NOVEL DESIGN OF MICROSTRIP PATCH ANTENNA FOR RFID APPLICATIONS

A Project report submitted in partial fulfillment of the requirements for the award of the degree of

BACHELOR OF TECHNOLOGY

IN

ELECTRONICS AND COMMUNICATION ENGINEERING

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ANITS

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

ANIL NEERUKONDA INSTITUTE OF TECHNOLOGY AND SCIENCES
(UGC AUTONOMOUS)
(*Permanently Affiliated to AU, Approved by AICTE and Accredited by NBA & NAAC with 'A' Grade*)
Sangivalasa, bheemili mandal, visakhapatnam dist.(A.P)

2020-2021

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CERTIFICATE

This is to certify that the project report entitled **" Novel Design of Microstrip Patch Antenna for RFID Applications"** submitted by **S.Hruthika (317126512110), SL.N.Sameera (317126512113), S.Lokesh (317126512108), M.Anusha (317126512093)** in partial fulfillment of the requirements for the award of the degree of **Bachelor of Technology** in **Electronics & Communication Engineering** of Andhra University, Visakhapatnam is a record of bonafide work carried out under my guidance and supervision.

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ABSTRACT

RFID stands for Radio Frequency Identification. RFID tags are gaining attention due to various applications such as asset tracking, people tracking, library, healthcare, ID badging, supply chain management, manufacturing and aerospace industry, transportation etc.

Microstrip patch antennas are being used for new high speed RFID reader systems. They are well suited for RFID reader systems due to their versatility, conformability, low cost, and low sensitivity to the manufacturing tolerances. The main advantage of patch antenna is its size which is relatively small compared to other radiators. The microstrip patch antennas can be integrated easily into various objects as a result of its small thickness and miniature profile.

Integrating microstrip patch antenna with RFID technology achieves significant performance and cost advantage due to its light weight, low fabrication cost, and the ability to fabricate feed lines and matching networks simultaneously with the antenna structure.

This project presents the design of microstrip patch antennas (MSPA), having a resonant frequency of 2.45 GHz, for Radio Frequency Identification (RFID) applications. A MSPA fed using inset feed was designed on a 4.4 permittivity Fr4 epoxy substrate. Later, a rectangular slot was added in order to further improve the performance of the antenna. The antennas have been simulated using the 3D EM High Frequency Structure Simulator (HFSS). The return loss, gain and radiation patterns of these Microstrip Patch Antennas were observed, analysed and compared to see which antenna has produced most optimum results and hence is ideal for RFID applications.

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I
INTRODUCTION

1.1 Project Objective

Radio Frequency Identification, commonly known as RFID is used to automatically identify and track tags attached to objects. It is a technology whereby digital data encoded in RFID tags or smart labels (defined below) are captured by a reader via radio waves.

In recent years, radio frequency identification technology has moved from obscurity into mainstream applications that help speed the handling of manufactured goods and materials. RFID enables identification from a distance, and unlike earlier bar-code technology, it does so without requiring a line of sight.

RFID tags are used in many industries. For example, an RFID tag attached to an automobile during production can be used to track its progress through the assembly line, RFID-tagged pharmaceuticals can be tracked through warehouses, and implanting RFID microchips in livestock and pets enables positive identification of animals. Tags can also be used in shops to expedite checkout, and to prevent theft by customers and employees.

An RFID tag can hold much more data about an item than a barcode can. In addition, RFID tags are not susceptible to the damages that may be incurred by barcode labels, like ripping and smearing. From the read distance to the types of tags available, RFID has come a long way and there is a bright future ahead.

At a simple level, RFID systems consists of three components: an RFID tag or smart label, an RFID reader, and an antenna. Microstrip patch antennas are being used for new high speed RFID reader systems. They are well suited for RFID reader systems due to their versatility, conformability, low cost, and low sensitivity to the manufacturing tolerances. The main advantage of patch antenna is its size which is relatively small compared to other radiators. Integrating microstrip patch antenna with RFID technology achieves significant performance and cost advantage due to its light weight, low fabrication cost, and the ability to fabricate feed lines and matching networks simultaneously with the antenna structure.

So, the main objective of this project is to develop a microstrip patch antenna that will produce optimal results in order for it be suitable for Radio Frequency Identification applications.

1.2 PROJECT OUTLINE

In this project, we will design various microstrip patch and slot antennas. Initially, microstrip patch antenna without any slots will be designed and simulated. Later, slots will be added and various antennas with different number of slots would be simulated using HFSS. The microstrip patch antenna designed will be for microwave frequency RFID tags.

This project presents the design of microstrip patch antennas (MSPA), having a resonant frequency of 2.45 GHz, for Radio Frequency Identification (RFID) applications. A MSPA fed using inset feed was designed on a 4.4 permittivity Fr4 epoxy substrate. Later, a rectangular slot was added in order to further improve the performance of the antenna. The antennas have been simulated using the 3D EM High Frequency Structure Simulator (HFSS). Taking into consideration, the return loss and the total gain as observed in the different designs of micro strip patch and slot antennas, the design having produced the most optimized results will be chosen as an effective solution for RFID applications.

II
RADIO FREQUENCY IDENTIFICATION (RFID)

2.1 Introduction to RFID

RFID stands for Radio Frequency Identification. It is a technology allowing devices to automatically identify information stored in a tag through radio waves. It is a technology which uses radio waves to automatically identify items or people. In general terms, Radio Frequency Identification systems consist of an RFID tag (typically many tags) and an interrogator or reader. The interrogator emits a field of electromagnetic waves from an antenna, which are absorbed by the tag. The absorbed energy is used to power the tag's microchip and a signal that includes the tag identification number is sent back to the interrogator. RFID belongs to a group of technologies referred to as Automatic Identification and Data Capture (AIDC) i.e,automatically identify objects, collect data about them, and enter those data directly into computer systems.

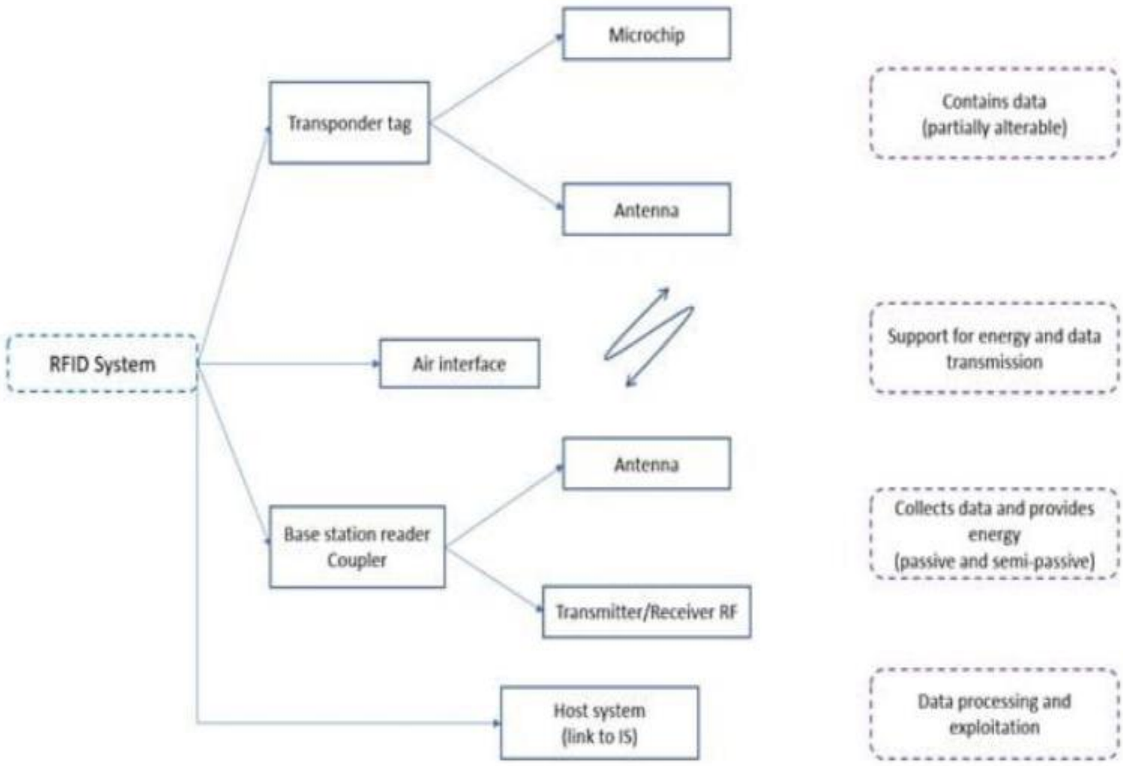

Figure 2.1: RFID system

RFID devices, commonly called tags, store information about a product in a digital format. The tag consists of a microchip that stores the information and an antenna that transmits the data. The tag may also be referred to as a label or transponder.
There are three basic types of RFID tags that are used to communicate with the readers: active, passive and semi-passive. RFID tags and readers communicate through a series of radiofrequency waves to transfer data. Depending on the type of tag being used, they can be read from a few centimeters to up to 200 meters away.

Through the use of RFID tags, users can uniquely identify their items to effectively track inventory or assets. Tags can store data in one of three ways: write once read many (WORM), read-only or read-write.

- **Write once, read many (WORM) tags** only allow information to be assigned to them once, and cannot be overwritten.
- **Read-only tags** have information stored in them during the manufacturing process. The information on these tags can never be changed.
- With **read-write tags**, information can be added or exchanged to the tag. However, most read-write tags have a serial number that cannot be changed.

2.1.1 Evolution of RFID

The use of RFID goes back to World War II, where it was used as a form of radar to locate Allied planes. In World War II, The Germans, Japanese, Americans, and British were all using radar to warn approaching planes from miles away. The British put transmitters on planes, which received signals from radar stations on the ground and broadcasted a signal back to identify the aircraft, thus, creating the first RFID system. Since then, RFID systems have come a long way. From Aerospace to logistics to football, RFID tracking systems are now on a very complex level, leaving users with incredible benefits.

Below is a quick history of the evolution of this technology –

Table 2.1: Evolution of RFID

YEAR	HISTORICAL FACT
1940	The concept of RFID is used for the first time to identify and authenticate aircraft in flight (IFF: Identify Friendly Foe). It is done to allow the identification of allied planes.
1970	From 1960-1970, RFID systems are kept as a confidential technology for military use to control access to sensitive sites, especially nuclear ones. But it seems that some companies have used it as well.
1980	Technological advances allow the appearance of the passive tag. The retro RFID tag modulates the wave radiated by the interrogator to transmit information. This technology eliminates the energy source embedded on the label, reducing its cost and maintenance.
1990	RFID technology begins to be normalized, allowing it to work with other systems.
1999	The Massachusetts Institute of Technology (MIT) founds the Auto-ID center. This is a research center specialized in automatic identification.
2003	The MIT center becomes EPCGlobal, an organization that promotes the Electronic Product Code (EPC), extending the barcode to RFID.
2005	RFID technologies are now widely used in almost all industrial sectors (aeronautics, automotive, logistics, transportation, health, daily life). The ISO (International Standard Organization) has largely contributed to the implementation of several standards (both technical and applied) to achieve a degree of interoperability.
2010	Creation of the National RFID Reference Center.

