Designed and measured frequency response of the EBG.

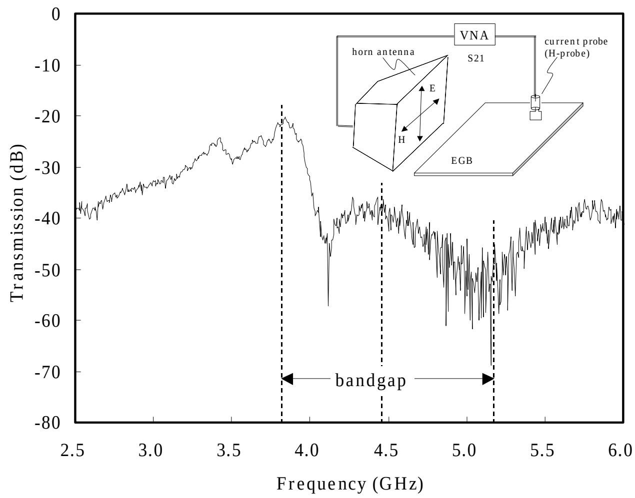


Fig.4 Measured surface wave transmission of the EBG.

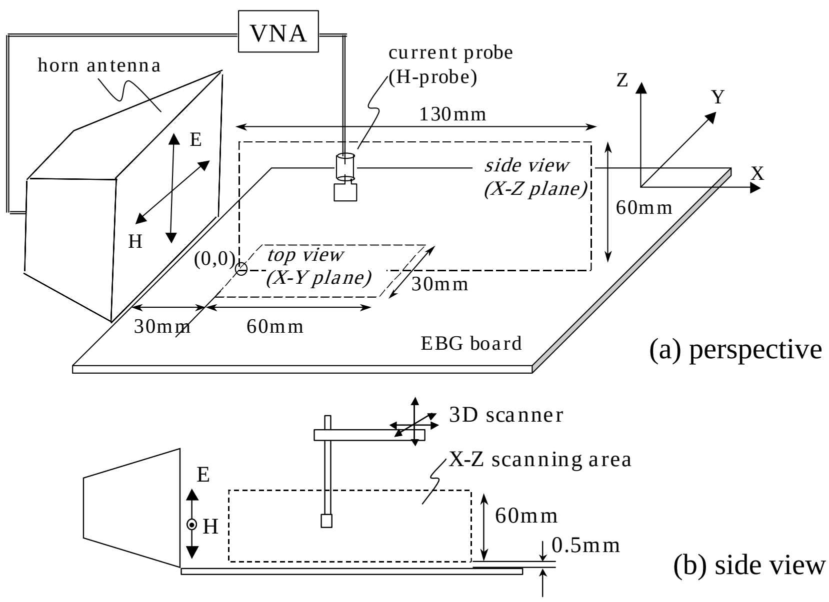
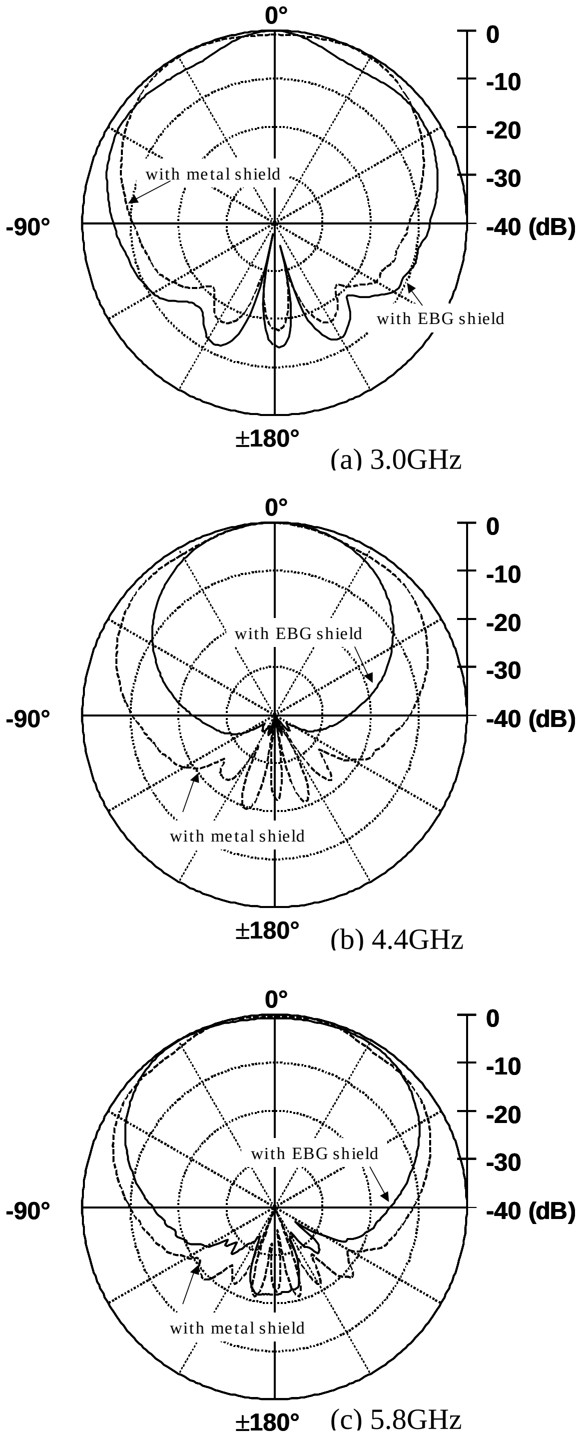


