DESIGN OF RFID ANTENNA WITH CIRCULAR POLARIZATION

Hassan Hamid Ekal
Department Of Communication Engineering, Faculty of Electrical and Electronic Engineering
University Tun Hussein Onn Malaysia, Johor, Malaysia

Abstract In this Report we will study about RFID antenna design. Here we will design antenna using High Frequency (HF) 13.56 MHz. All designing task will be done using circular polarization only. For this we will first try to understand what actually RFID is and for how many types of frequency range RFID antenna can be designed. Then we will see how many types of polarization is there and why we choose circular polarization. After these we will discuss about application of it. Then we will see steps for designing RFID antenna. We will discuss factors which should be keep in mind at a time of designing it. After these we will discuss on results of S11 and Radiation patterns in polar form. At last we will conclude our designing process.
Keywords: RFID, circular polarization, loop antenna.

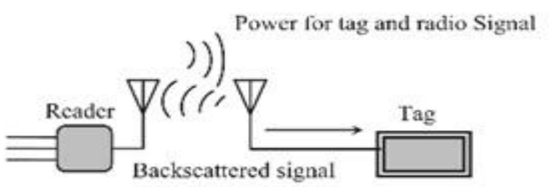
I. INTRODUCTION

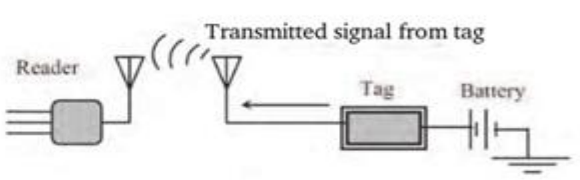
A. RFID and its applications

RFID stands for Radio Frequency identification. It is a part of AIDC (Automatic identification and data capture) technology. RFID is a new technology used for the identification of objects or personnel. There are normally three components required to complete the RFID system.

1> An electronic device called a tag which having some in-built data on it. It is attached to the objects to be identified.
2> A reader for communicating with the tag.
3> A host for data processing and for storing the information of the identified object.[3]

RFID tags can be active means have battery or passive means have no battery. Both types of tag are shown in below diagram.





Generally a passive RFID tag consists of two things, an antenna and RFID chip. It works as given below. A modulated RF signals are transmitted by RFID reader to the RFID tag consisting of an integrated circuit chip and an antenna. After receiving power from an antenna, the chip responds by doing variation in its input impedance. By doing so it is modulating the back scattered signal. Amplitude shift keying (ASK) is widely used modulation technique for RFID application. [5] It is rapidly replacing the bar code technology due to automatic identification techniques that facilitate management, enhanced security levels, more featured access control and tracking.[20]

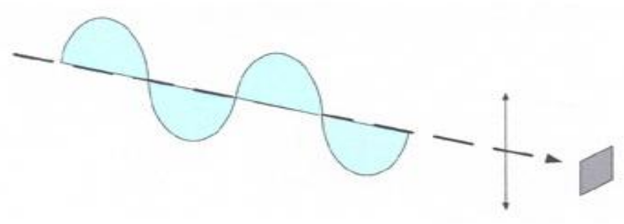
- Warehouse Management Systems
- Retail Inventory Management
- Toll Roads
- Automatic Payment Transactions
- Management and Tracking for high value asset
- Public Transportation
- Automotive Industry
- Livestock Ranching
- Healthcare and Hospitals
- Pharmaceutical Management Systems
- Military
- Marine Terminal Operation
- Manufacturing
- Anti-counterfeit

II. POLARIZATION

There are basic three types of polarization can be used for RFID application.

