Some Antenna Devices Based on PBG Systems

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Abstract: We apply a new software package that was designed for the simulation of photonic crystal structures for designing a novel type of antenna with promising features. We illustrate the procedure for an antenna consisting of a dielectric block that is coated with two conducting plates. Instead of air holes that are usually used inphotonic crystals, we insert metallic rods in the dielectric. As a result, we obtain interesting adaptive antenna.

Introduction

Photonic Crystals (PCs) [1] have recently attracted much interest in optics, because it is expected that PCs open the door to High-Density Integrated Optics. In fact, PCs are nothing else than periodic structures that exhibit a Photonic Band Gap (PBG), i.e., a frequency range where no electromagnetic wave can propagate through the PC. Interesting structures such as waveguides, resonators, splitters, filters, etc. can be obtained by introducing impurities or defects within the PC. Obviously, The concept of PCs is not limited to optics. It can easily be applied also in the microwave regime, where it can be applied to the design of novel antenna.

We recently have developed a software package [2] for the user-friendly analysis of 2D PC structures with arbitrary defects. This code is based on the Method of Auxiliary Sources (MAS) [3]. Since it is not limited to optical structures and can also handle metallic bodies, we can also apply it to the design of novel microwave antenna that may be called PBG antenna although they operate outside the typical frequency domain of photonics.

PBG antenna model

In the following, we consider a set of metallic rods in a dielectric. The rods may either passive antenna or active ones. In order to obtain a 2D model that can easily be analyzed with our software package, we assume that the dielectric block is contained between two parallel plates that are perfectly conducting (Fig. 1). The resulting 2D model gives an excellent insight in the mechanisms of PBG antenna and allows us to design adaptive antenna without expensive experimental work. However, this is a first step. For more relistic results, 3D simulations will be required that may also be based on the MAS.

The main advantage of the PBG antenna is the richness of effects that may be used for obtaining the desired antenna pattern. At the same time, this

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richness also creates problems for the synthesis, namely because simple design rules are missing. Our software package is therefor important for getting experience and for finding design rules for the future development of PBG antenna.

Numerical results

As illustrated in Fig. 1, we consider a sandwich-like antenna structure consisting of two metallic plates with the dielectric structure located in between. The dielectric area is used in order to reduce the geometric dimensions of antenna. A PC structure is first formed by a regular array of metallic rods in the dielectric. In a second step, defects, i.e., missing rods, are set in such a way that the desired antenna pattern is obtained. The antenna is feed by at least one active rod with an impressed current. By an appropriate placement of the defects we can obtain waveguide channels, resonators, and so on, as in standard PCs. Therefore we can obtain several radiating output ports with different phase shifts, These ports finally allow us to manipulate the radiation pattern.

The near field distribution for the resonance frequency and the radiation pattern of of a relatively simple model are presented in fig 2a and fig 2b respectively.

For obtaining adaptive antenna that permit steering the beam electronically, a slightly modified antenna structure has been investigated, shown in fig 3. In this case, the antenna is fed by the two active rods, placed at different locations (fig. 3a.). Changing the phase difference between the two sources up to 48 degrees, results in steering the beam direction as illustrated in Fig. 3. Note that the radiation pattern remains almost the same for different when the antenna is steered.

In Fig. 3, also the frequency response of the investigated antenna is shown. The pattern mentioned above and the near field plots in Fig. 3 correspond to the first resonance frequency.

It is known that PCs may be quite sensitive to tolerances in the fabrication process. Therefore, one of the main problems is to know the stability and admitted tolerances. Numerical simulations allow us to explore how inaccuracies affect the resonce frequencies, the Q-factor, and radiation parameters.

To investigate the effects of inaccurate fabrication, pseudo-random displacements of the positions and sizes of the rods were introduced and their influence on radiation pattern, near field, and resonance frequencies was studied.

As a test case, we consider the the antenna shown in Fig. 3, which has a quite narrow resonant peak i.e. a high Q-factor.

The resulting frequency responses for the different fabrication tolerances are shown in fig 4. One can see that a precision of fabrication up to 5% is acceptable, whereas lower precision leads to significant shifts of the resonance frequency and completely changes the inner field distribution, leading to misfunctioning of the device.

Conclusion

We have propsed a novel antenna structured based on the PBG concept of finit PCs. Furthermore, we have demonstrated that such structures can have very attracive features even in the relatively simple case that was considered. In addition to the analysis of the frequency response, the near field and far field patterns, we also have studied the impact of fabrication tolerances on the antenna properties. For more detailed investigations, 3D simulations will be required, but the present work clearly demonstrates the design procedure and shows how PBG antenna might look in the near future.

