NEW DEFECTED GROUND PLANE STRUCTURE FOR MICROSTRIP CIRCUITS AND ANTENNA APPLICATIONS

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ABSTRACT

In this paper, we propose a new design of a Defected Ground Structure (DGS) for use as an Electromagnetic Band Gap (EBG) configuration for printed antennas and circuits application. The proposed structure embodies a set of concentric annular rings of equal width and equal spacing. A set of prototypes designed for 10 GHz and fabricated on Taconic PTFE substrate (dielectric constant 2.33 and thickness 1.575 mm) has been examined experimentally using HP 8720C Network Analyzer. The DGS backed by another metal plane with variable spacing and filling by different dielectric materials are also investigated for circuit applications. Measured values of S_{21} show well defined stop band over 9 –11 GHz for all configurations.

INTRODUCTION

Electromagnetic Band Gap (EBG) structures have become very popular as well as an active area of research in the microwave and antenna communities. The EBGs are a new type of engineered materials that exhibit well defined stop and pass bands in the transmission characteristics and as such they find many applications in microwave printed circuit filters [1], [2] and antennas [3], [4]. A good fraction of these developments involves the ground planes printed with various patterns, slots and cuts [5]. In this paper, we propose a simple design of a Defected Ground Structure (DGS) in the form of a set of concentric annular rings of equal width and equal spacing as a wide band EBG material. The proposed configuration is easy to design and flexible to match with different dimensions of the circuits and should be suitable for both printed circuits and antenna applications.

DESIGN

The DGSs for our studies were created by etching concentric rings in the ground plane. The proposed structure embodies a set of concentric annular rings of equal width on the ground plane. Two configurations are considered : (i) three annular rings each of 1 mm width and 3mm intermediate spacing and (ii) three annular rings of same dimensions, but it starts with a central patch of 1 mm diameter. The schematic diagrams are shown in Fig. 1. The design was carried out for the stop-band centered at 10GHz. The transmission characteristics of the new DGS are studied with a set of prototypes fabricated on Taconic PTFE substrate with dielectric constant = 2.33 and thickness =1.575 mm. A microstrip line was designed for 10 GHz on this substrate and etched on the reverse side of the GP. SMA connectors were used and the measurements were done using a HP 8722C Network Analyzer.

RESULTS

The design parameters were determined on the basis of the simulation data. The commercial conformal finite difference time domain (CFDTD) full solver [6] was used for our design. The simulation data along with the measurements are presented in this section. The designed parameters of the defected ground plane are as shown in Fig.1. The measured transmission characteristics of a microstrip line etched on a substrate with and without a DGS #1 are shown in Fig. 2. For brevity the results for DGS #1 are presented. The DGS results in a stop band ($S_{21}| < -15$dB) over 9-11 GHz, where as that on normal ground plane shows $S_{21}| \approx -5$dB. A set of simulation data is also incorporated in Fig. 2 and this is found to closely correspond the measured curve. The nature of the simulation result differs from the measured results at the frequencies above 12GHz. The values of S_{21} have also been critically examined when the defected ground plane is backed by a metal plate with variable spacing and filling the space by different dielectric materials as shown in Fig.3. Suitable backing has been explored which should help it in using the DGS safely without any backward radiation. The measured S_{21} (not shown here) of the microstrip line with a DGS and a metal plate backing at 8.5mm shows a stop band from about 9 GHz to 11 GHz with minimum $S_{21} \approx -35$dB. Fig. 4 shows the simulation results of the transmission characteristics for different values of spacing.

The effect of a simple DGS structure in improving the mutual coupling between the elements of a two element circular patch array is studied using the simulation data. The schematic diagram of a two-element circular patch array with and without defected ground plane are shown in Figs.5 and 6. The simulation results of the E-plane coupling for the patches of radius 5mm and separated by a $\lambda_0/2$ are shown in Fig .7. Nearly 5 dB reduction in E-plane coupling between the radiating elements is apparent at 10GHz.

