# Multi-band Annular Ring Microstrip Antenna with Defected Ground Structure for Wireless Communication

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## ABSTRACT
An annular ring microstrip antenna (ARMSA) with a defected ground structure for multi-band operation is being proposed. Defected ground structure is produced by integrating a circular slot in the ground plane having different centre with the annular ring radiator patch. Microstrip line feed is used to excite the annular ring patch antenna placed on an FR4 substrate (dielectric constant $\varepsilon_r = 4$). Results of the proposed antenna are carried out using Ansoft HFSS simulation software, and compared with the measured results, which shows good agreement. It is observed that the proposed antenna shows four bands at $f_1 = 2.92$ GHz, $f_2 = 5.64$ GHz, $f_3 = 8.21$ GHz, and $f_4 = 10.53$ GHz with an impedance bandwidth of 70%, 50%, 20% and 10% respectively. The proposed antenna is suitable for S, C and X band wireless communication system.

## Keywords
Multi-band, Annular Ring Microstrip Antenna, Defected Ground Structure, Microstrip line feed.

## 1. INTRODUCTION
In today's modern era there is constant growth and requirement of development in the field of multi-band communication system. The growth and developments in these technologies has lead to a new trend in wireless communication, networking and satellite applications [1, 2]. There are few essential requirements while designing an antenna. The parameters which should be considered before designing any antenna are its size, cost, ease of fabrication. The limitations of the conventional microstrip antenna are its narrow bandwidth, efficiency, and size [3, 4, 5]. There is a tradeoff between among parameters for example if we optimize one parameter such as size (less than $\lambda/2$) this may lead to decrease in bandwidth, gain, radiation resistance. Annular ring shape is a very promising solution for these problems [6, 7]. In the recent years, several shapes have been proposed by antenna researchers to obtain multi-band, wideband and miniaturization of microstrip patch antenna. In addition of different shapes, diverse methods are also used for obtaining dual frequency and good efficiency such as: stacked antenna, cutting slots in the radiating patch or in the ground plane, or by changing the dielectric constant of the substrate [8-12].

These methods will give the wideband, dual band, but not multi bands [13-17]. One of the suitable methods is defecting the ground structure having a different centre with annular ring patch for obtaining multiple frequency bands.

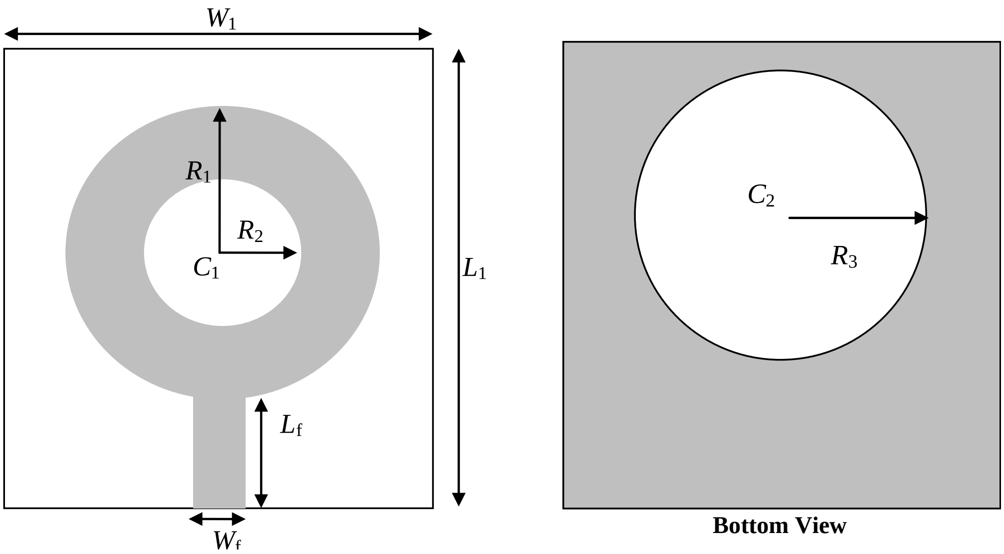
The objective of this work is to design an ARMSA with defected ground structure feed by microstrip line so that, it can operate on multiple frequency bands i.e. 2.92 GHz, 5.64 GHz, 8.21 GHz, and 10.53 GHz. Thus, a new design is being investigated along with the simulation and measurements obtained.

