Multiband and Miniaturized dual layer Antenna incorporated with FSS and DGS

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Abstract

A novel dual layer rectangular printed Antenna based on loop type Frequency selective surfaces with five concentric rings and I shaped defected ground structure (DGS) is designed and investigated. The designed antenna is for applications in C band, WiFi devices and some cordless telephones and X band radiolocation, airborne and naval radars as multiband operational frequencies are at 5.5GHz, 6.81GHz, 9.3GHz and thus covers two wireless communication band C Band (4 to 8 GHz) and X band (8 to 12 GHz) The bandwidth is 200 MHz, 300 MHz and 1 GHz respectively and measured gain of this designed antenna are 2.42dBi against 5.5GHz, 2.80dBi against 6.81GHz, 6.76dBi against 9.3GHz. The proposed antenna in addition to multiband operation also exhibits miniaturization. The Floquet port technique is used to analyze concentric rings. The results comparison of proposed structure with the basic dual layer antenna resonating at 5.5GHz shows that the patch area is reduced by 58.15% while the volume of the antenna is reduced by 81.5%.

1. Introduction

The advancement of the communications systems requires lightweight, low profile compact antennas. Microstrip patch antennas are popular due to these properties. But the main disadvantages of patch antenna is its narrow bandwidth, low gain and cross polarization [1].
The microstrip antennas are enriched by revolution in electronic circuitry, which lead to miniaturization and integration of antenna in wireless communication devices. Techniques of miniaturization, bandwidth and gain enhancement of microstrip Patch Antenna is an active area for current research topics as on today requirement for compact designs is increasing vastly [2-6]. Frequency selective surfaces and Metamaterials are periodic conductive surfaces, which are artificially made to increase the performance of Antenna for communication system. In 20th century, implementation of FSS and metamaterials on various microwave devices has shown new ways of altering the conventional properties of these devices. The frequency behavior of FSS depends on the various combinations of FSS elements and its shape and size. In [7] the arrangement of various ring shape elements leads to multiband operation of an antenna. The defected ground structures (DGS) play an important role in miniaturization of devices [8,9]. The I shape etched on the ground plane causes disturbance in current distribution which is responsible for increase in reactive components like inductance and capacitance [10] and also the slow wave property of DGS is used in size reduction of microstrip Antenna [8]. The size reduction of 45% is achieved using fractal gasket carpet Antenna and than by placing spiral arms in the same further reduces the size to 50% and multiresonant frequencies is obtained in [9]. The suppression of harmonics and size reduction of 43% is achieved by using DGS [10] further size reduction of 50% and 90% of microstrip antenna is presented in [12,13] using DGS and slots. The multiband operation in microstrip antenna is shown in [14] and [15] by etching Pentagonal and skew F shaped on Ground plane.
Artificial Magnetic Conductors are engineered surfaces, which are used to design an antenna as it has the property of the zero-degree reflection phase of PMC at a resonant frequency. A Perfectly Magnetic Conductor (PMC) do not occur in nature so an AMC structure is designed at the same resonant frequency, AMC is closely related with the electromagnetic band gap (EBG), high impedance surfaces (HIS), and frequency selective surfaces (FSS).
In this presented work, a novel concentric ring based loop type FSS is designed and analyzed on the basis Floquet port technique. The Concentric FSS is optimized and integrated with Printed Antenna and I shape DGS. The integration gives us multiband operation.
Further a basic printed antenna resonating at 5.5 GHz is designed and is compared with Proposed Composite antenna. It is observed that the composite antenna also shows miniaturization.

The novel composite proposed structure apart from multiband operation shows minitiaurization. The proposed antenna is designed and simulated on Ansoft HFSS v.14 and simulated results are experimentally verified [16].

2. Antenna Geometry And Design

A. Configuration

The proposed antenna geometry is shown in figure 1, it is a dual layer structure with printed antenna on dielectric layer 1, and the five concentric rings on the dielectric layer 2 and I shape defect is embedded on the ground plane. The Microstrip Printed Antenna on dielectric layer 1 is designed based on cavity model formulas [1].