In 2004, Walmart was one of the first fortune 500 companies to implement RFID, spending up to 50 million USD on RFID initiatives and pilot programs. This is one of the key events that set the base of the "high cost" image that many people tend to associate with RFID. Not only has the price gone down immensely, but implementation is proven to bring you a substantial return on investment (ROI) in a short amount of time. Companies in manufacturing, warehousing, and retail are now known to achieve up to a 200% ROI.

Today, RFID is a fast evolving market with a bright future. One thing driving the demand for RFID is Omni-channel retailing. The growing eCommerce and mCommerce requires better inventory tracking and management than ever before, leaving RFID as the answer. The demand is so high that it is projected to grow to a 24.5-billion-dollar market by 2020. The most innovative companies have adopted this system, and the more retailers that implement RFID, the more the price will drop. EPC Global predicted that the cost per tag will drop to just 5 cents per tag.

RFID has the capability to deliver dramatic benefits to companies in many industries. The next step is to decide whether or not your company will either participate in these trends and seize opportunities, or potentially end up playing catch-up.

2.2 How does RFID work?

The operating principle of RFID systems is based on the remote exchange of electromagnetic waves. Specifically, the reader transmits a signal at a given frequency to one or more radio tags located in its reading field and they also transmit a signal back. The electromagnetic field feeds the label and activates the chip.

To transmit the information recorded in the chip, the chip creates an amplitude or phase modulation on the carrier frequency. Once this information is received by the reader, it transforms it into binary code. The operation remains symmetrical in the opposite direction.

Passive RFID tags have no power of their own and are powered by the radio frequency energy transmitted from RFID readers/antennas. The signal sent by the reader and antenna is used to power on the tag and reflect the energy back to the reader.

Active RFID tags have a built-in power source (usually a battery) and their own transmitter. These are mostly UHF solutions.

The scenario of a radio frequency identification is therefore as follows:

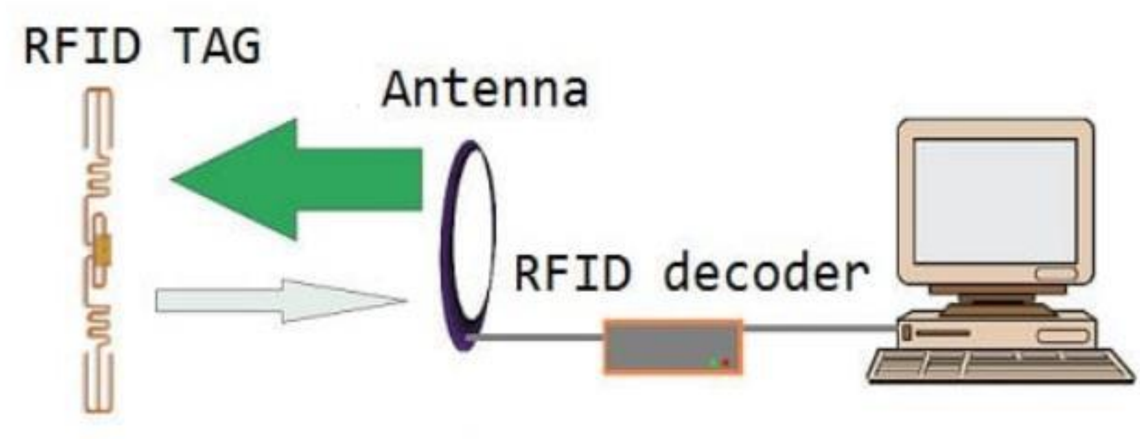

Figure 2.2: Working of RFID

1. The reader transmits energy by radio to activate the tag.
2. It queries the tags nearby.
3. It listens to the answers and eliminates duplicates or collisions between answers.
4. Finally, it transmits the results obtained to the concerned applications.

Most of the RFID systems operate on any of this two principles.

- Load Modulation
- Backscattered Modulations

A RFID reader stays powered on all the time and is normally powered from an external power source. So when it is ON, the oscillator in it generates a signal with a desired frequency but as the signal strength will be very less (which may lead to fading off the signal if it is transmitted directly) it has to be amplified which can be done using an amplifier circuit, inorder to propogate the signal to a longer distance we need to modulate the signal which is done by a modulator. With all these improvements the signal is now ready to be transmitted which can be done by an antenna which converts the electrical signal into a electromagnetic signal.

The RFID reader signals are everywhere with it's promity to detect a tag. When a RFID tag comes in the proxmity of the RFID reader the tag detects the readers signal through a coil present in it which converts the received RF signal into a electrical signal. This converted signal alone is sufficient to power up the microchip present in the tag. Once the microchip gets powered up, its function is to send the data (unique ID) which it is stored in it. The same way the signal came in, it is sent out through the same coil into the air.

As discussed earlier the RFID reader also has a transceiver in it. When the signal comes back from the tag through the antenna of RFID reader it is fed to the demodulator and then decoded by a decoder where the original data can be obtained and then further processed by a microcontroller or a microprocessor to perform a specific task.

Note that the above explanation is for a passive RFID tag. In case of an active RFID tag it detects the signal from the reader only to trigger the circuit and make the tag ready to send the data to the reader, since active tags have built-in power source.

Here are a few of RFID’s helpful features and functions:

- Tags can trigger alarms when moved
- Communication between readers and tags is not contingent upon orientation
- Data can be automatically read and stored
- Tags can carry unique or standardized product codes
- Items can be individually labeled, but read in mass
- Tag data is compatible with WMS and ERP systems
- Tags are difficult to reproduce/counterfeit

RFID tags contain an integrated circuit and an antenna, which are used to transmit data to the RFID reader .The reader then converts the radio waves to a more usable form of data. Information collected from the tags is then transferred through a communications interface to a host computer system, where the data can be stored in a database.

2.3 RFID Vs Barcode

Barcodes require individuals to manually scan each individual tag. Barcodes involve a line of sight, meaning the operator must see each tag he or she scans with a device. Individuals can oversee some tags or count other tags twice. Human error exists.

RFID, in comparison, is considered a non-line of sight technology. Users do not have to touch the packages or tags. The reader device operates via the RFID cloud. It can scan anything within a certain radius of the cloud. Counting can be done extremely efficiently and quickly without having a direct line of sight to the tag.

RFID technology is excellent for reducing labor time hours required for inputing manual data. It also improves data accuracy by eliminating human error risks. Instead of having to manually tag each individual package on a pallet, items can be bulk-wrapped and scanned from a distance.

Since barcoding is the foundation for proper inventory and item tracking, most businesses use it currently. Businesses can easily convert to the RFID technology. Converting simply means replacing barcode or serialized numbers with an RFID tag. Firms will also need to replace old barcode scanners with modernized RFID readers to make the transition.

Barcoding is time-consuming and requires more of a firm’s valuable resources. RFID technology saves time and frustration. It improves overall efficiency by utilizing lower amounts of company resources. In some cases, RFID technology can reduce tracking costs by three-fold. If your firm processes a minimal amount of high-dollar inventory items, though, it may not be worth the cost. RFID is ideal for companies needing to track large amounts of shipping and inventory.

RFID allows users to know exactly where products are located anywhere in the supply chain. Since information is available in real-time, users have the ability to see where items are in the supply chain. This RFID technology provides users with a perfect supply chain visibility. If a firm is unsure about whether RFID is a good fit, consulting with a professional at a barcode company can be a good idea.

Table 2.2: RFID Vs Barcode

	RFID	**Barcode**
Line of sight	Not required	Required
Read Range	Passive UHF RFID: 40 ft Active UHF RFID: 100+ ft	Several inches to several feet
Technology	Radio frequency (RF)	Optical laser
Identification	Uniquely identifies each item/asset tagged	Most only identify the type of item, but not uniquely
Interferance	Metal and liquids can interfere with some radio frequencies	Obstructed barcodes can not be read
Read / Write	Many RFID tags are read/write capable	Barcodes are read only
Automation	Most fixed readers ate automated and do not require human intervension	Most barcodes require human operation and are labor intensive

RFID does not to be scanned in a straight-line as barcode needs to scan a product. Barcodes are very cost-efficient compared to RFID. RFID can read the data from a bigger distance (10 feet to 30 feet approx.) than Barcode (From few inches to max. few feet). In many cases; barcode precision has been said to be the equivalent or surprisingly better than RFID tags. RFID Tags quickly read data compared to the barcode. Barcode is very simple to use as it is much smaller and lighter than RFID. RFID can read and write data, but barcode can only read data. Barcode can’t scan multiple items, so it provides accuracy and reliability. Hence, you don't have to worry about accidental scan. RFID can also maintain a product's history of maintenance, expiry date, etc.

The disadvantages of the barcode are as follows:

- It needs to be scanned in a straight line
- If the barcode is tempered there is no other way to scan the product
- Barcode only stores a small amount of data
- Barcode scanner needs to stay close to the product in order to scan the barcode

Advantages of RFID are as follows:

- RFID automatically collects data reducing human effort and error
- It does not need line to line to read data information
- It increases efficiency as it can read multiple tags at the same time
- RFID can read data from long distance
- The password is encrypted & data is secured. So, it provides great security
- RFID tags are reusable because they are covered with plastic

Figure 2.3: RFID Vs Barcode

2.4 Types of RFID systems

The RFIDs are broadly categorized into two types mainly based on the type of RFID tag used. The two systems are called Active RFID system and Passive RFID system.

1. Active RFID system

The Active RFID system has active tags which are powered up with a power source (a battery). So the active tags are capable of radiating their own Radio frequency signals to transmit the data that contains in the microchip, without depending upon the Reader's signals to power up. The active RFIDs are typically categorized under UHF RFID which has detection range up to 20 meters.

These active tags are further categorized into Transponders and Beacons.

a) Transponders:

As the name itself specifies that it receives a RF signal and emits another RF signal (usually data) as a response. The transponders are not active (powered up) all the time but they become active only when it detects a signal from a Reader and then powers up the microchip to get the data which is then transmitted back to the Reader. So transponders are the active tags which power ups only when the Reader transmits the signal. This allows the transponders to have high battery life compared to Beacons.

b) Beacons:

Beacons are the active tags which are powered up all the time but transmit the data only in specified time intervals (time interval can be once in a minute or once in a day). When the data is transmitted, corresponding Reader within its proximity detects the signal and respective action can be performed. Battery life span is low when compared to Transponders but is faster since it stays active all the time.

