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Performance Comparison of Different Shapes of Patch Antenna on Sapphire for RFID Application

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ABSTRACT: In this paper, a simple structure microstrip patch antenna with high front-to-back ratio is proposed for UHF-RFID tag at 870MHz on sapphire material as substrate. The performance of general structure rectangular patch antenna is designed and analyzed in ANSOFT-HFSSV13.0 simulator and the antenna characteristics are interms of returnloss, radiation pattern, half power beamwidth, front to back ratio and gain. Later, the work is extended to different patch shapes and compared the performance of all antennas. Hexagonal patch antenna is practically designed, analyzed with network analyzer and compared to simulated results.

KEYWORDS: RFID Tag, patch shape, gain, front-to-back ratio

I. INTRODUCTION

Now a days, increased a requirement of identification of object without contact [1]. A suitable technique to identify the objects without contact is a RFID (Radio Frequency Identification) system. RFID system is suitable in many areas like Security/access control, transportation, Supply chain management, rental item tracking, Toll collection, Automobile immobilizers, Baggage handling, Animal tracking etc. The basic RFID system [1] is shown in Fig.1.

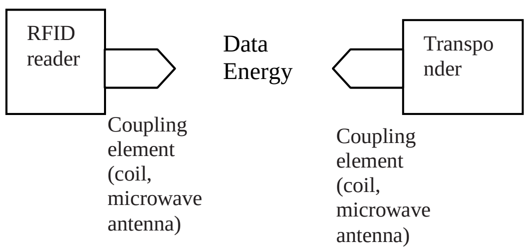

Fig.1. Basic diagram of RFID Tag

RFID Tag is classified into different types based on operating frequency, range to be measured, and type of coupling. RFID Tags generally designed in the frequency range of 135 KHz to 5.8GHz.

- Read range up to 1cm: Used closed coupling (by electric and magnetic fields) from DC to 30MHz. This range is suitable to security requirement like electronic door locking systems.
- Read range up to 1m: Inductive(magnetic) coupling and frequencies used below 135KHz or 13.56MHz. This range is suitable to animal identification or industrial automation.

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- Read range above 1m (Long range system): Electromagnetic waves coupling at UHF (868MHz to 915 MHz) and microwave range (2.5GHz/5.8GHz)

Microstrip antennas are suitable for long range RFID Tags. The antenna to be designed in the range 865-880MHz which is covered different spectral bands[2-3] used in several countries like India (865 - 867 MHz), Iran (865 - 868 MHz), South Africa (865.6 - 867.6 MHz), Singapore (866 - 869 MHz), US(902-928MHz), and Japan (950-956MHz).

A microstrip antenna, patch or planar antenna [4-5] consists of a patch of metal which acts as a radiating element laid on top of the grounded dielectric substrate of thickness 'h', with relative permittivity and permeability ε_r and μ_r .

The performance of an antenna depends on the shape of the radiator. The metallic patch may be of various shapes [4-5] like rectangular, circular [6], triangular, and hexagonal [7] etc.

The performance of antenna is generally measured in terms of radiation pattern, gain, directivity, front-to-back ratio (F/B) [8], return loss S_{11} in dB, frequency bandwidth from return-loss of below 10dB.

$$\frac{F}{B} = \frac{signal\ \ level\ in\ the\ forward\ \ direction}{signal\ \ level\ in\ the\ backward\ \ direction} \qquad (1)$$

II. DESIGN PARAMETERS

The designing equations[4-5] of different shapes of patch antennas is tabulated in Table.1The shape of the patch antenna and their dimensional values are calculated from Table.1.The dimensions of patch antenna is depending on the value of relative permittivity , thickness of the substrate and resonating frequency.

