A Review on Microstrip Patch Antenna for UHF RFID Tag Applications mounted on metallic surface

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Abstract— In this paper, we discuss different designs of microstrip patch antennas for UHF RFID Tag applications mounted on metallic surface. We discuss the various requirements of such designs like size, bandwidth, circular polarization. Out of UHF band 860MHz to 960MHz is assigned for RFID applications. In section I we reviewed the introduction of RFID. In section I we reviewed the introduction of RFID, section II classification of RFID tags are discussed. In section III we surveyed the designs of RFID Tags. In section IV conclusion of the paper.

***Index Terms*— Microstrip Antenna, Circular Polarization, Low Profile, Complex Impedance Matching, Metallic Surface, RFID.**

INTRODUCTION

RFID stands for Radio Frequency Identification. It is an automatic identification technology. This technology provides wireless identification and tracking capability that is more convenient than use of bar codes and optical scanners [7]. It transmits data without contact and Line-Of-Sight. Thus, the tagged items can be identified within the field without regard to orientation or position to affixed tag. This allows for many items to be interrogated instanteounsly without manual manipulation of the items. The information is sent to and read from RFID tags using radio waves. There are several frequency bands used in RFID which are low frequency (LF), high frequency (HF), ultra high frequency (UHF) and microwave. Owing to its longer read range, higher data transmission rate as well as larger storage capacity, UHF system are gaining more popularity compared to other systems [6]. A RFID system typically consists of tag, reader and information management platform. The RFID tag is composed of a RFID chip and an antenna. Since the energy interaction between the chip and the antenna is the most important issue, a successful antenna design is determined by conjugate impedance match between the chip and the antenna [2].

In some applications, tag needs to be mounted on the surface of metallic objects such as steel plates or steel containers. However, when printed dipole like antenna are placed on the metallic surface, it suffers severe performance degradation due to shift in operating frequency, distorted radiation pattern and impedance mismatch which quickly reduce its read range or even cannot be read. In order to mitigate this problem, several inverted-F antenna and microstrip patch antenna where they operate with a ground plane have been proposed. Although have been proven to work, they have narrow bandwidth. It is known that operating frequencies of each country varies from one another in UHF RFID system. Table 1 lists the operating frequency of several countries in the world [6].

TABLE 1: OPERATING FREQUENCIES OF SOME COUNTRIES

Country/Region	**Operating Frequency, f_c (MHz)**
New Zeeland	864-869
India	865-867
Europe	865-868
Hong Kong	865-868 & 920-925
Singapore	866-869 & 920-925
North America	902-928
Japan	916-921 & 952-956
China	917-922
Australia	918-926
Malaysia	919-923
Taiwan	922-928
China	920.5 - 924.5
Brazil	902 - 907.5 & 915 - 928
Canada	902 - 928

CLASSIFICATION OF RFID TAGS

RFID tag is an electronic circuit that exchanges data with an RFID reader through radio waves. It is the heart of the system. Tags are data carrying devices, so also called as transponder. RFID tag consists of two main parts: Integrated circuit (IC) and Antenna. IC is used for processing and storing data as well as modulating and demodulating radio waves transmitted /received by antenna. Antenna receives the radio waves. Due to dynamically functionality of tags, information can be added, modified or stored on a tagged item. RFID Tags can be classified into three categories on the basis of communication between tag and reader.

- Active RFID Tag
- Semi Active RFID Tag
- Passive RFID Tag

A. Active RFID Tag

These tags have their own internal power source (battery) and transmitter. They broadcast signal to the reader to transmit the information stored on microchip. Life of active tags depends upon the life of battery. Compared with passive tags, active tags are more accurate and reliable. But they are

larger and more expensive than passive tags. These tags transmit more than 100m.

B. Semi Active RFID Tag

These tags have own power source. Unlike active tags, these tags does not broadcast signal until RFID reader transmits one first. These tags transmit up to 100m.

C. Passive RFID Tag

Passive tags do not have battery and powered by a separate source typically in interrogator. This simply reflects back energy/radio wave coming from reader antenna. These are smaller, cheaper and easier to manufacture than active tags. Passive tags can be packaged in many different ways, depending on the specific requirements of RFID application. These tags transmit up to 10m.

