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Microstrip antenna with DGS based on CSRR array for WiMAX applications

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ABSTRACT

This paper reports a novel method for designing a miniaturized microstrip antenna with DGS based on CSRR array which operates in the frequency of 2.6GHz for low band WiMAX application. The proposed antenna is designed using ANSYS HFSS simulation software. The antenna with optimized parameters is fabricated using FR-4 substrate of thickness 1.6 mm. The simulated and measured performances of the antenna in terms of return loss, directivity and radiation patterns are presented in this work. When Complimentary Split Ring Resonators (CSRRs) array are placed on the ground plane, the resonant frequency is shifted to a lower value and patch size is reduced. The measurements were taken and compared with the simulated results. The performance characteristics obtained from the measurements show that the proposed antenna is suited for WiMAX application at 2.6GHz.

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1. INTRODUCTION

Metamaterials are artificially structured materials that show cumulatively negative values of magnetic permeability and electric permittivity upon a distinct frequency band [1], [2]. The use of the metamaterials in microstrip antenna design improve some of the basic features of antennas like gain, impedance matching, efficiency,bandwidth etc. [3].The concept of metamaterial was conceived around 1967 by Russian physicist Victor Veselago. The first metamaterial structure[4] was fabricated by Smith D.R etal in the year 2000.Several structures were proposed by the scientists to form metamaterials. The commonly used structures are the Split Ring Resonators (SRRs) and Complementary Split Ring Resonators (CSRRs).

The metamaterial structure can be designed in many ways and the introduction of Defected Ground Structure (DGS) on ground plane will effectively increase the inductance and capacitance of the overall electric circuits [5], [6].The drawbacks associated with the miniaturization of antennas are narrow band width expensive and reduction in radiation efficiency [7].Some of the design methods to overcome these drawbacks are Corrugation Structure [8], shorting pin [9] and Iris Structure [10]. The limitations of these miniaturization methods are poor performance and complexity of structures. The metamaterial based single CSRR structured antenna was designed at resonant frequency of 3.5GHz [11]. The reduction in size of the patch antenna was accomplished by loading CSRR on patch antenna [12]. Preliminary studies were done based on the miniaturization of antennas with defected ground structure [13-17].

In this paper we present the design and development of a 2.6GHz miniaturized microstrip antenna with DGS based on CSRR array for WiMAX applications.The resonant frequency is reduced by placing CSRR array on the ground plane with same physical size as compared to single layer CSRR structure. The miniaturization of antenna has been achieved by using DGS based on CSRR array structure with microstrip patch antenna.The design performance of patch antennas are affected by many split ring parameters.Some of the parameters are shape of the SRRs, width of the rings, and gap between rings.

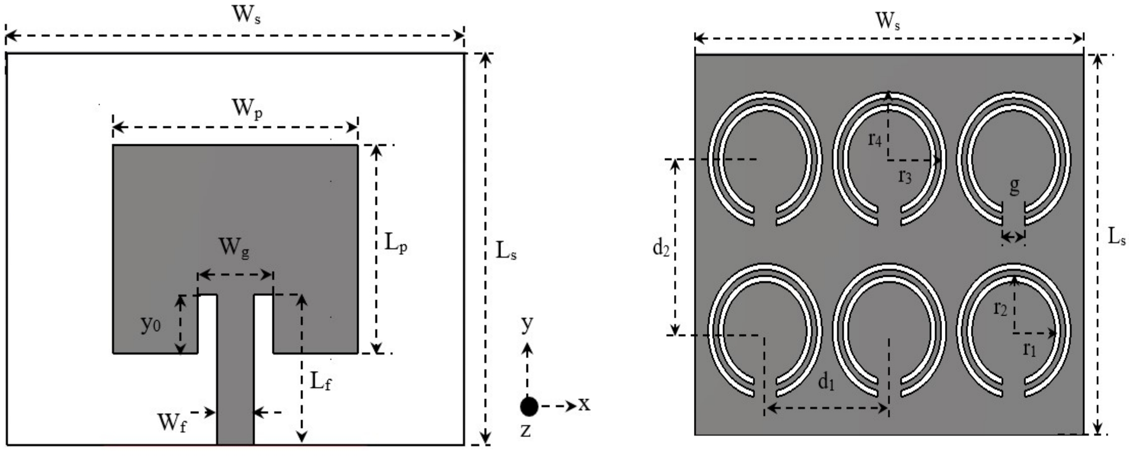
2. ANTENA DESIGN SPECIFICATIONS

The proposed microstrip antenna with DGS based on CSRR array was designed at 2.6GHz for WiMAX application. The antennas were designed using FR-4 substrate of thickness 1.6 mm and $\varepsilon r=4.4$. The physical size of the proposed antenna is same as compared with single CSRR structured microstrip antenna having 3.5GHz resonant frequency. By adding CSRR array structure on the ground plane,the resonant frequency of single CSRR structured antenna with 3.6GHz is reduced to 2.6GHz. The desired value of resonant frequency for the antenna can be tuned by adjusting the various geometric parameters and size of the CSRR. Two design methods were compared in this study, one for the single SRR antenna and the other for microstrip antenna with DGS based on CSRR array. The dimensions of both single and microstrip antenna with DGS based on CSRR array are tabulated in Table 1.

