Microstrip antenna with DGS based on CSRR array for WiMAX applications

Ajay V.G., Parvathy A.R., Thomaskutty Mathew
School of Technology and Applied Sciences, India

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.

Keywords: CSRR, DGS, Microstrip patch antenna, Metamaterials

Corresponding Author:
Ajay V.G.,
School of Technology and Applied Sciences,
Edappally, Kochi, India.
Email: ajayvg28@gmail.com

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 et al 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 bandwidth, 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
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.

![Figure 1](image1.png)

(a) Top view  
(b) Bottom view

Figure 1. CSRR Array structured microstrip antenna

![Figure 2](image2.png)

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.
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 -15.6 dB and that of microstrip antenna with DGS based on CSRR array is -13.8 dB. 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.

![Simulated results of single &CSRR array structured antenna](image)

![Simulated and measured variation of return loss characteristics](image)
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.

![Directivity of single CSRR structure based microstrip antenna](image1)

![Directivity of microstrip antenna with DGS based on CSRR array](image2)

3.3. Radiation Pattern

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

![Radiation pattern](image3)

(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>
<thead>
<tr>
<th>Paper</th>
<th>Frequency</th>
<th>Return loss</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ajay [11]</td>
<td>3.5 GHz</td>
<td>15.8 dB</td>
<td>31.04x37.76 mm²</td>
</tr>
<tr>
<td>Proposed Microstrip Antenna with DGS based on CSRR array for WiMAX Applications</td>
<td>2.6 GHz</td>
<td>13.8 dB</td>
<td>31.04x37.76 mm²</td>
</tr>
</tbody>
</table>
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.

REFERENCES

BIOGRAPHIES OF AUTHORS

Ajay V.G. was born in Kerala, India on 25th March 1979. He received his Bachelor's Degree in Electronics & Communication Engineering from Mahatma Gandhi University, Kerala, in 2002 and Master's Degree in Applied Electronics from Mahatma Gandhi University, Kerala, in 2009. From 2003 to 2013 he worked as Lecturer, Asst. Professor and Associate Professor in ECE Dept. at Carmel Engineering College, Perumbad-Ranny. From 2013 to 2016 he worked as Associate Professor in ECE Dept. at LBSITW, Trivandrum. He is currently pursuing his Ph.D Degree in Microwave Electronics at School of Technology & Applied Sciences, Mahatma Gandhi University Regional Center, Edappally, Kochi. His current areas of research include Microstrip Patch Antennas, Metamaterials, RFID etc.
E-mail: ajayvg28@gmail.com

Parvathy A. R. was born in Kerala, India on 9th July 1987. She received her Bachelor's Degree in Electronics & Communication from University of Kerala, in 2009 and Master's Degree in Communication Engineering from Mahatma Gandhi University, Kerala, in 2012. She is currently pursuing her Ph.D Degree in Microwave Electronics at School of Technology & Applied Sciences, Mahatma Gandhi University Regional Center, Edappally, Kochi with UGC Junior Research Fellowship. Her current areas of research include Microstrip Printed Slot Antennas, RFID etc.
E-mail: arpinmvk@gmail.com

Thomaskutty Mathew was born in Kerala, India on 30th May 1967. He received his Ph.D Degree in Microwave Electronics from Cochin University of Science and Technology Cochin, India in 1997. From 1995 to 1999 he worked as a Lecturer in Physics at Christ College, Irinjalakuda, India. Since 1999, he is working as faculty of the Department of Electronics, School of Technology & Applied Sciences, Mahatma Gandhi University Regional Center, Edappally, Kochi, India and presently working as Reader in the Department. During the period 2006-2008, he worked as a Post Doctoral Research Associate at Department of Electronics, University of Kent, Canterbury, U.K. His current area of research activities are in Microstrip antennas, Radar Cross Section, RFID, Wireless Sensor Networks etc. He is a member of IEEE Antennas and propagation society and IET (U.K).
E-mail: drtkmathew@gmail.com