TITLE: Simulation of the Finite Photonic Crystal-Based Adaptive Antenna

SIMULATION OF THE FINITE PHOTONIC CRYSTAL-BASED ADAPTIVE ANTENNA

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ABSTRACT

The present work is dedicated to the FPC based adaptive antenna structure simulation. The effectiveness of the photonic crystals in such implementation is discussed. Several types of antenna devices are presented. The influence of the inaccuracy during the technical realization of the device is studied.

INTRODUCTION

In the superhigh frequency band devices like mixers, separators, frequency filters, and splitter and so on are widely used. With the growth of operating frequency development of such devices also becomes complicated. In the sub-millimeter and optical frequencies range the devices of special type – so called photonic devices become efficient. The main part of such device is a crystal dielectric structure with the defects, introduced to it in special way. According to the nature of photonic crystals there are gaps in their spectrum, that causes some frequencies to be filtered out – and some – pass through. The ordinary absorbing media transforms the power of electromagnetic wave to heat. Instead, the band-gap does not dissipate power – it is accumulated and can therefore be supplied to necessary direction. The placements of defects in the crystal define its behavior towards the propagating wave – will it split, mix, or filter it. For example, one can introduce several "channels" to the crystal, that having different resonant capabilities will provide a way of exarticulation the carriers of different frequencies from the incoming signal. All these properties of the photonic crystals can be used also to develop an efficient antenna device having the specified parameters. Experimental way of developing and investigating such structures is either too time consuming and expensive, or quite impossible because some of the system's properties can not be easily changed continuously, or the defect's positions can not be arbitrary chosen.
In the present work several types of antenna are discussed, developed using the specially created software for the field propagation in FPC structures numerical simulation for the device's parameters optimization

MODEL

As a photonic crystal a rectangular body has been taken with the defects represented by the metallic rods, located inside it. The excitation is applied at the arbitrary point inside the crystal and is simulated by the cylindrical wire. The numerical solution of the corresponding electrodynamic problem is fulfilled using MAS [1]. By means of the created software several numerical results have been obtained, demonstrating the ability of such structure to serve as a core elements in complicated optical and SHF devices, as well as the capabilities of the software to analyze and simulate different configurations – to avoid expensive experimental development.

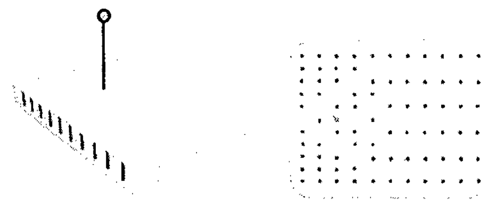


Fig 1. FPC antenna layout

Fig 2. Near field and radiation pattern

The presented sandwich-like antenna structure consists of a two metallic plates with the dielectric photonic crystal located between them (Fig.1). A periodical structure is formed by the homogeneously distributed metallic cylindrical rods inside the antenna volume. A defect is a vacancy – absence of the rod in the given cell. The antennas' feeding is supplied by a coaxial cable and is simulated by the linear current. The resonant channels are formed by the defects introducing a phase delays to the propagating in them wave, thus promoting the directed radiation behavior of the antenna. The near field distribution at the resonant frequency and the pattern of radiation is presented on Fig 2.

Fig 3. Near fields.

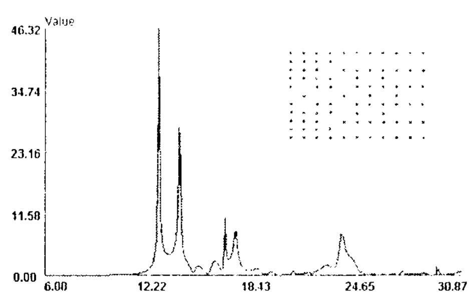


Fig 4. Frequency Response.

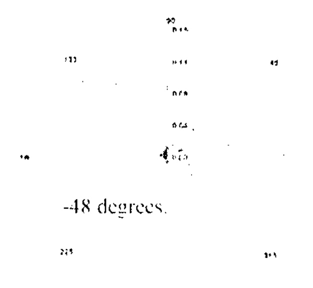


Fig 5. Patterns

In some application it is necessary for the antenna to be adaptive i.e. able to shift the beam of radiation electrically, for example, changing the phases of feeding currents.
For this purpose, a slightly altered FPC structure has been developed, shown on Fig 3. The feeding is applied by the two phased sources.
On Fig. 4 the frequency response of an antenna is shown. The presented near field plot correspond to the first peak's left slope. The nearer the frequency is to the resonant one, the more effective will be radiation, but the beam shifting possibility will be decreased. This rectangular antenna may be implemented when just slight beam steering capabilities are needed.