A. Linear Polarization:

Generally this polarization is used in dipole antenna. In this type of polarization, Electromagnetic wave propagates in one Vertical or Horizontal plane. It is same direction of the signal propagation. If tag orientation is fixed or known then this polarization is best suited for our application. RFID tag and antenna should be matched in polarization for acheving the best read rates. In this case EM waves looks as shown below:

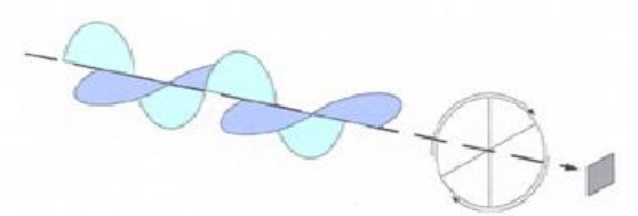


B. Circular Polarization

Generally this polarization is used in cross-dipole, patch, and loop or helix antenna. The EM wave propagates in circular manner forming a two planes making one complete revolution in one wavelength period. When tag orientation is not known to us, this is best polarization to use with our application. The RFID antenna emits a wavelength continuously so the rotational field will cover any tag that comes in its path at any instance of time. In compare with

 Copyright 2014.All rights reserved.

linear polarization 3db power loss is there in circular polarization. Below is the waveform which gives idea about EM wave of circular polarization [1].



Two types of circular antenna is there. Monostatic circular and Bistatic circualr.[12]

- Monostatic: It is the mostly used RFID antenna and It uses only one port to transmit and receive signals.
- Bistatic: It uses 2 RFID antennas in same body and use one port for transmit ion and the other port for receiving.

Here in our RFID application tag orientation is random and not fixed so circular polarization is best for our design.[18]

III. FREQUENCY

RFID system can be designed for following frequency ranges.

- Low Frequency – 125 khz to 134.2
- kHz.
- high Frequency - 13.56 MHz
- Ultra-High Frequency – 840 MHz to 960 MHz
- Microwave – 2.4 GHz to 5.8 GHz

Here in our RFID application we are designing antenna for high frequency 13.56 MHz.

IV. RFID ANTENNA

To transfer data to the reader from tag RFID uses radio waves. RFID tags extract all of the power from the field of reader. A system like coupled inductance is formed by tag and antenna of reader. This scenario is shown in below diagram. The tag's loop antenna behave as a secondary of transformer.

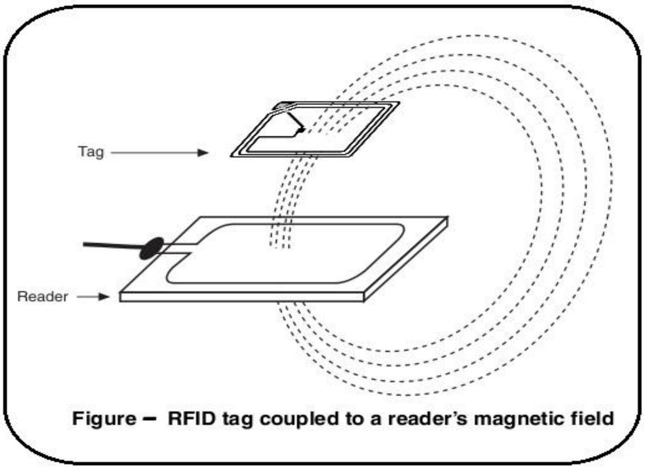


Figure – RFID tag coupled to a reader's magnetic field

For RFID, antenna can be designed in so many loop shapes which are shown below.[13]