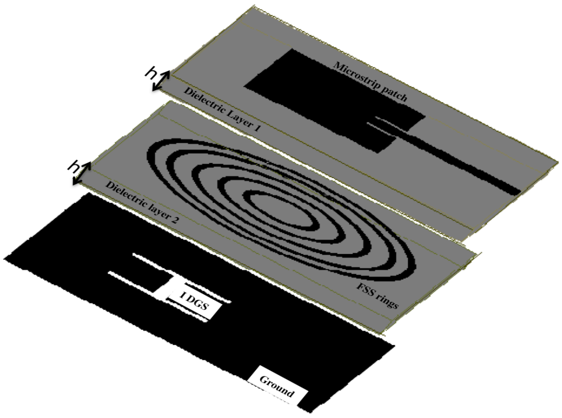
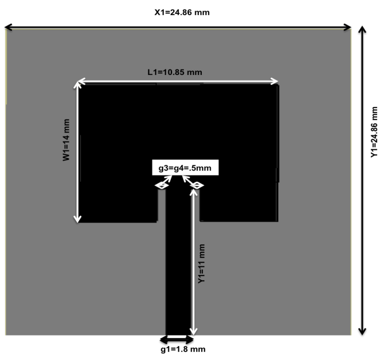
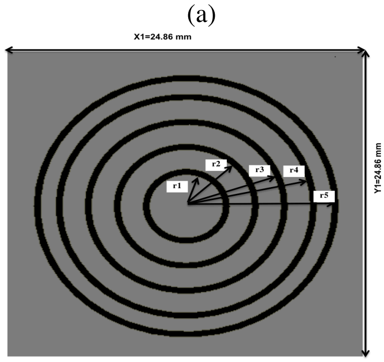


Figure 1: Proposed Composite Antenna

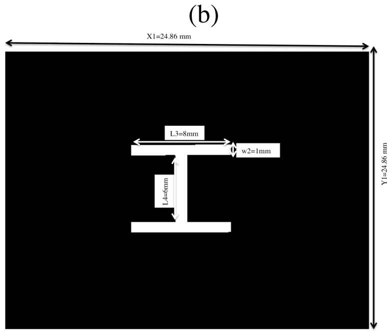
The optimized antenna is proposed and designed based on the following configurations that are taken into consderations shown in figure 1(a-c).



(a)



(b)



(c)

Figure 2: a) Micostrip Antenna b) Concentric Rings c)I Shape DGS

2.1.1. Printed Microstrip Antenna resonant at 7.4 GHz

Dual layer Inset fed printed antenna is designed on RT Duroid 5870 having dielectric constant 2.2 and loss tangent 0.0012 the calculated length and width of the microstrip antenna is 14mm and 1.85mm respectively and thickness of 3.2mm. This antenna is fed through 50ohm transmission line. This Antenna resonates at 7.4 GHz.

2.1.2. Concentric Ring FSS AMC Design

In his part Concentric Ring FSS is investigated using Floquet port technique. In the design of inductive AMC, which is a Frequency Selective Surface (FSS) of concentric rings is backed by a ground plane. The AMC is designed on dielectric layer 2 is a RT duroid 5880 with dielectric contant 2.2 and loss tangent 0.0009. Loop type FSS structure that consists of five concentric rings with dimensions r5=10mm, r4=8.5mm, r3=6.5mm, r2=4.5mm, r1=2.5mm and width 0.5mm is embedded in the layer as shown in figure 3b.The ring structure is taken as multiple rings can be placed in one one dielectric layer. The concentric rings are a periodic structure of 5 rings, which shows FSS behavior and is predicted on the basis of Floquet Port Technique.

As shown in figure3, the reflection phase varies from +90 to-90 degree the reflection phase is 0 at the resonance frequency of inset feed antenna. It is also observed that the reflection magnitude is Zero at 5.5 GHz, 6.81GHz and 9.3GHz.
The frequency for concentric FSS ring can be estimated by the following equation:

$$\lambda = \frac{c}{f} = 2\Pi r \qquad 1$$

where, λ is resonant wave length, c is the speed of light in vacuum, f is the resonant frequency of the ring

2.1.3. I shaped Defective Ground Structure (DGS)

The *DGS is* used for miniaturization of antenna in the present paper. The inclusion of DGS in the proposed structure has validated the same. I shaped DGS as shown in figure 2(c) with parallel arms of length 8mm, width 1mm and height 6mm is embedded in the ground plane as Defected Ground Structure.

2.1.4 Printed Microstrip Antenna resonant at 5.5 GHz

A basic dual layer antenna with patch area 10.85mm×22mm is desigened and simulated using HFSS software which is resonant at 5.5 GHz. Basic dual layer antenna when compared with proposed antenna shows reduction in surface of patch area by 58.15% and the volume of the antenna is reduced by 81.5% is shown in table1.

