IOSR Journal of Electronics and Communication Engineering (IOSR-JECE)
e-ISSN: 2278-2834,p- ISSN: 2278-8735.Volume 14, Issue 4, Ser. II (Jul.-Aug. 2019), PP 51-60
www.iosrjournals.org

Investigation and Simulation of the practical design benchmarks of Micro-Strip Patch Antennas (MSPA) and Micro-Strip Patch Slot Antennas (MSPSA) and their implementations within the domain of RFID applications.

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Abstract- *The macro-strip antenna is an electromagnetic radiator which creates electromagnetic field. The main job of antenna the received electromagnetic waves in space into electrical currents in conductor or vice versa. It mainly depends on whether the transmitting or receiving the signal. This kind of antenna is able to deliver large communication distances but this antenna coverage is very weak which is part of the main drawbacks of these antennas [3]. The aim for the improvement in bandwidth with the presence of air layer substrate, the patch antenna can be used at different RFID applications since there will a bandwidth enhancement. Moreover, this research will be endeavouring the circular polarization for the patch antenna that could be well matched the detection of the signal in different angular variations. this research aims to present a number of applications and its correlation of micro-strip antennas (MSPA) like RFID usage such as Supply Chain Management (SCM), Toll Free RFID Wi-Fi, Wi-MAX, RF energy harvesting, Cognitive radio, GSM, Radar and ultra-wide band [15]. Micro-strip antennas (MSPA) are likewise devouring demerits such as low gain and low efficiency in which this research is endeavoring to solve and modify ,This is the part where the tag antenna's design to meet the specifications using highly efficient simulation environment represented by High Frequency Simulation (HFSS Version 11) for the best of antennas simulation and modelling***.***

Keywords*: Micro-Strip Patch Antenna (MSPA), Micro-Strip Patch Slot Antenna (MSPSA), Radio Frequency Identification (RFID), High Frequency Structure Simulator (HFSS), Reflection Coefficient (RL), Supply Chain Management (SCM).*

Date of Submission: 09-09-2019 Date of acceptance: 25-09-2019

I. Introduction

The Micro-Strip Patch Antenna (MSPA) and Micro-Strip Patch Slot Antenna (MSPSA) are prevalent printed resonant antennas for narrow-band microwave wireless link requests such as Wireless Frequency IDentification (RFID) arrangements that need semi-hemispherical coverage. Recently, micro-strip antennas are driving an imperative part in non-wired communication structures due to their numerous gains such as non-heavy weightiness, low profile, little charge, uncomplicated assimilation/deployment within structure of planar besides straight forward manufacturing and electrically compact antenna suffers from low gain, though, it delivers simplicity in integration in communication devices and cost efficiency [15]. Consequently, it is quite indispensable to recognize totally the characteristics of micro-strip antennas.

The objective of this research is to design and evaluate the performance of micro-strip antennas (MSPA and MSPSA). The design parameters include micro-strip antenna measurements, antenna feeding methods and a number of polarization schemes though the performance disputes comprise antenna gain enrichment, bandwidth concerns besides customized micro-strip antennas.

There could be a substantial amount of trade-off between enhancing antenna gain (S21) in correspondence to return loss (S11) in S-parameters formation and computations. Scattering parameters or S-parameters to designate the input towards output association amid nodes or ports or even terminals within electrical system. For example, if there were two numbers of ports that can be named as Port 1 besides Port 2, then S12 characterizes the transfer of power from output port (Port 2) towards input port (Port 1) as can be depicted in Figure 1 [4].

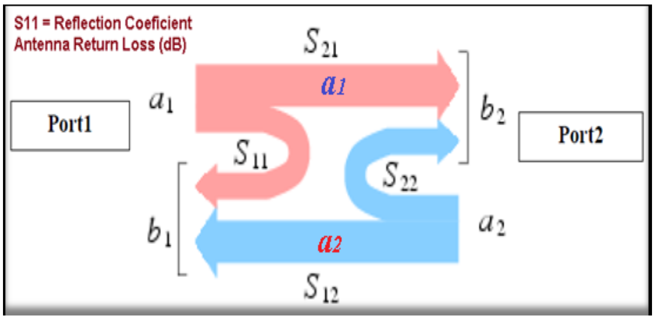

Figure 1. S- Parameters showing S11, S 1, S22 and S12 respectively [4].