TABLE.1: Designing (dimensions) equations for different shapes of patch antenna

Shape of the patch antenna	Size of the patch antenna
Rectangular patch	$W = \frac{c}{2f_r}\left(\frac{\epsilon_r+1}{2}\right)^{-1/2}, L = \frac{c}{2f_r\sqrt{\epsilon_e}}$
Circular patch	$Radius(a) = \frac{F}{\left\{1 + \frac{2h}{\pi\varepsilon_r F}\left[\left[ln\frac{\pi F}{2h}\right] + 1.7726\right]\right\}^{\frac{1}{2}}}$ $F = \frac{8.791}{f_r\sqrt{\varepsilon_r}}10^9$
Triangular patch	$f_r = \frac{2c}{3a_{eff}\sqrt{\epsilon_e}}$ $a_{eff} = a + h/\sqrt{\epsilon_r}$
Hexagonal patch	$\pi a_{eq}^2 = \frac{S^2 3\sqrt{3}}{2}$ **a_{eq}= 0.9094S** where S= Length of the side arm $f_r = \frac{1.1k_{nm}c}{2\pi\sqrt{\epsilon_r}\,S}$

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III. RESULTS

Different shapes of patch antenna were designed in HFSS and discussed their characteristics as follows.

Rectangular patch antenna:

A rectangular patch antenna was designed on sapphire substrate (ε_r=10) at resonant frequency of 870MH with coaxial feed. The patch dimensions are derived from Table.1and designed in HFSS and simulated. The size of the substrate is 8x8 cm^2 with 0.156cm height and dimensions of patch width and length are 5.4 cm and 5 cm respectively. The geometrical structure in HFSS is shown in Fig.2.The simulated return loss is shown in Fig.3. It shows good tuning at required frequency at 869.35MHz with S_{11} is -13.85dB (Table.2).

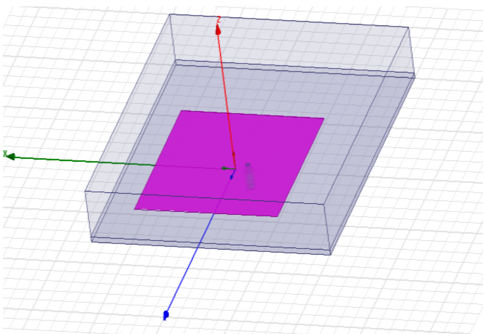

Fig.2 Rectangular patch antenna at 870MHz

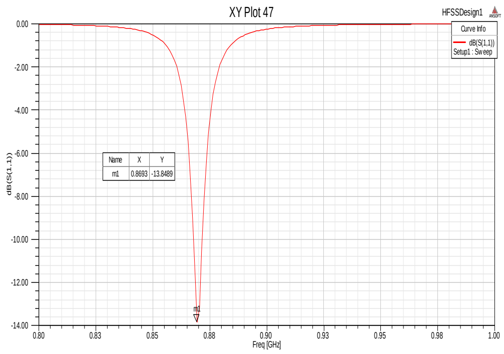

Fig.3 Return loss S_{11} (dB) of rectangular patch antenna

Figure4 shows radiation pattern characteristics interms of directivity (dBm) and it radiated maximum signal in broadside direction and some power in backward direction. It offers 120^0 half power beam width and F/B is 22.03dBm (Table 3). Red line indicates that radiation on φ=0^0 plane and black line indicates radiation on φ=90^0 plane. The electric field distribution on patch is shown in Fig.5.

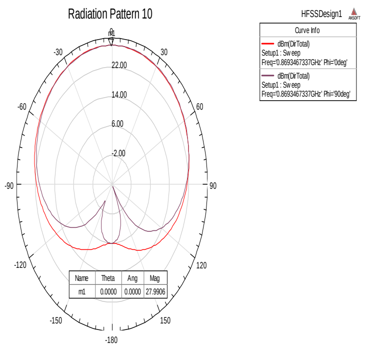

Fig.4 Radiation pattern of an antenna at 869.35MHz

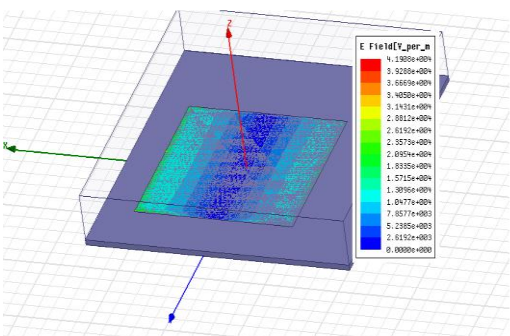

Fig.5 Electric Field distribution on patch

Circular Patch antenna:

