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Stacked Circularly Polarized Microstrip Antenna for RFID Applications

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ABSTRACT:A broadband, circularly polarized, stacked, ring-slotted microstrip patch antenna is designed for universal ultra-high-frequency (UHF) radio frequency identification (RFID) reader application. The antenna is composed of two asymmetric, square patches with a ring slot on each and suspended one above another with the help of FR4 and air substrates. A microstrip stub is added at the lower patch to improve impedance bandwidth and impedance matching of this proposed antenna. The lower patch is fed by a single feed coaxial probe. Circularly polarized(CP) radiation can be achieved by asymmetrical patcheswith diagonally placed ring slots on them. The measurement shows that the designed antenna achieves-10 dBreturn loss bandwidth of 22.95% (839-1044MHz). The simulated -10 dB return loss bandwidth is 23.18% (831-1035MHz) and simulated 3 dB axial ratio bandwidth of 10.80% (860-955MHz). The simulated peak gain is 7.35dBi (within the range of 831-1035MHz)and total antenna efficiency is 70.49%.

KEYWORDS: Microstrip antenna, circular polarization, ring slot, stacked patches, RFID readers.

I.INTRODUCTION

Microstrip antennas are very popular because of their many advantagessuch as low profile, conformable to planar and non-planar surfaces, simple design and lower cost to fabricate using modern printed-circuit technology, mechanically robust when mounted on hard surfaces, compatible with MMIC designs, and versatile in terms of resonant frequency, polarization, pattern and impedance. On the contrary, they have low gain and narrow bandwidth, typically 1–5%, which is the major limiting factor for the widespread application of these antennas. By overcoming these limitations, using different techniques and design methods,microstrip antennas can be used in a large number of applications such as high performance aircraft, satellite, space-crafts and missile applications etc. Besides these,RFID readeris also one of the major applications[1].

RFID is a technology that provides wireless communication featuring identification and tracking capabilities. In recent years, RFID technology has evolved at a fast pace and applied to many service industries, distribution and supply chains and manufacturing companies. In an ultra-high-frequency (UHF) RFID system, the reader emits signals through reader antennas. An RFID tag, located at the client consists of an antenna and an application-specific integrated circuit (ASIC). The tag is activated and queried for its information by the reader. The querying signal from the reader must have enough power to activate the tag ASIC to perform data processing, and send back the information over a required reading distance. Since the RFID tags are always randomly oriented in practical usage and the tag antennas are normally linearly polarized, circularly polarized (CP) reader antennas are utilized in UHF RFID systems for ensuring the reliability of communications between readers and tags [2]. The total frequency span of the UHF band for worldwide RFID systems is within the frequency range from 840 MHz to 960 MHz. The RFID system operates in the bands from 902 MHz to 928 MHz in America, from 865 MHz to 867 MHz in Europe, and from 840 MHz to 955 MHz in the Asia-Pacific region. In the Asia-Pacific region, the UHF RFID frequency range is different in different countries, such as in China (920.5 MHz to 924.5 MHz), Japan (952 MHz to 955 MHz), India (865 MHz to 867 MHz), Hong Kong (865 MHz to 868 MHz and 920 MHz to 925 MHz), Taiwan (920 MHz to 928 MHz), Korea (908.5 MHz to 910 MHz and 910 MHz to 914 MHz), Singapore (866 MHz to 869 MHz and 923 MHz to 925 MHz), and Australia (920 MHz to 926 MHz)[3]. Thus, a circularly polarized reader antenna needs to cover the full UHF band (850 MHz to 960 MHz) for worldwide RFID applications[3].

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Circular polarization can be achieved by exciting two orthogonal modes of equal amplitude and 90° phase difference. These are advantageous as they provide flexible and independent orientation between transmitter and receiver. They are not sensitive to antenna orientation. Circular polarization also reduces multipath effects and reflection losses of wireless data transmission system[4].A circularly polarized, stacked, circular slotted microstrip antenna was designed to improve axial ratio bandwidth.Additionally, a microstrip stub is used as impedance matching network [5].Stacked probe fed antenna was designed in which hybrid coupler was used to form feeding network for the circular polarization radiation[6].