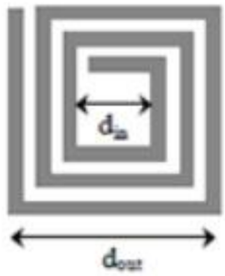


Fig 1

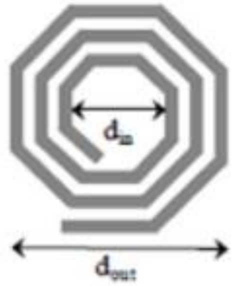


Fig 2

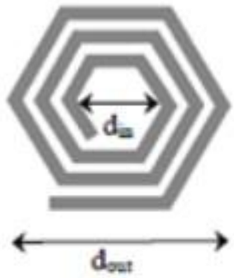
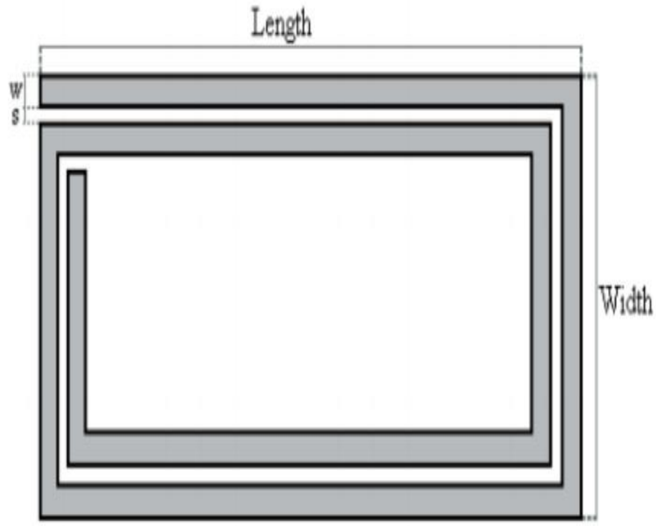


Fig 3

Out of these design we choose the design shown in Figure 1.

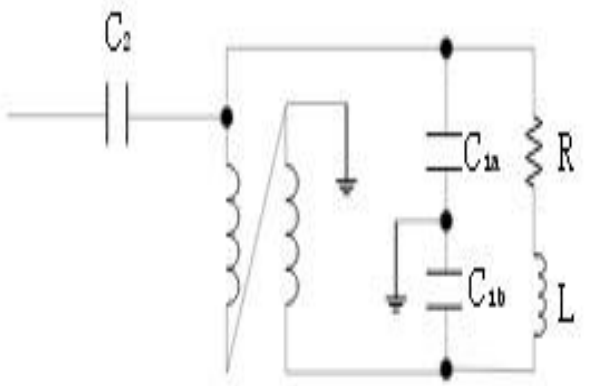
V. METHODOLOGY

We need to design a 13.56 Mhz loop antenna. Let us study the methodology used for designing loop antenna. The figure given below shows the proposed loop antenna to be designed.



In most of the cases, RFID reader has a requirement of around 50 ohm impedance. In order to get maximum power transfer, the key thing is to match the reader to antenna's impedance. Matching the impedance is really important as it assures that maximum power gets transferred to the antenna. If impedance is not matched properly, power will be lost during transmission resulting to poor reader range. Figure given below shows the match circuit of the loop antenna that operates at 13.56MHz.[15]

 Copyright 2014.All rights reserved.



Here the rectangular antenna loop can be modeled as inductance that is resonating with 2 capacitors in series i.e. C1a and C1b at resonating frequency. In order to control the quality factor of antenna, we have added a series resistor R. Also a parasitical capacitor has been kept between the antenna design and the ground. Because the signal that is send to the receiver is an unbalance input and the balun has to be used to reduce common noise. We have also used a transmission line transformer whose turn ratio is 1:1. [4]

Now for designing the loop antenna, the inductance value has to be calculated. The equation given below calculates the value with high accuracy.[17]

L(uH) = S x 0.008 x Ln(S x 1.414 / 2D + 0.379)

Here L is in micro Henry, S is the side and signifies the center length of antenna in cm, D is the diameter of cable in cm.

Now that we have the value for inductor, let us determine values of two series capacitors.