The next section deals with multiband antenna design technique used for wireless communication, in detail. Section 3 covers experimental results and its discussion. Section 4 concludes all the discussion made earlier.

## 2. ANTENNA DESIGN CONSIDERATION
The design of the ring shape proposed antenna has been shown in figure 1 (a), (b). The proposed antenna consists of a defected ground structure and a circular radiating patch connected to a microstrip feed line. The antenna was fabricated and printed on a FR-4 substrate having relative permittivity $\varepsilon_r = 4.4$, thickness $h = 1.6$ mm and loss tangent $\tan\delta = 0.024$. The overall size of the antenna is $35 \times 30 \times 1.6$ $mm^3$. The simulation software High-Frequency Structure Simulator (HFSS) [18] is used to optimize the dimensions of the proposed design on the basis of best performance. The width of the microstrip feed line is fixed at 1.5 mm to achieve $50\Omega$ characteristic impedance. An annular patch having outer radius, $R_1 = 11$ mm and inner radius $R_2 = 6$ mm is taken having centre position $C_1 = (0, 0)$ and provided a feed of width, $W_f = 1.5$ mm with an outer radius of annular ring, a circle of radius $R_3 = 12$ mm with a circle centre position at $C_2 = (-3.5, 0)$ is cut in ground plane to make defected ground plane. For obtaining multi bands and better return loss along with an efficiency of 88%, following parameters of the proposed antenna have taken which are shown in table 1 as given below:

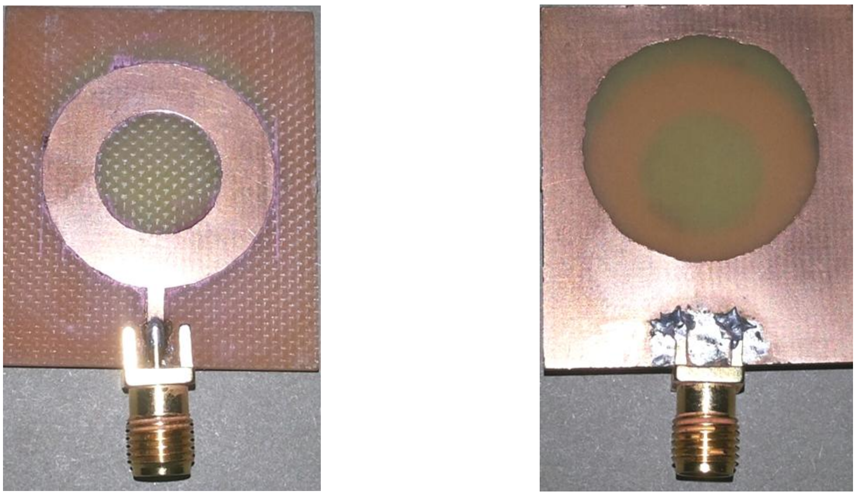
**Table 1 Proposed antenna design parameters**

| **Parameters** | $L_1$ | $W_1$ | $R_1$ | $R_2$ | $R_3$ |
|---|---|---|---|---|---|
| **Units (mm)** | 35 | 30 | 11 | 06 | 12 |
| **Parameters** | $W_f$ | $L_f$ | $C_1$ | $C_2$ | |
| **Units (mm)** | 1.5 | 7.5 | 0,0 | -3.5,0 | |




**Top View** **Bottom View**

**(a)**



**Top View** **Bottom View**

**(b)**

**Figure 1 (a) proposed antenna geometry and (b) image of fabricated antenna (Drawing is not in scale)**

## 3. DISCUSSION OF RESULTS

### 3.1 Variation of Patch Parameters

Figure 2 shows, the simulated return loss of the proposed antenna with outer radius $R_1$ varies from 10 to 12 mm. Bandwidth for return loss (< 10 dB) for the above said antenna decreases as the radius $R_1$ increases from 11 mm to 12 mm. Therefore, it is decided to take $R_1$ = 11 mm as the results of the multiband ARMSA covers four bands.

Further, Figure 3 shows the simulated results of the proposed antenna with inner radius $R_2$ varies from 5 mm to 7 mm. It was observed that the return loss of the antenna decreases as the value of radius increases. Therefore we took $R_2$ = 6 mm as the optimum radius, to get multi-bands from 2.92 GHz to 10.53 GHz frequency range.

