A Broadband Circularly Polarized Patch Antenna for UHF RFID Applications

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Abstract

A broadband circularly polarized patch antenna is proposed for UHF (840 – 960 MHz) RF Identification (RFID) reader applications. The antenna consists of two oblique thin slot cut square patches and a suspended microstrip line with open-circuited at the end. The feed for the main patch is given by four probes which are sequentially connected to the suspended microstrip feed line. It presents a systematic, empirical design technique to obtain optimum return loss, axial-ratio (AR) and gain. The stacked patches and feed line is surrounded by an air medium, the air medium act as a substrate. Parametric studies are carried out to demonstrate the effects of antenna geometry parameters on the performance. The proposed antenna can be a good reader for UHF RFID applications.

1. Introduction

RFID support a larger set of unique IDs than bar codes and provides additional data such as manufacturer details, product type and even measure atmosphere such as temperature. RFID is not cheap as available in the market labeling technologies, but it offers more added values and is now at a critical price point that could enable its large-scale adoption for managing consumer retail goods [2]. Today RFID is mostly used as a medium for numerous tasks including managing supply chains, possession of livestock, preventing from pirated goods, status of building access, and supporting automated checkout. The barcode is still the dominant player in supply chain industries and departmental stores. However RFID is replacing barcode technology by the major advantage of being independent of line of sight problems and scanning the objects from a distance.

It offers the promise of reduced workers, enhanced visibility, and improved database management. RFID advantages over Barcode, Reader can read and write data to RFID tags without line of sight problem, it can work under different environments and give maximum life time approximately 10 years. Fast read and write by the time taken for read/write being a few milliseconds. Now RFID tags are made with very good memory capacities ranging from (16 – 64) Kbytes which is many times more than a typical barcode. RFID tags can work with GPRS and has been used for tracking. RFID tags can also integrate with other technologies. For example, it is used with wireless sensor networks for better connectivity [3].

1.1. RFID Principles

Different types of RFID tags exist, but are broadly classified into active and passive. An active tag requires a power source and is either connected to a powered device or to a battery and is often limited by the lifetime of its source. Being dependent on a powered source puts limitations on Active RFID tags. Cost, size, lifetime makes them impractical for regular use. On the other side, Passive RFID is of interest because of the fact they are independent of power source and maintenance. Passive RFID also have the advantages of long life and being small enough to fit into a practical adhesive label. A passive RFID tag consists of mainly three parts: an antenna, a semiconductor chip (embedded unit) attached to the antenna, and some encapsulation to protect the tag from the environment. As explained before, passive RFID tags don't carry any powered device and became active only upon exposure to external energy [3].

The RFID reader does the work for activating and communicating with the passive RFID tag. The passive RFID tag antenna captures energy from the reader and is responsible for communicating the data between tag and reader. A different approach is using tag passwords so that a tag could omit important information only if receives the right password. The dilemma is in the reader having to know the identity tag. Another solution is using a timer based mechanism that the causes the tag to change the password periodically with a predefined mechanism [1]. Circular polarization can be obtained if two orthogonal modes are excited with a 90° time-phase difference between them. This can be obtained by adjusting the physical dimensions of the patch and using either single, or two, or more feeds. There have been some suggestions made and reported in the literature using single patches.

By using two coax feeds separated by 90° which generate fields that are orthogonal to each other under the patch, as well as outside the patch. Also with this two-probe arrangement, each probe is always positioned at a point where the field generated by the other probe exhibits a null; therefore there is very little mutual coupling between the two probes. To achieve circular polarization, it is also required that the two feeds are fed in such a manner that there is 90° time-phase difference between the fields of the two, this is achieved through the use of a 90° hybrid. To achieve circular polarization, the magnitude of the axial ratio must be unity while the phase must be ±90°. This is can be achieved by both the numerator and denominator are of equal magnitude and 90° out of phase [4].