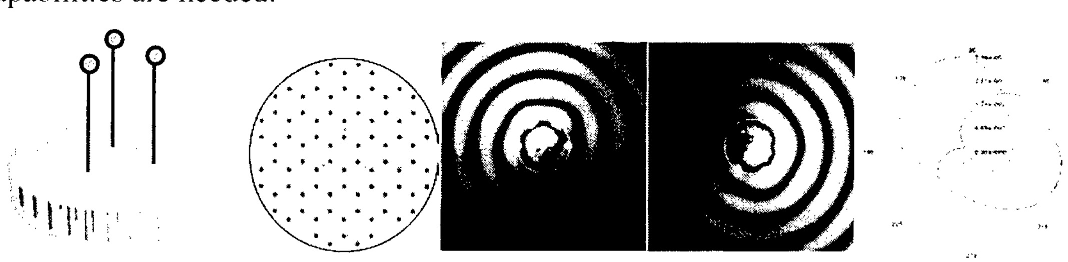


Fig 6. The hexagonal FPC structure, its near fields and Patterns at different feeding phases sets

More flexible and omni-steerable antenna can be built up using the symmetrical hexagonal lattice as the core for the FPC (fig 6).

Here three independent sources are placed symmetrically relative to the lattice thus providing a possibility to radiate in fact, in any direction, depending on the feeding current's phases and amplitudes selection. The fig 5 show the near field distribution along with the corresponding patterns of radiation (fig 7). Such antenna can be used in some kind of radar or autotracking systems.

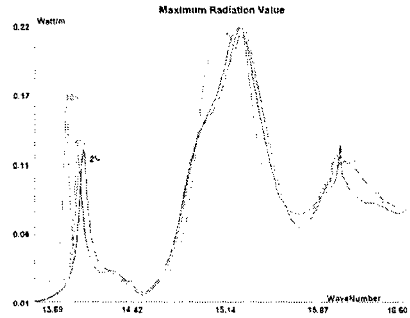
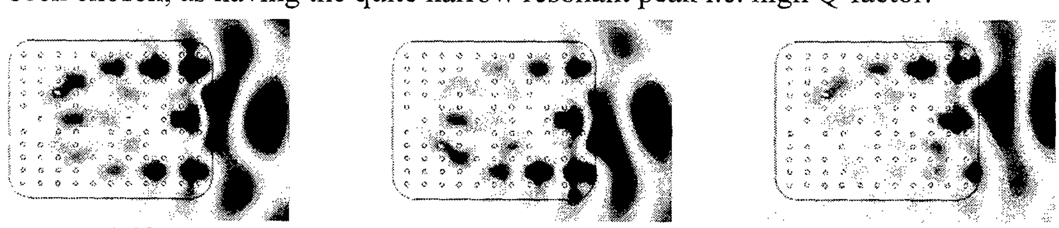


Fig. 8. Spectrum

The important thing, which must be taken into account when developing such devices, is how the inaccuracy in the real technical realization of the device may affect the position and Q-factor of the resonances and other radiation parameters. To investigate these conditions a possibility of giving the pseudo-random displacements to rod-s position and sized have been introduced and the influence on pattern, near field, and position of resonances has been studied.

As an under test problem the rectangular antenna has been chosen, as having the quite narrow resonant peak i.e. high Q-factor.



a) 2% b) 5% c) 10%

Fig. 9. Influence of inaccuracy during device implementation

The resulting frequency responses for the different assembly precision are shown on Fig 8. One can see that during realization of the device a precision of up to 5% is quite acceptable, and the lower precision lead to significant displacement of the operating frequency and completely changes the inner field distribution, leading to misfunctioning of the device Fig 9.

CONCLUSIONS

FPC structures proved to be efficient for use as a core element in antenna devices, providing high degree of flexibility, and allowing to create complicated devices using simple core elements, such as metallic stocks, that is quite easy realizable by the modern technology. A software package has been developed allowing real time design and simulation of the FPC based devices, including the finite precision limitation of technical realization of the device, which makes it directly applicable for engineering calculations.

REFERENCES

[1] R. Zaridze, G. Bit-Babik, K. Tavzarashvili, N. Uzunoglu, D. Economou. "Wave Field Singularity Aspects Large-Size Scatterers and Inverse Problems." IEEE Transactions on Antennas and Propagation, vol. 50, No. 1, January 2002, p. 50-58.

[2] J. Joannopoulos, R.Meade, J.Winn "Photonic Crystalls: Modeling the flow of light", Princeton University Press, 1995