Considerations for EBG Loss in Antenna Applications

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Abstract

The EBG (Electromagnetic Band Gap) structure is frequently considered as a lossless surface when working with external radiators. In practice there will be loss in many applications. This paper demonstrates EBG loss performance in antenna applications. Simulations are validated experimentally using a reverberation chamber with good agreement.

1. Introduction

The EBG structure was originally demonstrated by Sievenpiper [1]. It has novel characteristics such as in-phase reflection and suppression of surface current over a prescribed band of frequencies. This has lead to extensive research and applications, especially in antenna technology demonstrating the advantages of such structures, such as improved antenna direction, bandwidth, and front - to - back ratio. In most occasions, the loss induced by the EBG is not determined since the EBG structures are always analysed and considered as a lossless surface. It is true that the surface current is weak in the band gap. However when the EBG surface is less than 1/20λ from the antenna, both reflection of its radiated wave and coupling of the evanescent waves (TE and TM mode) to leaky and surface wave modes supported by the EBG leads to increased loss [2]. In this paper, we propose a slot antenna over two EBG structures to improve the directivity. We obtain the measured and simulated efficiency of the antenna with and without EBG. From the comparisons, the losses caused by the EBG should be considered when the EBG is close to the antenna.

2. Antenna and EBG structure

Fig. 1(a) shows the configuration of the proposed 2.8 GHz slot antenna and the EBG structures. The slot antenna is based on Taconic RF-35 with a thickness of 1.52mm. The antenna size is 30 mm × 36 mm. The EBG in Fig. 1(b) consists of two 8×8 small metal squares positioned over a solid metal plane. The space between patches and ground plane is filled with Taconic CER-10, the thickness is 3.18mm (ε_r =10, loss tangent = 0.0035 at 2.8 GHz). One of the two EBGs is a typical mushroom structure that has periodical vias in the substrate layer and the other has no via, but both include a top metal layer (FSS layer) and a metal ground plane. According to the effective medium model [2], both have the same in-phase reflection bandwidth from 2.6 GHz to 3.1 GHz for the normal incident plane wave, but the surface-wave suppression band gap is different. The EBG without via only suppresses the TE mode part of the incident wave below a band edge caused by the top metal layer (FSS layer). The mushroom EBG is able to suppress both TE and TM over a band gap caused by the top metal layer (FSS layer) and via array in the substrate. Usually the wave-suppression band gap can be identical to the in-phase reflection band. This is relevant to the key parameters in the EBG design; permittivity and substrate thickness, shape and periodicity of the FSS layer. To effectively improve the antenna performance, we have to ensure that the surface suppression band coincides with or exceeds the in-phase reflection bandwidth, otherwise the surface wave is excited and part of the incident energy does not propagate into free space. Our EBG design was based on the effective medium model for the resonant frequency and the in-phase reflection band from 2.6-3.1 GHz. The bandwidth (return loss < -10 dB) of the slot antenna in free space is from 2.7 GHz to 3.1 GHz which is completely in the EBG in-phase reflection band.

Fig. 1 (a) Slot antenna and (b) EBG structure (8×8 elements) with via and without vias

3. Results

The slot antenna with EBG was measured in a reverberation chamber. The reverberation chamber is used to measure the antenna efficiency. The radiation efficiency is defined as being the total radiated power divided by the maximum available power when the antenna is impedance matched. The antenna efficiency includes the effects of mismatch, as well as absorption in the antenna and its near field environment, which is defined as being the total radiated power divided by the total incident power [3].

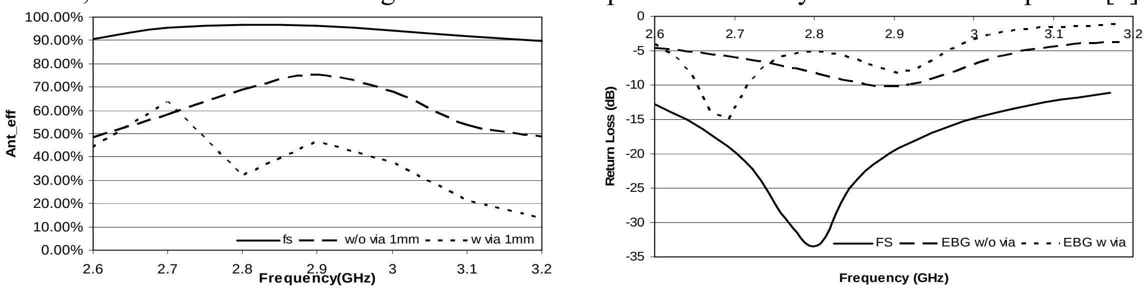

Fig. 2(a) The simulated antenna efficiency comparison, (b) The return loss comparison of slot antenna in free space, with the via_less EBG and mushroom EBG at 1mm separation by Micro-stripes 7

When the EBG structure is placed 1 mm (1/100λ) away from the slot antenna, the antenna bandwidth decreases; however the separation is 2 mm and 3mm, the bandwidth becomes larger than that of 1mm as shown in Fig. 3 - Fig. 6.

