Cavity Backed Antennas with PBG-Like Substrate or Superstrate Materials

Lijun Zhang[a], Harry Contopanagos[a], Nicolaos G. Alexopoulos[b] and Eli Yablonovitch[a]
[a]Department of Electrical Engineering, UCLA
Los Angeles, CA 90095
[b]Department of Electrical and Computer Engineering, UCI
Irvine, CA 92697

Abstract

This paper presents an investigation of the effect of perforated magnetodielectric materials in the design of cavity backed microstrip antennas. These Photonic Band Gap (PBG)-Like materials may be loaded with heterogeneous material inclusions and used as substrates and/or radomes (superstrates) in the presence of the antenna. A variety of optimized antenna-radome designs will be discussed.

1. Introduction

The rigorous analysis of an elementary antenna radiating in the presence of a Photonic Band Gap (PBG) layer has been introduced by Yang et al. [1]. In addition, Yang et al. [2] investigated the reflection and transmission properties of a plane wave in multilayered PBG materials. In this paper we investigate the use of PBG-Like structures to improve antenna performance. Cavity backed microstrip antennas are considered and their radiation properties are analyzed. It has been shown that to improve microstrip antenna gain, a substrate-superstrate configuration can be used [3]. Substantial gain enhancement can be obtained, with the use of multiple superstrates [4,5] or with a single PBG layer [1]. In the latter case a gain enhancement of 14.5 dB was found for an elementary printed dipole. This enhancement is due to a strong excitation of leaky wave modes in the PBG layer. Motivated by this result, we examine in this paper the important issue of using PBG substrates/superstrates within the framework of practical, laterally finite, compact cavity-backed patch antennas. To obtain PBG effects, the unit cell size should be comparable to the operating wavelength, otherwise the material will be electrically equivalent to a uniform medium. On the other hand, due to the realistic limitation of compact lateral size, not too many unit cells can be included, and the system reacts in principle differently than its infinite PBG counterpart (hence our terminology "PBG-Like").

2. Analysis

The modeling technique we use is a combined Finite-Element Integral-Equation method (FE-IEM) [6,7] and we created a new numerical code based on it. For the cavity region, we use the FEM while we use a surface integral equation to establish the boundary condition at the cavity aperture. We will

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provide details on the formulation of our method, the development and further capabilities of our design method for other applications in ref [8].

3. Numerical Examples

The first example shown in Fig. 1 is a rectangular patch antenna backed by a uniform dielectric loaded cavity used in [7]. The cavity size is about half wavelength at the operating frequency, and the patch size is around three quarters of the wavelength. It is seen in Fig. 2 that the gain is usually around 5dB at two resonant frequencies. The input impedance data agrees well with those in [7], which proves the accuracy of our code.

Next, the rectangular patch antenna on PBG-Like substrate is studied in Fig. 3. The PBG-Like substrate consists of four by four unit cells, each unit cell being about half electrical wavelength, at a target operating frequency range, computed by a volumetrically averaged permittivity. Permittivity contrasts of 10 to 1 and 36 to 1 have been used. Maximum gains of 7.5dB and 9.0dB were found for these two cases respectively.

Finally, the effect of PBG-Like superstrate on the patch antenna is investigated and shown in Figs. 4,5. The superstrate consists of five by five unit cells. A frequency scan of the antenna pattern has been done, and it is found that, at certain frequency range, two main beams will arise, and at another frequency range there will be strong radiation into the horizon (8dB). Maximum gain over 10.0dB has been found for both E and H Plane. A variety of additional optimized designs have been performed. These results will be discussed during the presentation.

4. References

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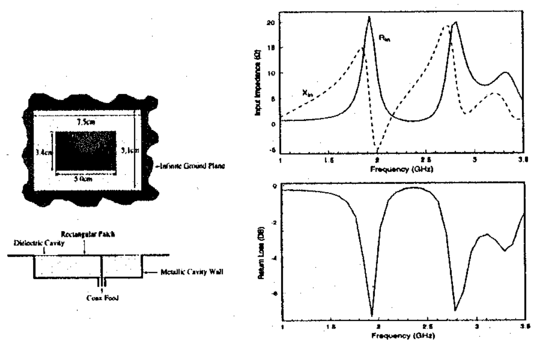

Figure 1: Cavity Backed Patch Antenna on Uniform Substrate

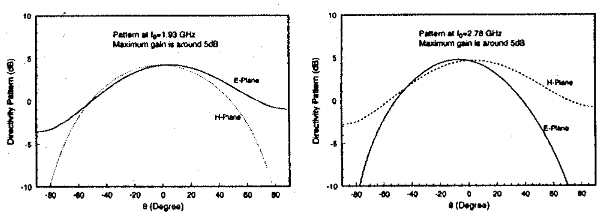

Figure 2: Directivity Pattern for Antenna in Fig. 1

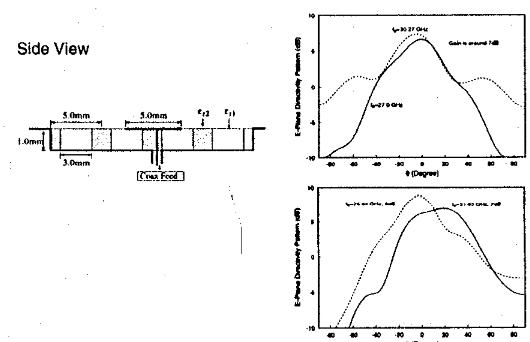

Figure 3: Patch Antenna on PBG-Like Substrate.

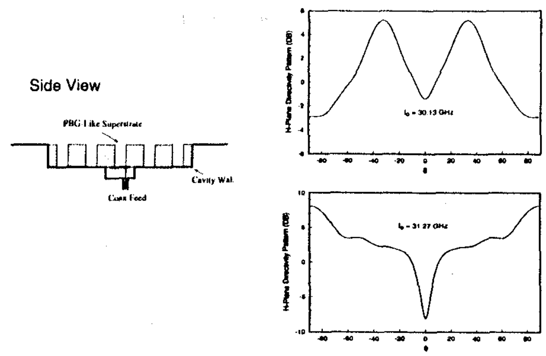

Figure 4: Patch Antenna with PBG-Like Superstrate. Unit cell of the superstrate is same as in Fig.3, patch size is 3.0mm×3.0mm, lower cavity size is 5.0mm×5.0mm.

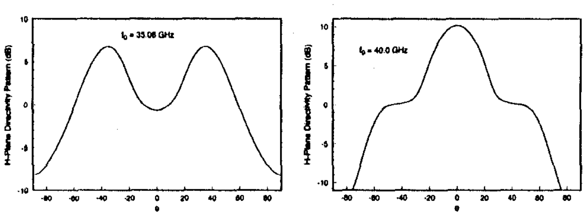

Figure 5: Directivity Pattern for Antenna in Fig. 4 (5 by 5 unit cells).