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Bandwidth Enhancement of Rectangular Array Using Cross Slots DGS Pattern in Ground Plane

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ABSTRACT: A novel compact design for bandwidth enhancement of rectangular microstrip array is presented in this paper. The basis for achieving the bandwidth enhancement is through metamaterial structure. Two types of metamaterial namely EBG and DSG are studied. Metamaterial structures are used for further antenna performance improvement, which suppress surface waves and improve the design characteristics. In this paper two cross slots cuts in the ground plane, which enhance the bandwidth of reference antenna. This shape produces bandwidth ranging from 15.30 GHz to 17.66 GHz, gives impedance bandwidth of 2.3649 GHz, whereas reference antenna without DSG is having impedance bandwidth of 290 MHz.

KEYWORDS: Rectangular patch array, EBG, DGS, modified ground, Defected ground, HFSS-13.

I. INTRODUCTION

In recent years, a new technology has emerged which may be the key to developing wideband microstrip antennas. This technology manipulates the substrate in such a way that surface waves are completely forbidden from forming, resulting in improvements in antenna efficiency and bandwidth, while reducing sidelobes and electromagnetic interference levels. These substrates contain so called Photonic Crystals. Also known as electromagnetic band-gap (EBG) structures and electromagnetic band-gap materials (EBMs), are a class of periodic metallic, dielectric, or composite structures that exhibit a forbidden band, or band gap, of frequencies in which waves incident at various directions destructively interfere and thus are unable to propagate [6]. Based on the dimensional periodicity of the crystal structure, the band gaps can be in one, two, or three-dimensional planes, with the level of complexity increasing as the dimensions increase. EBG structure is perturbed by either removing or adding a material with a different dielectric constant, size, or shape, a "defect" state is created in the forbidden gap, where an electromagnetic mode is allowed, and localization of the energy occurs. However, in implementing EBG, a large area is needed to implement the periodic patterns and it is also difficult to define the unit element of EBG [9]. Whereas the defected ground structure (DGS) has similar microwave circuit properties as EBG. This paper focuses the effect of two element microstrip patch antennas array on a uniform substrate with DGS structures [1],[6].

In this case, the ground of microstrip antenna is defected by etching the ground plane. Recently, many shapes of slot have been studied: circle dumbbells and concentric ring-shape [1]. Yuli Zulkifli, Susy Tri Lomorti, Eko Tjipto Rahardjo in , " Improved Design of Triangular Patch Linear Array Microstrip Antenna Using Isosceles Triangular - Defected Ground Structure[1]," proposed that application of DGS are to suppress harmonic suppress cross-polarization radiation from patch antenna , improves impedance matching and enhance bandwidth and gain . Nasimuddin, Zhi Ning Chen, and Xianming Qing, "A Compact Circularly Polarized Cross-Shaped Slotted Microstrip Antenna [3]," proposed cross pattern which enhance the bandwidth and gain of antenna . WeiXing Liu, YinZeng Yin, WenLong Xu, and ShaoLi Zuo , "Compact Open-Slot Antenna With Bandwidth Enhancement, [8]" in this paper an inverted-L-shaped open slot antenna in ground plane and a linear tapered slot antenna are presented to enhance the impedance bandwidth. In this article array of two rectangular microstrip antenna with two slots in ground plane has been proposed. This DGS shape can improve the antenna performance of the reference antenna .Two cross-shaped slots are cut in the ground plane. The radiation performance of the antenna is characterized by the dimension of the DGS and by locating the

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DGS at specific position has been optimized to give wide bandwidth. This slot shape DGS is added to obtain EBG effect. This will be proven by simulation of array using simulation software HFSS-13.

II. DESIGN OF ANTENNA ARRAY

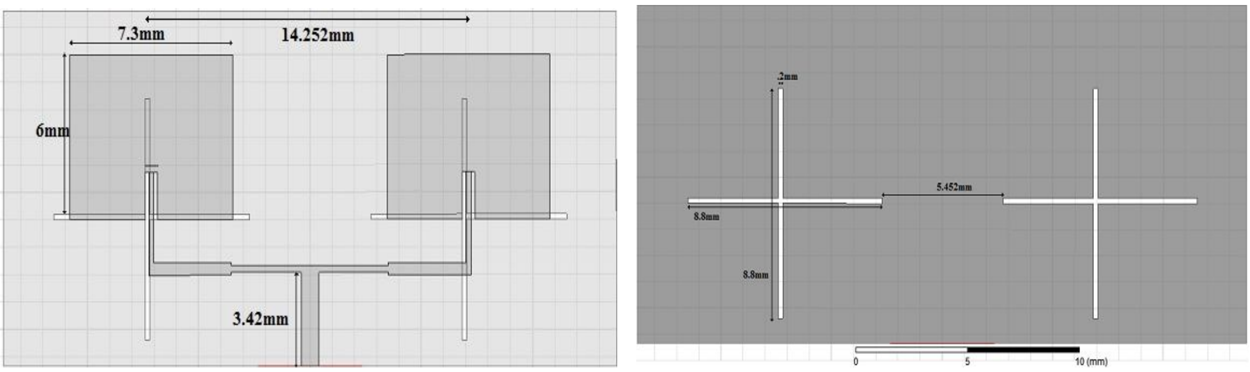
The array of antenna is shown in Figure 1. The array consists of two rectangular patch array and fed by micro stripline. The following classical equations are used to designed array [2], [5].