In the active RFID system, the reader sends signal to the tag using an antenna. The tag receives this information and resends this information along with the information in its memory. The reader receives this signal and transmits to the processor for further processing.

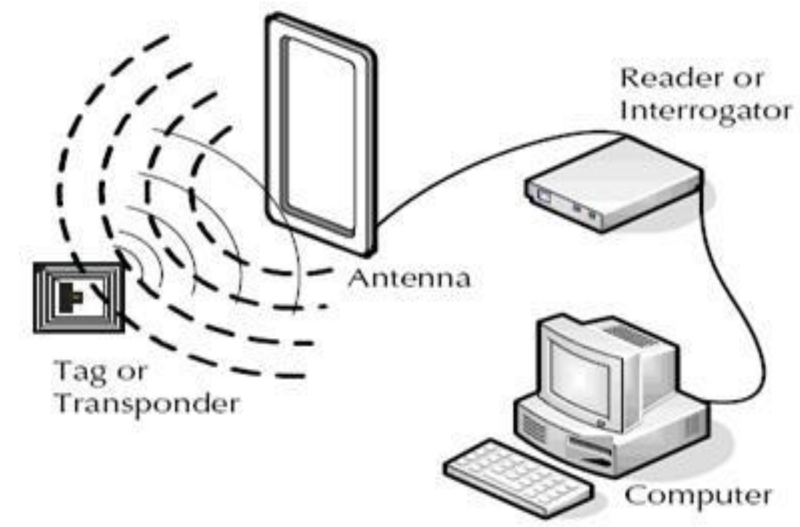

Figure 2.4: An Active RFID system

2. Passive RFID system:

This is the most commonly used type of system that you can find in ID cards, banking cards etc. It consists of passive tags which doesn't have any battery to power up the chip in the tag. Instead the Reader transmits the RF signals which are detected by the tag. These RF signals induce current into the tag's antenna which is then used to power up the chip. Then the tag responds with the data in the chip through the coiled antenna which is detected by the Reader and respective action will be performed. These are generally seen in maintaining attendance systems at offices and colleges.

A Passive RFID system using Induction coupling method: In this approach the RFID tag gets power from the reader through inductive coupling method. The reader consists of a coil connected to an AC supply such that a magnetic field is formed around it. The tag coil is placed in the vicinity of the reader coil and an electromotive force is induced it by the virtue of Faraday's law of induction. The EMF causes a flow of current in the coil, thus producing a magnetic field around it. By the virtue of Lenz law, the magnetic field of the tag coil opposes the reader's magnetic field and there will be a subsequent increase in the current through the reader coil. The reader intercepts this as the load information. This system is suitable for very short distance communication. The AC voltage appearing across the tag coil is converted to DC using rectifier and filter arrangement.

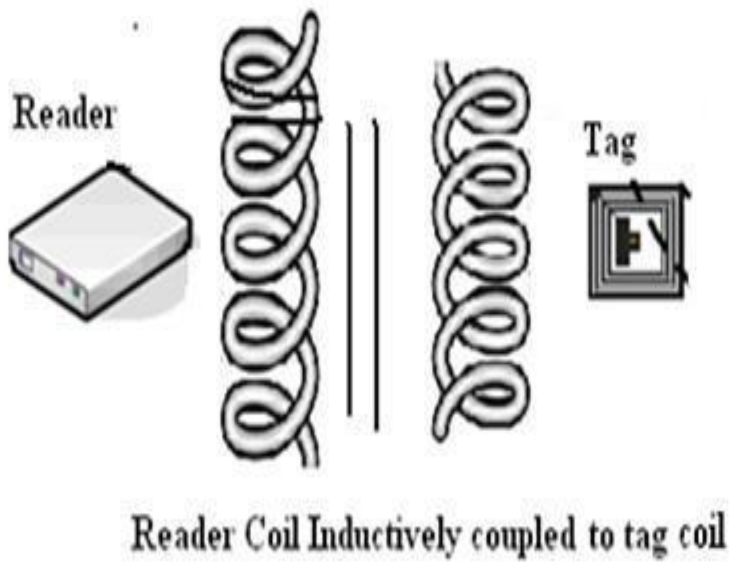

Figure 2.5: Passive RFID using Inductive Coupling

A Passive RFID system using EM wave propagation method: The antenna present in the reader transmits electromagnetic waves which are received by the antenna present in the tag as potential difference across the dipole. This voltage is rectified and filtered to get the DC power. The receiver antenna is kept at different impedance which causes it to reflect a part of the received signal. This reflected signal is received by the reader and monitored accordingly.

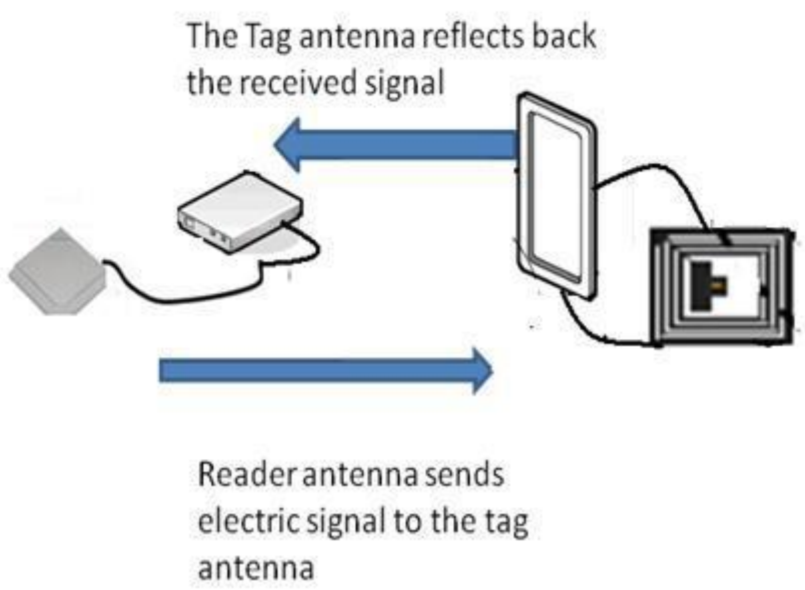

Figure 2.6: Passive RFID using EM-wave transmission

2.5 Applications of RFID

Applications that benefit from RFID are endless. These applications of RFID extend from broad areas like inventory tracking to supply chain management and can become more specialized depending on the company or industry. Types of RFID applications can span from IT asset tracking to textile tracking and even into specifics like rental item tracking.

What sets a potential RFID application apart from applications that can use other types of systems is the need to uniquely identify individual items quickly and more efficiently where traditional systems fall short. Below are a few applications that are successfully using RFID technology.

1.Logistics & Supply Chain Visibility

Winning in the supply chain means increasing efficiency, reducing errors, and improving quality. In chaotic manufacturing, shipping, and distribution environments, real-time data on the status of individual items provides insights that turn into actionable measures.

2. Item Level Inventory Tracking

Tracking assets on the item level is beneficial across a broad cross-section of industries, but the retail sector has one of the highest ceilings in terms of opportunity from the use of RFID. As mentioned above, tracking items through the supply chain is wonderful, but now think about tracking items through the supply chain all the way to the point of sale. With a well designed inventory system sharing data across all business units.

3. Race Timing

Timing marathons and races are one of the most popular uses of RFID, but often race participants never realize they're being timed using RFID technology, and that's a testament to RFID's ability to provide a seamless consumer experience.

4. Attendee Tracking

If you've ever managed a large conference before, you'll know that it's key to keep the flow of traffic moving at a steady pace, especially in and out of seminars. With an RFID attendee solution, eliminate the need for registration lines at entrances.

5. Materials Management

In construction and other related industries, materials are often the largest project expenditure. On large job sites, simply finding materials can be problematic. RFID solutions like Jovix take the guess work out of the equation.

6. Access Control

Certain areas require an expected level of security and access. From doors to parking lots, RFID access control tags restrict access to only those pre-approved.

7. IT Asset Tracking

IT assets such as server blades, laptops, tablets, and other peripherals are costly investments for any company, not to mention that information stored on those items could prove detrimental in the wrong hands. IT asset tags give your IT team the ability to quickly do an inventory count and make sure everything is in place.

8. Tool Tracking

For industries that rely on a large variety of tools, fasteners, and other items, managing the availability of those assets is a frustrating process. Depending on the level of complexity, RFID tool tracking systems track which tools have been grabbed, which employees have taken resources, and which resources haven’t been returned to the tool crib.

9. Kiosks

Many kiosks use RFID to either manage resources or interact with users. DVD rental kiosks use RFID DVD tags to make sure customers receive their selected movie rental. Other examples of RFID kiosks include interactive media displays where an embedded RFID reader interrogates badges or cards.

10. Library Systems

An RFID library solution improves the efficiency of circulation operations. While barcodes require line of sight, RFID tags can be read from multiple angles which means the checkout and check-in process is significantly faster. Also, as noted above in the retail section, taking inventory of books on the shelf is dramatically faster.

11. Laundry Management

Large companies like casinos often manage thousands of employee uniforms. With an RFID laundry management system, operations can track which uniforms were assigned to specific employees, the age of uniforms, the number of times washed, and identify missing uniforms. RFID laundry tags provide a new level of visibility for laundry management.

12. Interactive Marketing

RFID in marketing brings a certain level of interaction to campaigns. Whereas traditional advertising campaigns push a message onto the consumer, interactive campaigns invite the consumer to engage with the brand.

13. RTLS (Real Time Location System)

In some applications, you need to track the real-time location of assets, employees, or customers. Whether you're measuring the efficiency of worker movements, the effectiveness of a store floor plan, or tracking the location of valuable resources, RFID systems provide visibility in any number of locations.

2.6 Important Factors

1. Return on Investment (ROI)

When considering purchasing and deploying any new system, two of the most important questions to answer are if and when the company will see a return on its investment. Fixed costs, recurring costs, as well as the cost of switching in terms of labor costs, all must be evaluated before implementing a new system.

Before implementing an RFID system, both Application Feasibility and Cost Feasibility should be assessed.

2. Application Feasibility

Application Feasibility refers to the process of determining if the application is suitable for use with RFID. Like all technology, RFID has limitations. Environmental constraints, read range limitations, and asset material composition are just a few of the different aspects that can severely impact how effective an RFID system is for a specific application. The Application Feasibility process should entail scoping of the project and the project's environment as a starting point, and then determining if RFID (or another technology) is the right fit for the application.

3. Cost Feasibility

Cost Feasibility refers to assessing if implementing an RFID system is achievable from a monetary perspective. Cost Feasibility includes not just if an ROI is possible, but it also includes working with current numbers and prospective numbers to determine the estimated timeline for a return on investment. RFID systems can be expensive. They require an initial investment for testing and working with different types of equipment and tags (which may be a sunk cost for the company if the technology doesn't pan out). After the testing phase, deployment costs begin. Only after a system has been implemented and is working properly can the timeline begin for seeing a return on the investment.