An annular ring slotradiator and a hybrid patch couplerwere used in circular polarized antenna for RFID applications. The hybrid patch coupler wasintegrated with the annular ring slot antenna to radiate the circular-polarized wave[7][8]. To improve the axial ratio bandwidth stacked microstrip antenna was proposed using C-type coaxial probe single feed [9].

II.DESIGN

The key design consideration of UHF RFID reader antennas is to achieve good impedance matching, high gain, and desired circular polarization characteristics over the specified RFID band with the considerationof size, weight, and cost.

The geometry of the proposed antenna is shown in the figure 1. Antenna consists of a stack, made up of two asymmetric square patches, that isa lower patch and anupper patch. Stacked structures usually broadenthe axial ratio bandwidth and return loss bandwidth. Upper patch with dimensions L2=W2=110mm is placed over the lower patch with dimensions, L1=W1=79.5mm. The ground plane area is g × g = 200mm [5].

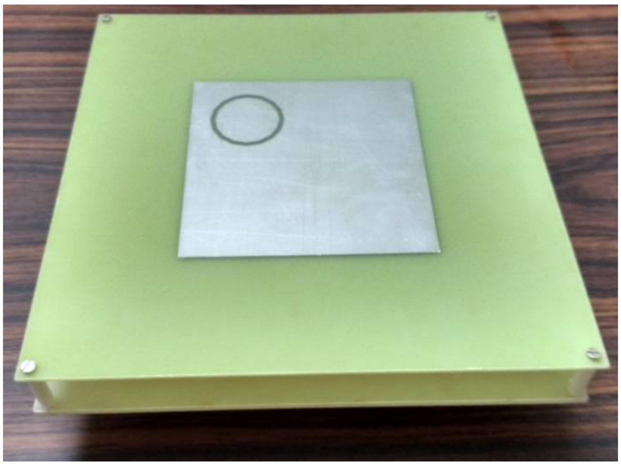

Fig. 1 Structure of the proposed antenna

In stacked structures, as the height of the antenna increases,surface waves are generated whichmay increasethe quality factor.To avoid this problem, there aredifferent solutions. Slotted geometry is one of the solutions. Slots can be used to reducethe stored energy between patch and ground plane, resulting in low quality factor withhigher bandwidth (wideband).Accordingly, in the proposed antenna, circular ring slot is used to get improved axial ratio bandwidth and also better quality of circular polarization. A ring slotalso enables higher gain.As shown in figure 2, in this geometry slot 1 is placed on the lower patch at (-23,-23,3.2) position and slot 2 is placed on upper patch at (-27.5,-27.5,27.8) position. Ring slot 1 with an inner radius of 13mm and outer radius of 15.5mm, while Ring slot 2 with inner radius of 15.5mm and outer radius of 18mm are selected after an optimization process. Inner radius and outer radius of both slots and also their positions are selected such that exciting two orthogonal modes of equal amplitude and 90° phase difference can generate circular polarization.

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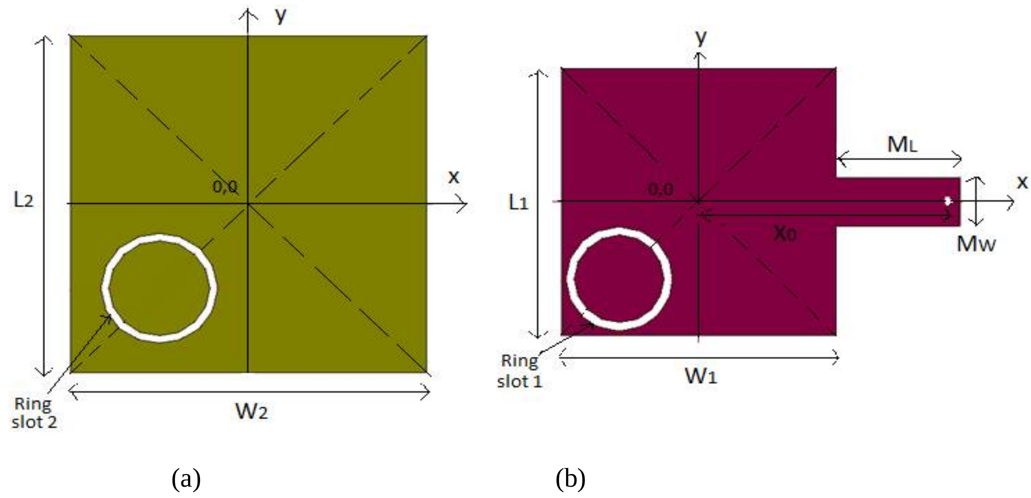