### 3.2 Variation of Ground Parameters

Figure 4, shows the simulated results of the proposed multiband ARMSA showing the effects of slot in the ground plane. For the solid ground plane (without any slot), the return loss condition appears to be worse over the entire frequency band. As for the case of ground plane with radius $R_3$ = 11 mm the matching condition still not acceptable at 2.92 GHz and 5.64 GHz. However, the four resonant bands appear around 2.92 GHz, 5.64 GHz, 8.21 GHz, and 10.53 GHz. The similar case appears when the radius $R_3$ = 13 mm is taken. Therefore, it is decided that the ground plane with radius $R_3$ = 12 mm is taken which improves the results for the entire frequency band.

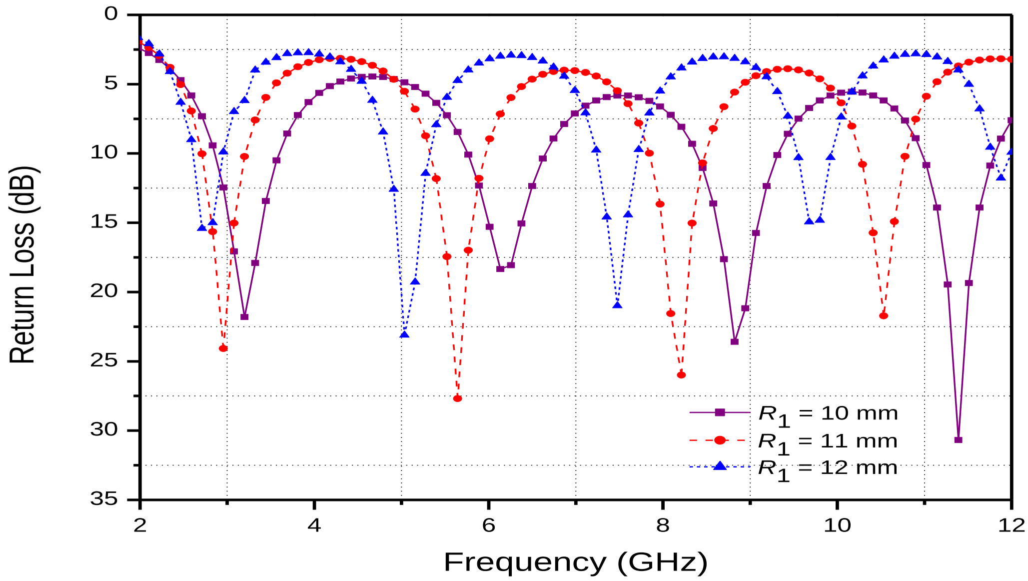



**Figure 2 Variation in return loss with frequency for different radius ($R_1$), other parameters are same as listed in Table 1.**

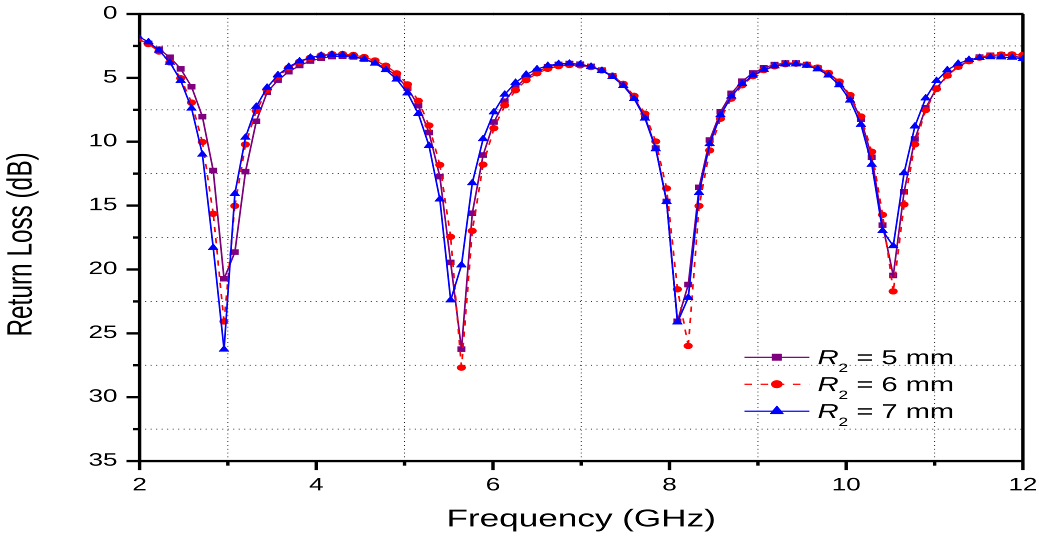



**Figure 3 Variation in return loss with frequency for different radius ($R_2$), other parameters are same as listed in Table 1.**