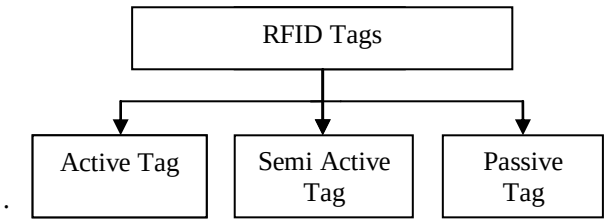

Fig. 1 Classification of RFID Tags

LITERATURE REVIEW

In [1] the author had presented passive UHF band RFID tag antenna design mounted on metallic surface. This antenna is fabricated on FR4 substrate (relative permittivity 4.4 and loss tangent 0.02) with the thickness of 1.6mm. The size of ground plane is 70mm × 70 mm. The antenna consists of radiating square patch (47mm × 47 mm) with cross slot of S_y and S_x of width 1mm (44.5mm and 44mm respectively). This slot is inserted to achieve compact size and circular polarization. S_y is longer than S_x will results in obtaining Left-Hand Circular Polarization (LHCP). The L-shaped open end line is connected to a tag chip and terminated by a shorting pin is capacitively coupled to the patch. The RFID tag chip is ALIEN IC Higgs whose impedance is 13.5-j110Ω at 915MHz. The input impedance of the antenna must be in conjugate match with the impedance of the tag for delivering maximum power between tag and antenna. To achieve conjugate impedance of antenna L- shaped narrow strip is used. The dimensions of this strip are formed by two strip lines L_x (32mm) and L_y (41.2mm). To achieve low input resistance for the tag antenna at around 13.5Ω, the gap distance d is set to be 1.5mm.

The measured 10 dB impedance bandwidth of tag antenna is 48MHz (906-954MHz) centered at 930MHz and 3dB circular polarization bandwidth is 6MHz (922-928MHz). The value of axial ratio (AR) is 0.69 at 925MHz. Read range can be achieved up to1.4m in free space and 2.8m when mounted on metallic surface at different orientation.

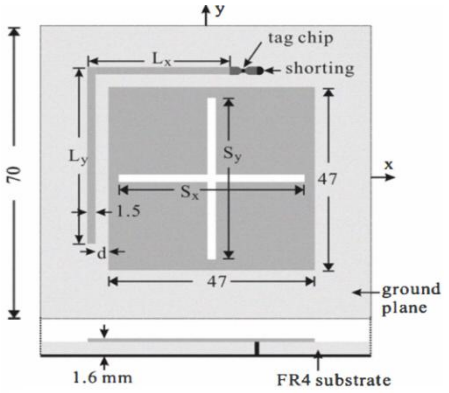

Fig. 2 Square Patch Radiator with cross slot [1]

In [2] author had proposed a low cost novel wideband antenna design for a passive RFID tag mountable on metallic surface. It has very simple structure without any shorting pins or shorting walls. The antenna is fabricated on FR4 substrate of thickness of 2mm (relative permittivity 4.6 and loss tangent 0.015). The size of ground plane is 73mm × 50 mm. It consists of two radiating patches and these patches are inductively coupled to each other. The dimensions of this antenna are as: L=73mm, W=50mm, m=72mm, n=37mm, a=20mm, b=10mm, d=0.8mm, e=2.5mm, r=1.5mm, c=3mm, t=1.8mm, q=10mm, g=16mm, u=15mm. This design uses inductively coupled loop feeding technique and the coupling strength is controlled by the distance between the radiating patch and feeding loop as well as the shape of feeding loop. This antenna is designed for tag chip of ALIEN Higgs strap whose impedance is 12 - j133Ω at 915MHz.The impedance of this antenna should be in conjugate with the tag chip i.e. 12+ j133Ω for transferring maximum power between tag chip antenna. The sensitivity of the chip is -14dBm.

The measured 10 dB impedance bandwidth of tag antenna is 590MHz (657MHz-1.25GHz). Read range is achieved up to 5.69m without metal and 5.06m when mounted on metallic surface.

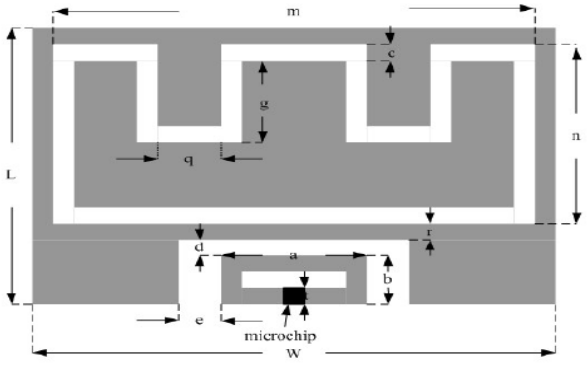

Fig. 3 Novel broadband antenna [2]