Fig. 2 Asymmetric square patches (a) upper slotted patch (b) lower slotted patch with stub and feed.

Lower patch is placed on substrate FR4 (h1 = 3.2 mm, εr1 = 4.2, and tanδ1 = 0.02).Upper patch is placed on substrate FR4 (h3= 1.6 mm, εr3= 4.4, and tanδ3= 0.02). Air substrate (h2= 23 mm, εr2= 1.0006) is sandwiched between lower patch and upper substrate as shown in the figure 3.For single feed antennas, CP waves are generated when assymmetry is introduced to the geometry;hence the use of asymmetric patches in the proposed antenna.

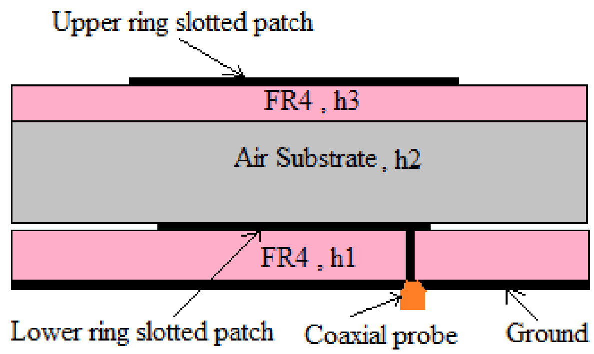

Fig.3 Cross section view of the proposed antenna.

Changein the thickness of the air substrate varies the axial ratio bandwidth. At the end of lower patch, a microstrip stub is connected, which is usedto match theantenna to the 50-ohms feed line. Bytuning width and length of microstrip stub, the input impedance of this antenna can be changedeasily, and a good matching condition is achieved. Microstrip stub length (M_L) of 36mm and microstrip stub width (M_W) of 14.5mm is selected [5]. The gain of the antenna is also somewhatdependent on the width of the microstrip stub. To feed thering slot antenna, a single feed coaxial probe is provided (at the position of Xo=72.75mm) on the microstrip stub connected to the lower patch of the proposed antenna [5].

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III.RESULTS AND DISCUSSION

The simulated results are obtained from the IE3D commercial simulator. The simulated and measured result of return loss bandwidth of proposed antenna is shown in figure 4 and figure 5 respectively. The simulated -10 dB return loss bandwidth is 23.18% (831-1035MHz) and measured -10 dB return loss bandwidth is 22.95% (839-1044). It agrees well with the simulated results with only a slightly frequency shift, which is mainly caused by the poor characteristics of the FR4 substrate and fabrication losses. Fig. 6 shows simulated 3 dB axial ratio bandwidth. The simulated 3 dB axial ratio bandwidth ofthe proposed antenna is 10.80% (860-955MHz). The gain and total antenna efficiency is also affected to a slight extent by the air substrate thickness. The simulated peak gain is 7.35dBi (within the range of 831-1035MHz) as shown in figure 7 and total antenna efficiency is 70.49% measured at resonant frequency 880MHz as shown in figure 8.The simulated radiation pattern of the proposed antenna is shown in figure 9.E-left and E-right CP radiations are shown. To achieve better results of proposed model, the designed antenna is optimized for bothring slots (that is its inner and outer radius), antenna height and air substrate thickness.

Only the return loss bandwidth of the fabricated antenna has been measured while return loss bandwidth, gain, antenna efficiency and radiation pattern are simulated results.