Fixed Costs

Fixed costs are one-time costs that are associated with getting started. In an RFID deployment, a fixed cost is typically associated with hardware like readers, antennas, and cables needed to setup the system. Fixed costs do not necessarily mean that you will not ever purchase that item again, it just means that the item is not used once and then discarded or consumed during the application. If you plan to set up an initial system and then expand that system later, hardware will still be considered a Fixed Cost. RFID tags are only considered to be a fixed cost when they are continually reused throughout the system.

Recurring Costs

Recurring costs are attributed to items that are used once and then discarded or consumed during the application. An RFID label is a common example of a recurring cost in an RFID system. Because of their low-cost, these tags are frequently applied once and kept on an item for its lifespan (or discarded after use). If an RFID printer is used, then printer ribbon would also be a recurring cost. If a software license renews annually or is purchased as a SaaS (Software as a Service) product, then it too should be factored as a recurring cost.

4. Environmental Factors

RFID systems can be susceptible to certain materials and environmental factors that can cause diminished read ranges and affect overall system accuracy. Metal and liquids are the two most common sources of interference for RFID applications, but they can be mitigated with the proper RFID tags, equipment, and planning.

As UHF RFID becomes more commonly used with liquid-filled items or metallic items, more and more tags are released with new ways to lessen these problems. In addition, techniques have been developed that can help mitigate the effects of these items, like working with tag placement and spacers.

III
RFID COMPONENTS

3.1 RFID Reader

What is an RFID Reader?

An RFID reader is the brain of the RFID system and is necessary for any system to function. Readers, also called interrogators, are devices that transmit and receive radio waves in order to communicate with RFID tags. RFID readers are typically divided into two distinct types –Fixed RFID Readers andMobile RFID Readers. Fixed readers stay in one location and are typically mounted on walls, on desks, into portals, or other stationary locations.

A common subset of fixed readers is integrated readers. An integrated RFID reader is a reader with a built-in antenna that typically includes one additional antenna port for the connection of an optional external antenna as well. Integrated readers are usually aesthetically pleasing and designed to be used for indoor applications without a high traffic of tagged items.

Mobile readers are handheld devices that allow for flexibility when reading RFID tags while still being able to communicate with a host computer or smart device. There are two primary categories of Mobile RFID readers – readers with an onboard computer, called Mobile Computing Devices, and readers that use a Bluetooth or Auxiliary connection to a smart device or tablet, called Sleds.

Fixed RFID Readers typically have external antenna ports that can connect anywhere from one additional antenna to up to eight different antennas. With the addition of a multiplexer, some readers can connect to up to 32 RFID antennas. The number of antennas connected to one reader depends on the area of coverage required for the RFID application. Some desktop applications, like checking files in and out, only need a small area of coverage, so one antenna works well. Other applications with a larger area of coverage, such as a finish line in a race timing application typically require multiple antennas to create the necessary coverage zone.

Types of RFID Readers

The most common way to categorize readers is to classify them as either fixed or mobile. Other ways to differentiate between RFID readers include categories like connectivity, available utilities, features, processing capabilities, power options, antenna ports, etc.

- Frequency Range- 902 – 928 MHz US, 865 – 868 MHz EU, Etc.*
- Mobility– Fixed Readers, Integrated Readers; Mobile Readers
- Connectivity Options– Wi-Fi, Bluetooth, LAN, Serial, USB, Auxiliary Port
- Available Utilities– HDMI, GPS, USB, Camera, GPS, GPIO, 1D/2D Barcode, Cellular Capabilities
- Processing Capabilities– OnBoard Processing, No OnBoard Processing
- Power Options– Power Adapter, PoE, Battery, In-Vehicle, USB
- Available Antenna Ports– No External Ports, 1-Port, 2-Port, 4-Port, 8-Port, 16-Port

Reader Pricing

A reader will usually be the most expensive component in an RFID system. RFID readers can vary from around $400 to up to $3,000 or more depending on the features and capabilities required. One of the less-expensive classes of readers is USB readers, which has an average price point of around $400. USB readers generally have short read ranges and are used for desktop applications. Handheld readers and fixed readers vary greatly in pricing depending on features and functionality offered.

Selecting an RFID Reader

- How much read range do you require for your application?
- Any excessive environmental conditions to consider? Excessive heat, cold, moisture, impact, etc.?

- Will you be adding the reader to a network?
- Where will the reader be placed? Fixed location, or on a vehicle?
- Does the reader need to be mobile?
- How many read points/read zones will you need?
- How many tags might need to be read at one time?
- How quickly will the tags be moving through the read zone? For example, is this a slow-moving conveyor belt or fast-moving race?

How the reader is powered is one of the first things to note when purchasing an RFID reader. In certain applications, such as mobile, manufacturing, or warehouse-based, outlets are limited or unavailable, which narrows down the power options. Four options are available when deciding how to power an RFID reader.

1. Power Adapter – The most common way to power an RFID reader is plugging it into an outlet via a power adapter. Before using this method, ensure that an outlet is in close proximity to where the reader will be installed.

2. PoE – Another popular way to power an RFID reader is PoE, or Power over Ethernet. PoE uses an Ethernet cable to both power the reader and send/receive data. After setting up a reader via PoE, cabling can be run up to 100 feet and still reliably provide power to the reader. The advantage of using PoE (vs. a power adapter) is the elimination of the need to run AC power to a reader’s location, which may add up to considerable savings in moderate to large deployments.

3. Battery – Generally specific to mobile readers, batteries provide power while allowing the reader to be cordless and mobile. Batteries are very convenient but they still must be charged, usually after several hours of continuous use. A best practice is to have spare batteries along with a charging station that can charge multiple batteries at once.

4. In-Vehicle – Applications that require an RFID reader within a vehicle (e.g. truck, forklift, etc.) should consider a reader that has been developed specifically for use in vehicles. Powering an RFID reader through a vehicle is a great solution for reading

RFID tags while driving around large areas like laydown yards or for reading pallets as a forklift picks them up. Not many readers on the market have been designed specifically for such use, but the ones that have are ruggedized and contain loose wires that can be connected directly to the vehicle's wiring.

3.2 RFID Tags

What is an RFID Tag?

An RFID tag in its most simplistic form, is comprised of two parts – an antenna for transmitting and receiving signals, and an RFID chip (or integrated circuit, IC) which stores the tag's ID and other information. RFID tags are affixed to items in order to track them using an RFID reader and antenna.

RFID tags transmit data about an item through radio waves to the antenna/reader combination. RFID tags typically do not have a battery (unless specified as Active or BAP tags); instead, they receive energy from the radio waves generated by the reader. When the tag receives the transmission from the reader/antenna, the energy runs through the internal antenna to the tag's chip. The energy activates the chip, which modulates the energy with the desired information, and then transmits a signal back toward the antenna/reader.

On each chip, there are four memory banks– EPC, TID, User, and Reserved. Each of these memory banks contains information about the item that is tagged or the tag itself depending on the bank and what has been specified.

Hundreds of different RFID tags are available in many shapes and sizes with features and options specific to certain environments, surface materials, and applications.

Types of RFID Tags

Because there is such wide variety of RFID applications, there are also a wide variety of RFID tags and ways to categorize them. A common way to divide tags into types is inlays vs. hard tags. Inlays are cheaper, typically varying between $0.09 - $1.75 depending on the features on the tags. Hard tags are generally more rugged and weather resistant and vary between $1.00 - $20.00.

- Form Factor – Inlay, Label, Card, Badge, Hard Tag
- Frequency Type– LF, NFC, HF, UHF Passive (902 – 928 MHz, 865 – 868 MHz, or 865 – 960 MHz), BAP, Active
- Environmental Factors– Water resistant, Rugged, Temperature resistant, Chemical resistant
- Customizable– Shape, Size, Text, Encoding
- Specific Features/Applications– Laundry Tags, Sensor Tags, Embeddable Tags, Autoclavable Tags, Vehicle Tags, High Memory Tags
- Specific Surface Materials–Metal mount tags, Glass mount tags, Tags for Liquid-filled items

Based on frequency used, RFID tags are classified as follows:

a) Low Frequency:

- General Frequency Range: 30 - 300 kHz
- Primary Frequency Range: 125 - 134 kHz
- Read Range: Contact - 10 Centimeters
- Average Cost Per Tag: $0.75 - $5.00
- Applications:Animal Tracking, Access Control, Car Key-Fob, Applications with High Volumes of Liquids and Metals
- Pros: Works well near Liquids & Metals, Global Standards
- Cons: Very Short Read Range, Limited Quantity of Memory, Low Data Transmission Rate, High Production Cost

b) High Frequency:

- Primary Frequency Range: 13.56 MHz
- Read Range: Near Contact - 30 Centimeters

- Average Cost Per Tag: $0.20 - $10.00
- Applications: DVD Kiosks, Library Books, Personal ID Cards, Poker/Gaming Chips etc.
- Pros: NFC Global Protocols, Larger Memory Options, Global Standards
- Cons: Short Read Range, Low Data Transmission Rate

c) Ultra-High Frequency

- General Frequency Range: 300 - 3000 MHz
- Primary Frequency Ranges: 433 MHz, 860 - 960 MHz

There are two types of RFID that reside within the Ultra High Frequency range: Active RFID and Passive RFID.

i) Active RFID tags:

- Primary Frequency Range: 433 MHz, (Can use 2.45 GHz - under the Extremely High Frequency Range)
- Read Range: 30 - 100+ Meters
- Average Cost Per Tag: $25.00 - $50.00
- Applications: Vehicle Tracking, Auto Manufacturing, Mining, Construction, Asset Tracking
- Pros: Very Long Read Range, Lower Infrastructure Cost (vs. Passive RFID), Large Memory Capacity, High Data Transmission Rates
- Cons: High Per Tag Cost, Shipping Restrictions (due to batteries), Complex Software may be Required, High Interference from Metal and Liquids; Few Global Standards

ii) Passive RFID tags:

- Primary Frequency Ranges: 860 - 960 MHz
- Read Range: Near Contact - 25 Meters
- Average Cost Per Tag: $0.09 - $20.00

- Applications: Supply Chain Tracking, Manufacturing, Electronic Tolling, Inventory Tracking, Asset tracking
- Pros: Long Read Range, Low Cost Per Tag, Wide Variety of Tag Sizes and Shapes, Global Standards, High Data Transmission Rates
- Cons: High Equipment Costs, Moderate Memory Capacity, High Interference from Metal and Liquids

d) Microwave frequency RFID tags (SHF tags):

RFID systems that operate at microwave frequencies at 2.45 GHz and 5.8 GHz are known as SHF (Super High Frequency) RFID Systems. The frequency range in which SHF RFID systems operate are those which are globally unlicensed, allowing these systems to be used globally. However, these frequency bands are crowded and can be prone to interference as many devices such as cordless phones and microwave ovens use these frequencies.