Without changing the basic dimensions of substrate and feed technique, simulation is extended to circular patch microstrip antenna. The patch dimensions are derived from Table.1 and designed and simulated in HFSS. The geometrical structure (radius is 3.19cm) in HFSS was shown in Fig.6.

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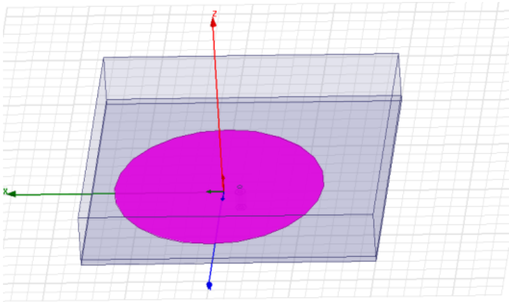

Fig.6 Circular patch antenna at 870MHz

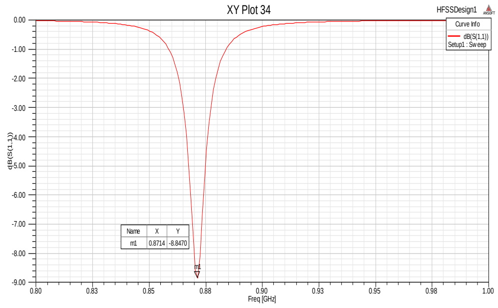

Fig.7 Returnloss S_{11} (dB) of circular patch antenna

The simulated return loss is shown in Fig.7 and shows that the antenna is tuned at frequency 871.36MHz and directivity (dBm) is shown in Fig.8. It has maximum directivity 28.39dBm in broadside direction with 116^0 HPBW. It has F/B is 22.69 dBm(Table-3). The electric field distribution on patch is shown in Fig.9.

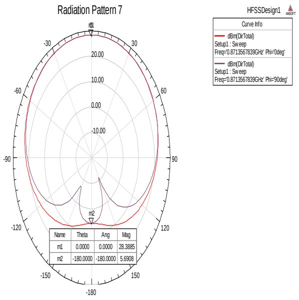

Fig.8 Radiation pattern of an antenna at 871.36MHz

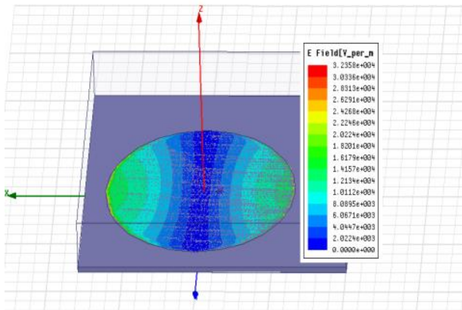

Fig.9 Electric Field distribution on circular patch

Triangular patch antenna:

Simulation was carried out for triangular patch microstrip antenna without changing the basic dimensions of substrate. The patch dimensions are derived from Table.1and designed in HFSS and simulated. The geometrical structure (each sidearm size 7.22cm) in HFSS was shown in Fig.10.