2. Antenna Structure and Implementation

In high-performance space communication and missile applications where size, weight, cost, performance, easy to install and performance on space profile are constraints, low-profile antennas are required. Presently there are many other commercial and government applications such as wireless and mobile radio communications that also required with similar specifications. To fulfill these requirements microstrip antennas can be used. These antennas are conformable and low profile to planar, non planar surfaces, simple and inexpensive to manufacture using modern printed-circuit technology, when mounted on rigid surfaces are mechanically robust which are compatible with MMIC designs when the particular mode and patch shape are selected in terms of resonant frequency, impedance, polarization and pattern the MMIC is versatile. In addition, by adding loads between the patch and the ground plane, such as varactor diodes and pins, adaptive elements with variable resonant frequency, polarization, impedance and pattern can be designed [4].

Globally, for RFID application they allocate frequency range are (840-960) MHz, each country has its own allocated frequency for UH F RFID applications, e.g., (840.5–844.5) MHz and (920.5–924.5) MHz in China, (866.0–869) MHz in Europe, (902–928) MHz in North and South America, (865-867)MHz in India and (952–955) MHz in Japan, and so on [5]. Therefore, a universal reader antenna with desired performance across the entire UHF RFID band would be beneficial for RFID reader system configuration and implementation and cost reduction.

2. 1. Antenna Design

The antenna is composed of an oblique thin slot cut square patch, a feed line network printed on the bottom of the patches and ground plate. The circular polarization radiation of the proposed antenna is excited by four cylinder probes which transmit four signals that have equal amplitude with a quadrature phase difference (0° or 360°±, 90°±, 180°±, and 270°±) generated from the feed network (6). In order to obtain good read performance of an antenna, the RFID reader antenna needs to be designed for circular polarization, because circularly polarized antennas having the property of increase orientation diversity and reduce the loss caused by the multi-path effects between the reader antenna and the tag. Generally, circular polarization commonly needs two orthogonal linear polarizations with a 90°± phase shift. Circular polarization antennas can be categorized into two types: single-fed type and multi-fed type. Commonly one used method to achieve wide AR bandwidths is the use of parasitic elements [7].check your margins to see if your print area fits within the space allowed.

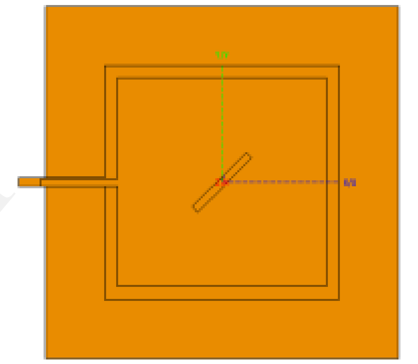


Fig.1.Top View

Fig 1 shows the top view of the proposed antenna. The antenna consists of four layers of conductor, which includes two oblique thin slot cut square patches are acting as radiating patches, an open ended suspended microstrip feed line, and a finite-size ground plane. Air substrate is used in the proposed antenna to achieve higher gain, broader bandwidth, heat reduction and lower cost. Here the antenna having composition which are ground plate, on the right above we have feed line network, two square patch namely oblique thin slot cut main patch, oblique thin slot cut parasitic patch.

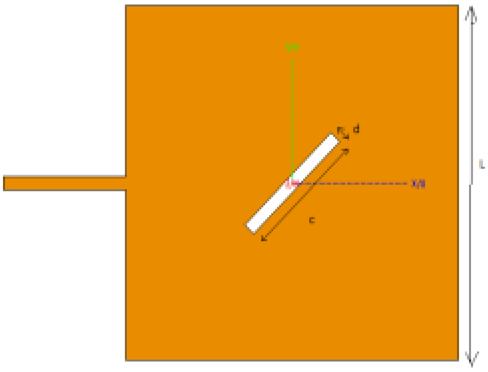


Fig.2.Top View of Oblique thin slot cut square patch

Fig 2 shows the top view of oblique thin slot cut square patch for the proposed antenna.

