1-D AND 2-D PHOTONIC BANDGAP MICROSTRIP STRUCTURES

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ABSTRACT: *Recently, 2-D photonic bandgap reflectors in microstrip technology have been proposed. Finite-element 3-D electromagnetic simulation shows negligible values of the fields outside the central row of the periodic pattern. This suggests the use of 1-D patterns to reduce the transversal size of the reflectors. Simulations and measurements have been realized, giving very similar performance for both 1-D and 2-D structures.* © 1999 John Wiley & Sons, Inc. Microwave Opt Technol Lett 22: 411–412, 1999.

Key words: *photonic bandgap (PBG); microstrip; Bragg reflectors*

I. INTRODUCTION

Bidimensional photonic bandgap (PBG) reflectors in microstrip technology have been proposed in the last year [1, 2]. The idea of employing PBG structures was first used in the optical frequency domain [3], but lately, it has been scaled to a wide frequency range, including microwaves.

PBGs are periodic structures which exhibit a bandgap, a band of frequencies in which electromagnetic propagation is not allowed. Due to this frequency-selective property, they can be employed as band reflectors, behaving as Bragg reflectors. One of the greatest advances in the development of these structures in the microwave range has been their implementation in microstrip technology. Several approaches have been proposed to produce a PBG in microstrip technology. The simplest and most effective way is to etch the periodic pattern in the ground plane of the microstrip line [2].

Until now, the periodic patterns used to implement microstrip PBG reflectors were 2-D. Finite-element three-dimensional electromagnetic simulation reveals that field levels outside the central row of the periodic pattern are negligible. This suggests that PBG reflectors consisting of only the central row of the pattern (1-D) will have similar behavior as a 2-D reflector. The advantage of a 1-D implementation is a considerable reduction in the transverse dimension of the reflector.

In this paper, 1-D and 2-D microstrip PBG reflectors are compared in simulation as well as in measurement, obtaining almost identical results.

II. 1-D AND 2-D PBG REFLECTOR DESIGN

The PBG reflectors are implemented in microstrip technology by etching circles in the ground plane following a periodic pattern. The 2-D reflector has three rows of circles [2], while the 1-D reflector has only one row, which corresponds to the central row of the 2-D structure (Fig. 1). The rest of the design parameters of the periodic pattern (radius of the circles r and distance between the center of the circles a) will be the same for both cases. The conductor strip at the top plane has a width w, corresponding to 50 Ω for a conventional microstrip line.

Two simulations and two measurements will be performed, both of them comparing 1-D and 2-D structures. The simulated prototypes have an operation frequency of 11 GHz with ratios $r/a = 0.25$ and $r/a = 0.45$. The substrate has $\varepsilon_r = 10.2$ and thickness $h = 25$ mils, which gives, for the physical dimensions, the values $a = 5$ mm and $w = 0.6$ mm. The design with $r/a = 0.25$ reproduces the optimal one presented in [2], while the design with $r/a = 0.45$ is presented as an upper limit of the r/a ratio. The measured prototypes have the same r/a ratios of 0.25 and 0.45, but

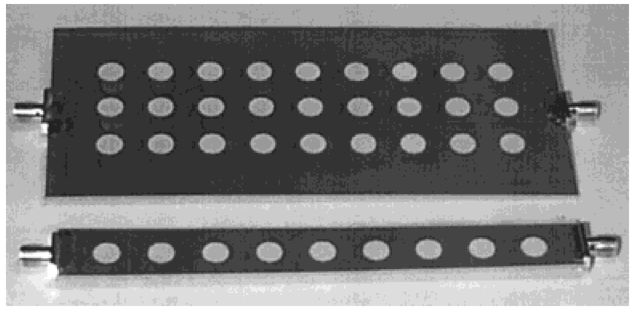


Figure 1 Photograph of a 2-D PBG microstrip reflector and a 1-D PBG microstrip reflector. The r/a ratio is 0.25 for both structures