A port can be loosely described as each local whereas we can deliver voltage and current [2]. Normally a contact arrangement alongside two radios (radio 1 and radio 2) hence the radio terminals (which hold manipulation to the two antennas) should be the two ports. S11 then would be the reflected power radio 1 is trying to deliver to antenna 1. S22 would be the reflected power radio 2 is attempting to deliver to antenna 2. And S12 is the power from radio 2 that is delivered through antenna 1 to radio 1. Note that in finished S-parameters are purposes of frequency.

Practically, the most normally cited parameter with respect to radio wires is S11. S11 speaks to how much power is reflected from the radio wire, and consequently is known as the reflection coefficient (at times composed as gamma: or return misfortune. On the off chance that S11=0 dB, at that point all the power is reflected from the antenna and nothing is transmitted. On the off chance that S11=-10 dB, this suggests if 3 dB of intensity is conveyed to the reception apparatus, - 7 dB is the reflected power. The rest of the power was "acknowledged by" or conveyed to the antenna. This acknowledged power is either emanated or ingested as misfortunes inside the reception apparatus. Since antenna are commonly intended to be low misfortune, in a perfect world most of the influence conveyed to the reception antenna is emanated [2].

Basically an antenna is an electromagnetic radiator which creates electromagnetic field. The foremost function of antenna is to transform electromagnetic waves in space into electrical currents in conductor or vice versa. It mainly depends on whether the antenna is transmitting or receiving the signal. There are several types of antenna under three main categories which are Omni-directional, directional and semi-directional antenna. Omni-directional antennas are designed in such a way that they can radiate in all directions [3]. It is quite handy to install for its horizontal pattern. These types of antennas can deliver large communication distances but coverage under the antenna is very poor which is one of the main drawbacks of Omni-directional antenna [3]. Directional antennas are designed for diverting the RF energy to specific direction to further distances. Consequently, it is possible to cover long areas but effective beam width decreases. For the point to point links these antennas are used. Sometimes, it is needed in the base stations where a sector needs to be covered by separate antennas. Panel antennas are the examples of directional antenna. Semi-directional antennas operate in a constricted fashion and are designed to provide a directed signal over a large area. This is similarly known as micro-strip antenna. A schematic section of MSPA can be shown in Figure 2 [20].

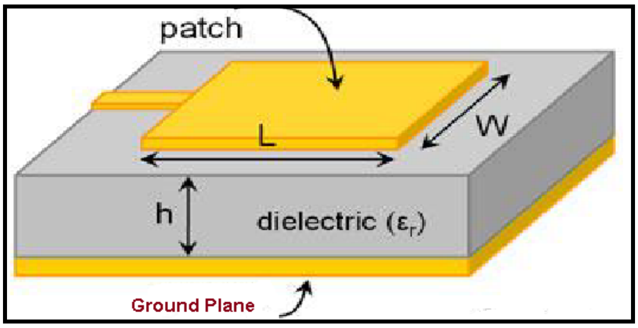

Figure 2. Patch Antenna structure with its basic dimensions

An RFID system is a vastly composite structure, which requires a diverse disciplines of studies, namely an antenna design, signal processing, information networking design as well as RF hardware design. The main concentration of this research project will be on integrated antenna design and modelling novelties devoted mainly to RFID applications with optimized Return Loss (S11) and overall antenna gain performance represented by S21 as antenna gain as shown in Figure 3. The PhD research project will investigate integrated antennas in regards to their advantages and distinctive merits towards RFID applications. These antennas are

Micro Strip Patch Antenna (MSPA) and Micro Strip Patch Slotted Antenna (MSPSA). A basic RFID system structure which includes the antennas with other system components can be seen in Figure 3 [4]. .

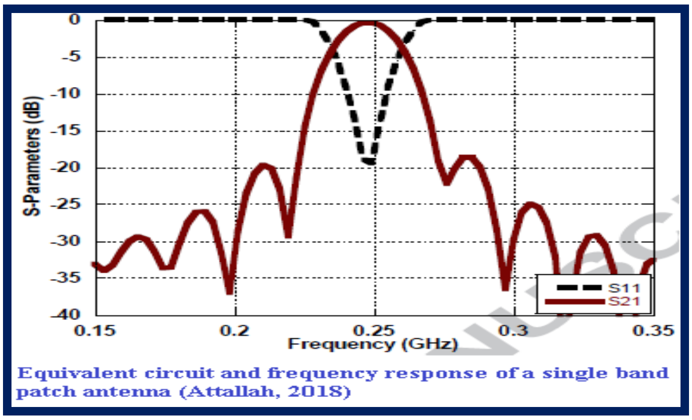

Figure 3. The frequency response as well as the equivalent circuit of the single band patch antenna [2].