$$W = \frac{1}{2f_r\sqrt{\mu_0\epsilon_0}} \times \sqrt{\frac{2}{\epsilon_r+1}} \quad (1)$$

W = L = 166mm

The patches are square in shape so L=W. The oblique thin slot cut is obtained by, the length of the oblique thin slot cut by

$$c = \frac{L}{2.72} = \frac{W}{2.72} \quad (2)$$

C = 57.35mm

The width of the oblique thin slot cut by

$$d = \frac{c}{10} = \frac{L}{27.2} = \frac{W}{27.2} \quad (3)$$

d = 5.735mm

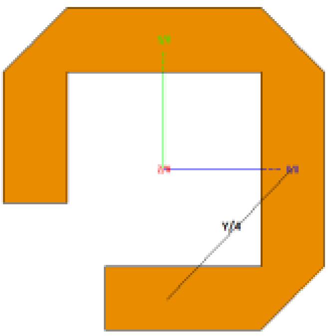


Fig.3.Feed line Network

The extension of length in square patch has been obtained from oblique thin slot cut values.

Fig 3 shows the top view of the feed line network for the proposed antenna.

The length and width of the feed line network has been calculated from diagram Fig 4.

$$\lambda/4 = C0/4f_r \quad (4)$$

$$\lambda/4 = 83.33\text{mm}$$

By Applying Pythagoras theorem we can calculate the length and width of square feed line network, the calculated value is given by 117.84mm.

The proposed antenna is designed using software CADFEKO. Which is based on the Method of Moments (MoM) technique forms the basis of the FEKO solver. Other techniques such as the Multilevel Fast Multi pole Method (MLFMM), the Finite Element Method (FEM) Uniform Theory of Defraction (UTD), Geometrical optics (ray launching) and Physical Optics (PO) have been implemented to allow the solving of electrically large problems and inhomogeneous dielectric bodies of arbitrary shape [8]. The oblique thin slot cut square patches, feed line network and ground plane are all made of copper and fixed using plastic spacers. Metallic screws are used as the probes to connect the microstrip feed line network and the main patch. A coaxial cable is connected to the microstrip feed line network to simplify the antenna structure, where the coaxial cable is split into two wires (screen and core) and the wires are soldered to the suspended feed line and the ground plane separately [9].

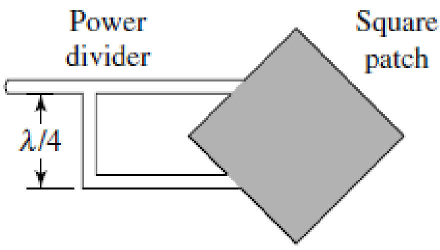


Fig.4.Ideal feed line network

3. Simulated Results

3. 1. Return Loss

S-parameters describe the input-output relationship between terminals (or ports) in an electrical system. If we have 2 ports (intelligently called Port 1 and Port 2) then S12 represents the power transferred from Port 2 to Port 1.

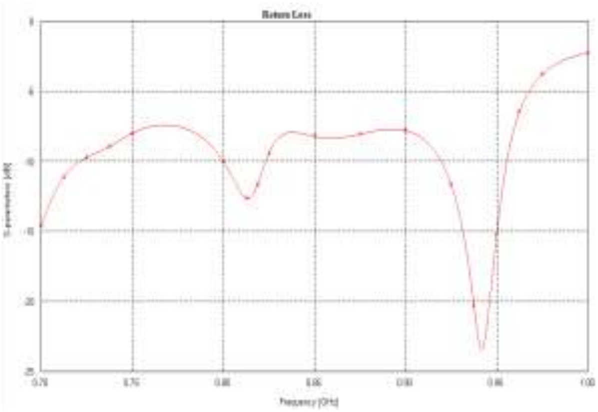


Fig.5 (a).Return Loss

3. 2. 3 D Radiation Pattern

This Demonstration plots the normalized E-radiation pattern of a UHF RFID Reader antenna with sinusoidal current distribution on Z axis. There is a one-to-one correspondence between X, Y, Z and the colours red, green, blue. View results in linear or dB units.