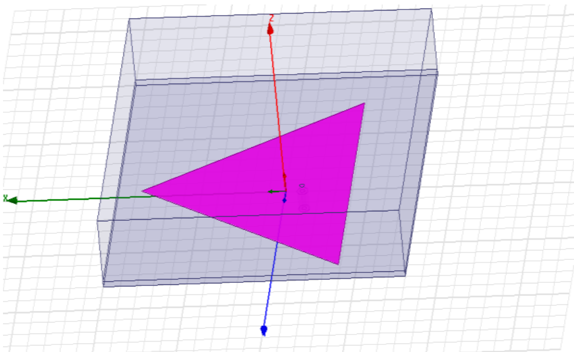

Fig.10 Triangular patch antenna at 870MHz

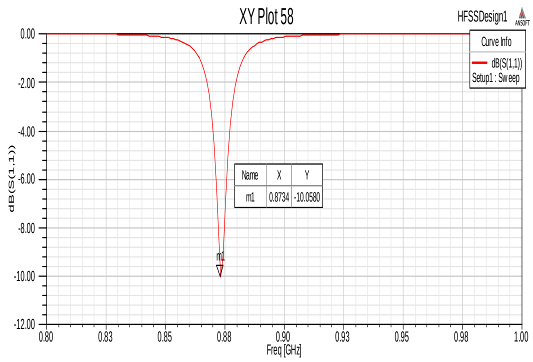

Fig.11 Returnloss S_{11} (dB) of triangular patch antenna

The simulated return loss is shown in Fig.11. The antenna was tuned at frequency 873.37MHz (Table.2) and directivity (dBm) was shown in Fig.12. It has maximum directivity 28.10dBm with 112^0 HPBW. It has the value of 20.91dBm (Table-3).The electric field distribution on patch is shown in Fig.13.

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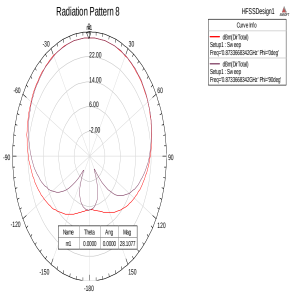


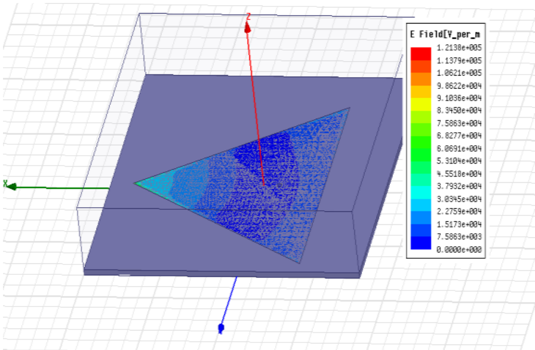
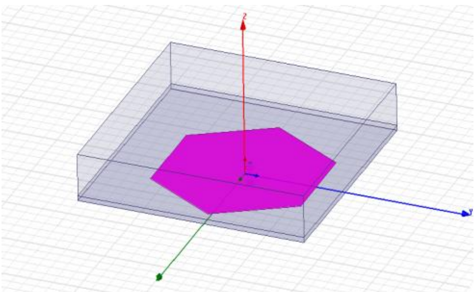


Fig.12 Radiation pattern of an antenna at 873.37MHz

Fig.13 Electric Field distribution on circular patch

Hexagonal patch antenna:

For hexagonal patch microstrip antenna the design and simulation was carried out by HFSS without changing the basic dimensions of substrate. The patch dimensions are derived from Table.1. The geometrical structure (each sidearm size 3.45cm) in HFSS is shown in Fig.14.



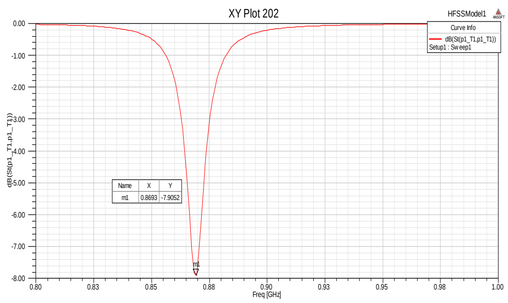
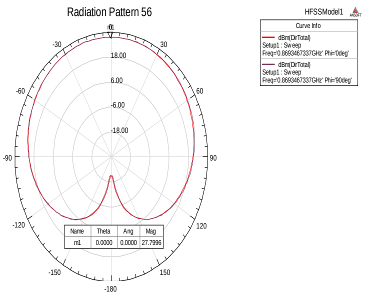