SHF RFID systems are based on far-field radiative coupling or backscatter coupling principles. They have short wavelengths and can thus be used with metals.

They use a mix of passive, battery assisted and active tags based on what the application requires. These tags also have a large read range of over 300 feet. The read range for SHF Active RFID tags is significantly higher to active tags as compared to SHF passive tags.

Almost all microwave tags use 2.45 GHz. Microwave tags are available as passive, semi-passive, and active types. The passive and semi-passive tags use backscatter coupling to communicate with interrogators, and active types use their own transmitter to communicate. Passive microwave tags are usually smaller than passive UHF tags and have the same read range of about 15 feet. The semi-passive microwave tags have a read range of about 100 feet, while the active microwave tags have read range of about 350 feet. Passive microwave tags, due to low demand, are more expensive than passive UHF tags, but they share the same advantages and disadvantages.

Table 3.1: RFID Tags

Frequency Bands	Antenna	Data & Speed	Read Range	Usage
Low Frequency (LF) 125 kHz – 134 kHz	Induction Coil on Ferrite Core, or flat many turns	Low Read Speeds – Small Ammount of Data (16 bits)	Short to Medium 3-5 feel	– Access Control – Animal Tagging – Inventory Control – Car Immobilizer
High Frequency (HF) 13.56 MHz	Induction Coil flat 3-9 turns	Medium Read Speed Small to Medium amounts od Data	Short 1-3 feet	– Smart Cards – Item or Case level Tagging – Proximity Cards – Vicinity Cards
Ultra High Frequency (UHF) 860 MHz – 960 MHz	Single or Double Dipole	High Read Speed Small to Medium amount of Data	Medium 1-30 feet	– Pallet or Case Level Tagging – DOD & Walmart Mandates
Microwave Frequency 2.45 GHz & 5.4 GHz	Single Dipole	High Read Speed Medium Amount of Data	High 1-300 feet	– Container Rail Car – Auto Toll Roads – Pallet Level Tracking

3.3 RFID Antennas

What is an RFID Antenna?

RFID Antennas are necessary elements in an RFID system because they convert the RFID reader's signal into RF waves that can be picked up by RFID tags. Without some type of RFID antenna, whether integrated or standalone, the RFID reader cannot properly send and receive signals to RFID tags.

Unlike RFID readers, RFID antennas are dumb devices that receive their power directly from the reader. When the reader's energy is transmitted to the antenna, the antenna generates an RF field and, subsequently, an RF signal is transmitted to the tags in the vicinity. The antenna's efficiency in generating waves in a specific direction is known as the antennas gain. To put it simply, the higher the gain, the more powerful, and further-reaching RF field an antenna will have.

The RFID antenna gives off RFID waves along a horizontal or vertical plane, which is described as the antenna's polarity. If the RF field is a horizontal plane, is it described as horizontally linear, and the same principle applies to an RFID antenna that creates a vertical plane.

An antenna's polarity can have a significant impact upon a system's read range. The key to maximizing read range is to ensure an antenna's polarity aligns with the polarity of the RFID tag. If these do not match up, for instance, a vertical linearly-polarized antenna and a tag with a horizontal linearly-polarized antenna, the read range will be severely reduced.

A circularly-polarized antenna transmits waves that continually rotate between horizontal and vertical planes in order to give an application enhanced flexibility by allowing for RFID tags to be read in multiple orientations. However, because the energy is divided between two planes, a circularly-polarized antenna's read range is shorter versus a similar gain linear antenna.

Types of Antennas

RFID Antennas, like most RFID equipment, can be divided into different categories that help to narrow down the best antenna for an application. Even though antennas are grouped by a few different factors, the most common groupings for RFID Antennas are polarity (circular vs linear) and ruggedness (indoor vs. outdoor).

- Frequency Range– 902 – 928 MHz, 865 – 868 MHz, 860 – 960 MHz
- Polarity– Circular, Linear
- Ruggedness– Indoor IP Rated, Outdoor IP Rated
- Read Range– Proximity (Near-Field), Far-Field

- Mounting Type– Shelf Antenna, Ground Antenna, Panel Antenna, Portal Antenna

RFID Energy Flow

The way that energy flows through an RFID system is key to understanding RFID antennas and the role they play.

Energy enters an RFID reader through a power cord or Ethernet connection and is directed through the RFID reader, out one of the antenna ports and into the center pin of an RFID cable. It is then sent through the length of the cable and, depending on length and insulation rating of the cable, a small amount of energy is lost due to cable loss. Energy then moves through the opposite center pin, through the center antenna connection located on the grounding plate and into the radiating element. It is then radiated out in the form of RF waves toward the RFID tag in range.

The size and area of the RF waves depend on the gain and beamwidth of the antenna along with the size of the elements inside the antenna like the grounding and radiating plates. Each antenna is made with different elements so each one will radiate the waves differently in some aspect or another.

The waves are received by the RFID tag's antenna, sent to the integrated chip, and modulated with the pertinent information such as EPC or TID number. The tag then uses the leftover energy to backscatter RF waves back to the antenna. That information is then sent back through the antenna and cable and is decoded within the RFID reader.

Antenna Pricing

Most RFID antennas are typically priced between $50 and $300 per antenna, but there are a few that cost more because of key, application-specific factors, such as ground/mat antennas. These antennas are specialized for applications such as race timing and must be rugged enough to survive and perform well while people, bikes, or even go-carts run over them. Specialized antennas can increase a system's cost significantly but are also an investment that can be the difference between a functioning and non-functioning system.

Selecting an RFID Antenna

- How much read range do you need?
- Is it possible to always know or control the orientation of the RFID tag relative to the antenna's position in your application?
- Any excessive environmental conditions to consider? Excessive heat, cold, moisture, impact, etc.?
- Will the antenna be mounted indoors or outdoors?
- Size limitations (i.e. the antenna can be no larger than x by y by z inches)?

3.4 RFID Cables

RFID Antenna Cables facilitate communication between the RFID reader and RFID antenna. Without the cable, the reader cannot power and send signals to the tags via the antenna. Choosing an RFID cable may seem like an easier task than choosing other components; however, cables can vary greatly in three specific ways – connector types, length, and thickness/insulation rating – so, it is important to take all three into consideration before purchasing.

The longer the cable, the greater the loss. You can combat that loss by using a better-insulated, higher rated cable (see cable loss chart below). The downside to using a higher rated cable is that it is thicker and, as such, a little harder to work with as it doesn't bend as easily as its lower rated cousins.

If the desired read range is relatively short (only a few inches to a few feet), you may still be able to use a lower rated cable, but if you want to maximize read range, then you'll want to use a higher rated cable.

Lastly, when choosing a cable, you need to consider the gain of the RFID Antenna you are using. All things being equal (i.e. reader power setting, cable length and rating, RFID tag being used), if you were to use a low gain antenna(e.g. 5 dBic) vs. a higher gain antenna (e.g. 9 dBic) you'd see a big difference in read range. So, factoring in the gain of the antenna is important as it can impact the type of cable you need in order to achieve your desired results.

When determining the right connectors for either end of the cable, first look at the connectors on the RFID reader and the antenna. For example, if an RFID reader has an RP-TNC Female connector, one side of the cable should have an RP-TNC Male connector and vice-versa.

The cable length and thickness (also called insulation rating) will vary depending on your specific solution. The length of the cable is usually determined by how far apart the RFID reader and antenna are, but it’s important to note that, the longer the cable, the more power will be lost in transit. One way to combat that power loss it to use a higher insulation rating. The longer the length of the cable, the better insulated the cable needs to be in order to maximize efficiency and reduce the amount of power lost along the length of the cable. Of note, as the insulation rating increases, the cable will be thicker and more rigid, which will make it more difficult to bend and work with when turning corners or running through conduit.

Cables have one job – to transfer energy; but, just as important, cables must be properly built to combat potential energy loss. Energy loss happens in every system; the key here is to understand how it is lost from a cable in order tofight it.

Three components make up a coaxial cable, and are important to understand in order to select the correct cable for an application.

Length – The longer the cable, the farther the energy has to travel. No antenna cable is perfectly insulated; so, the farther the energy travels, the more energy it will lose. In some applications, the reader is farther from the antenna due to the nature of the application. If a long cable must be used, it is important to use the appropriate level of insulation required to combat loss.

Insulation Rating – The higher the insulation rating, the thicker and more protected the cable. The most common ratings used with UHF coaxial cables are 195 series, 240 series, and 400 series. The downside to a thicker, more insulated cable is that the cable is less pliable and could be difficult to position in a tight space.

Connectors – Connectors are located at both ends of a cable, and their type is determined by the connectors on the reader and antenna being used in the application. Later, this guide will walk through what types of connectors are compatible with each other.

IV
MICROSTRIP PATCH ANTENNA (MSPA)

4.1 Introduction to MSPA

An antenna that is formed by etching out a patch of conductive material on a dielectric surface is known as a patch antenna. The dielectric material is mounted on a ground plane, where the ground plane supports the whole structure. Also, the excitation to the antenna is provided using feed lines connected through the patch.Using a microstrip technique by fabricating on a printed circuit board thus is also known as Microstrip antenna or printed antenna.Micro strip antennas are low-profile antennas

A metal patch mounted at a ground level with a di-electric material in-between constitutes a Micro strip or Patch Antenna. These are very low size antennas having low radiation.

In telecommunication, a microstrip antenna usually means an antenna fabricated using photolithographic techniques on a PCB. It is a kind of internal antenna. They are mostly used at microwave frequencies. Most microstrip antennas consist of multiple patches in a two-dimensional array. The antenna is usually connected to the transmitter or receiver through foil microstrip transmission lines. The radio frequency current is applied (or in receiving antennas the received signal is produced) between the antenna and ground plane. Microstrip antennas have become very popular in recent decades due to their thin planar profile which can be incorporated into the surfaces of consumer products, aircraft and missiles; their ease of fabrication using printed circuit techniques; the ease of integrating the antenna on the same board with the rest of the circuit, and the possibility of adding active devices such as microwave integrated circuits to the antenna itself to make active antennas.

The most common type of microstrip antenna is commonly known as patch antenna. Antennas using patches as constitutive elements in an array are also possible. A patch antenna is a narrowband, wide-beam antenna fabricated by etching the antenna element pattern in metal trace bonded to an insulating dielectric substrate, such as a PCB, with a continuous metal layer bonded to the opposite side of the substrate which forms a ground plane. Common microstrip antenna shapes are square, rectangular, circular and elliptical, but any continuous shape is possible. Some patch antennas do not use a dielectric substrate and instead are made of a metal patch mounted above a ground plane using dielectric spacers; the resulting structure is less rugged but has a wider bandwidth. Because such antennas have a very low profile, are mechanically rugged and can be shaped to conform to the curving skin of a vehicle, they are often mounted on the exterior of aircraft and spacecraft, or are incorporated into mobile radio communications devices.