Micro-Strip Patch Antennas and Micro Strip Patch Slot Antennas with their implementations for Radio Frequency IDentification (RFID) form the background of this research project. In reality an RFID system, is a vastly composite structure, which requires a diverse disciplines of studies, namely an antenna design, signal processing, information networking design as well as RF hardware design. The main concentration of this research project will be on an antenna integrated design modelling novelties devoted entirely for mainly RFID applications with optimized Return Loss (S11) and total antenna gain performance. The research project will investigate integrated antennas in regards to their advantages used for RFID applications. These antennas are Micro-Strip Patch Antenna which will be acronym to (MSPA) and Micro-Strip Patch Slot Antenna that will be acronym to (MSPSA) along the course of this research project. A plain RFID system structure which includes the antennas with other system components can be seen in Figure 4.

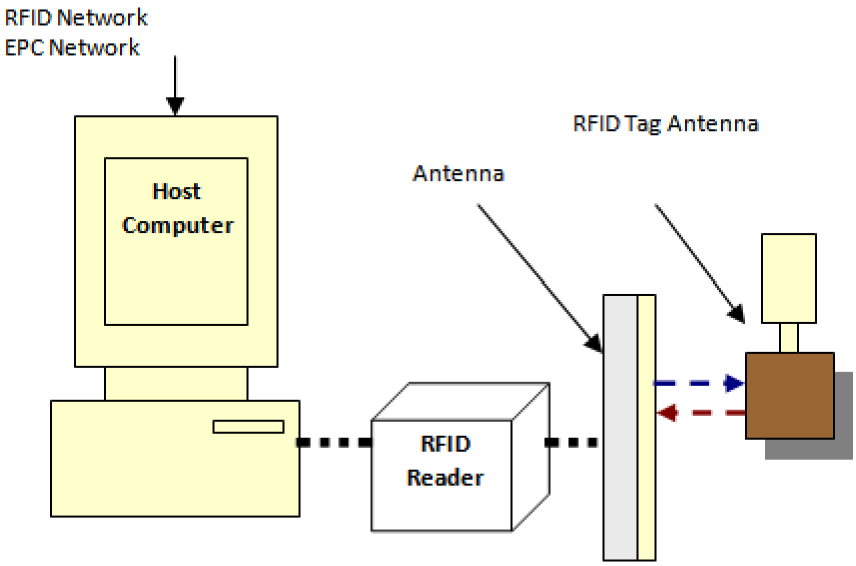

Figure 4. A plain structure of RFID System

As depicted in Figure 4, the computer which has the host role is to connect readers of RFID to the network of RFID (recognised as something called Network of Code from Electronic Product Code (EPC)). An RFID reader within several reader antennas is connected. Tags of RFID are Passive antennas and power-driven by reader antennas in order to feed these RFID tags can be always detected and identified by RFID readers [4].

II. Research Problem Statement

The necessity for objects' or animals' or even human's automatic monitoring, identifying and tracking using radio waves has headed to extreme research and investigations in the domain of (RFID systems). The definitive objective is to facilitate the procedure and to lessen however much power as could reasonably be expected physical human involvement (Kaufmann, 2013). RFID is viewed as the path forward to understand the objective and to influence global task by covering the operating range of frequencies of ultra-high frequency (UHF) on Radio Frequency IDentification RFID applications and from 860 MHz to 960 MHz, few antennas engineering techniques will be employed. These techniques involve the moving design phases on what is so called Micro-Strip Patch Antennas (MSPA) and Micro- Strip Patch Slot Antennas (MSPSA) respectively. The design phases will be attempted on MSPA group then moving towards MSPSA group which will enable higher possible antenna gain, lowest return losses or frequency coefficient of the most optimized modelled antennas.

Nevertheless, the patch antenna has few demerits represented by its low profile, stumpy gain and weak impedance matching as well as unmatched bandwidth. It has experienced high return loss and high reflection coefficient [3]. This is where this PhD research work is attempting to solve by producing few design criteria’s from MSPA and then move towards MSPSA design phases so as to obtain highest antenna gain possible, lowest antenna return losses or reflection coefficient and better impedance matching by employing an efficient feeding technique, executing slotting methodologies and enhancing antenna gain. The antenna return loss can be termed as within S-parameters variables in which will be named here as S11 [11].