2.1.5 Composite Antenna resonant at 5.5 GHz, 6.81GHz & 9.3 GHz

The composite antenna proposed in this paper presents integration of concentric ring FSS and DGS in Printed Microstrip Antenna with inset feed.

Printed Antenna resonant at 5.5 GHz when compared with proposed composite antenna shows reduction in surface of patch area by 58.15% and the volume of the antenna is reduced by 81.5% is shown in table1.

Figure 3: The reflection phase and magnitude of AMC at 5.5 GHz, 6.81 GHz and 9.3 GHZ

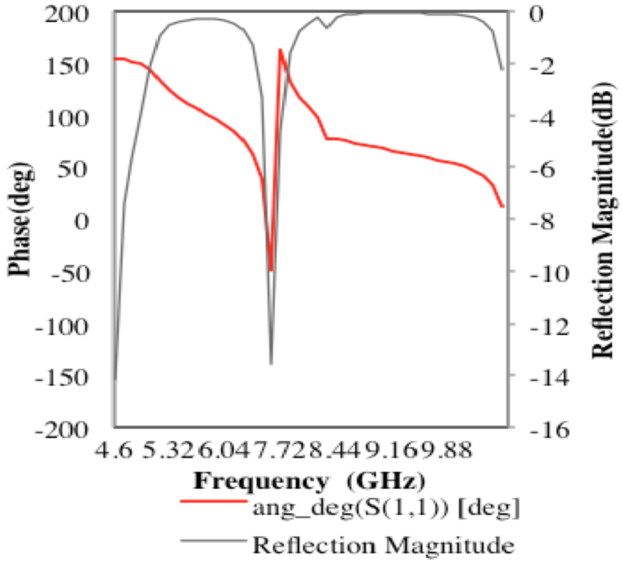


Table 1: Reduction % comparison between basic Antenna and Proposed Antenna

Parameter	Proposed Composite Antenna	Basic Antenna at 5.5 GHz	Reduction(%)
Patch area	14mm×10.85mm	16.5mm×22mm	58.15%
Antenna volume	25mm×24.86mm×3.2mm	30mm×35mm ×3.2mm	81.5%

3. Results And Discussion

The incorporation of Concentric rings and DGS in printed antenna has shown Return Loss S_{11} at the frequencies 5.5GHz, 6.81GHz, 9.3GHz as 34dB, 32dB and 39dB and is compared to Reference Antenna. The comparison table2 has shown that the combined effect of FSS rings and DGS has resulted in multiband operation and shift in freqiuency which also shows size reduction. In table 1 the basic antenna surface of patch area is reduced by 58.15% and the volume of the antenna is reduced by 81.5% as compared to proposed

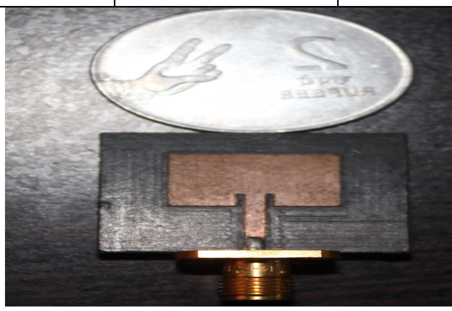
Thus it can be shown from table 1 & table 2 that the integration of FSS Concentric rings and DGS into an inset fed antenna resulted in miniaturization and multiband operation which is the main objective of this proposed antenna .

4. Measument Results

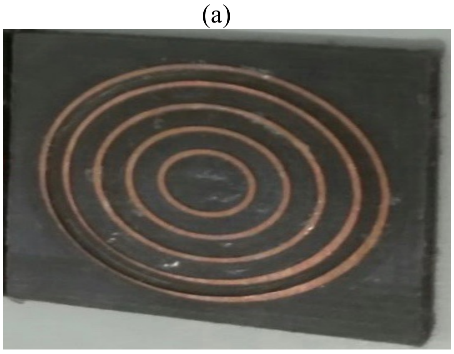
The proposed antenna is fabricated and is shown in Figure 5(a-c), Figure 5a shows the top view, 5b shows the substrate layer 2 and the bottom view is shown in figure 5c. The snap shot of the return loss is shown in Figure 6(a) . The comparison of simulated and measured results has shown good agreement and is shown in figure 6(b).The measurd VSWR parameter of proposed antenna is experimentally verified and the results are shown in Figure 7. The E plane gain of the proposed antenna is shown in Figure 8.