Air substrate thickness – It is observed that the optimal circular polarization radiation is achieved with an air substrate thickness of 23 mm when the thickness is varied from 20mm to 26mm. Above and below 23mm, the antenna gain and axial ratio bandwidth are found to decline.

Slot 1 inner radius – When varying the inner radius of ring slot 1 from 8mm to 14 mm, impedance bandwidth decreases while the axial ratio bandwidth initially decreases (up to a radius of 11mm) and then increases back. At 13mm most optimal readings for return loss bandwidth, axial ratio bandwidth, gain and antenna efficiency are seen. Beyond 13 mm most of the aforementioned parameters decline.

Slot 1 outer radius – When varying the outer radius of ring slot 1 from 14mm to 16.5mm, the maximum circular polarization radiation, gain, efficiency and return loss bandwidth are observed only at 15.5mm. At other radius, none of the parameters are complaint to the RFID range.

Slot 2 innerradius – Most of the performance measurement parameters (circular polarization radiation, gain, efficiency and return loss bandwidth) are less sensitive to changes in the inner radius of slot 2.Considering the optimal radius of slot 1 as discussed above, the inner radius of slot 2 was varied between 11mm to 17mm with the best results found at 15.5mm.

Slot 2 outer radius – When varying the outer radius of ring slot 2 from 16mm to 21mm, the best resultsfor circular polarization radiation, gain, efficiency and return loss bandwidth are observed at 18mm compared to other radii.Notably, at 19mm the best circular polarization is achieved. However, other parameters are non-complaint to the RFID range at 19mm.

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The simulated return loss bandwidth is shown in figure 4 and measured return loss bandwidth is shown in figure 5.