Fig.14 Hexagonal patch antenna at 870MHz

Fig.15 Returnloss S_{11} (dB) of Hexagonal patch antenna

The simulated return loss was shown in Fig.15. The antenna is tuned at frequency 869.35MHz and directivity (dBm) is shown in Fig.16. It has maximum directivity of 27.79dBm in broadside direction with 120^0 HPBW. It has F/B is 48.58dBm(Table3).The electric field distribution on patch is shown in Fig.17.



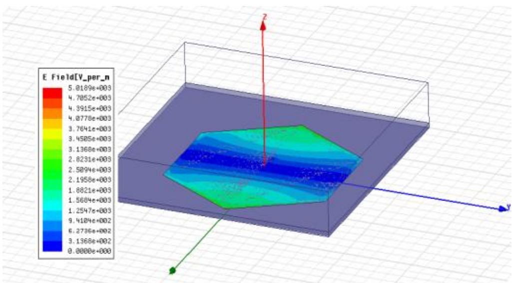


Fig.16 Radiation pattern of an antenna at 869.35MHz

Fig.17 Electric Field distribution on Hexagonal patch

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TABLE.2
Simulated results of different shapes of antenna, patch area and resonant frequencies

Patch Shape	**Area of the patch(cm^2)**	**Resonant frequency(MHz),**
Rectangular	27	869.35 -13.85
circular	32	871.36 -8.85
Triangular	23	873.37 -10.10
Hexagonal	31	869.35 -7.91

Fig.18 shows the comparison of returnloss of all antennas. It shows that all antennas are almost tuned at required frequency. Fig.19 shows that the directivity (dBm) of all antennas on same graph and it shows all antennas are radiated in broadside direction with slight variation of half power beamwidth. Hexagonal patch antenna offers high front-to-back ratio (48.58dBm) than all remaining antennas as shown in Table-3.

TABLE.3: Directivity, HPBW and F/B of all antennas

Patch Shape	**Directivity (dBm) at resonant frequency**	**HPBW (deg)**	**Front-Back Ratio (dBm)**
Rectangular	27.99	120	22.03
circular	28.39	116	22.69
Triangular	28.10	112	20.91
Hexagonal	27.79	120	48.58

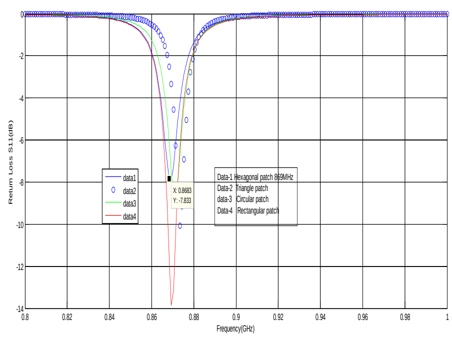

Fig.18. Comparison of return losses of all types of antennas

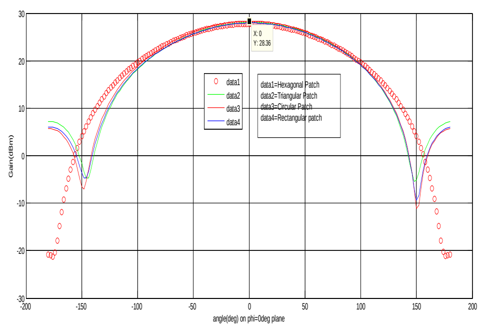

Fig.19 Comparison of directivity of all types of antennas

Practical Results:

Design equations from Table1, the side arm size of hexagonal patch antenna S=3.45cm at resonant frequency of 870MHz, an antenna is designed in HFSS (8cm x 8cm x 0.156cm) and simulated. After simulation of an antenna (Fig.14), for optimum results, arm size was adjusted to 3.36cm and fabricated. Figure20a &b shows a ground plane

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and top view of designed practical antenna with its hexagonal patch structure. Figure21 shows the measured (with network analyser) return loss and Fig.22 shows a good agreement between theoretical and measured values.