Table 1. Parameters of Single CSRR and CSRR Array Structured Microstrip Patch Antennas

Parameters	Dimensions (mm)
Ls	31.04
Ws	37.76
Lp	16.475
Wp	20
Wf	3.059
Wg	6.11
y0	4.61
Lf	12.161
Ls	31.04
Ws	37.76
Lp	16.475

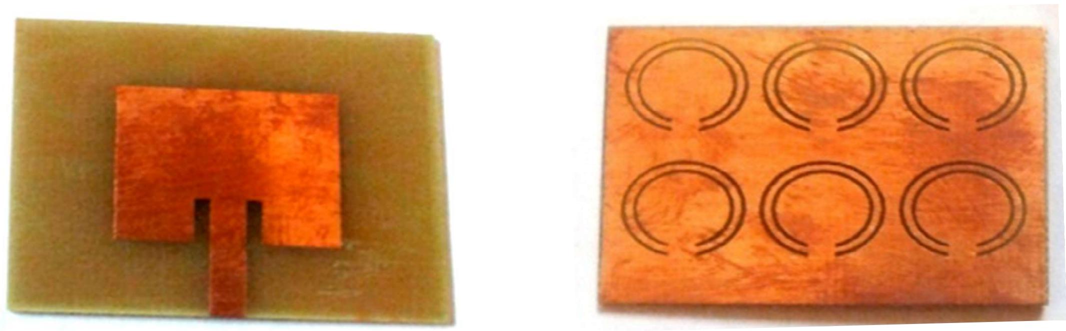
Figure 1 represents the geometry of the proposed CSRR array structured microstrip antenna. The two circular rings has inner radius r_1=4 mm, r_3=5mm and outer radius r_2=4.5 mm& r_4=5.5 mm respectively. The gap (g) of the ring is 2.24mm and width is 0.5mm. The distance between circular rings (d_1 & d_2) along X direction and Y directions are 12mm and 14mm respectively.



(a) Top view (b) Bottom view

Figure 1. CSRR Array structured microstrip antenna

Figure 2 shows the physical view of the microstrip antenna with DGS based on CSRR array and fabrication was done using the FR-4 substrate. The resonant frequency of the microstrip antenna with DGS based on CSRR array was shifted to 2.6 GHz.



(a) Top view (b) Bottom view

Figure 2. Physical view of fabricated antenna

3. RESULTS AND ANALYSIS

3.1. Return Loss

Figure 3 depicts the simulated return loss characteristics of single CSRR antenna and the proposed miniaturized microstrip antenna with DGS based on CSRR array.The antenna shows good performance in the respective frequency band. The simulation results for return loss single CSRR microstrip antenna is -15.6dB and that of microstrip antenna with DGS based on CSRR array is -13.8dB. Bandwidth of the antenna can be found from the return loss plot. Figure 4 shows the simulated and measurement results of return loss S11 from microstrip antenna with DGS based on CSRR array.