Table 2: Results of Proposed Antenna and reference Antenna

Parameters	Proposed Composite Antenna	Printed Antenna[17] without Concentric Rings and DGS
Frequency	5.5GHz,6.81GHz, 9.3GHz	7.4GHz
Return loss	34dB, 32dB, 39dB	17.97dB
Gain	2.42dBi, 2.80dBi, 6.76dBi	3.46dBi



(a)



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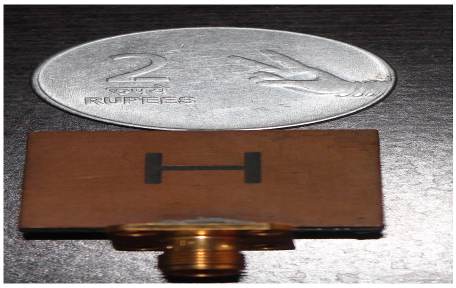

(c)

Figure 5: Printed Composite Antenna prototype a)Top View b)Middle Layer c)Bottom layer

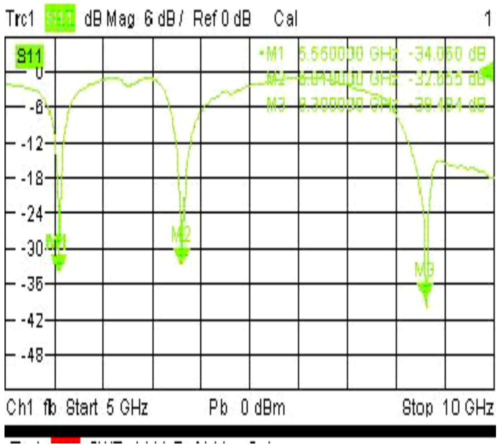

Figure 6: a. Return Loss of experimentally measured proposed Antenna: dual layer printed Antenna integarted with FSS rings & DGS.

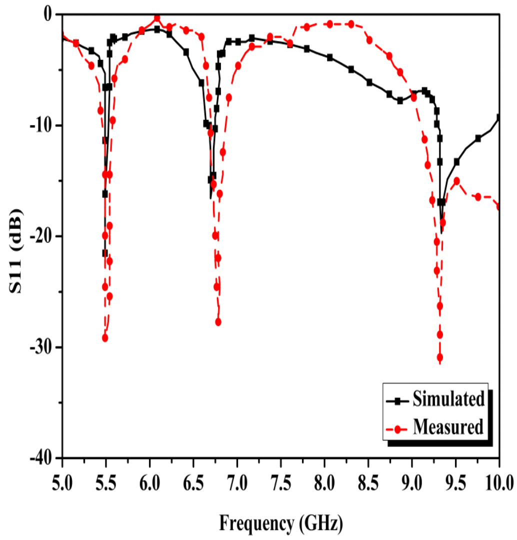

Figure 6: b. Comparison of Return Loss of experimentally measured and simulated proposed Antenna.

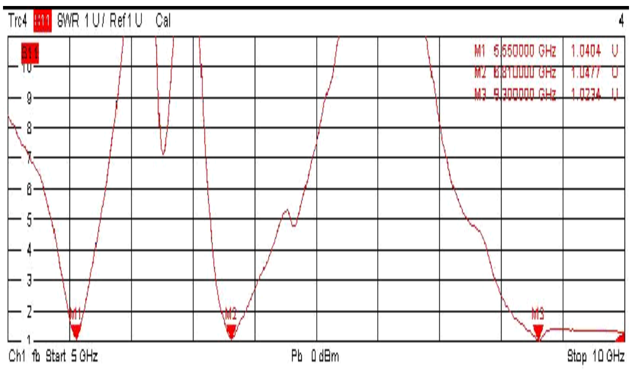

Figure 7: VSWR of experimentally measured proposed antenna.