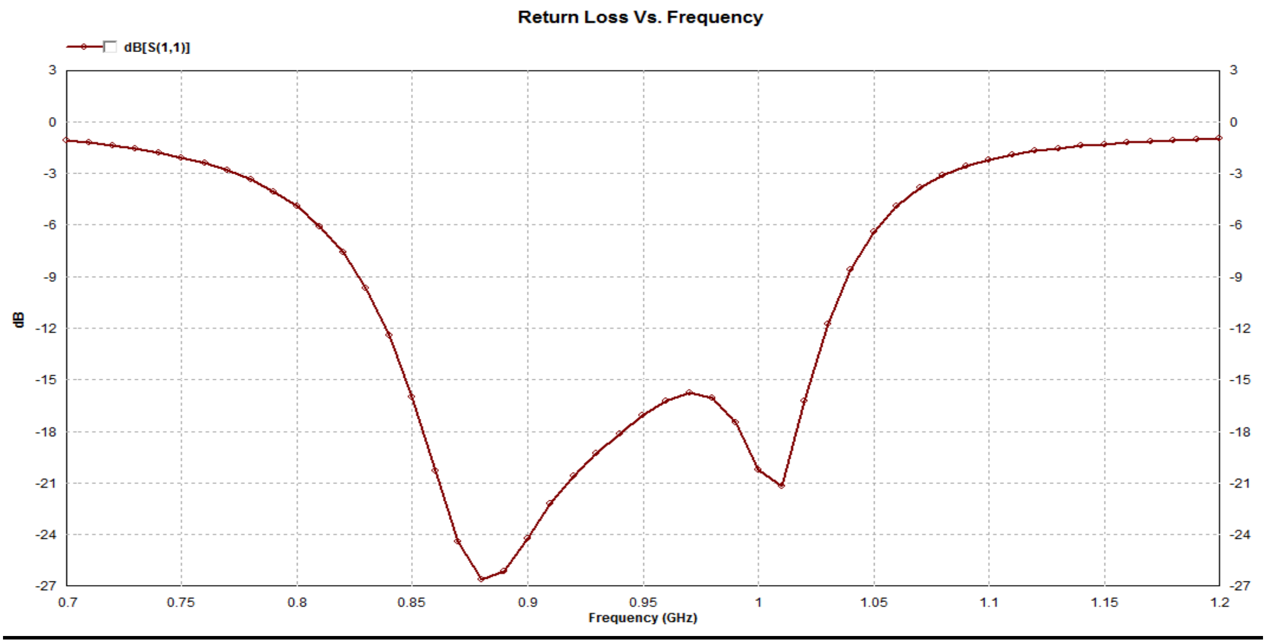

Fig. 4 Simulated return loss bandwidth

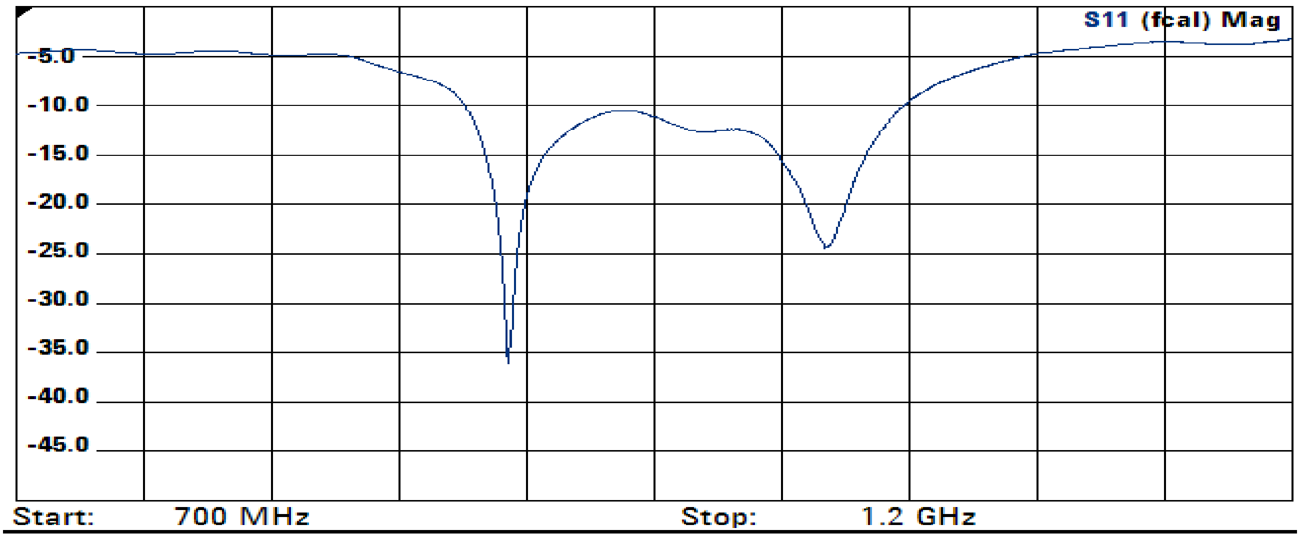

Fig. 5 Measured return-loss bandwidth

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Figure 6 shows simulated axial ratio bandwidth Vs. frequency graph.