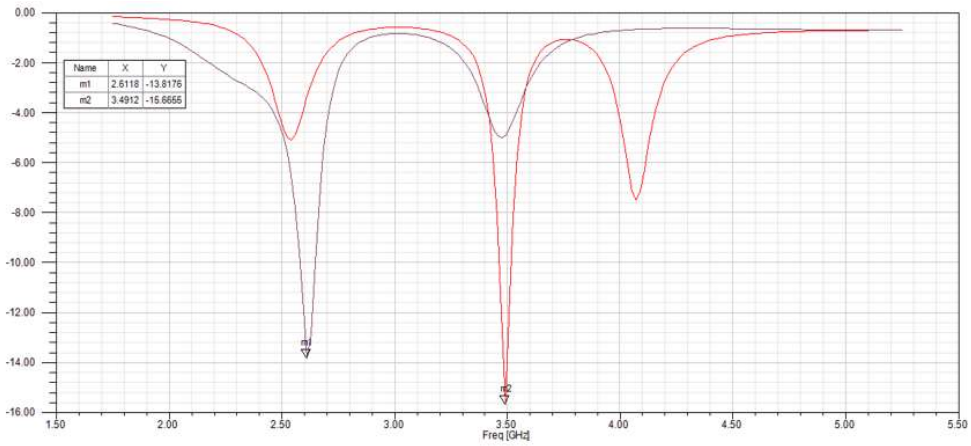


Figure 3. Simulated results of single &CSRR array structured antenna

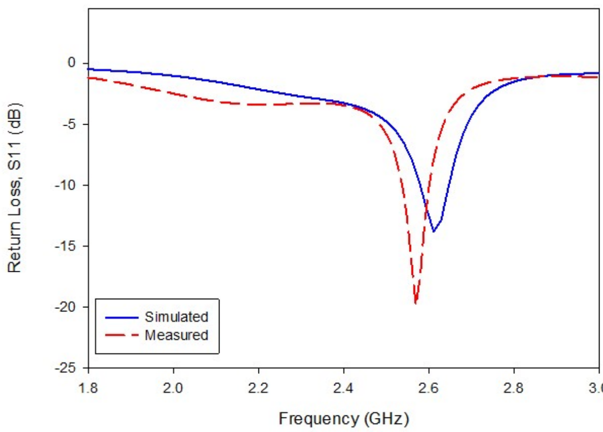


Figure 4. Simulated and measured variation of return loss characteristics

3.2. Directivity

The simulated results of directivity for single CSRR structured antenna is 5.84 and the microstrip antenna with DGS based on CSRR array is 4.57. The values of directivity infer that the antennas are highly directive. Directivity of the antennas are shown in Figure 5 and Figure 6.

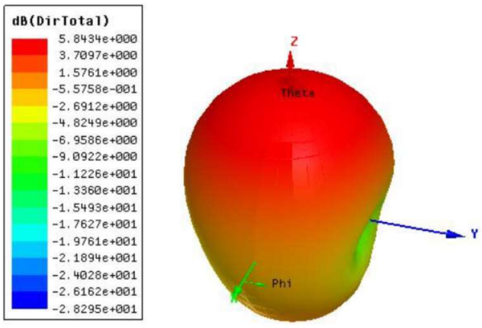
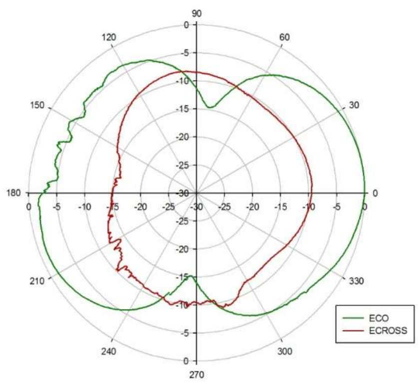


Figure 5. Directivity of single CSRR structure based microstrip antenna

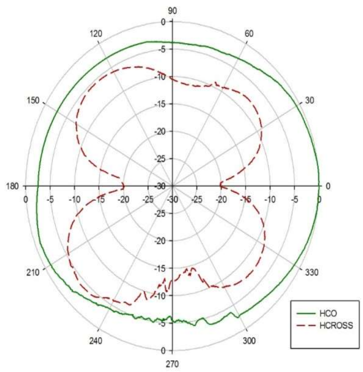
Figure 6. Directivity of microstrip antenna with DGS based on CSRR array

3.3. Radiation Pattern

Figure 7 represents the measured results for radiation pattern of the proposed microstrip antenna with DGS based on CSRR array.



(a) E plane pattern



(b) H plane pattern

Figure 7. Measured Radiation pattern of the proposed CSRR array structured antenna

A comparison between the proposed work and a recently published antenna structure with the same physical size is tabulated in Table 2. As per the comparison, the proposed miniaturized microstrip antenna with DGS based on CSRR array is compact along with reduction in resonant frequency.

Table 2. Comparison Chart of the Proposed Antenna and Recently Published Paper

Paper	Frequency Return loss	Size
Ajay [11]	3.5 GHz-15.8 dB	31.04x37.76 mm^2
Proposed Microstrip Antenna with DGS based on CSRR array for WiMAX Applications	2.6 GHz-13.8 dB	31.04x37.76 mm^2

4. CONCLUSION

The miniaturized microstrip antenna with DGS based on CSRR array was designed using ANSYS HFSS and analyzed the various performance characteristics. The resonant frequency of the microstrip antenna with DGS based on CSRR array has been reduced from 3.5GHz to 2.6 GHz with the same physical size. The performance analysis of the microstrip antenna with DGS based on CSRR array was verified from measured and simulated results. The simulated results of directivity at 2.6 GHz is 4.57 and the return loss is 13.80.

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