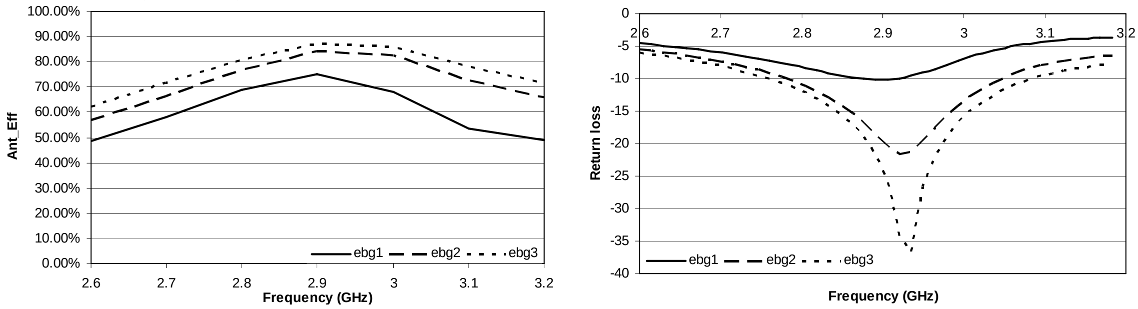

Fig. 4 (a) The simulated antenna efficiency (b) The return loss of the antenna and via_less EBG comparison at 1, 2, 3 mm separation

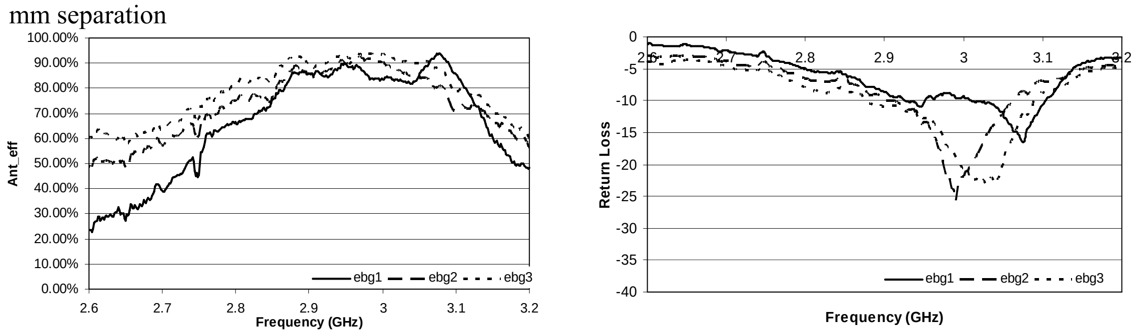

Fig. 5(a) The measured antenna efficiency (b) The measured return loss of the antenna and via_less EBG (without via) comparison at 1,2, 3 mm separation

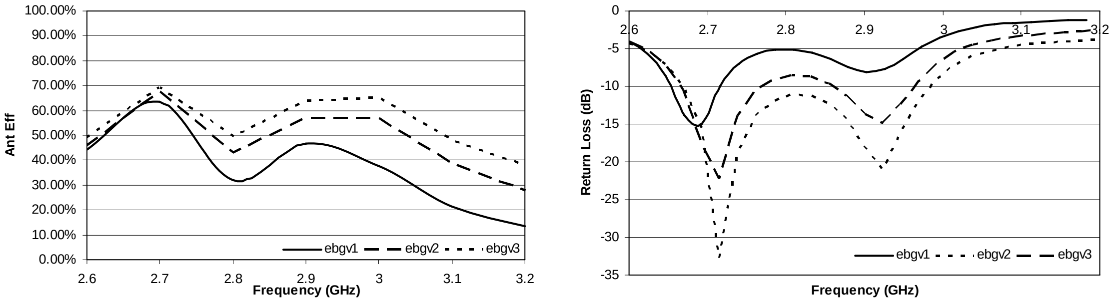

Fig. 6(a) The simulated antenna efficiency (b) The return loss of the antenna and mushroom EBG comparison at 1,2,3 mm separation

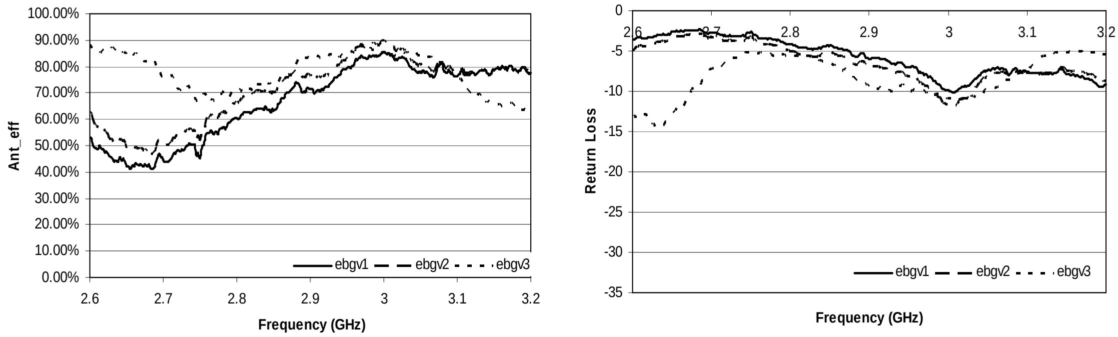

Fig. 7 (a) The measured antenna efficiency (b) The measured return loss of the antenna and mushroom EBG comparison at 1,2,3 mm separation by simulation

4. Conclusion

As shown in the above figures that the EBG is extremely close to the slot antenna, the loss induced by the EBG should be considered. In this case, the loss is attributed to the substrates loss and induced current on the metal surface and vias. Also the bandwidth significantly reduced at the expense of higher directivity and front to back ratio that the EBG provides because the EBG works as a resonating structure for its in-phase reflection feature. Nonetheless the bandwidth increases for larger separation. The mushroom EBG gives more effect on the return loss of the slot antenna compared to that of the via_less EBG. The reasons for this need to be further investigated in the future.

References

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