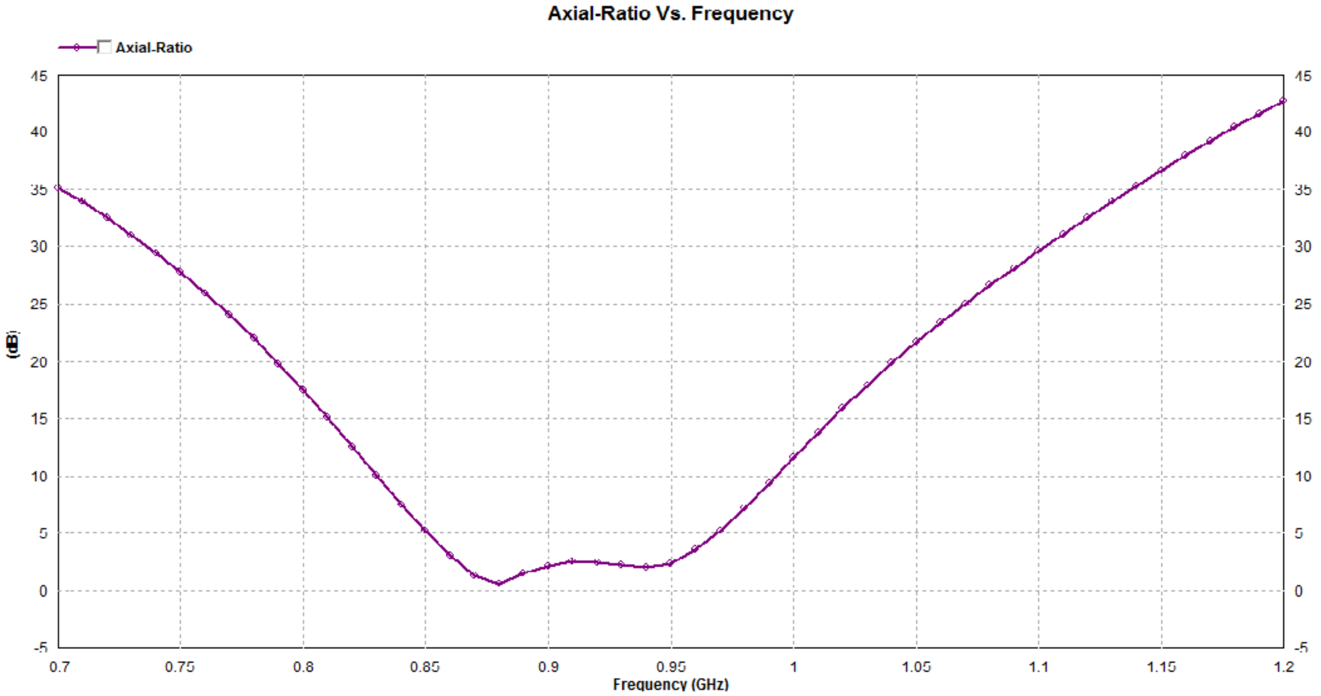

Fig. 6 Simulated axial ratio bandwidth

Simulated total field gain Vs. frequency graph is shown in figure 7.