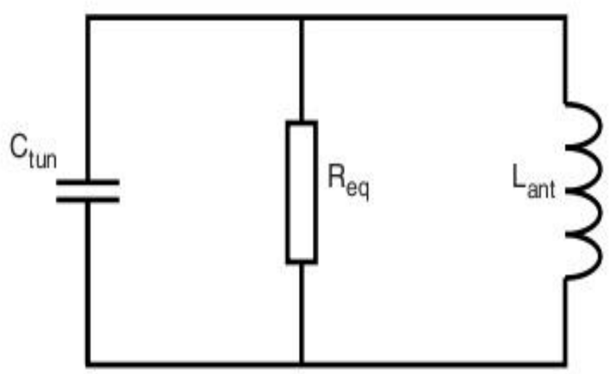
C1a = C1b = C / 2 = 1 / (2πfres)2 L

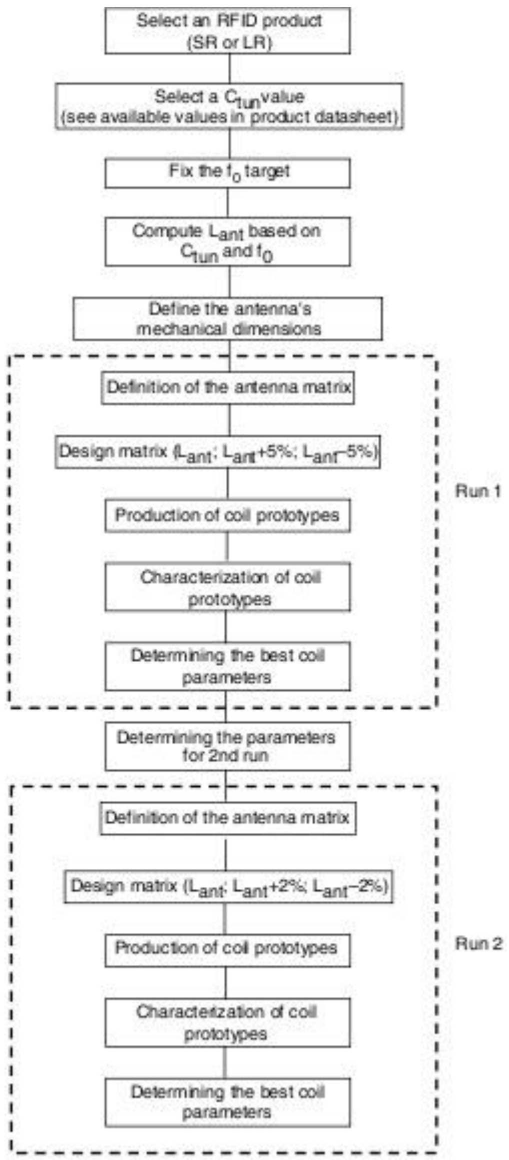
Here fres is the resonating frequency. We can use the above values to calculate C2.

C2 = C x sqrt (Zin/Zout)

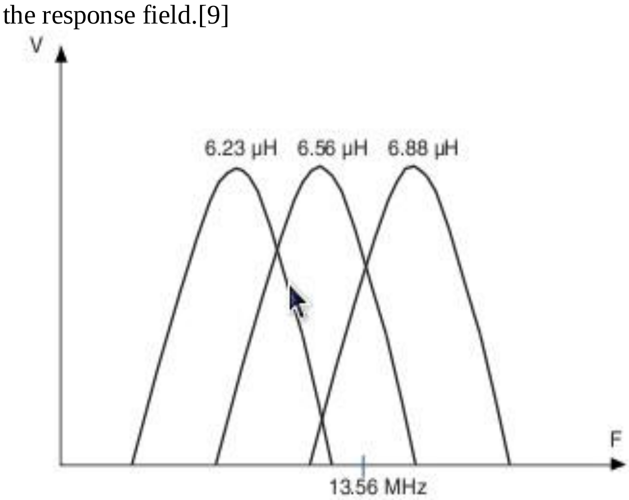
We can take Zin equal to 50 ohm while Zout is the equivalent parallel resistance. The flow chart shown below shows the exact procedure used for designing the loop antenna.[14] We need to define antenna's mechanical dimensions required. The coil length has to be of 8 cm, coil width being 8 cm with 5 turns. The width of the track has to

be 0.4 cm with the track separation of 0,4 cm.



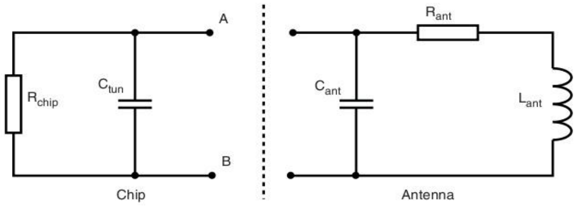


The samples of the coil are defined using the Hp 8712ET analyzer with reflection mode and 7405-901 Eaton 6 cm loop probe. This probe will generate the field thereby analyzing the response field.[9]



 Copyright 2014.All rights reserved.