Microstrip patch antennas are widely used in the microwave frequency region because of their simplicity and compatibility with printed-circuit technology, making them easy to manufacture either as stand-alone elements or as elements of arrays.

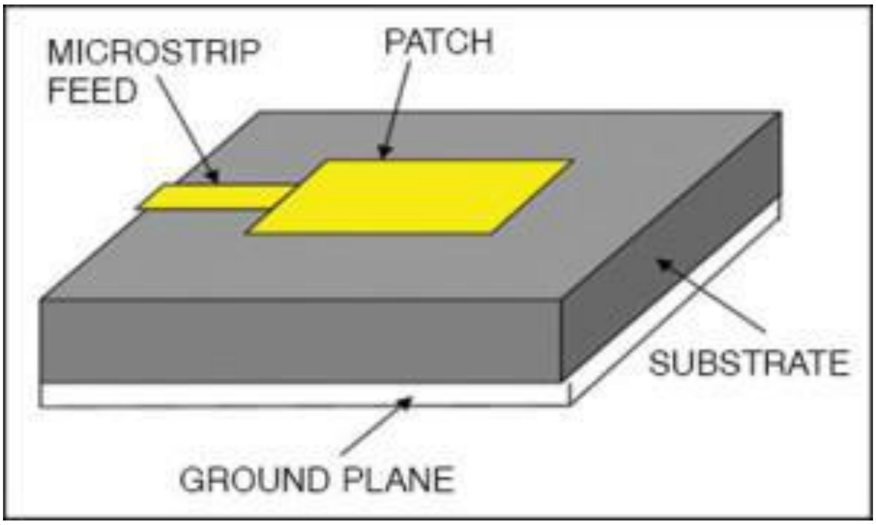

Figure 4.1: MSPA components

4.2 Antenna Parameters

1. Gain:

Gain is one of the realized quantities in antenna theory. In general, gain is less than directivity. It introduces ohmic and other losses. It is defined as the ratio of the radiation intensity in a given direction from the antenna to the total input power accepted by the antenna divided by 4π.

2. VSWR:

VSWR is for Voltage Standing Wave Ratio. It is the ratio of maximum to minimum voltage.
First, the reflection coefficient ρ can be written as the absolute value of the magnitude of a voltage reflection coefficient at the input terminals of the antenna.

3. Bandwidth:

The bandwidth of an antenna is the range of frequencies over which the antenna can operate properly. If the highest fre- quency of the band is FH, lowest frequency of the band is FL and the center frequency of the band is FC, then bandwidth can be defined as BW=100×(FH −FL)/FC
Different antennas have their own bandwidth as per its design considerations.

4. Return loss

Return loss is the reflection of the power of a signal, when it is entered in a transmission line.

5. Frequency Range

The patch antennas are popular for low profile applications at frequencies above 100MHz.

Characteristics of Microstrip Patch Antenna

1. The patch of the antenna must be a very thin conductive region, **t<<λ0** (: λ0 free space wavelength).
2. The ground plane must have comparatively very large dimensions than the patch.
3. Photo-etching is done to fabricate the radiating element and feed lines on the substrate.
4. A thick dielectric substrate with dielectric constant within the range of 2.2 to 12 provides good antenna performance.

5. Arrays of microstrip elements in the antenna configuration provide greater directivity.
6. Microstrip antennas provide high beamwidth.

A very high-quality factor is offered by a patch antenna. A large Q results in a narrow bandwidth and low efficiency. However, this can be compensated by increasing the thickness of the substrate. However, the increase in thickness beyond a certain limit will cause an unwanted loss of power.

4.3 Construction and Working of MSPA

Construction of a basic MSPA:

Patch antenna has 2D geometry. These antennas come in various shapes where its shape is defined by the shape of the metallic patch placed on the dielectric material.

The patches can be rectangular, square, circular, triangular, annular or elliptical in shape.

Suppose we have a rectangular patch antenna, which is formed by fabricating a rectangular metallic patch on a dielectric coated ground plane. This can be said in simple terms that a dielectric material having a conducting patch is supported by a ground plane.

Here we have shown the simplest form of patch antenna where the patch etched on the substrate is half-wavelength long while the thickness of the same is extremely less than λ. Also, excitation to the antenna is provided through feed lines connected to the patch.

Here the substrate which is nothing but the dielectric material is used to separate the strip from the ground plane.

The figure here represents the top view of the microstrip antenna:

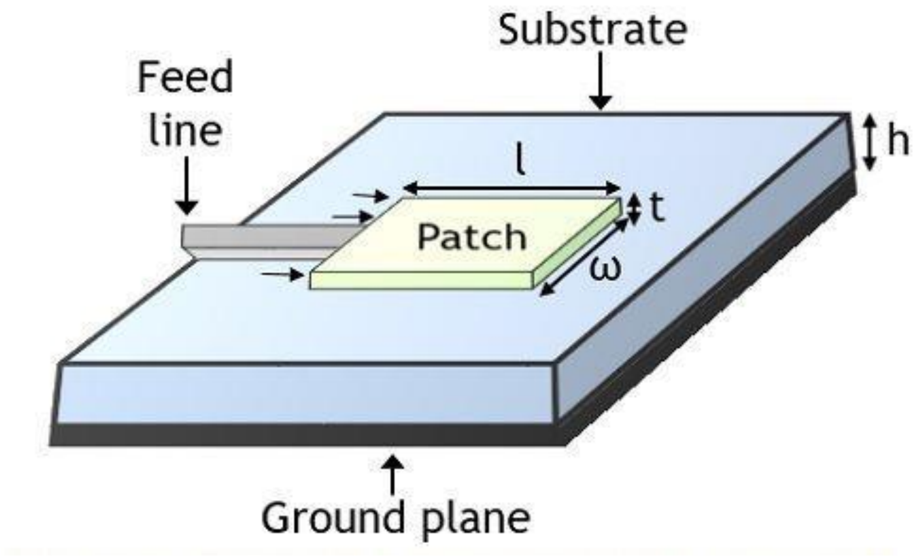

Figure 4.2: Structure of MSPA

Basically the patch or strip and the feed lines are photo-etched on the surface of the substrate. As we have already discussed that patches can be formed in multiple shapes, however, due to easy fabrication rectangular, circular or square-shaped patches are generally used.

Till now we have discussed a single patch etched on a substrate. But patch antennas can also be formed with a collection of multiple patches on a dielectric substrate. Either single or multiple feed lines are used to provide excitation to the antenna.

The presence of arrays of microstrip elements provides greater directivity, higher gain, increased transmission range with less interference.

Working of Micro strip Antennas:

A microstrip or patch antenna operates in a way that when current though a feed line reaches the strip of the antenna, then electromagnetic waves are generated.The radiating element and feed lines are placed by the process of photo-etching on the di-electric material. Usually, the patch or micro-strip is choosen to be square, circular or rectangular in shape for the ease of analysis and fabrication. The following image shows a micro-strip or patch antenna.

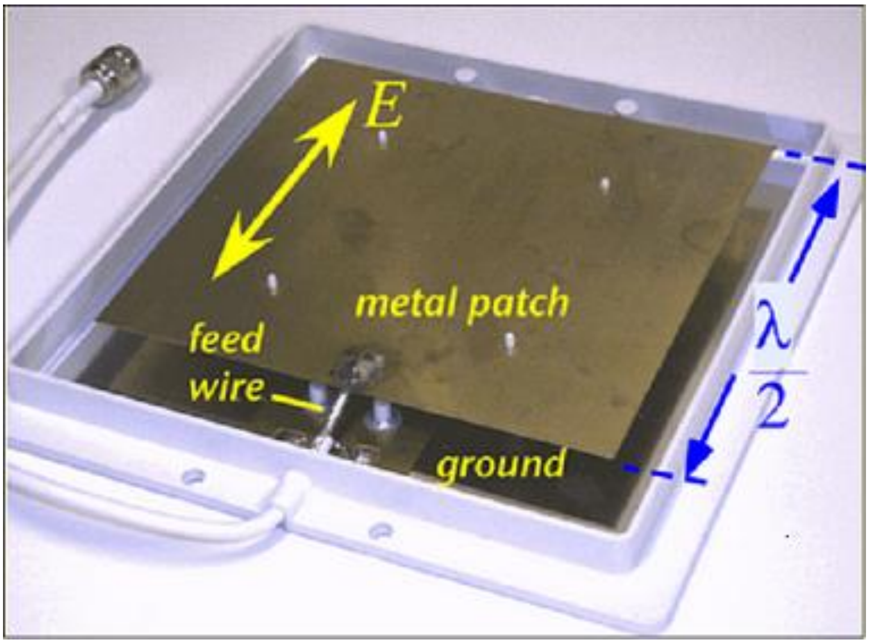

Figure 4.3: Practical MSPA

The length of the metal patch is λ/2. When the antenna is excited, the waves generated within the di-electric undergo reflections and the energyis radiated from the edges of the metal patch,which is very low.

4.4 SHAPES OF THE MICROSTRIP PATCH

Different shapes of the microstrip patch gives us the different output parameters. So, to get the better and efficient one, the shape and dimensions of the microstrip patch must be defined properly.The commonly available shapes of patch antenna are rectangular, circular, dipole, triangular, square,eliptical and circular ring. So, to get the better and efficient one, the shape and dimensions of the microstrip patch must be defined properly.