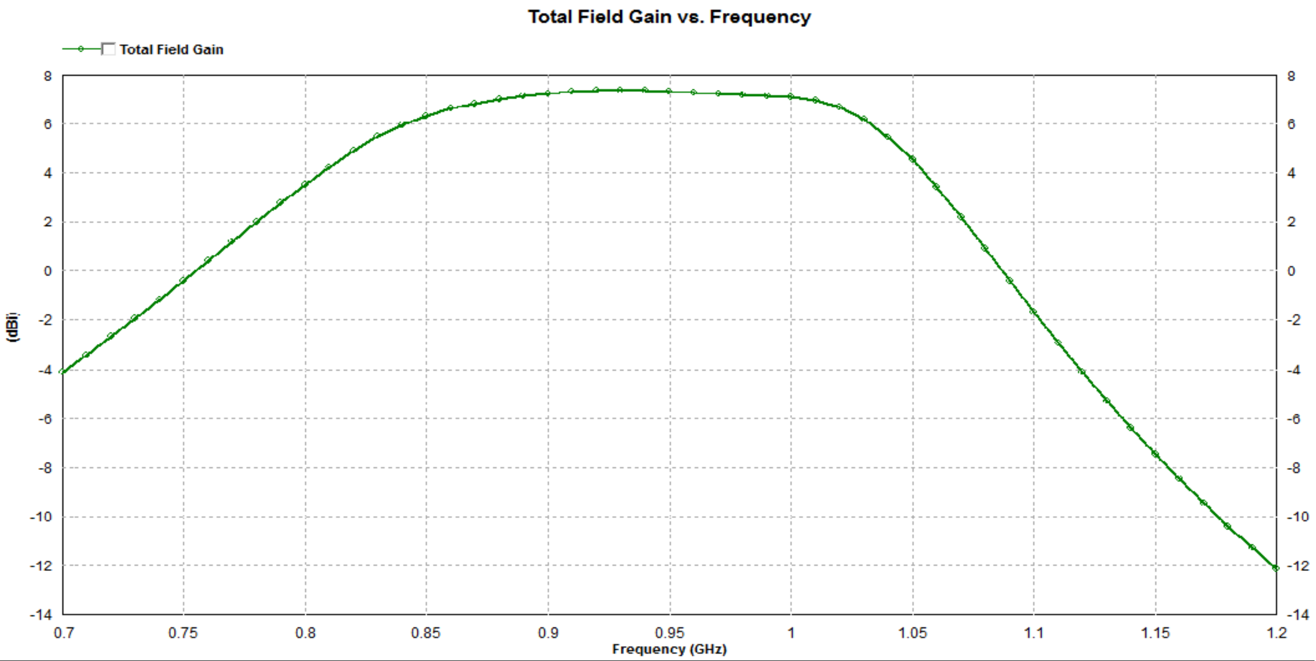

Fig. 7 Simulated gain of the proposed antenna.

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Simulated antenna efficiency vs. frequency graph is shown in figure 8.

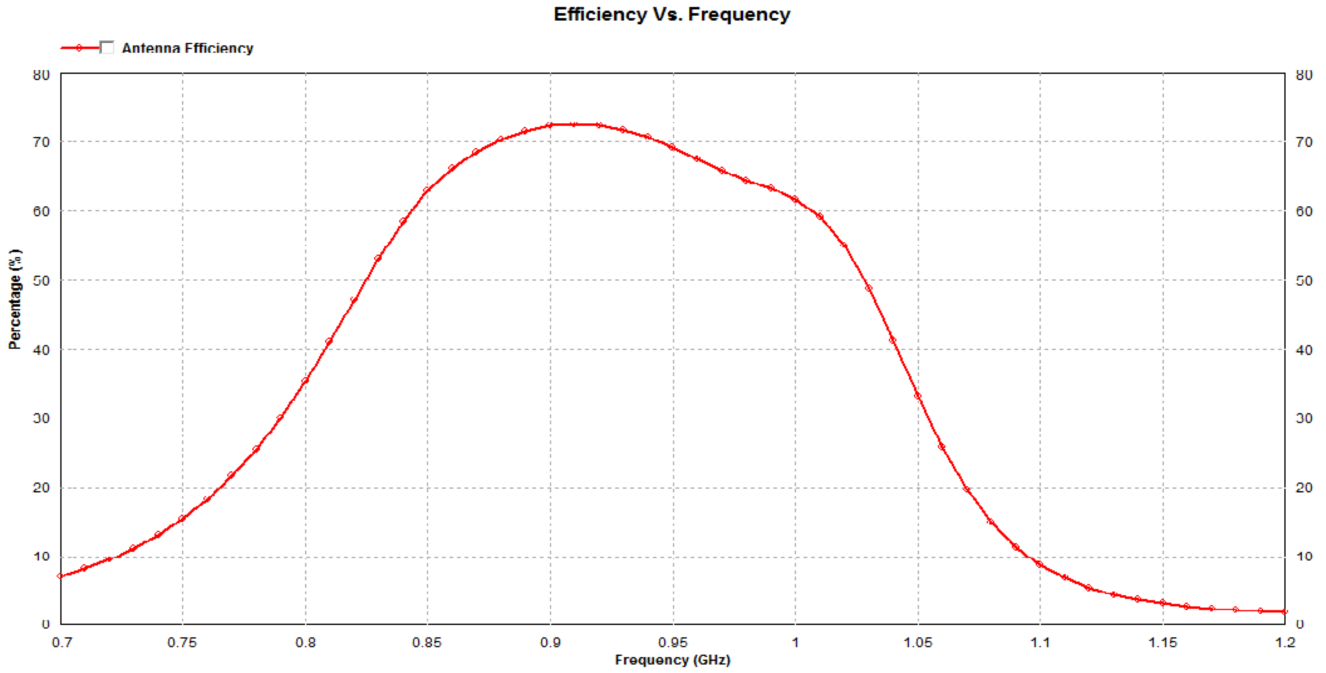

Fig. 8 Total antenna efficiency of the proposed antenna

Simulated radiation patter at centre frequency 880MHz is shown in figure 9.

