S Parameters Study of PDGS with Defected Rectangles

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Abstract—PDGS with defected rectangles can be used to prohibit the propagation of electromagnetic waves within a certain band of microwave frequency. The precise S parameters of PDGS are obtained through FDTD analysis in this paper. PDGS with defected rectangles have excellent stopband characteristic when periodic unit amounts and structure sizes meet definite conditions. The deepness and width of stopband will increase with the increase of periodic unit amounts and etched rectangle sizes. The precise relation given in the paper will provide powerful tool for the analysis and design of PDGS as microwave filter. Moreover, according to circuit theory the defected areas can be realized by not only rectangle, but also other geometries such as triangle, circle, and so on.

Keywords-PDGS; periodic unit amounts; structure sizes; S parameters; FDTD

I. INTRODUCTION

Defected ground structures (DGS) are recently one of the hottest topics which are researched in microwave domain, which developed from the photonics bandgap (PBG) structures. DGS can change the effective dielectric constant of material and distributed capacitor and distributed inductance by etching the defected form on the ground of microwave circuit. DGS can achieve high-performance which can not be obtained by conventional technology. Because of the advantage of DGS, such as having small structure size and simple model, it has been widely used in the design of microwave filter, oscillator, coupler, power amplifier and antenna. PDGS are the structures that are etched periodically on their ground plane, which can be used to prohibit the propagation of electromagnetic waves within a certain band of frequency. Consequently, PDGS are very easy to implement, but also can suppress the harmonic responses and improve efficiency. Broadband filter can be implemented through the cascading of many PDGS, which have wide application prospects in microwave circuits and antenna domain.

Owing to the complexity of PDGS, the conventional analysis methods of electromagnetic field are not appropriate for PDGS. Finite-difference time-domain (FDTD) method (1) is frequently utilized to analyze PDGS, which is a kind of electromagnetic numerical value analysis methods that are precise and strict. FDTD is a numerical method based on the difference principle. It can turn the problem of continuous electromagnetic field region into the problem of discrete systems through using the numerical solution of the discrete points to substitute approximately the real solution of the continuous region. Maxwell equations are operated by direct difference in time-domain. Scattering, transmission and absorption that met in transmission process are implied in algorithm, not being processed specially (2). FDTD has a strong ability of simulating many complex structures, and can gain time domain waveform of the subject investigated. Frequency characteristic can be correspondingly obtained by Fourier transform, furthermore it can avoid sick results likely occurring in the process of calculating equations, and decrease largely memory space and computing time, so FDTD method is applied to research PDGS. In this paper, FDTD with the perfectly matched layer (PML) absorbed boundary is used to analyze PDGS because it has an advantage over traditional Mur absorbed boundary, such as more simple feedback model, smaller calculation space, faster convergence, unconstrained by angle of incidence and frequency. In the paper, FDTD procedure that has been compiled with C++ and Matlab languages has both simplified program and can save compute time.

II. S PARAMETERS OF PDGS

PDGS with defected rectangles are the structures that are etched periodically using the rectangular holes on their ground plane. Rectangular defected areas and one connecting slot correspond to the equivalently added inductance (L) and capacitance (C), respectively. Accordingly, a resonance occurs at a certain frequency because of the parallel L-C circuit. Inversely, it is intuitively known that the equivalent circuit includes a pair of parallel inductor-capacitor. In addition, slow wave characteristics are observed due to the added L-C components of the PDGS (3). PDGS can be used to prohibit the propagation of electromagnetic waves within a certain band of microwave frequency. The structures are called PDGS in order to incarnate their structures characteristic. The structures are shown in Fig.1, in which the rectangular holes are periodic unit, l1 is the length of the whole structures, l2 is the width of the whole structures, w is the width of microstrip line, d is the space between periodic unit, a and b are the structure sizes.

PDGS with defected rectangles shown in Fig.1 have obvious stopband characteristic after being analyzed with FDTD, whose frequency of stopband center (f0) within microwave frequency channel is a function of the space (d) between periodic units. The approximate function relationship (3~8) is shown in equation 1 (the rectangular holes being supposed equal intervals distribution).

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\[ f_0 \approx \frac{c}{2d\sqrt{\varepsilon_r}} \]  
(1)

In which \( c \) is ray velocity, \( \varepsilon_r \) is relative dielectric constant.

Figure 1. The structure of one dimension PDGS

After one dimension distribution PDGS whose periodic unit being defected rectangles as shown in Fig.1 are analyzed with FDTD, the whole structure size is \( l_1=120 \text{mm}, l_2=30 \text{mm}, \) the width of microstrip line is \( w=3 \text{mm}, \) the space between periodic unit is \( d=20 \text{mm}, \) the relative dielectric constant is \( \varepsilon_r =2.65, \) the thickness of dielectric slab is 1mm.

The change of \( S_{11} \) and \( S_{21} \) parameter is already shown in Fig.2 and Fig.3 when \( a=6 \text{mm}, 7 \text{mm}, 8 \text{mm}, 9 \text{mm} \) respectively. Periodic unit amounts \( n \) are 5 and \( b=9 \text{mm} \) constantly. It is obvious that PDGS with defected rectangles have excellent stopband characteristic within the frequency band 3–6.5GHz. And the depth and width of stopband will increase with the increase of the structure size \( a. \)

Figure 2. The \( S_{11} \) parameter of PDGS

The change of \( S_{11} \) and \( S_{21} \) parameter is already shown in Fig.4 and Fig.5 when \( b=6 \text{mm}, 7 \text{mm}, 8 \text{mm}, 9 \text{mm} \) respectively. Periodic unit amounts \( n \) are 5 and \( a=9 \text{mm} \) constantly. It is obvious that PDGS with defected rectangles have excellent stopband characteristic within the frequency band 3–6.5GHz. And the depth and width of stopband will increase with the increase of the structure size \( a. \)

Figure 3. The \( S_{21} \) parameter of PDGS

The change of \( S_{11} \) and \( S_{21} \) parameter is already shown in Fig.6 and Fig.7 when periodic unit amounts \( n \) is 2, 4, 5 respectively. The structure size \( a=7 \text{mm}, b=8 \text{mm} \) constantly. It is obvious that PDGS with defected rectangles have excellent stopband characteristic within the frequency band 3–6.5GHz. And the depth and width of stopband will increase with the increase of periodic unit amounts \( n. \)

III. CONCLUSIONS

The precise transmission parameters have been obtained through the electromagnetic simulation. Rectangular defected areas and one connecting slot correspond to the equivalently added inductance and capacitance, respectively. Accordingly, a resonance occurs at a certain frequency because of the parallel
inductance-capacitance circuit. Inversely, it is intuitively known that the equivalent circuit includes a pair of parallel inductor-capacitor from the resonant phenomenon in the S-parameter. This means that the microstrip structure having PDGS with defected rectangles does not have all-pass characteristics, but restricted passband properties.

PDGS with defected rectangles are the structures that are etched periodically on their ground plane using the rectangular holes. Through analyzing PDGS with defected rectangles by FDTD in this paper, it is drawn that they have excellent stopband characteristic if the periodic unit amounts are biggish. The depth and width of stopband will increase with the increase of the structure sizes a and b. PDGS with defected rectangles will have better stopband with periodic unit amounts n being bigger. The precise relation given in the paper will provide powerful tool for the analysis and design of PDGS with defected rectangles as microwave filter. According to circuit theory, the defected areas can be realized by not only rectangle, but also other geometries such as triangle, circle, bowtie, spiral, and so on.

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