Microstrip Line Fed Slot Antenna with PBG Superstrate

Lijun Zhang * [a], Nicolaos G. Alexopoulos [b] and Eli Yablonovitch[a]

[a]Department of Electrical Engineering, UCLA
Los Angeles, CA 90095
Email: lzhang@ee.ucla.edu, eliy@ee.ucla.edu

[b]Department of Electrical and Computer Engineering, UCI
Irvine, CA 92697
Email: alfios@uci.edu

ABSTRACT

The effect of using a superstrate PBG material on a microstrip line fed slot antenna is investigated. The PBG material is composed of periodic metallic blocks inside a host dielectric material with high material permittivity, and exhibits a complete bandgap at the design frequency of the slot antenna. Simulation results show that by adding the PBG layer as a superstrate, radiation in the E-plane near the endfire direction is suppressed, while radiation in the H-plane is enhanced.

I. Introduction

Photonic Band-Gap (PBG) materials are essentially periodic structures which can suppress the propagation of certain waves along certain directions in some frequency ranges (bandgaps). The application of PBG materials in printed antenna design has received significant attention recently. Dipole and patch antennas with PBG substrate or superstrate have been analyzed in [1][3] and gain enhancement has been found, which can be due to the excitation of a leaky wave mode as discussed in [2]. It is also found that these PBG materials only exhibit partial bandgaps [2][4]. A novel printed PBG material with a complete bandgap has been analyzed in our previous paper [5], application of such a material in patch antenna design can be found in [6], where gain and bandwidth enhancement has been determined. These effects are essentially due to the increased aperture efficiency and dual aperture effect.

In this paper, we investigated the effect of using a superstrate PBG material on a microstrip line fed slot antenna. From the equivalence principle, a microstrip line fed slot acts as a magnetic dipole, the radiation pattern is similar to that of an electrical dipole by interchanging the E- and H-plane. Surface wave effects on the radiation pattern of printed dipoles on uniform substrate have been discussed in [7]. In this paper we found that by adding a PBG cover with a gap at the resonant frequency of the slot antenna, the radiation in the E-plane near the endfire direction is suppressed, while the H-plane radiation is enhanced. These properties will be exploited in our later slot array antenna design.

II. Bandgap properties of the PBG material

The PBG material used in this work is composed of periodic metallic blocks inside a host dielectric substrate. In order to make the slot size comparable to the unit cell size of the PBG material, high permittivity materials with $\epsilon_r = 10.0$ are used. The bandgap of the PBG material is designed to be at the operating frequency of the slot antenna. Using the efficient finite element method presented in our previous paper [5], the bandgap properties of this material are obtained and are plotted in Fig. 1. We found that there exists a complete bandgap between the first and second mode, which are TM and TE modes respectively. In our design the slot antenna will operate inside this gap.

III. Slot antenna with PBG superstrate

The antenna configuration is shown in Fig. 2, a narrow rectangular slot is cut in the ground plane. On one side of the ground plane there is a PBG layer, while on the other side there is the feeding microstrip line. In order to study the effect of the PBG cover, we design the slot antenna to resonate inside the bandgap and we choose the frequency to be 11.0GHz. A FDTD code is written to get the simulation results. Firstly, we do an optimization to find the resonant length of the slot and the offset of the microstrip line with respect to the slot. It is found that the optimum slot length and the feeding microstrip line offset are both half of the effective wavelength. This is because the slot radiation resistance is in shunt with the resistance seen toward the open end of the microstrip line. This implies that the microstrip line offset must be half of the effective wavelength to guarantee the open circuit is transformed to the slot position. Therefore the feeding microstrip line only sees the radiation resistance of the slot, where the slot is typically a half wavelength to obtain a match between the feedline and the slot. In the simulation, the PBG material is terminated by a metallic cavity for numerical convenience, which is resonable since the wave is attenuating inside the bandgap.

The return loss is shown in Fig. 3. At the design frequency 11.0GHz, the return loss is less than -10dB. The directivity patterns are also shown in Fig. 3, where we plotted the pattern for the slot antenna without any cover for comparison. It is seen that inside the bandgap frequencies radiation in the E-plane near the endfire direction is suppressed, while radiation in the H-plane is enhanced. For frequencies outside the bandgap the patterns are degraded.

References

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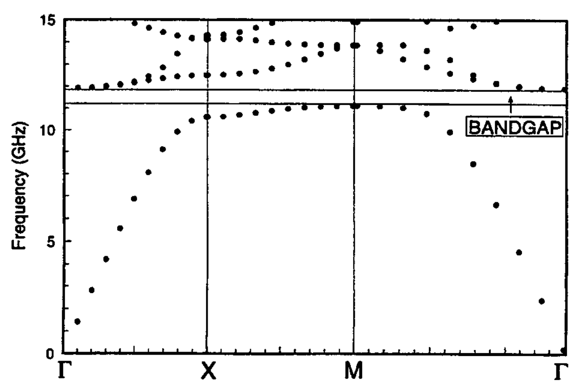

Figure 1: Bandgap information of the PBG material composed of periodic metallic blocks inside a host dielectric material. $\epsilon_r = 10.0$. Unit cell size is $10mm \times 10mm$, the PEC block is $6mm \times 6mm$. The thickness of the PBG is $2.0mm$.

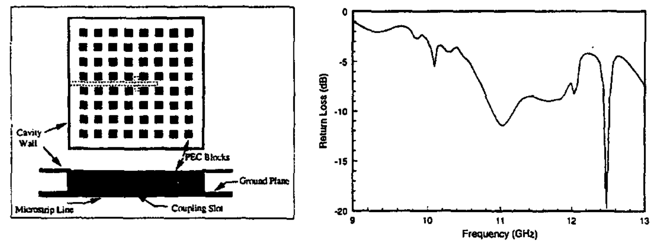

Figure 2: Microstrip line fed slot antenna with PBG superstrate, 6X6 unit cells are used in the FDTD simulation. Return Loss is shown in the right hand side. The design frequency is 11.0GHz. Sizes are: slot length=4.0mm, slot width=0.5mm, feedline offset=4.5mm.

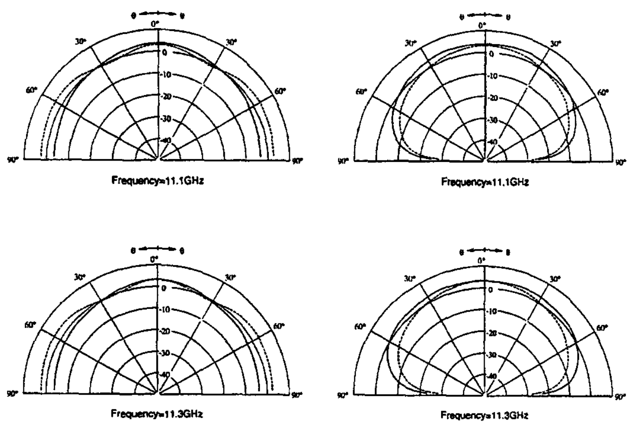

Figure 3: Directivity pattern. Left-hand side for E-plane pattern, right-hand side for H-plane pattern. Solid line is for the antenna with PBG superstrate, dashed line for no superstrate. For frequencies inside the bandgap.