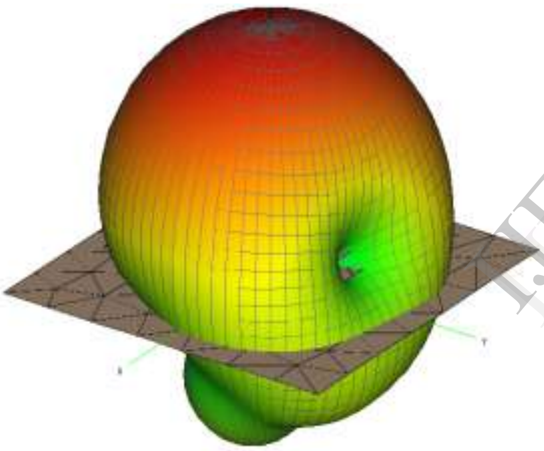


Fig.5 (b).3 D Radiation Pattern

3. 3. Gain

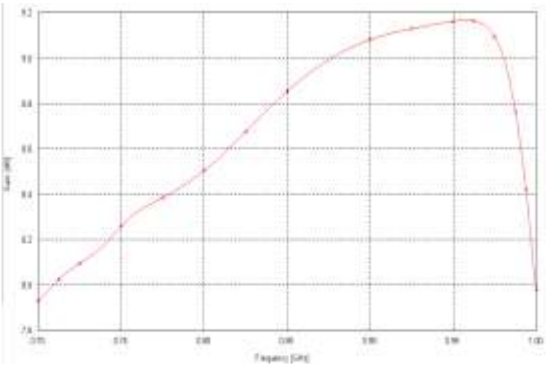


Fig.5 (c).Gain

Antenna Gain describes how much power is transmitted in the direction of peak radiation to that of an isotropic source. An antenna with a gain of 3 dB means that the power received far from the antenna will be 3 dB higher (twice as much) than what would be received from a lossless isotropic antenna with the same input power. Once generated, there are many options available for showing the display.

3. 4. Axial Ratio

The axial ratio is the ratio of orthogonal components of an E-field. The components are equal magnitude, the axial ratio is 0 dB (or 1). Axial ratios are often quoted for antennas in which the desired polarization is circular.

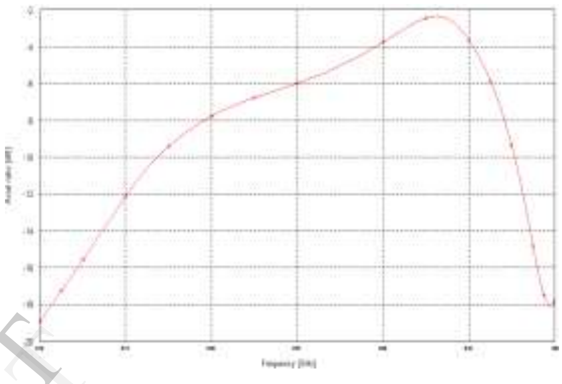
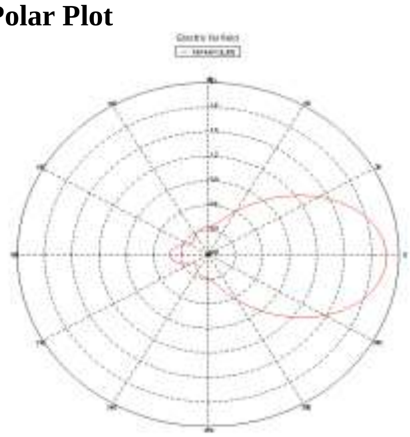
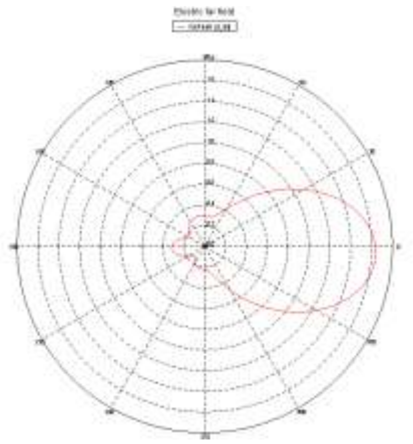