$$W = \frac{c}{2fo\sqrt{\frac{\varepsilon_r+1}{2}}}$$

$$\Delta L = 0.412h\,\frac{(\varepsilon_{reff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{reff}-0.264)\left(\frac{W}{h}+0.8\right)}$$

$$L_{eff} = L + 2\Delta L$$

$$\varepsilon_{r\,eff} = \frac{\varepsilon_r+1}{2} + \frac{[\varepsilon_r-1]}{4}\,[1+12\tfrac{h}{a}]^{-1/2}$$



(a) (b)

Figure 1: (a) Geometry of 1×2 Rectangular array with Cross slots in Ground Plane (Top view) , (b) cross slots in ground plane (bottom view).

The dimension of ground plane is 12.91mm × 27.55mm. To fabricate the antenna, Roger RT/ duroid 5880 (tm) is used. The dielectric material has thickness ‘h’ of .254 mm with ε_r = 2.2 and tangential loss of .0009. The microstrip patch antenna include the length as 7.3 mm and width as 6 mm .The rectangular patches are separated by a distance of 14.52mm , The network is designed to realize impedance matching by using quarter wavelength impedance transformers [3]. The network has a center line of 100 which is fed at its center by a 50Ω transmission line. The impedance is transformed to 50Ω through a 70:7 quarter wavelength line as shown in Figure 1 (a) . Figure 1 (b) shows the dimension and position of slots, which is optimized to give wideband are separated by 5.452mm with length as 8.8 mm and width as .2mm in cross pattern.

III. SIMULATION AND RESULT

This section outlines the result of array using HFSS-13 and analyzes the 1×2 array with and without defected ground structures. Figure 2 shows simulation result of return loss, both of antenna design with and without defected slots in ground (DGS).

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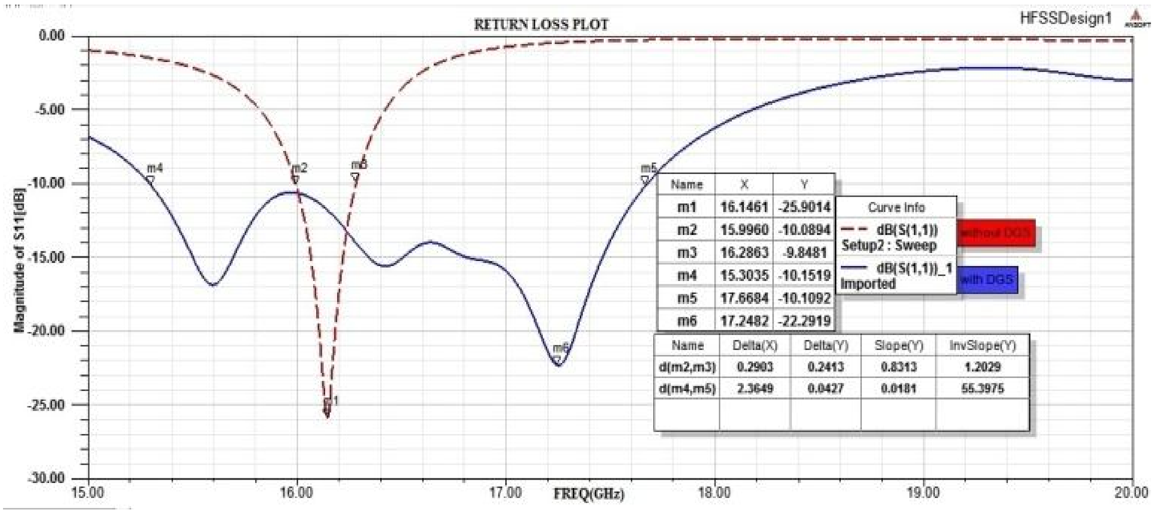

Figure 2 : Simulated reflection coefficient (in dB) of designs shown in Figure 1.