Fig.20Fabricated Antenna a)Ground Plane(left), bottom view b) Hexagonal Patch, Top View(Right)

Fig.21 Return Loss S_{11}(dB) Vs Frequency (MHz) (Left) (b)Measured in Network Analyzer (Right)

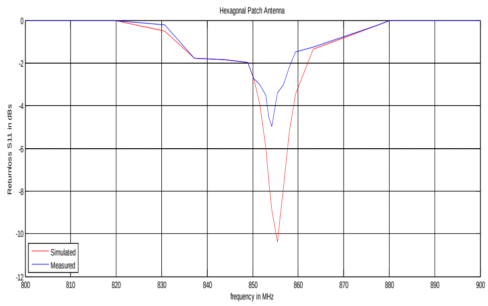

Fig.22 Reflection Coefficient of S_{11} measured (blue) simulated(red)

IV.CONCLUSION

A microstrip patch antenna is designed for RFID Tag application at 870MHz on sapphire material with high front-to-back ratio(F/B). Antenna design equations are given in section 2 and based on that antennas are designed in HFSS and simulated. The performance of all antennas discussed in section 3 and results are tabulated. Fig.18 shows that all antennas are almost tuned at required frequency and area of all patch antennas are almost equal (Table 2) and directivity also similar shown in Table 3. Among all the antennas, hexagonal antenna gives high front-to-back ratio shown in Fig.19 and Table 3 and suitable to the required application. Finally, hexagonal patch antenna is practically designed and measured values compared to simulated values (Fig.22).

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Dr. A.Jhansi Rani obtained her B.Tech Degree in Electronics and Communications Engineering from Velagapudi Ramakrishna Siddhartha Engineering College, Vijayawad in1991and M.Tech Degree in Microwave Engineering from Institute of Technology, Banaras Hindu University, Varanasi in 1993. Later she joined as a Faculty in ECE Dept., of V.R.Siddhartha Engineering College, Vijayawada. She obtained Ph.D. Degree from JNTU, Hyderabad in August 2008. Presently, she is working as a Professor of ECE at V. R. Siddhartha Engineering College. Dr.Jhansi has more than 20 years of teaching experience, and has about 50 technical publications in various International and National Journals and Conferences to her credit. She is the Life Member of FIETE, MISTE, BMESI, MSEMCEI. She received grants from DST, DLRL and AICTE in the area of Aperture and smart Antennas. Her fields of interest include Electromagnetics, Smart Antennas, Analysis of Microwave Components, EM Waves and Transmission Lines, Numerical Methods and Applications.

Dr. A.Mallikarjuna prasad is a Professor of Electronics and communication Engineering. He has more than 20 years of experience in teaching.. He is Life Member of ISTE, IETE, ISI, Society of EMC. He won best teacher award by student evaluation of 2008 batch outgoing students. Dr. A.Mallikarjuna prasad did his B.Tech in ECE from Nagarjuna University, during 1984-88. He did his M.Tech in Electronics & Instrumentation from Andhra University in 1992 and completed his Ph.D in 2009 from JNTU in the field of Antennas . He has joined JNT University service as Associate Professor of ECE in June 2003. He got promoted as Professor in ECE during Nov 2011. Dr. A.Mallikarjuna prasad worked in various capacities as Deputy Warden, Officer –in-Charge of Book-bank and Officer-in-charge of Hostels .Dr. A.Mallikarjuna Prasad has guided about 40 students in M.Tech Instrumentation Engineering and presently guiding 8 research students for their PhD works. His areas of interest are Antennas and Process control Instrumentation. He has 20 publications in various International and National Journals and conferences. He has conducted a "National Workshop on Electromagnetic field applications" in the year2004.