III. Motivation

Micro-Strip Patch Antenna (MSPA) plays a vital role in the development of integrated compact antennas and microwave industry. Due to the MSPA ease of manufacturing and integration, making this antenna effectively utilized in RFID applications. The real challenge is when the design methodology of Micro-Strip Patch Slot Antenna (MSPSA) is merged with MSPA design methodologies which in turn will generate a potentially better gain and an improved return loss or reflection coefficient. The research starts with detailed modelling of MSPA and presents the achieved results. Then the research further investigates the novel MSPSA design and presents its optimized results proven to be efficient for RFID in particular and other applications such as wireless and satellite communications in general, [15].

IV. Participation

Two key capacities of contribution accessible by this research project. The first area of contribution is on the intensive design and modeling of MSPA and the second is a comprehensive design technique on MSPSA for RFID applications in particular.

The second area of contribution for this project is the introduction of a novel component design of MSPSA to be a practical component design for RFID implementations. Then project presents a compact Micro-strip Patch Antenna MSPA and other compact antenna designs that are improved versions of MSPA by merging the concept of slot-loading technique thus forming novel practical MSPSA components.

The survey on integrated antenna MSPA design is next furthered into the design of a single slot double slot and three slots MSPSA antennas. These MSPA and MSPSA antennas support UHF band operation, [17].

V. RFID System’s Antennas

RFID changes and advancement possesses been commercialized in the areas of mobile contact, logistics, producing, transportation, and condition care, [17]. RFID arrangement usually uses frequencies amid 100 KHz and 5.8 GHz reliant on its requests as shown in table 2.1. Basically, an RFID arrangement is a tag or transponder and a transceiver or reader. The tag contains of an antenna joined alongside an application-specific integrated circuit (ASIC) chip. So as to detect and activate a tag, a center station (reader) transmits a modulated sign as depicted in Figure 2.1. Micro-strip patch and slot antennas are becoming more likable and accepted for work in wireless implementations such as RFID requests exceptionally in UHF group because of their low-profile structure. Antennas for countless telecom and martial requests need slender and conformal construction and micro-strip patch antennas are the most suitable antennas to encounter these criteria.

Another field where they have been used successfully is in satellite telecommunication used as a feed for larger gain antennas. Conventional micro-strip patch antennas (MSPA) have a conducting patch printed on established microwave substrate as shown in Figure 5 [1].

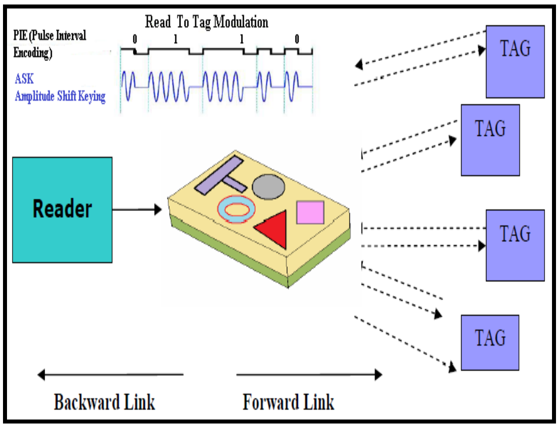

Figure 5: RFID System Components [1].

Micro-trip Patch Antenna or MSPA is a standout amongst the most energizing and entrancing improvement in antennas and electromagnetic (EM) history. It belongs to the classification of printed strip antennas, for example, dipoles, openings, and decreased spaces [16].

The shapes of integrated micro-strip patches can be as shown below in Figure 6: rectangular without and with slots, circular, triangle from upper top and bottom line elliptical, circular ring, square, and dipole [3].

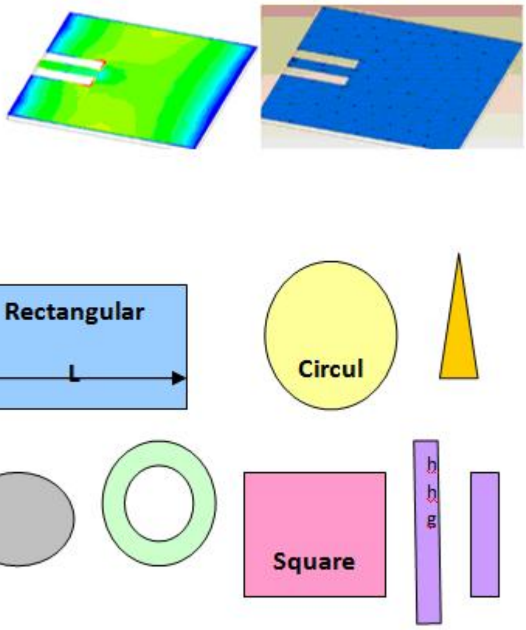

Figure 6 Shapes of integrated micro-strip patches.