In [3] author had discussed a compact broadband dual coupling feed circularly polarized RFID tag antenna mounted on metallic surface. It is fabricated on FR4 substrate (relative permittivity 4.4 and loss tangent 0.02) with the thickness of 1.6mm. The size of ground plane is 100mm × 100 mm. The

antenna consists of radiating square patch (58mm × 58 mm) with centrally loaded by a cross slot of S_1 and S_2 of width 2.8mm (41.4mm and 42.3mm respectively).In this antenna dual coupling feed is used. The feed consists of two microstrip feed lines named as feed-line#1 and feed-line#2 of unequal lengths L_1 (path AB) and L_2 (path CD) respectively, are used to link between the tag chip and two coupled lines. The patch is capacitively excited by applying the electromagnetic coupling technique by the length of two coupled lines, L (16mm), is located at a distance, d (1mm), away from the radiating square patch. The Alien IC Higgs is used as RFID tag chip which exhibits an impedance of 13.5 -j110Ω and the impedance of antenna should be in conjugate is required.

The measured 6-dB return-loss bandwidth of the tag antenna is 25MHz (902–927 MHz), and its corresponding 3-dB axial-ratio (AR) bandwidth is 20 MHz (903–923 MHz). Read range of this antenna is 4.39m in free space and 4.62m when mounted on metallic surface.

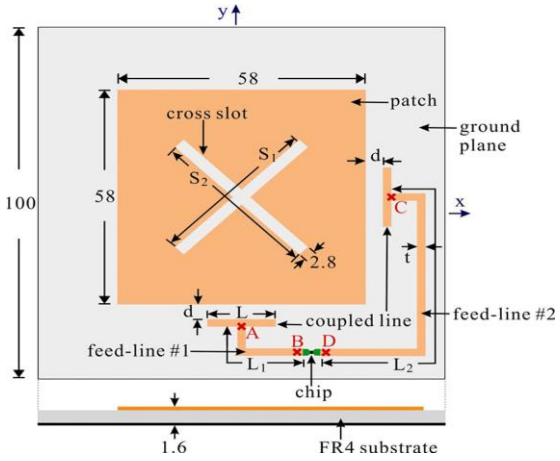

Fig. 4 CP RFID Tag Antenna [3]

In [4] author had presented a compact circularly polarized circular microstrip RFID tag antenna. The antenna is fabricated on a FR4 substrate with thickness 1.6mm, relative permittivity 4.4, and loss tangent 0.02. The size of ground plane is 80mm × 80 mm. It consists of circular patch (Diameter = 56mm) with a cross slot of width of 1mm unequal arm lengths S_x and S_y located at the center along x-axix and y-axis respectively. To excite the radiating circular patch by electromagnetic coupling the pairs of arc microstrip lines are used, whereby the coupling distance is *d*. These arcs are of same length L (20mm) and width t(2mm) and located with the direction of ϕ = 135° are a distance 1mm apart. In this design the tag chip used is Alien Higgs, which exhibits an impedance of 13 - *j*111Ω at 915 MHz. To obtain maximum power transfer, the input impedance of the tag antenna must be design to be 13 + *j*111Ω.

The measured 10-dB return-loss bandwidth of the tag antenna is 40 MHz (901−941 MHz) and its 3-dB axial-ratio bandwidth is 6 MHz (912−918 MHz). The read range of this tag antenna when measured with the LP reader in free space is 1.62m to 1.92m at all ϕ angles and when it is mounted on metal its range is 3.0m to 3.58m. The read range of this tag antenna when measured with the CP reader in free space is increased from 1.92m to 2.4 and when it is mounted on metal its range is increased from 3.58m to 4.6m.