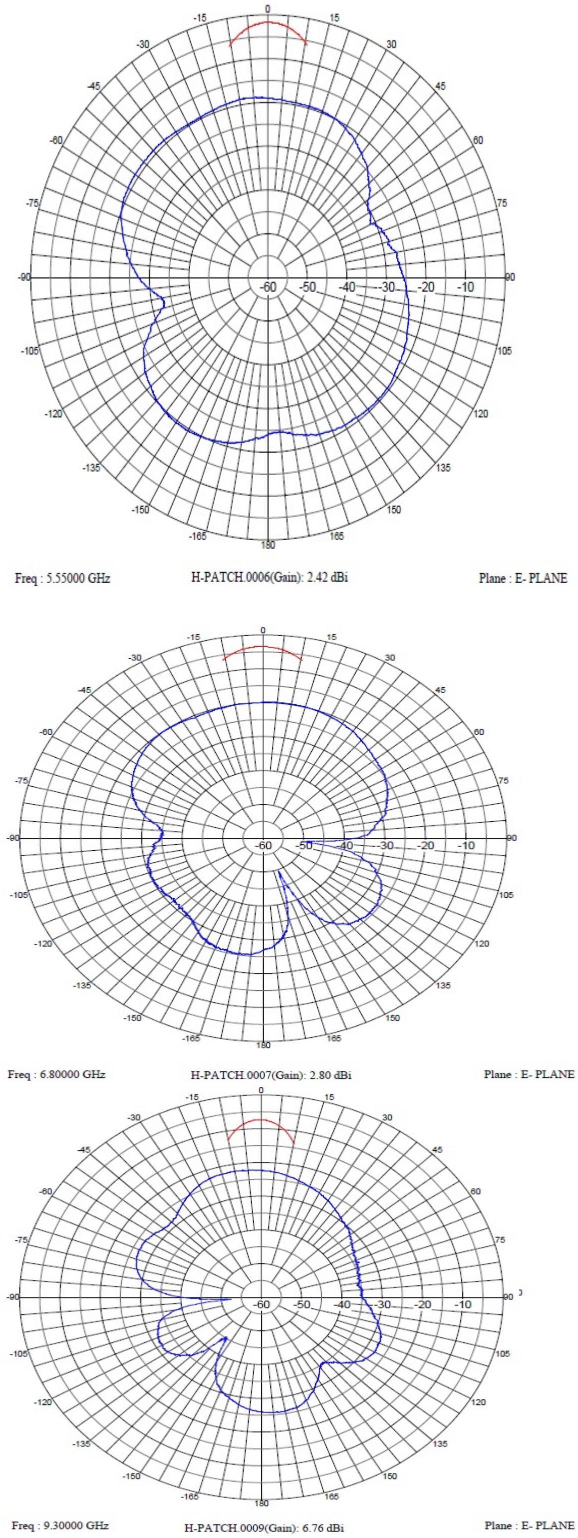

Figure 8: E plane of experimentally measured proposed antenna at frequencies 5.5GHz, 6.81GHz, 9.3GHz

Table 3:Comparison Table with published model

`References	Frequency	Size of Antenna (mm)	Gain	Structure	Band	feed
Ref[18] 2011	5.8GHz	12.5x17.5	Above 5dbi	AMC with Jerusalem FSS	Single Band	Patch Antenna coaxial feed
Ref[19] 2013	5.2GHz & 5.8Ghz	41.06X51.50	3.95 dBi and 5.61dBi	AMC with DGS	Dual band	Patch Antenna coaxial feed
Ref[20] 2016	5.8GHz	---	6.96dBi	AMC with square patch FSS	Single Band	Circle Connected Dipole Antenna
Proposed Antenna	5.5GHz,6.81GHz, 9.3GHz	25×24.86	2.42dBi, 2.80dBi, 6.76dBi	AMC with Concentric Ring FSS and DGS	Multiband Miniaturization	Patch Antenna inset feed

5. Conclusions

The size reduction have been achieved by a novel dual layer rectangular printed Antenna based on concentric rings and defected ground structure (DGS). The antenna incorporated with concentric rings and DGS which exhibits multiband operation at 5.5GHz, 6.81GHz and 9.3GHz. The change in the resonant frequency to a lesser value with proposed antenna is promising because it suggests a reduction in the dimension of the patch antenna and shows a multiband operation. By this technique, we have been able to reduce the printed antenna size up to 58.15% and the volume of the antenna is reduced by 81.5% as compared with a conventional printed antenna. VSWR values obtained at resonating frequencies 5.5GHz, 6.81GHz and 9.3GHz are 1.04, 1.04 and 1.02 respectively which are closer to ideal value 1 for all frequencies of the proposed antenna and is ideal for applications like Wi-Max, some cordless telephone, radio location, airborne and naval radars.

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