The following figure shows some of the common shapes of patches in use:

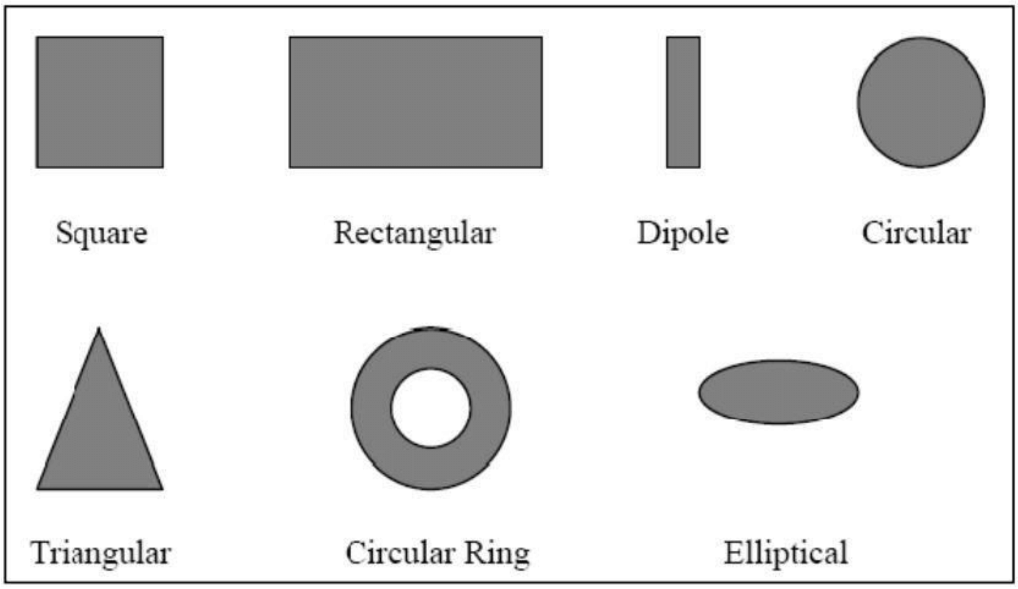

Figure 4.4: Different patch shapes

The most commonly employed microstrip antenna is a rectangular patch which looks like a truncated microstrip transmission line. It is approximately of one-half wavelength long. When air is used as the dielectric substrate, the length of the rectangular microstrip antenna is approximately one-half of a free-space wavelength. As the antenna is loaded with a dielectric as its substrate, the length of the antenna decreases as the relative dielectric constant of the substrate increases. The resonant length of the antenna is slightly shorter because of the extended electric "fringing fields" which increase the electrical length of the antenna slightly. An early model of the microstrip antenna is a section of microstrip transmission line with equivalent loads on either end to represent the radiation loss.

4.5 FEEDING TECHNIQUES

Feeding techniques are classified in two categories. The one is contacting and the other is non-contacting. There are four types of the feeding techniques and they are coaxial probe, microstrip line, aperture coupled and proximity coupled.

4.5.1 Coaxial Probe Feed

In this feeding method, inner conductor of coaxial cable is connected to the microstrip patch of an antenna and outer one is connected with ground plane. Mostly, the feed networks are isolated from the microstrip patch, but in this mechanism, it is not like that. Spurious radiation minimization, easy fabrication and efficient feeding are the advantages of coaxial feeding method.

Advantages

- Easy of fabrication
- Easy to match
- Low spurious radiation

Disadvantages

- Narrow bandwidth
- Difficult to model specially for thick substrate
- Possess inherent asymmetries which generate higher order modes which produce cross-polarization radiation.

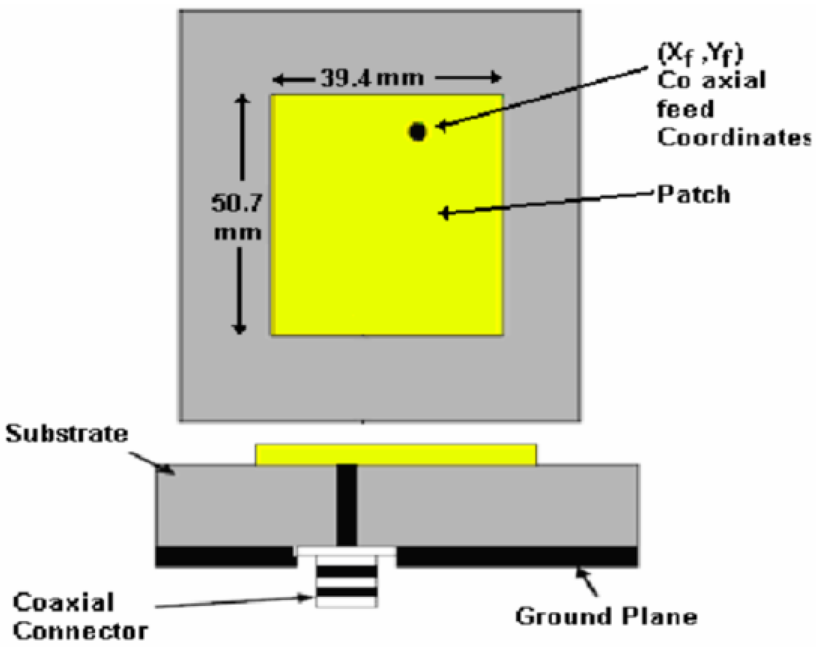

Figure 4.5: Microstrip coaxial probe feed

4.5.2 Microstrip Line Feed

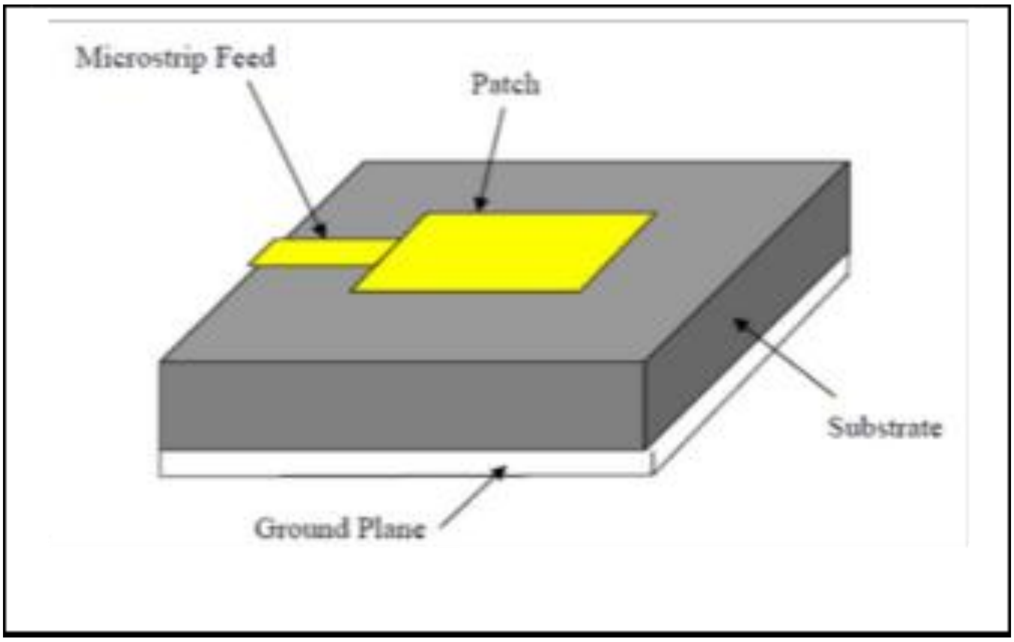

Figure 4.6: Microstrip Line Feed

Microstrip line feed is one of the easier methods to fabricate as it is a just conducting strip connecting to the patch and therefore can be consider as extension of patch. It is simple to model and easy to match by controlling the inset position. However the disadvantage of this method is that as substrate thickness increases, surface wave and spurious feed radiation increases which limit the bandwidth

It is a feeding technique, in which the microstrip patch is di- rectly connected with the conducting microstrip feed line. The dimensions of the feed line are different than microstrip patch. It is easy to fabricate and match. The microstrip line feed is as shown in Figure 4.6.

4.5.3 Aperture Coupled Feed

Aperture coupling consist of two different substrate separated by a ground plane. On the bottom side of lower substrate there is a microstrip feed line whose energy is coupled to the patch through a slot on the ground plane separating two substrates. This arrangement allows independent optimization of the feed mechanism and the radiating element. Normally top substrate uses a thick low dielectric constant substrate while for the bottom substrate; it is the high dielectric substrate. The ground plane, which is in the middle, isolates the feed from radiation element and minimizes interference of spurious radiation for pattern formation and polarization purity.Its advantage is that it allows independent optimization of feed mechanism element.This feed is having two substrates, which are different from each other and are separated by a ground plane. In this method, the microstrip patch and feed line are coupled through a slot in the ground plane. Minimization in inter- ference and pure polarization are the advantages of aperture coupled feeding method. The aperture coupled feed is as shown in Figure 4.7.

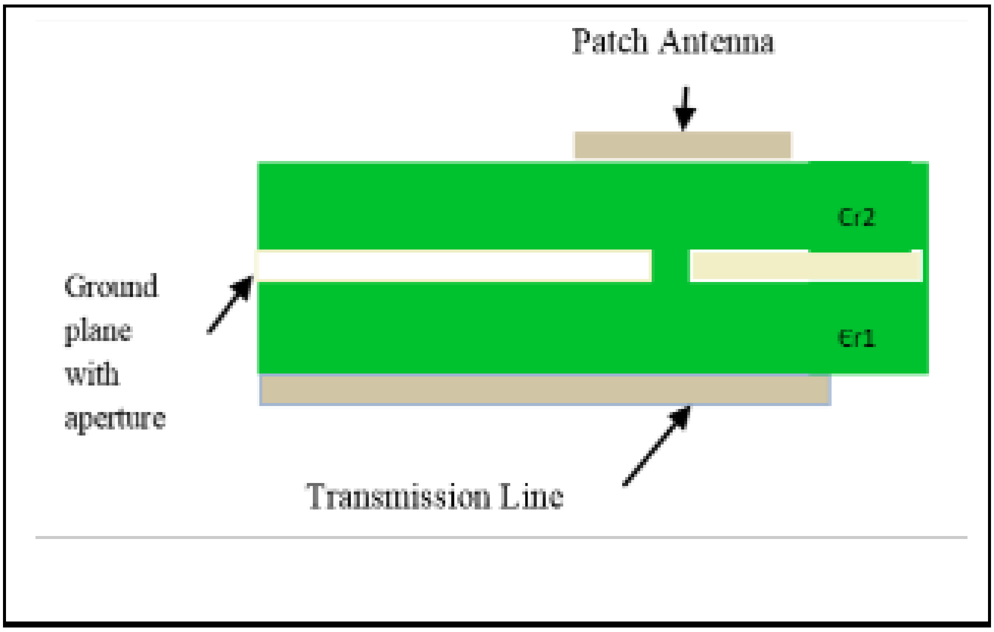

Figure 4.7: Aperture Coupled Feed

4.5.4 Proximity Coupled Feed

Proximity coupling has the largest bandwidth, has low spurious radiation. However fabrication is difficult. Length of feeding stub and width-to-length ratio of patch is used to control the match.

The fabrication of this feeding method is bit complicated com- paratively. Two dielectric substrates are used in this tech- nique. The microstrip patch is there at the upper surface of the upper dielectric substrate and the feed line is there between two substrates. It provides highest bandwidth and avoids spu- rious radiation. The proximity coupled feed is as shown in figure 4.8.