Acknowledgment
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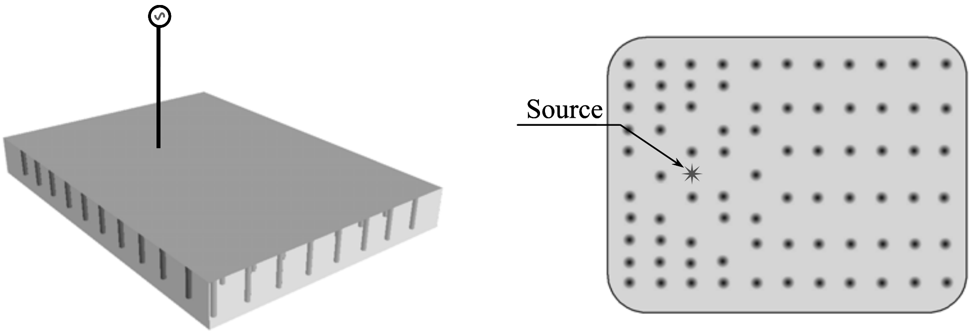


Fig.1. PBG Antenna geometry

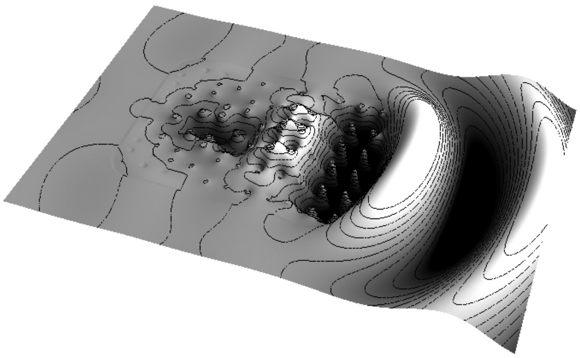


Fig.2 a. Near field distribution

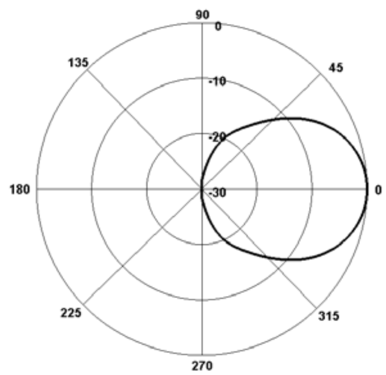


Fig.2 b. Radiated pattern in DB

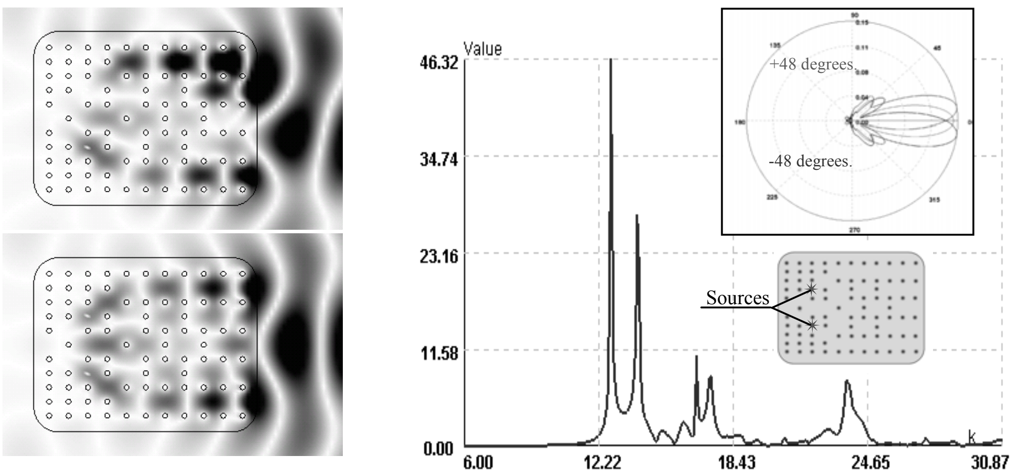
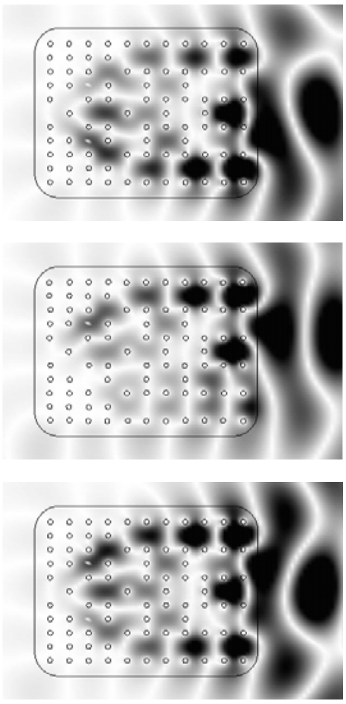


Fig. 3. Near fields



2%

5%

10%

Fig. 3. Frequency response and radiated pattern

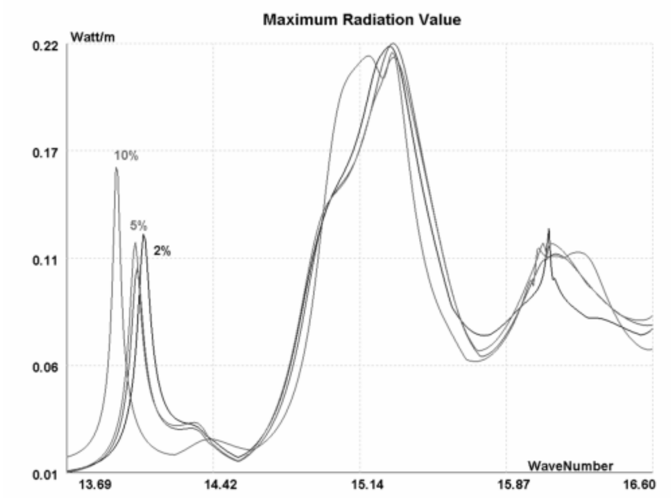


Fig. 4.
Influence of inaccuracy during device implementation

Fig. 4 Analysis of fabrication tolerances

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