As can be realized in Figure 2.3, there are many degrees of freedom in the modelling and design of a new Micro-strip Patch Antenna. The dimensions of the patch antenna (Length, Width) will affect the impedance behavior of the antenna [4]. The width of the Micro-strip Patch Antenna plays a key act in finished size of the printed antenna. If the width is decreased the finished patch conductor size decreases. An supplementary capacitance is crafted by fringing fields associated alongside the close proximity of the top and bottom patch conductor edges as shown in Figure 7. This extra fringing capacitance lowers the operation frequency of the patch antenna. The electric field of open micro-strip in a patch antenna does not stop abruptly at the tip of the upper conductor instead it extends somewhat beyond the end of the micro-strip line as given in Figure 2.4. The fringing field effects are taken into consideration by introducing either a capacitance or an equivalent length of line Δd as shown in equation 1 [5]:

$$\Delta d = 0.412\,h\,\frac{\varepsilon e + 0.300\ w/h\ + 0.262}{\varepsilon e + 0.258\ w/h + 0.813} \qquad (1)$$

Where w = width of line substrate
h= height of the substrate

εe = the equivalent permittivity

supplied by micro-strip transmission line has bordering or fringing fields close to the substrate line with the field excitation from the strip line along the path length/. This can be appeared in Figure 7 with bordering or fringing electric field (Sun, 2018)

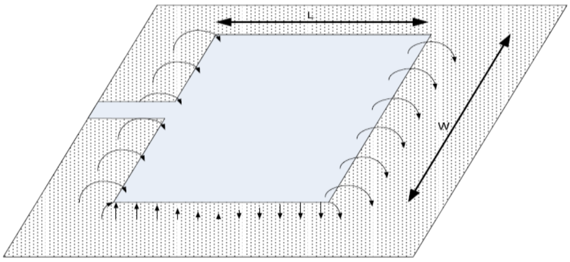

Figure 7 Microstrip Patch Antenna fed by microstrip transmission line, shown with fringing electric field [17].

Practical micro-strip lines, that have width-to-height ratios w/h that does not exceed unity, and can vary above the interval 0.1 < w/h < 10.Typical heights h measurements are of the order of millimeters. Fringing results cannot be flouted completely and the easy assumptions the fields of the parallel plate line are not valid [17].

Acquaintances among elements in a micro-strip circuit are made with micro-strip lines, with a uniform straight upper conductor placed on the top of the dielectric substrate with a ground plane on the bottom side as appeared in Figure 8. The structure is not homogenous, because the electromagnetic field extends over two media: air and dielectric. After that wave propagation cannot be transverse electromagnetic (TEM), since waves in the two media travel with different velocities. In order to satisfy the boundary conditions, so waves are neither transverse electric and magnetic field must have non- zero longitudinal components, so waves are neither transverse electric (TE) nor Transverse Magnetic (TM) but exhibit hybrid character [9].

The electromagnetic field gets progressively more concentrated within dielectric substrate as frequency increases, which indicates that the equivalent (effective) permittivity of the micro-strip structure depends on the signal frequency and the propagation is dispersive [9]. Due to the inhomogeneous nature of the micro-strip, a complete analysis develops into great involvement therefore approximations were developed that are the most regularly rather sufficient for micro-strip designs as shown in Figure 8.

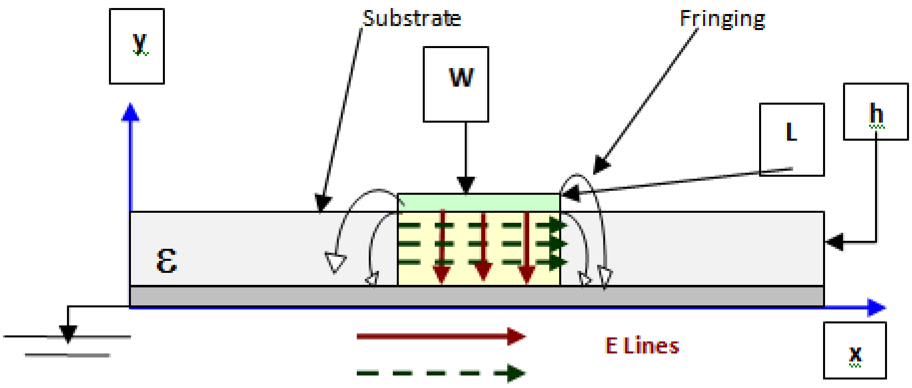

Figure 8. Micro-strip Patch Antenna as a micro-strip transmission line with fringing electric field.