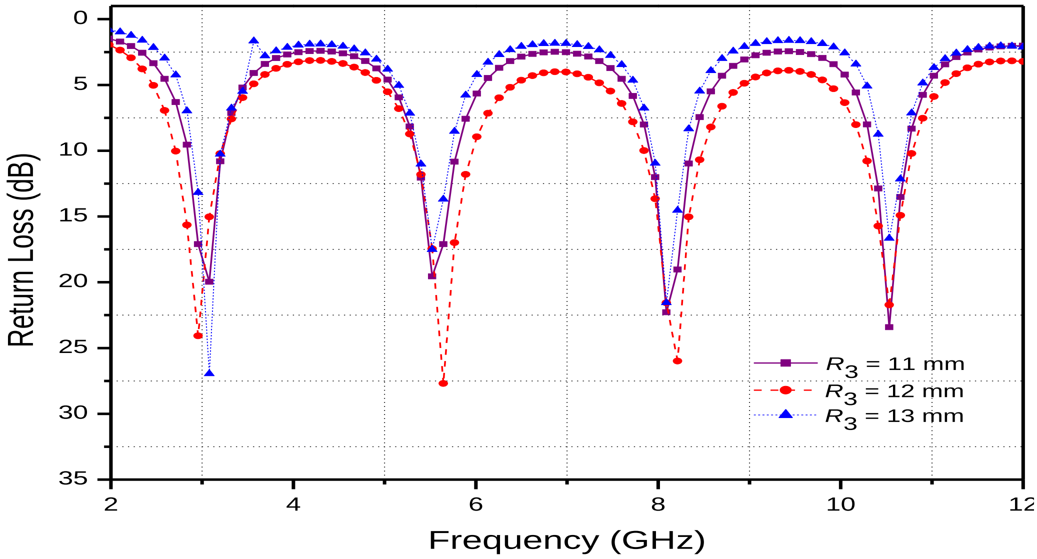



**Figure 4 Variation in return loss with frequency for different radius ($R_3$), other parameters are same as listed in Table 1.**

## 3.3 Variation of Microstrip Feed Parameters

Figure 5, shows the simulated results of the proposed multiband ARMSA with width of microstrip feed $W_f$ varies from 1.0 mm to 2.0 mm. It was observed that the antenna shows better return loss at $W_f$ = 1.5 mm. Therefore it is decided to take $W_f$ = 1.5 mm as the optimum width for obtaining multi-bands from 2.92 GHz to 10.53 GHz frequency range with better return loss. While Figure 6, shows the simulated results of the proposed multiband ARMSA with length of microstrip feed $L_f$ varies from 7.3 mm to 7.7 mm. It was observed that the bandwidth is almost same in all the four bands, but the return loss varies. Therefore it is decided to take $L_f$ = 7.5 mm as the optimum length to obtain better return loss with multi-bands.