The above figure helps to determine the best parameter for coil by doing the ideal tuning. The equivalent circuit of the antenna design is shown below. Since the antenna is made up of wire material, the equivalent circuit shows a wire with an internal resistance Rant along with the inductance Lant. The capacitance value that the bridge produces is Cant and represents the parasitic elements.[19]



This circuit can further be simplified and expressed as the one given below. The calculations can be made by considering the equivalent circuit.

Here $R_{eq} = (R_{chip} \times R_{p\_ant}) / (R_{chip} + R_{p\_ant})$.

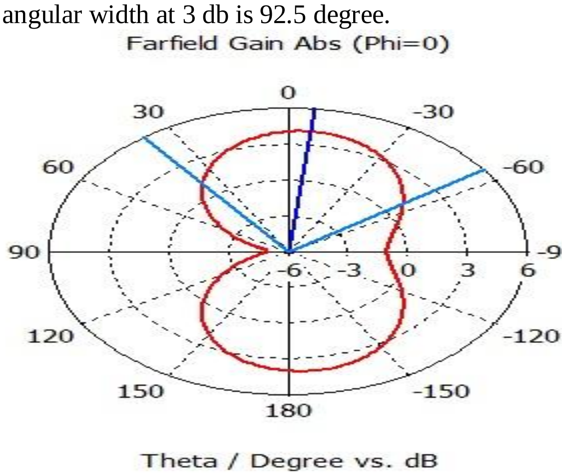
Also $R_{p\_ant} = R_{s\_ant} \times (1 + (L_{ant} \times w / R_{s\_ant})^2)$

where the angular frequency is represented by w. The resonant frequency for a LC parallel oscillating circuit can also be calculated by the formula given below. $f_0 = 1 / (2pi \times sqrt(L_{ant} . C_{tun}))$. While the quality factor of the equivalent circuit is given by $Q = R_{eq} / (2pi \times f_0 \times L_{ant})$. Let us see an example calculation of inductance of antenna coil.[11] $L_{ant} = 1 / ((2 \times 3.14 \times 13.56 \times 10^6)^2 \times 21 \times 10^{-12}) = 6.56$ micro henry. This inductance value can be used for design of various types of coils like circular, spiral and square loop coils. Using the $L_{ant} = L_0 + \sum M$ where M gives the mutual inductance present between each segments of antenna while $L_0 = \sum L_j$. Here j runs from 1 to s i.e. number of segments. The parameter L_j gives self inductance of every segment of antenna.[8]

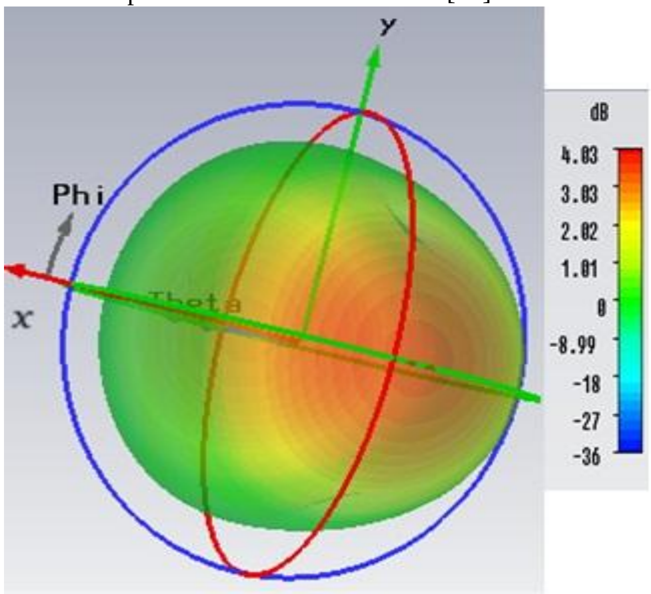
VI. RESULTS AND DISCUSSION

By simulating our observation (frequency v/s s1,1 parameters) for RFID antenna through CST simulator for S parameters we gets following graph.[6]

The loop antenna has a polarization as shown in below figure. For Generating below graph, we used 13.56 MHz frequency. From the graph we can observe that Main lobe has magnitude of 4.0 db and has a direction of -6.0 degree. It has an angular width at 3 db is 92.5 degree.