VI. Literature Review (LR)

Represents the comprehensive LR to investigate and evaluate the pervious published work in the area of Micro-Strip Patch Antenna MSPA for almost the last 5 years. Few design techniques will be presented to have a clear realization of the level of MSPA and MSPSA innovations and developments especially with their role in RFID applications and practical implementations. This LR will evaluate all the aspects of the antennas parameters namely: Directivity, Efficiency, Gain, Return Loss, Reflection Coefficient, VSWR, Antenna beam width.

VII. Examples of some of the papers

[4] counseled a compact meandered cross-shaped slot circularly polarized antenna suitable for the range of ultra high frequency (UHF). The S11 value of this antenna can be displayed in Figure 2.5

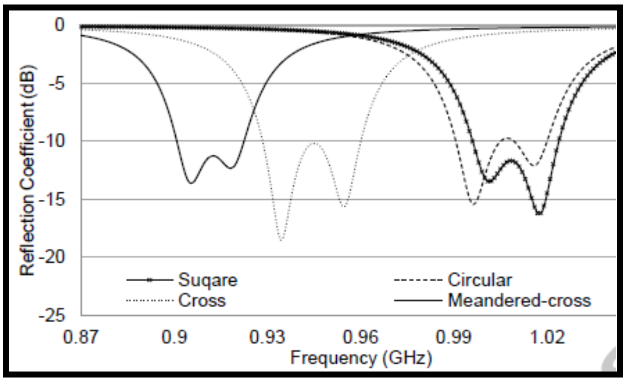

Figure 2.5 S11 value for Polarised Antenna for Handheld UHF RFID Reader [4].

In other research project, [2], the authors designed the dual group coupled resonators group bypass filter that uses two C shaped defected ground constructions (DGSs)Dual group wireless strength transfer (DB-WPT) applications. S11 value of -22 dB has been obtained and can be seen in Figure 2.6. S21 as well can be noticed in the Figure as well with the operating frequency of 0.25 GHz range

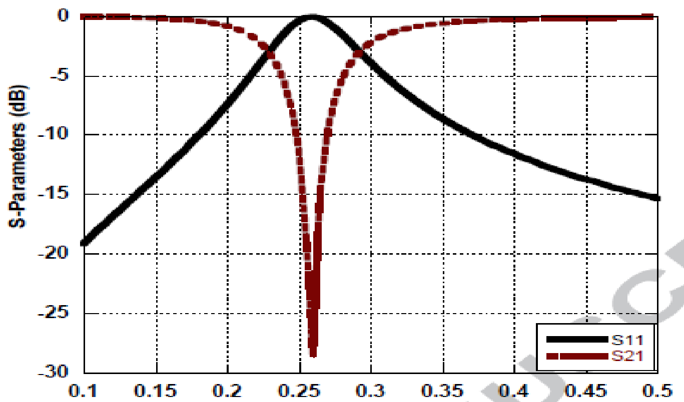

Figure 2.6 S11and S21 values for dual band coupled resonators [2].

While in the research of [10] they recommended compact circularly polarized co-designed filtering annular slot antenna (ASA) for mobile communications namely radio frequency identification (RFID), S11 values can be seen in Figure 9.

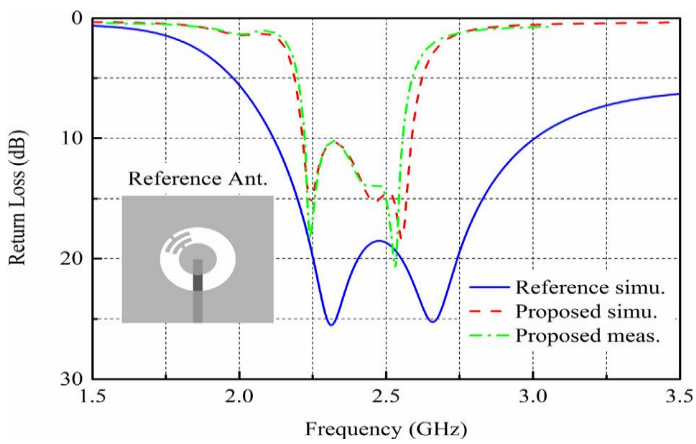

Figure 9 S11 values for dual band frequencies [10]

[20] has tested one main radiation patch and one parasitic radiation patch with air as the dielectric used for UHF RFID. S11 values can be noticed in Figure 10 at frequency of 850 MHz.