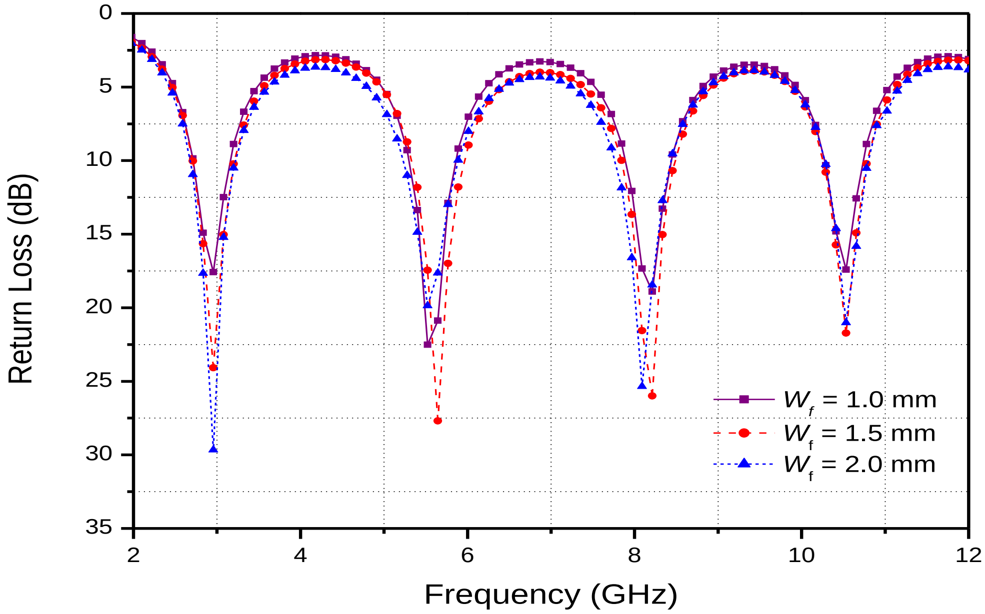



**Figure 5 Variation in return loss with frequency for feed width ($W_f$), other parameters are same as listed in Table 1.**

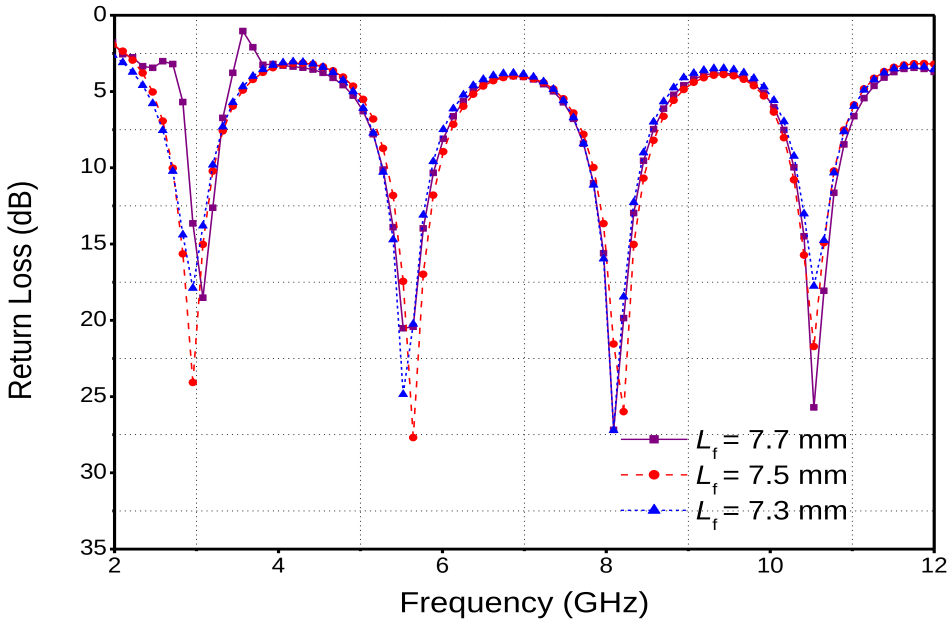



**Figure 6 Variation in return loss with frequency for feed length ($L_f$), other parameters are same as listed in Table 1.**

An Agilent 8757E scalar network analyzer was used to measure the performance of the proposed antenna such as return loss. There is a balanced agreement in measured and simulated return loss curves of the proposed multiband ARMSA that is shown in figure 7. The small difference between measured and simulated results is due to the effect of SMA (Sub Miniature version A) connector soldering and fabrication. The designed antenna shows multiband between 2.92 GHz to 10.53 GHz frequency range.