CONCLUSION

A simple defected ground structure is designed and investigated theoretically and experimentally for X-band printed antenna and microstrip circuit applications. The simulated and measured transmission characteristics of a microstrip line etched on a normal and a defected ground plane show a wide stop band (transmission coefficient below –10dB) over 9 to 11 GHz frequency range. The S_{21} parameter has also been examined when the defected ground plane is backed by an additional metal plate with variable spacing and filling by dielectric materials. The metal backing was seen to produce even lower values of S_{21} of around -20 to –35dB. The use of the defected ground plane was also found to reduce mutual coupling in a microstrip array and its value can be –5dB at 10 GHz.

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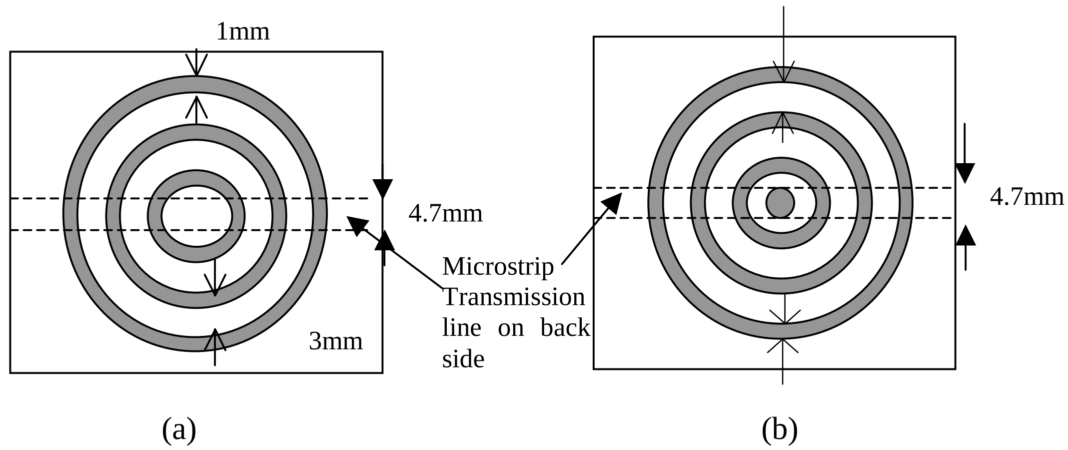

Fig .1 Front view of the defected ground plane with microstrip transmission line on the back side of a Taconic substrate of height 1.575mm and ε_r =2.32. (a) Geometry #1, (b) Geometry #2

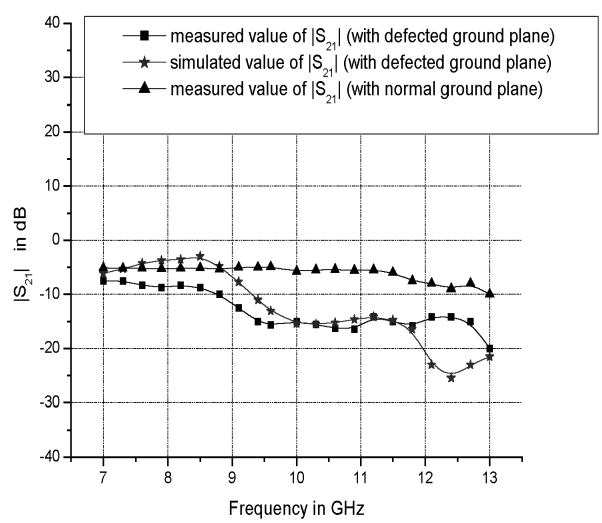

Fig.2 Measured and simulation transmission characteristics of a microstrip line with defected ground plane #1 and normal ground plane.