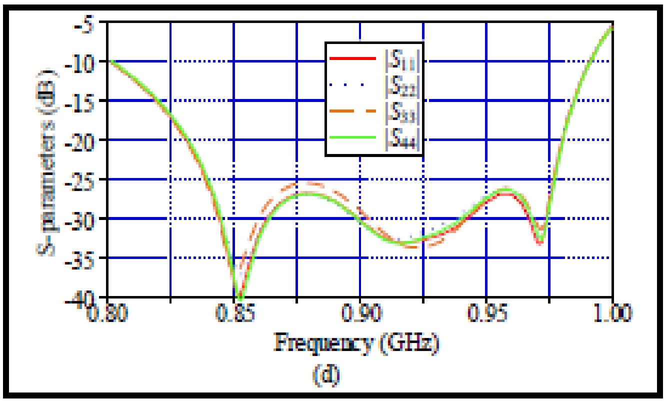

Figure 10. S11 values at 850 MHz UHF RFID [20].

VIII. MSPA Circular Polarized CP antenna.

A circular polarized CP antenna is projected to use easy feed construction alongside vertical ground encircling a exuding agent and contrasted to the author's design [3]. A High Frequency Construction Simulator (HFFS) was utilized to design the CP antenna and examine it. Features of the CP antenna design are delineated, and simulated outcomes are gave and discussed.

The Circularly polarized (CP) micro-strip antenna with vertical ground for RFID (Radio Frequency Identification) applications of reader is presented. The antenna is composed of a radiant patch on a substrate and a vertical ground encircling four parts of the antenna. The vertical ground reduces the resonant frequency around 25 % contrasting to that without vertical ground [8]. The simulation results display that the projected CP antenna possesses good impedance and radiation characteristics above the demanded bandwidth as will be gave in this study paper.

The design starts with the following steps:

1) Generating the model objects of the above bricks based on their design measurements.
2) Assign materials of PEC.
3) Creating and modeling the port.
4) Assign Boundaries for the air box.
5) Starting the analysis (analyze all in HFSS) model project and perform complete simulation.

IX. Assign outlines.

Now the ideal possesses been crafted, we demand to allocate frontier conditions. In HFSS, radiation borders are utilized to simulate open setbacks that permit waves to exude infinitely distant into space. This is shown in Figure 3.1. The air box here is basically the total of height (h) of the substrate and height of the air layer substrate and air box top layer boundaries. Figures 11 and 12 show the complete initial model by HFSS version 11 which displays the final CP antenna design with the probe and the patch. Also the air box containing the substrate, air layer substrate and the patch.

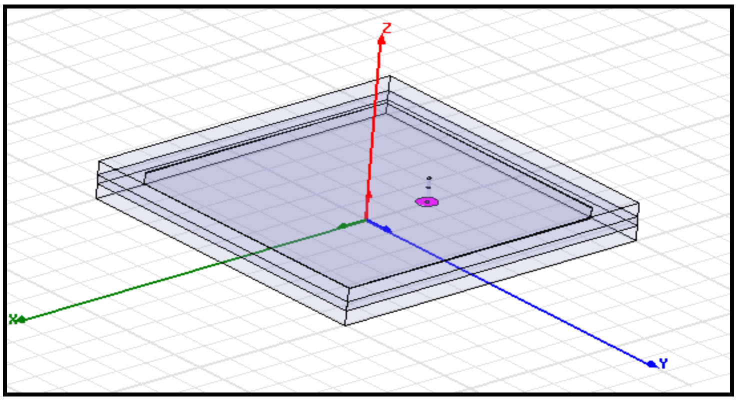

Figure 11 CP antenna design modeled using HFSS environment showing the probe port position.