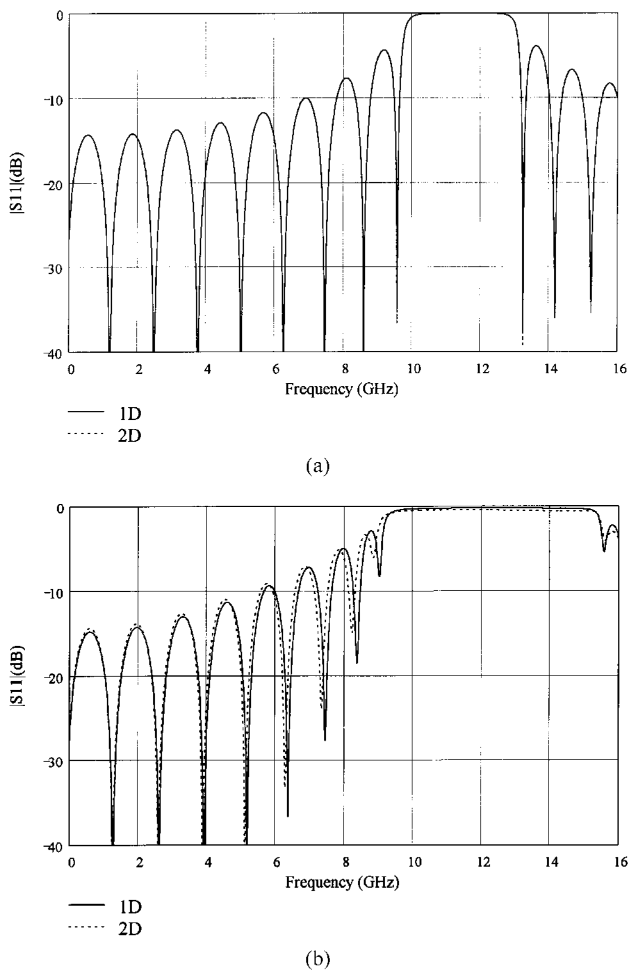


Figure 2 Simulated S_{11}-parameter for two PBG microstrip reflectors, operating at a frequency of 11 GHz, with (a) $r/a = 0.25$ and (b) $r/a = 0.45$. The filled line corresponds to the 1-D reflector, while the dotted line corresponds to the 2-D one

their design frequencies are 3 GHz, in order to be measured with our HP 8753 D vector network analyzer (up to 6 GHz). In this case, the substrate used is the Rogers RO3010^{TM} with an $\varepsilon_r = 10.2$ and thickness $h = 50$ mils. The physical dimensions this time are $a = 18.9$ mm and $w = 1.2$ mm, being the prototypes constructed by means of a numerical milling machine. In all cases, the number of periods taken is nine. The value of the period a is obtained from the verification of the Bragg condition for the operation frequency of the reflector [4]. Thus, the reflected frequency will have a guided wavelength $\lambda_g = 2 \cdot a$. In our calculations, λ_g has been estimated as the guided wavelength in the unperturbed microstrip line. Recent research carried out by our group has provided a more accurate expression to assess the necessary value for the period a [5].

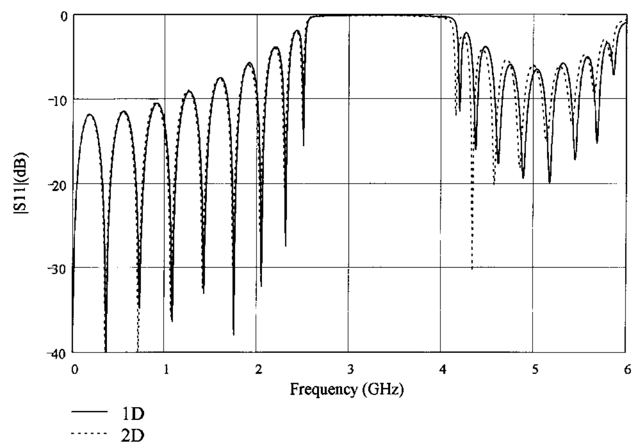
III. SIMULATION AND MEASUREMENT

First, a 3-D finite-element electromagnetic simulation of a simplified structure having two periods was done using HP^{TM} HFSS simulation software. The results showed that the level of the fields is negligible outside the central row of the periodic pattern, suggesting the implementation of 1-D structures.

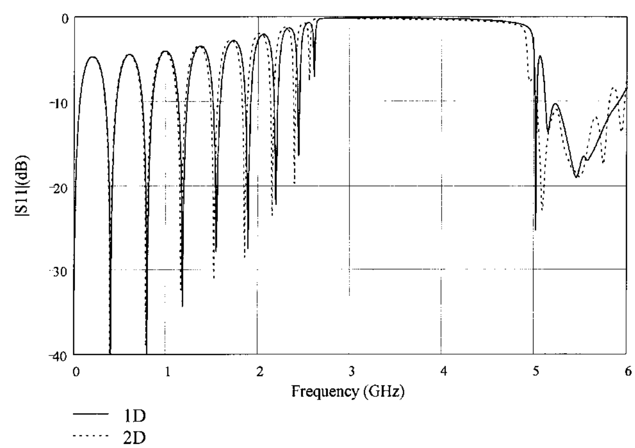
The 1-D and 2-D PBG reflectors designed at 11 GHz have been simulated using HP^{TM} Momentum and MDS software. The 1-D and 2-D PBG reflectors designed at 3 GHz have been measured with an HP^{TM} 8753D vector network analyzer. The results are presented in Figures 2 and 3.

The results reveal that 1-D and 2-D reflectors have almost identical behavior. In all cases, the differences found are minimal, although they are slightly larger in the $r/a = 0.45$ case. This shows that differences will be greater as the r/a ratio is increased, due to coupling effects between the rows of holes, caused by the proximity of their borders. Still, these differences are very small.

Further simulations realized using other substrates show similar results.



(a)



(b)

Figure 3 Measured S_{11}-parameter for two PBG microstrip reflectors, operating at a frequency of 3 GHz, with (a) $r/a = 0.25$ and (b) $r/a = 0.45$. The filled line corresponds to the 1-D reflector, while the dotted line corresponds to the 2-D one

IV. CONCLUSIONS

A 1-D PBG microstrip structure has been proposed and discussed. Its behavior as a reflector has been compared with the behavior of the recently proposed 2-D microstrip structure [2], giving in all cases very similar results. This is due to the high confinement of the fields around the conductor strip that are present in the microstrip line.

The layout of this 1-D structure is, on the other hand, notably more compact than the layout of its equivalent 2-D structure, making it a more efficient choice for the implementation of PBG microstrip reflectors.

Tapering techniques also have been applied to these 1-D reflectors, giving the same successful results as in the 2-D ones [6].

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