Fig.5 (d).Axial Ratio

3. 5. Polar Plot



At 900MHz



At 950MHz

Fig.5 (e).Polar Plot

The antenna that is produced is typically graphed so we can understand the performance. Generally called a “Radiation Pattern Plot”. The radiation Pattern Plot is presented in a Polar style plot or Rectangular style plot.

4. Parameter Studies

In this section, circular polarization radiation mechanism and parametric studies of the proposed antenna are presented to provide more detailed information about the antenna design and optimization. The parameters under study include the height of the feed line network, height of radiating patch, size of radiating patch, height of antenna radome, and diameter of the hollow cylinder 4. To better understand the influence of the parameters on the performance of an antenna, only one parameter will be varied at a time, while others are kept unchanged unless especially indicated.

4. 1. An oblique thin slot cut Main Patch

It is found that the oblique thin slot cut in main patch c*d shows a significant effect on the axial ratio of the antenna. The uncut patch exhibits the widest impedance bandwidth, but the narrowest axial ratio bandwidth. The increasing of improves c*d the axial ratio bandwidth and achieves better impedance matching.

4. 2. An oblique thin slot cut Parasitic Patch

As oblique thin slot cut has a greater effect on the axial ratio, while the gain of the antenna is hardly affected. If the parasitic patch becomes a square the antenna features dramatic axial ratio bandwidth reduction. So axial ratio bandwidth and gain are mostly functioning of Patches.

4. 3. Height of the Patch

The operating band is shifted down as the height increases. Furthermore, the effect is more severe at higher frequencies. When the parasitic patch is fixed close to the main patch, a slight effect on the performance of an antenna. Increasing height makes the antenna size larger.

4. 4. Diameter of Feeding Probes

The study shows that the diameter of the feeding probe has a slight effect on impedance matching, axial ratio, and gain. However, the very thin probe causes poor impedance matching and axial ratio reduction. The long and thin feeding probes introduce a large inductance to degrade the impedance matching. Furthermore, the large inductance also disturbs the phase characteristic at the feeding point, and thus, degrades the axial ratio performance.

4. 5. Open end Feed line Network

The open-circuited termination will cause reflection on the feed line, and thus, affect the magnitudes and phase difference of the feeding currents at the four probes. The optimal axial ratio is achieved when the last probe is positioned at the edge of the strip line. Increasing open terminal greatly degrades in axial ratio.

4. 6. Size of the Ground Plate

The antenna with the larger ground plane has superior performance. When the ground plane is smaller than 200*200 mm, the performance of the antenna degrades in terms of impedance, gain, and axial ratio, especially at the lower frequencies. For instance, the axial ratio bandwidth is reduced. 250*250 mm achieves good radiation performance. Further increasing the ground plane size only enhances the gain. Further changes in the ground plate size offer a simple way to improve the antenna performance.

5. Conclusion

In this paper, a broadband sequentially fed circularly polarized stacked patch antenna has been presented for universal UHF RFID applications. This feature will benefit RFID system configuration and implementation, as well as cost reduction. By using a simple feeding structure and the optimized antenna has achieved the desired performance over the UHF band the effects of the oblique thin slot cut patches, height of the parasitic patch, the size of the feeding probes, open end feed line network and the size of the ground plane are on the performance of the antenna. The information derived from the study will be helpful for antenna engineers to design and optimize the antennas for UHF RFID applications. By modifying the radiator shape and oblique cut, designing feeding structures, varying height between patches.

5. References

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