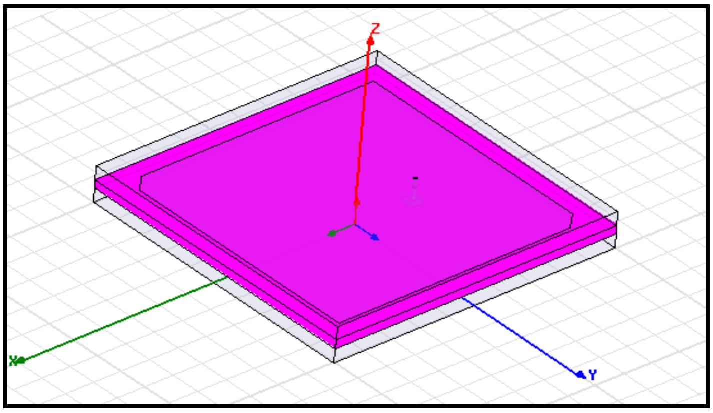

Figure 12 MSPA CP antenna design modeled using HFSS environment showing the patch and substrate.

The initial results of our simulation for the MSPA antenna return loss (S11) value was 4 dB at 840 MHz as indicated in Figure 13

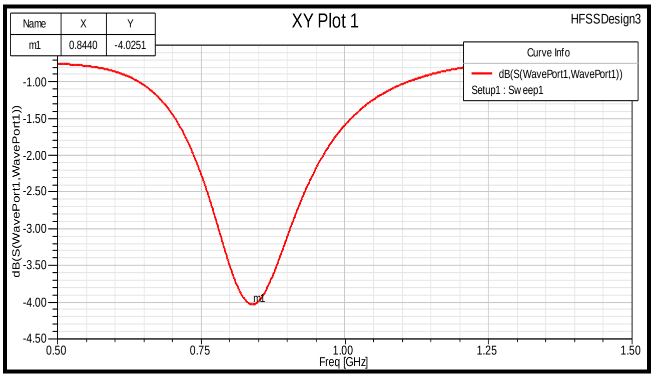

Figure 13 CP antenna design modeled using HFSS environment Return Loss (S11) with the original air box.

As portrayed in Figure 13 the initial value of S11 is giving an optimal performance. However, the published MSPA antenna design has good starting point of S11 or antenna reflection coefficient reaching the value of 4 dB. The attempt is to start working on the areas of boundary represented by the air box.

The Micro-strip Patch Antenna (MSPA) antenna system design iterations started by increasing the airbox dimensions and were specified and selected into approximately 40 mm height and 40mm width. The shape of the new modeled air box can be modeled and simulated using our proposed HFSS simulation engine environment.

The new modeled MSPA antenna design with the new air box dimensions is shown in Figure 3.4 with all the layers.

The new approach of the initial MSPA antenna design with the new air box boundaries shows that the return loss (RL) (S11) has improved from 4 dB to almost 4.4 dB an increase of about a dB at a frequency of 840 MHz. This reflects that the larger air box provides a better boundary for the antenna modeling thus increasing the return loss and having a better S11. This can be shown in Figure 14.

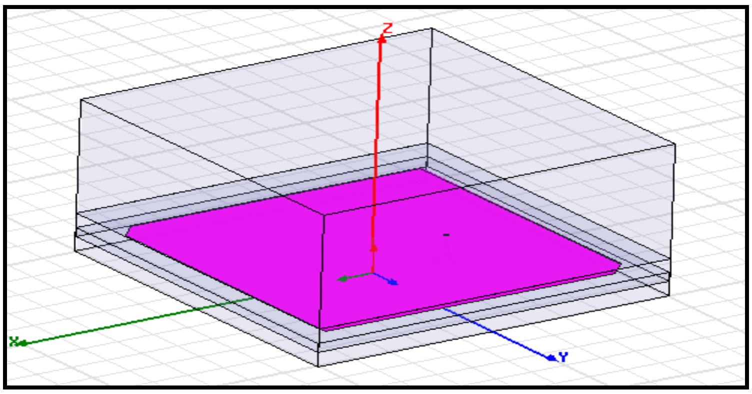

Figure 14 CP antenna design with the new air box containing the patch

X. Conclusion

The modeling, design and analysis of the newly redesigned the MSPA antenna with simulation using the presented design procedure could be initially successful. After trying various air box boundary dimensions, it has been concluded that with higher air box boundary the return loss RL which is referred to S11 has increased from 4 dB with the small airbox to approximately 14 dB for the larger air box boundary. It was realized that by a further increase of the air box boundary the antenna design is expected to reach an S11 of 20 dB. The design model was accurate and very similar to the original that have been modeled as a novel published MSPA antenna design from the authors. The initial design of MSPA was structured, formed, modeled and then finally fully simulated successfully using HFSS simulation techniques.

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