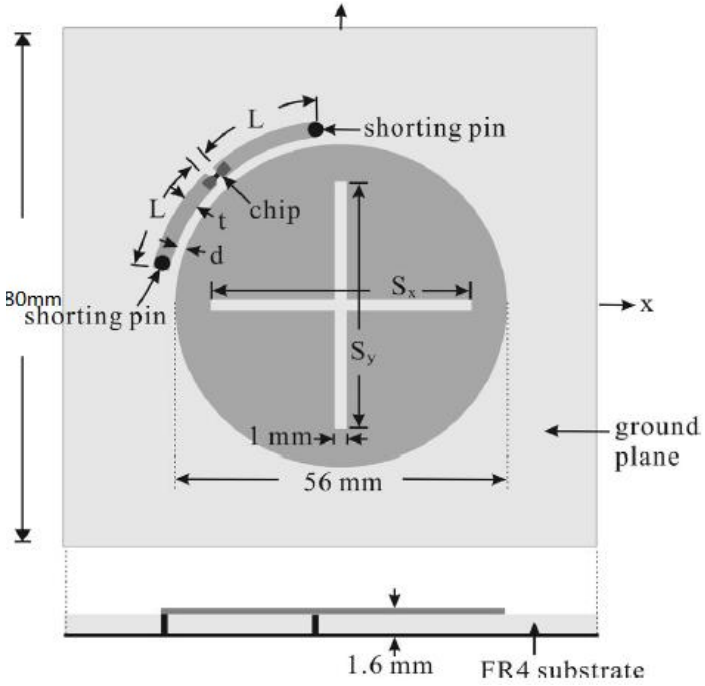

Fig. 5 CP Circular Patch Antenna [4]

In [5] author had discussed a planar wideband microstrip patch antenna for UHF passive RFID tag. It covers all operating frequencies of Ultra High Frequency band. This antenna is fabricated on FR4 substrate (relative permittivity 4.4 and loss tangent 0.02) with the thickness of 1.6mm. The size of ground plane is 87mm×45mm. Two C-shaped patches are used. These patches are inductively coupled fed by rectangular loop feeding network. Dimensions of patches and feeding network are as: W1=10mm, W2=10mm, L1=74mm, L2=69mm, Ws=1mm, Ls=30mm, d1=d2=2mm, W_{inset} =4mm, t=0.0358mm, h=1.6mm, a=29mm, b=10mm, W_f=2mm. Alien Higgs-3 microchip is used , whose impedance is 31-j212 Ω at 915 MHz. To deliver maximum power between chip and antenna the impedance should be in conjugate.

The simulation and measurement results show impedance bandwidth of 159 MHz and 155 MHz (Return loss ≥ 3 dB) respectively when mounted on metal plate.

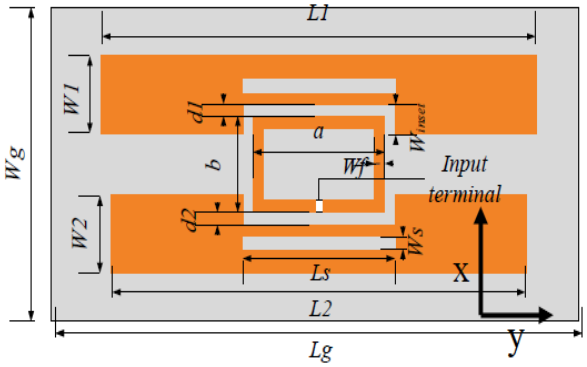

Fig. 6Wideband Patch Antenna with Two C-shaped Patches [5]

In [6] author had discussed a planar wideband patch antenna for UHF RFID tag applications mountable on metallic surface. The size of ground plane is 130mm×63mm. This antenna is fabricated on FR4 substrate (relative permittivity 4.4 and loss tangent 0.02) with the thickness of 1.6mm. Three different shapes of radiating patches are used with slightly different resonance frequencies were employed to achieve wide impedance bandwidth. The shapes of the patches were derived from rectangular patch. Out of these two patches were meandered to reduce its size. Alien Higgs-3 microchip is used, whose impedance is 31-j212 Ω at 915 MHz and its sensitivity is -18dBm. In tag antenna design the efficient power transfer is done only if the complex impedance of tag chip is in conjugate with the tag antenna. The triangular loop feeding technique is used to excite the radiating patches by inductive coupling. The dimensions of the patches and feed network are as: W1=7mm, $L1_{p1}$=10mm, $L2_{p1}$=37mm, $L3_{p1}$=10mm, $L4_{p1}$=12mm, W2=5mm, $L1_{p2}$=15mm, $L2_{p2}$=37mm, $L3_{p2}$=14mm, $L4_{p2}$=14mm, W3=5mm, L3=86mm, c=29.4mm, b=34mm, s=d1=d3=2mm, d2=1mm, t=0.0358mm, h=1.6mm.

The simulated and measured impedance bandwidth of 113 MHz and 117 MHz (return loss ≥ 6 dB) was achieved to cover the entire UHF RFID operating frequency band worldwide. The read ranges of this antenna are different for different countries. In Europe, North America, Japan the read range in free space is 2.68m, 6.18m, 2.99m and when mounted on metal surface 3.33m, 3.61m, 2.80m respectively.