Fig.5 Measurement setup for surface wave distribution over the EBG.

Table. 1 Front-to-Backward (F/B) radiation ratio of various antennas.

	3.0GHz	4.4GHz	5.8GHz
with EBG	10.8	32.6	20.8
with Metal	14.8	18.3	18.3



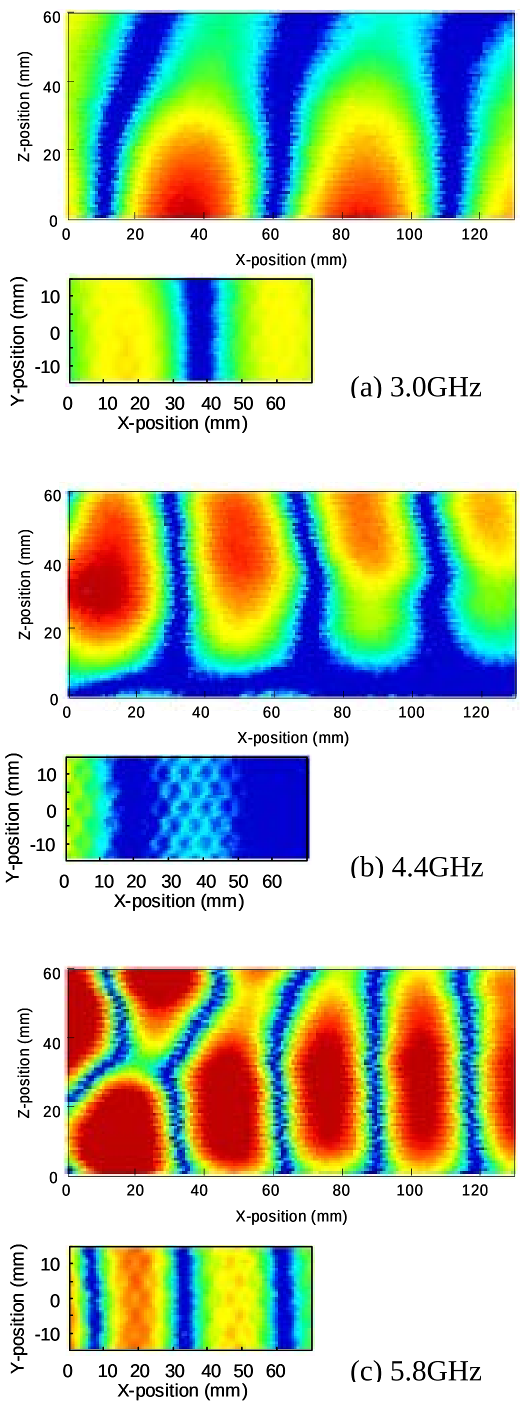


Fig.6 Measured beam patterns of patch antenna with EBG/metal shield.

Fig. 7 Measured surface wave distribution over EBG board.