Figures 8 (a) to 8 (d) shows the measured and simulated far field radiation patterns in the H and E planes at frequencies 2.92 GHz, 5.64 GHz, 8.21 GHz, and 10.53 GHz. It has been searched out that the multiband ARMSA has good radiation patterns at all frequencies in both the planes. This pattern works on S, C and X band and is most suitable for wireless communication systems

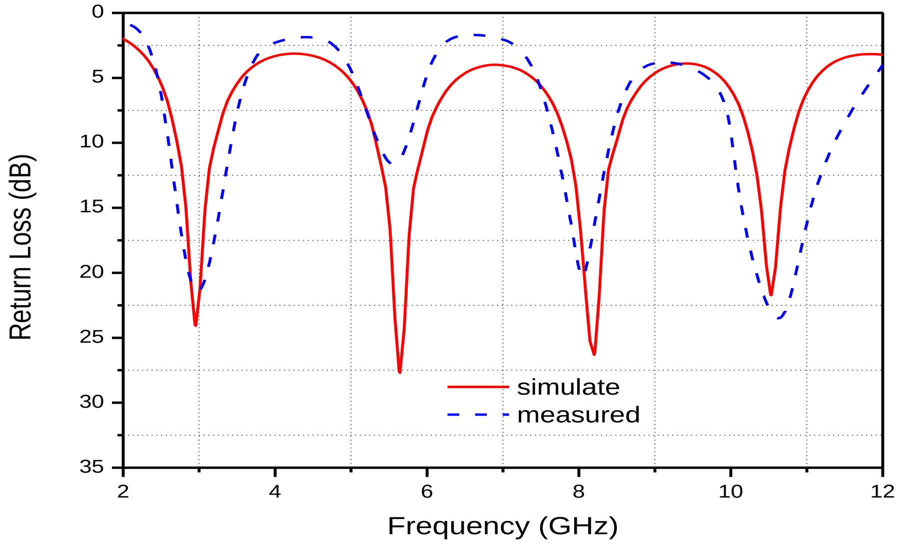
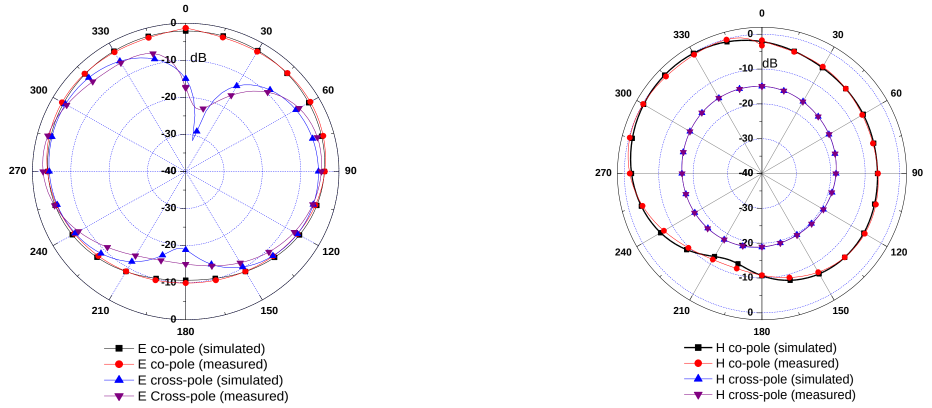
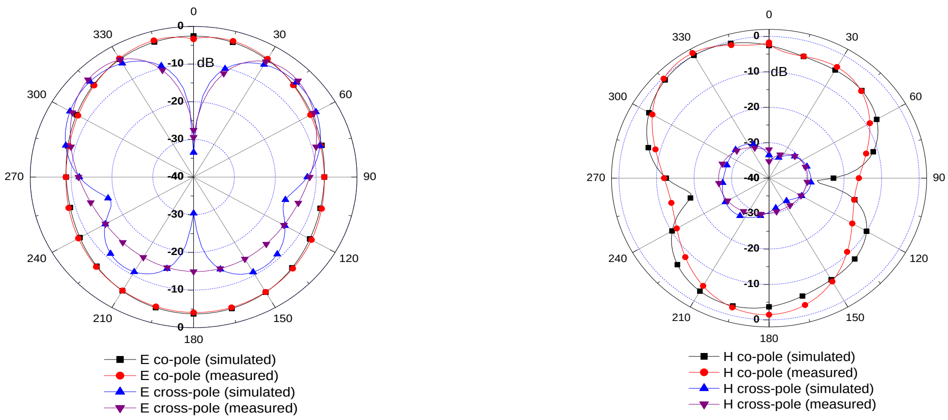