By using CST simulator we got following 3 dimensional plot of radiation patterns of our RFID antenna.[10]



For this radiation pattern following factors have been considered.

Type: Farfield

Approximation: enabled (kR >> 1)

Monitor: farfield (f = frequency_centre)

Component: Abs

Output: Gain

Frequency: 13.56 MHz

Rad. efficiency: 0.0007427 db

total efficiency: -0.02713 db

Gain: 4.035 db

VII. CONCLUSION

Thus we have presented a simple rectangular loop antenna for on-body applications. The circuit model was designed to provide the rectangular loop antenna with inductive coupling to provide a resonating frequency of 13.56 MHz antenna with gain of around 4 db and the return loss of -10 db. If the coupling feeding mechanism is optimized, accurate impedance is matched along with 2 orthogonal components having a 90◦ difference in phase to obtain circular polarization. The designed inductively coupled rectangular loop antenna can be used in the RFID cards with many on-field applications due to optimized small size and high performance of antenna.

RFERENCES

[1] D. Senić, D. Poljak, and A. Šarolić, "Electromagnetic field exposure of 13.56 MHz RFID loop antenna, "Telecommunications and Computer Networks (SoftCOM), 2010 International Conference on Software, pp. 23-25, 2010.

[2] W. Liu, L. Q. Wong, and M. M. Wong, "Simulation and design for 3D RFID application," in Proc. IEEE International Conference on Emerging Technologies and Factory Automation, pp.1326-

 Copyright 2014.All rights reserved.

1331, 2008.
[3] S.F. Pichorim and P. J. Abatti, "Design of coils for millimeter and sub mill meter sizes biotelemetry," IEEE Trans. Biomed. Eng., vol. 51, no.8, pp.1487-1489, 2004.
[4] C.Steve Q. Chen, and V. Thomas, "Optimization of inductive RFID technology," 2001 IEEE International Symposium on Electronics and the Environment, pp. 82-87, 2001.
[5] H.-S. Kim D.-H. Won and B.-J. Jang Simple design method of wireless power transfer system using 13.56MHz loop antennas" IEEE International Symposium on Industrial Electronics (ISIE), pp. 1058-1063, 2010.
[6] C. Mansap, P. Wounchoum, C. Phongcharoenpanich, and D. Torrungrueng, "Trapezoidal Dual Loop Antenna for Radio Frequency dentification," Asia-Pacific Microwave Conference, pp.1478-1481, 2006.
[7] R. F. Harrington and J. Mautz, "Electromagnetic behaviour of circular wire loops with arbitrary excitation and loading," in Proceedings of the ,Institution of Electrical Engineers,vol.115pp.68-77, 1968.
[8] Stutz man's 3rd edition of Antenna Theory and Design provides a more pedagogical approach with a greater emphasis on computational methods.
[9] Thomas A . Milligan - 2005 - Preview - More editions
[10] Modern Antenna Handbook Constantine A. Balanis
[11] Antenna Engineering Handbook, Fourth Edition John L. Volakis - 2007
[12] The Handbook of Antenna Design, Volume 1 Alan W. Rudge - 01-Jan-1982
[13] Antenna analysis Edward A. Wolff - 1966
[14] Antenna Design: A Practical Guide George J. Monser - 1996
[15] Antenna Theory: Analysis and Design Constantine A. Balanis - 03-Dec-2012
[16] International Conference on Antennas and Propagation, 28-30 ..., Volume 1 Institution of Electrical Engineers. Electronics Division
[17] Electromagnetics Robert Stratman Elliott
[18] Antennas and wave propagation,A. R. Harish, M. Sachidananda - 16-Jul-2007
[19] 1974 international IEEE/AP-S symposium program & digest: June 10-12, 1974, Georgia Institute of Technology, Atlanta, Georgia
[20] Antennas and Wave Propagation G. S. N. Raju, Raju

 Copyright 2014.All rights reserved.