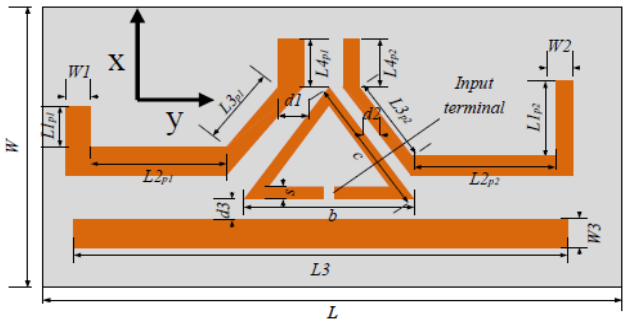

Fig. 7 Patch Antenna with three different shapes of patches [6]

In [7] author had proposed a novel circularly polarized annular-ring tag antenna for RFID UHF band mounted on metallic surfaces. The antenna is fabricated on a FR4 substrate with thickness 1.6mm, relative permittivity 4.4, and loss tangent 0.02. The size of ground plane is 74mm×74mm. The radiating patch is annular-ring (outer diameter is 59.2mm and inner diameter is 54mm) with two slits (width 1mm and 2mm) along x-axis which makes the antenna size much less than that of regular circularly polarized circular microstrip antenna. Two short-circuited arc microstrip lines of the length L and width t are symmetrically located with the direction of 135°and are a distance 1.5 mm apart. the pairs of arc microstrip lines are used to excite the radiating annular-ring patch by electromagnetic coupling, where the coupling distance is d=2.1mm. RFID tag chip is used in Inpinj's product—MonzaTM4 QT, whose impedance is 11- j143Ω at 915 MHz. For transferring maximum power between the tag chip and antenna the impedance of antenna should be 11 + j143Ω.

The 10 dB return-loss bandwidth of the tag antenna is measured to be 215MHz (720-935MHz), while its 3 dB axial-ratio bandwidth is 6MHz (919-925 MHz). The read range of this antenna is 3.5m in free space at all angles and increased to 5.5m when mounted on metal surface.

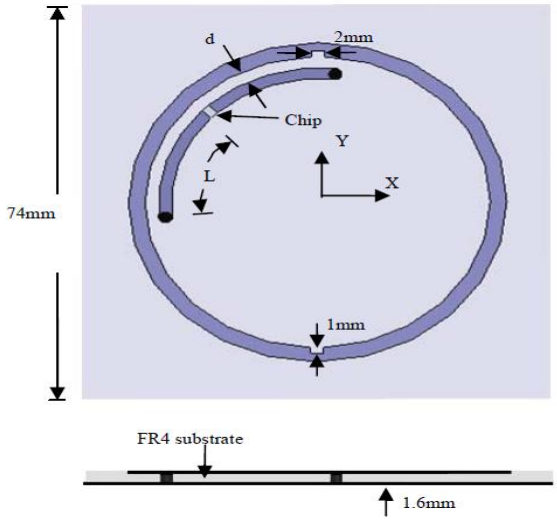

Fig. 8 Novel Design of tag antenna with annular-ring patch [7]

II. CONCLUSION

In this paper, we discussed different designs of antennas for UHF RFID Tag and their characteristics. These papers are discussed based upon their size, return loss (RL) bandwidth, axial ratio (AR) or circular polarization (CP) bandwidth and their read range. These parameters are summarized below in table II.

TABLE 2: SUMMARY OF ABOVE DISCUSED PAPERS

Name of paper	Size of Ground Plane (mm)	Size of Patch (mm)	RL Band width (MHz)	AR or CP Band width (MHz)	Read Range (m)	
					In free space	On metal surface
Homg-Dean Chen. et.al [1]	70×70	47×47	48	6	1.4	2.8
Debiao Li.et.al [2]	73×50	72×37	59	------	5.69	5.06
Horng-Dean Chen. et.al [3]	100×100	58×58	25	20	4.39	4.62
Yen-Ming Tseng.	80×80	Diameter=56	40	6	2.4	4.6

et.al [4]						
M. S. R. Bashri .et.al [5]	87×45	Patch1=74 ×10,Patch 2= 69×10	159	-----	-----	-----
M. S. R. Bashri .et.al [6]	130×63	Sides of Patch1=10 ×37×10×1 2, Patch2=15 ×37×14×1 4, Patch3=86 ×5	117	-----	2.8,6 .18, 2.99 in Euro pe, Nort h Ame rica, Japa n	3.33, 3.61, 2.80 in Europ e, North Ameri ca, Japan
Ran Liu.et. al [7]	74×74	Inner diameter= 54, outer diameter= 59.2	215	6	3.5	5.5

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