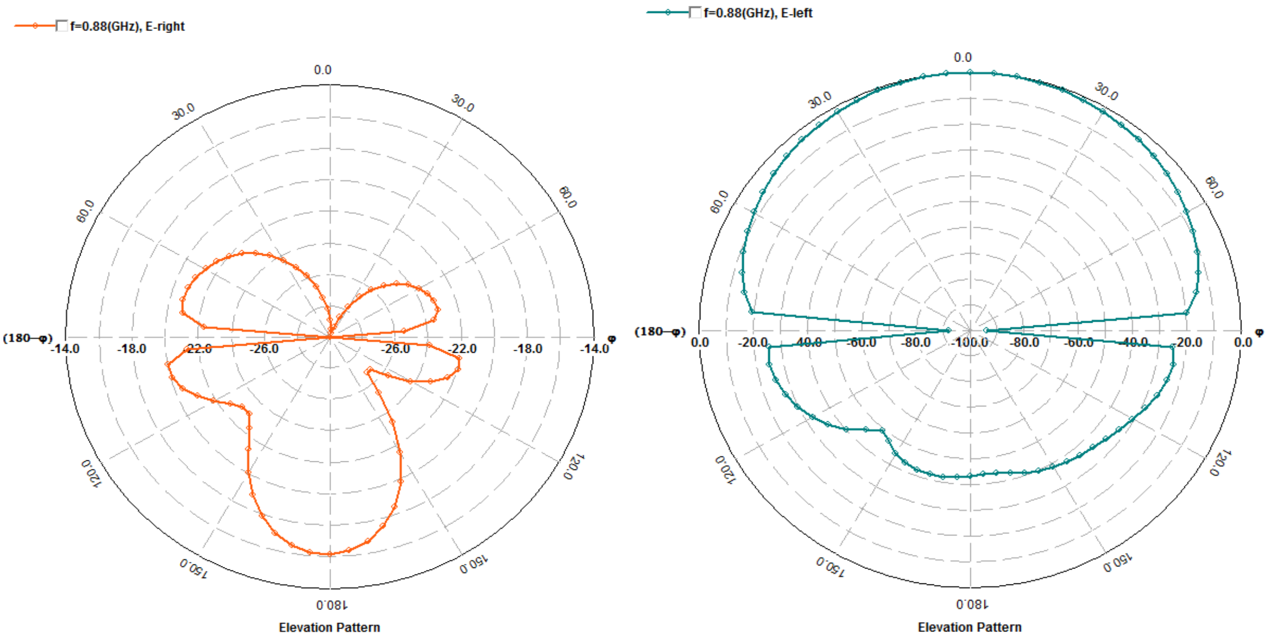

Fig. 9 Simulated radiation pattern at 880MHz

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Based on the simulated and measured return loss bandwidth results, the proposed antenna has a good performance in the entire UHF band and is a good candidate for the RFID reader antenna.

IV.CONCLUSION

Based on above considerations, the proposed antenna has been designed and fabricated, with measured results obtained only for the return loss bandwidth. Geometry is designed for universal UHF RFID reader application and its acceptable frequency range is 840MHz-960MHz. A design for a circularly polarized, single feed, stacked, ring slotted patch antenna is presented. By varying ring slots, feed positions and air substrate thickness, two orthogonal modes are generated which enable circular polarization. The proposed antenna provides improved axial ratio bandwidth and better quality of circular polarization. The advantage of ring slot used in the proposed antenna is improved gain and antenna efficiency as compared to a circular slot. Also, instead of foam substrate, air is used as a substrate in this configuration to achieve higher gain, broader bandwidth, and lower cost. The air-filled antenna does not utilize any foam materials, so foam-fitting process during fabrication is not required, which provides simplicity and ease of fabrication for antenna designing. The proposed antenna is also advantageous because it is not suffering from moisture absorption and temperature dependency. Besides, the multilayered arrangement has also facilitated impedance bandwidth broadening compared to circular slotted stacked geometries. The measured return loss bandwidth of 22.95% (839-1044MHz) conforms to the simulated results of 23.18% (831-1035MHz) within the specified range of RFID reader application. The simulated 3-dB axial ratio bandwidth is 10.80% (860-955MHz). Also, the antenna is cost efficient and is well suited for RFID reader applications.

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