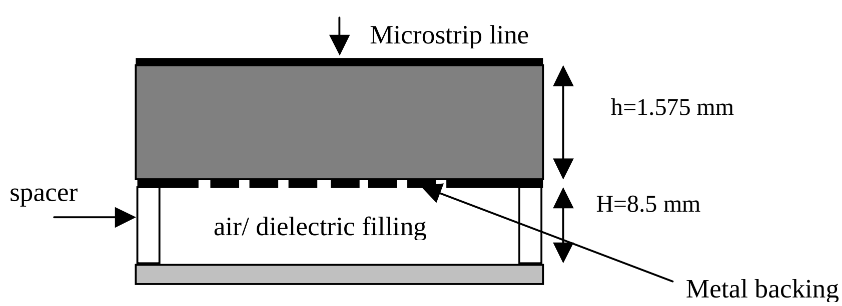

Fig .3 Cross Sectional view of the defected ground plane backed by metal plate.

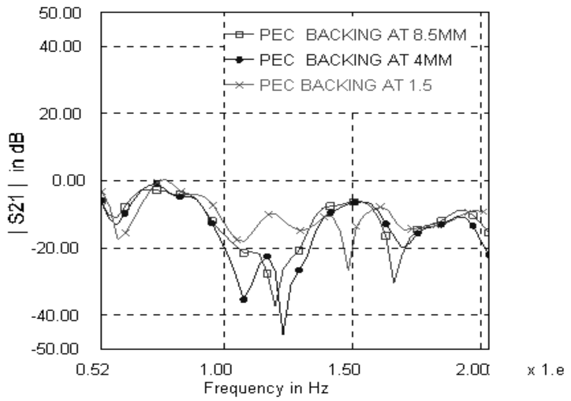

Fig. 4 Simulation data of transmission characteristics of a microstrip line with DGS #1 backed by a metal plate at three different spacing: 8.5mm, 4mm and 1.5mm and filled by air dielectric.

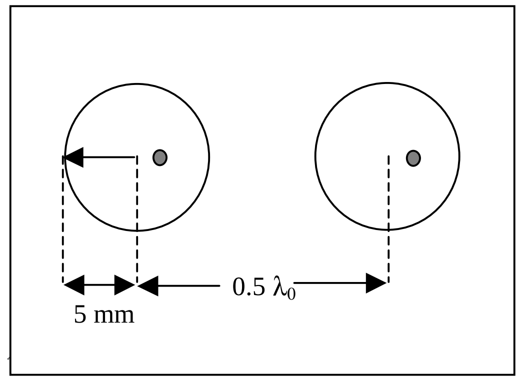

Fig .5 Two element circular patch array on a normal ground plane

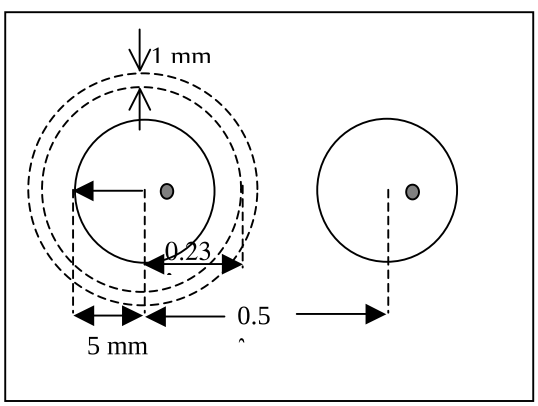

Fig .6 Two circular patch antennas separated by $\lambda_0/2$ spacing and E-plane coupled on a defected ground plane #1.

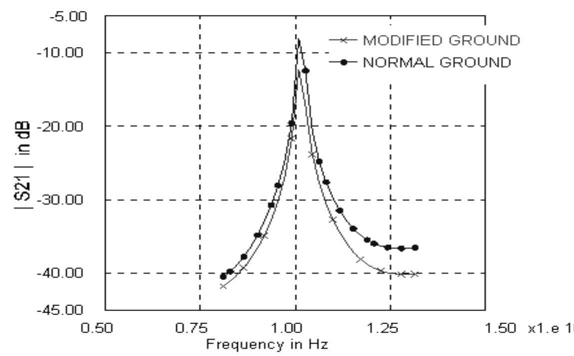

Fig .7. Simulation results of $|S_{21}|$ for the two element arrays shown in Figs. 5 and 6,