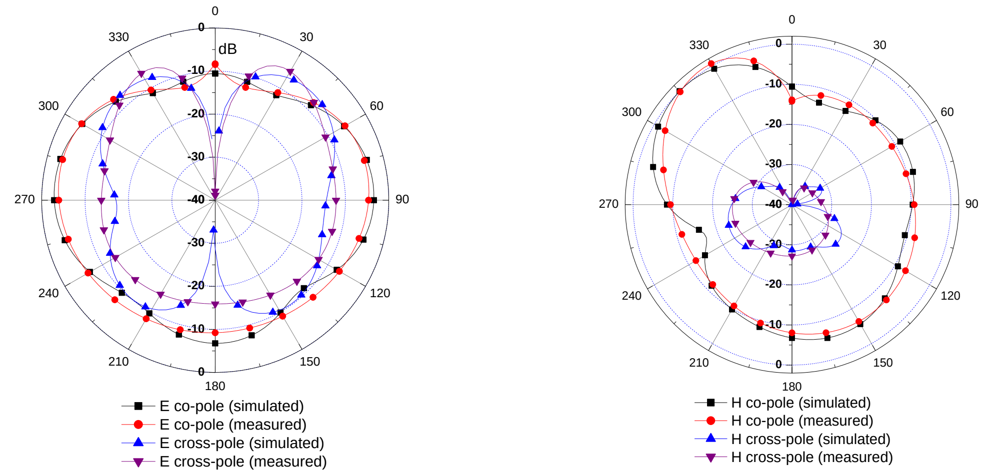

**Figure 7 Simulated and Measured Return Loss of proposed antenna.**



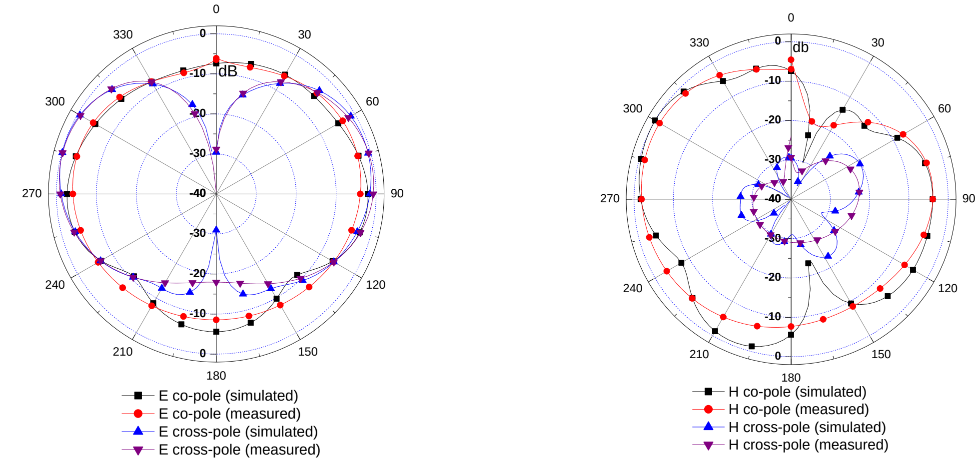

**(a)**




**(b)**




**(c)**




**(d)**

**Figure 8 Measured and simulated radiation patterns of various resonance frequencies for the proposed Multiband ARMSA at (a) 2.92 GHz (b) 5.64 GHz (c) 8.21 GHz (d) 10.53 GHz**

# 4. CONCLUSION

The proposed ARMSA with defected ground structure for multiband operation has been designed, simulated and fabricated. The effect of defected ground structure on multiband has been studied using HFSS simulation software. The four different frequencies range 2.92 GHz, 5.64 GHz, 8.21 GHz, and 10.53 GHz generally works on S, C and X band and it has been found out most suitable for wireless communication systems. The antenna has an efficiency of 88% and omnidirectional radiation patterns over the entire frequency band. The antenna has a bandwidth of over 15.76%, 10.78%, 7.74%, and 5.5% in the frequency ranges from 2.7325 to 3.2 GHz, 5.345 to 5.95 GHz, 7.8475 to 8.48 GHz, and 10.193 to 10.78 GHz. The future scope of the proposed antenna includes the measurement of gain, time delay and mathematical analysis.

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## 6. AUTHOR PROFILE

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**Kshitij Shinghal** has 14 Years of experience in the field of academic and is actively involved in research & development activities. He obtained his Masters (Digital Communication) in 2006 from UPTU, Lucknow and Ph.D. degree from Shobhit University. He started his career from MIT,
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