Antenna without DGS resonant at frequency of 16.14 GHz with return loss of -25.9 dB and have the bandwidth of 290 MHz. Whereas for antenna with DGS resonates at 15.60 GHz and 17.24 GHz with return loss of -16.82 dB and -22.29 dB respectively. As the slots in the ground improve the performance characteristics as it suppress the harmonics and enhance the bandwidth of antenna. The antenna with DSG is having impedance bandwidth of 2.3649 GHz which is 2.70 GHz more than of reference antenna.

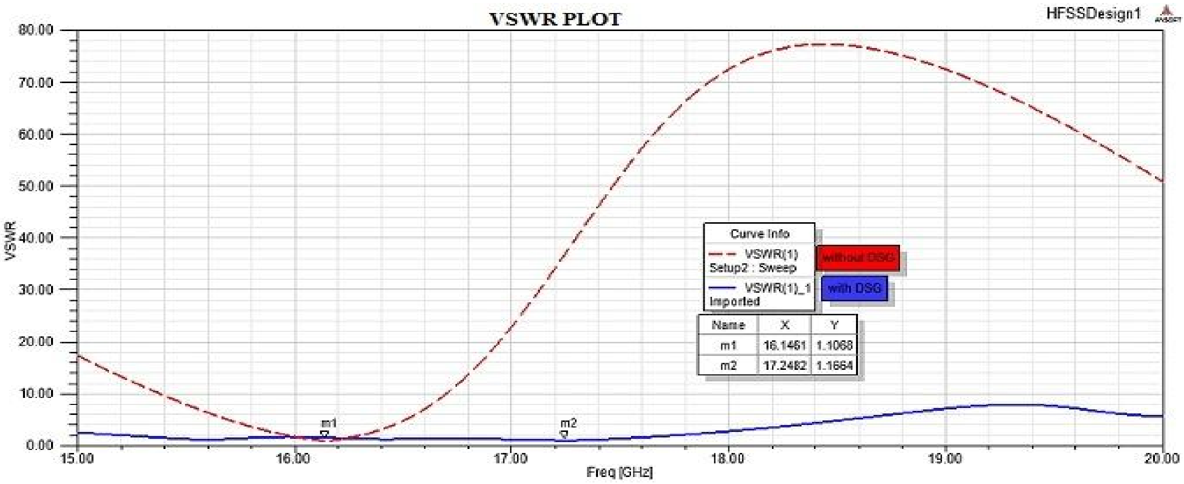

Figure 3: VSWR graph of antenna with and without DGS.

Another important performance parameter of antenna is VSWR. For a lossless antenna its value is equal to 1, but due to ohmic losses, mismatch losses, mutual coupling effects among patches degrade the antenna performance. From Figure 3 its shows that's VSWR is better for defected ground antenna for a wide range of frequency and best value is 1.15 whereas reference antenna is having less range with minimum of 1.10. Figure 4 shows the radiation pattern of antenna, due to cross slots structure in the antenna the power is radiated towards the lower side also, but improved for DGS.

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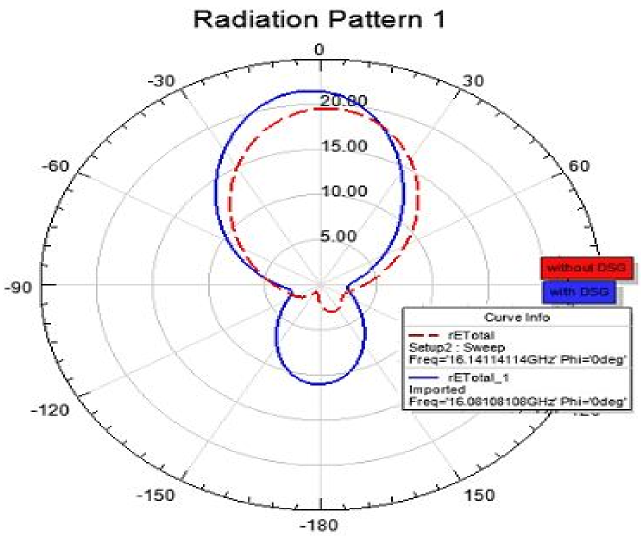

Figure 4 : Radiation Pattern of 1×2 Rectangular array with Cross slots in Ground Plane at Phi =0° .

IV. CONCLUSION

In this rectangular array with cross slots in ground plane was simulated and the obtained performance was evaluated. The use of metamaterial structure periodical cross slots were introduced and analyzed. It is shown that, the microstrip antenna bandwidth performance was improved by using cross slots. This shape produces bandwidth ranging from 15.30 GHz to 17.66 GHz, gives impedance bandwidth of 2.3649 GHz, whereas reference antenna without DSG is having impedance bandwidth of 290 GHz.

The design can be improved with different basic parameters such as type of substrate, dielectric constant, the thickness of the substrate and different type of feeding methods. Design different EBG structures to make comparison. From this work, we can also design the EBG structure for different operating frequency and even for multiband frequency.

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