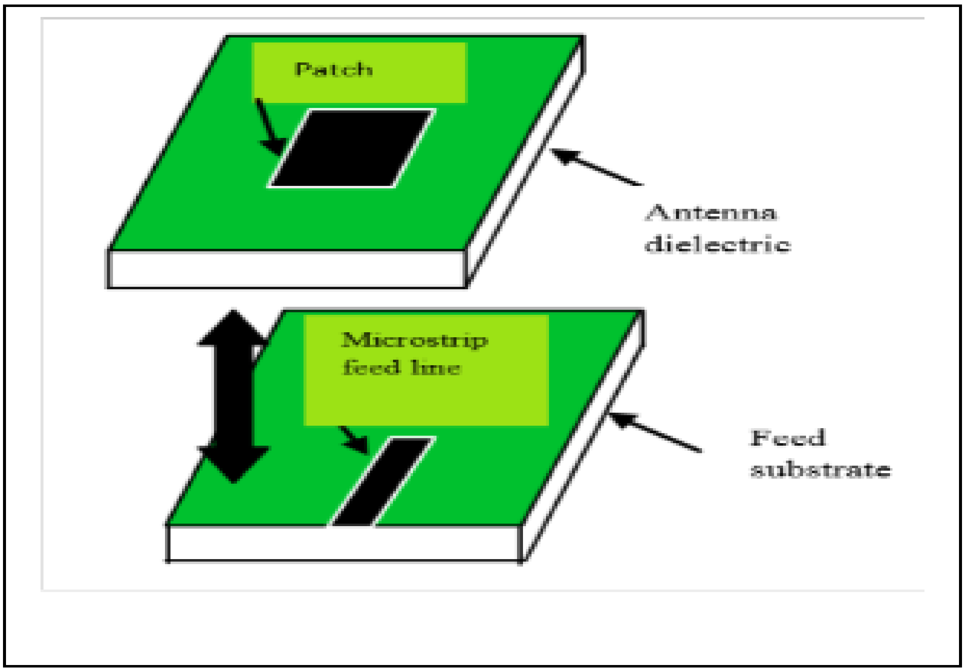

Figure 4.8: Equilateral Triangle Shaped Patch

Table 4.1: Comparision of different feeding techniques

Characteristics	Microstrip Line Feed	Coaxial Feed	Aperture coupled Feed	Proximity coupled Feed
Spurious feed radiation	More	More	Less	Minimum
Reliability	Better	Poor due to soldering	Good	Good
Ease of fabrication	Easy	Soldering and drilling needed	Alignment required	Alignment required
Impedance Matching	Easy	Easy	Easy	Easy
Bandwidth (achieved with impedance matching)	2-5%	2-5%	2-5%	13%

4.6 Effect of Slots on MSPA

The basic concept is that a slot in the ground plane behaves as a load which when added to the antenna can be used to bring the input impedance point closer to the characteristic impedance (e.g. 50ohms). This improves the input impedance match and hence the S11. Ofcourse multiple slots placed in close proximity will couple with each other giving more complicated impedance patterns.

1. EFFECT ON SLOTS ON THE GAIN

Gain relates the intensity of antenna in a given direction to the intensity that would be produced by a hypothetical ideal antenna that radiates equally in all direction or isotropically and has no losses. By using high permittviity substrate and by different shape of slot we can enhance the gain of antenna.

2. EFFECT OF SLOTS ON RETURN LOSS

Return loss is the difference between forward and reflected power in dB generelly measured at the input to the coaxial cable connected to the antenna. If the power transmitted by the source is and the power refelcted back is then return loss is given by divided by . For maximum power transfer the return loss should be as small as possible. This means ratio ⁄ should be small as possible.Selection of feeding technique for a microstrip patch antenna is important decision because its affects the bandwidth ,return loss ,VSWR patch size and smith chart. Using double or dual slot stacked patch technique use can get better return loss by increases the length and width of slot antenna return loss can be reduced.

3. EFFECT OF SLOT ON RADIATION PATTERN

Radiation patterns of slots are computed by using E fields slot behave as magnetic dipole when the slots are at ground plane. The E plane radiation pattern changes significantly for the finite size ground plane. This is due to diffraction effects from the edges of the finite size ground planes. The E plane radiation pattern extented ground plane shows that the slots tends to become magnetic dipole. Due to lack of some experimental facilities the measured results are not provided. The radiation pattern by slot show the diffraction effects from the edges of finite size ground plane only affects the E plane radiation patterns of slots.

By using different shape of slots we can improve efficiency of antenna as compared to conventional microstrip patch antenna. By the use of slot we can enhance bandwidth, gain. Axial ratio and radiation pattern is also improved. By the use of slot microstrip antenna can be used in many application.

V
RESULTS AND DISCUSSIONS

5.1 Modelling and Simulation

The resonate frequencies used for operation of microwave frequency RFID tags is is 2.45 GHz and 5.4 GHz. In this project, antennas were designed for 2.45 GHz frequency, which is for microwave frequency tag.

The MSPA designed has been further optimized utilizing slot antenna technique. This project proposes two different microstrip patch slot antennas (MSPSA) that has been comparatively analyzed and modeled using HFSS. The first design initiates microstrip patch antenna with its rectangular patch. It is simulated using Fr4 epoxy substrate having permittivity of 4.4. The modeled patch has a width of 27.3 mm and a length of 38 mm. The height of substrate was chosen as 3.6 mm. Further, the gain was improved by adding slots as shown in remaining designs.

5.1.1 Antenna Design 1

The first design of microstrip patch antenna is with a rectangular patch of width of 27.3 mm and a length of 38 mm above on Fr4 epoxy substrate. This substrate has a relative permittivity of 4.4. The material assigned to ground plane and patch is conducting copper material. Inset feeding is used and the microstrip patch antenna is excited using lumped port. This design has no slots as shown in figure 5.1.

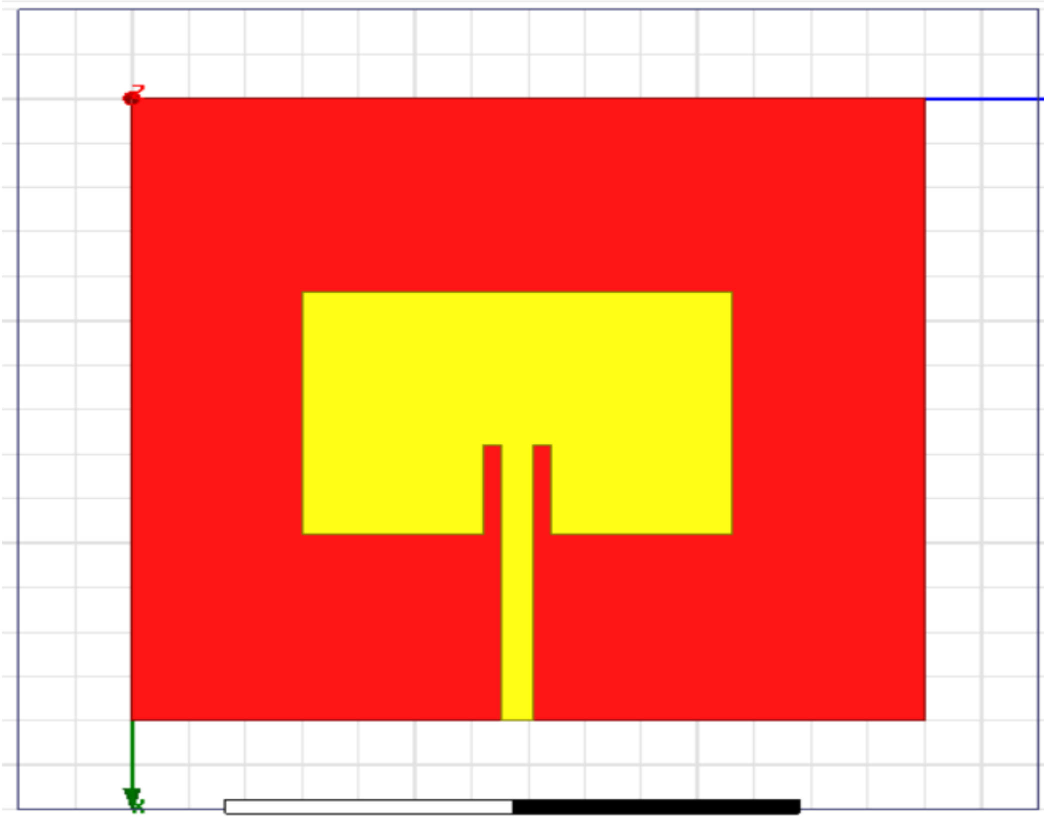

Figure 5.1: MSPA design 1 (no slots)

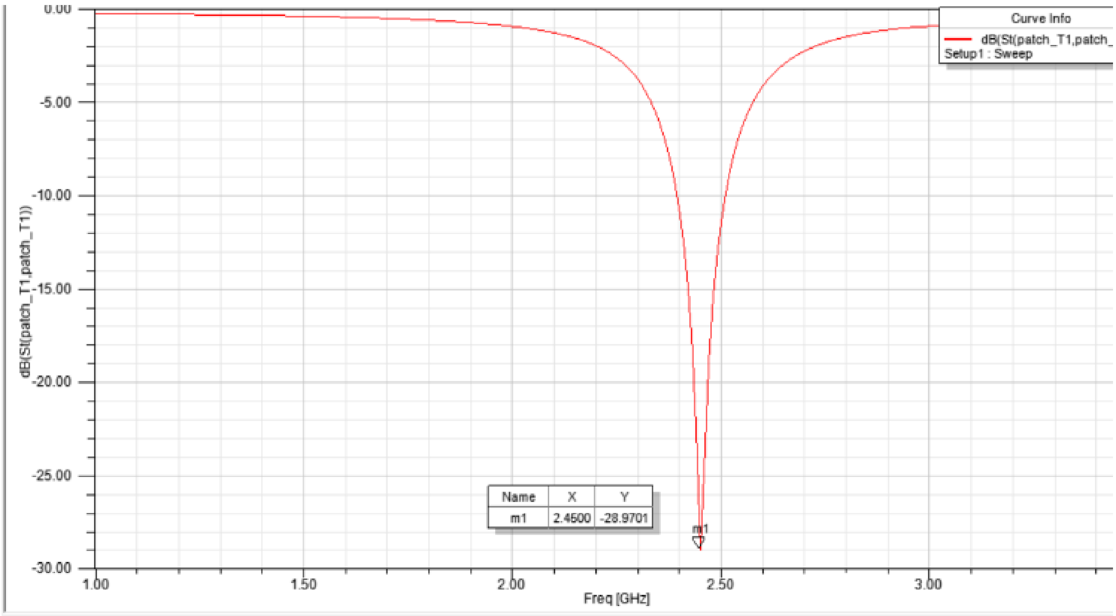

Figure 5.2: Return Loss (S11) for MSPA design 1

This microstrip patch antenna design 1 structure has been modeled and simulated using HFSS environment. This design has produced a return loss (S11) well above the nominal value of -10 dB, which is -28.9 dB at 2.45 GHz resonant frequency as shown above in figure 5.2.

Also, the parameter most important for RFID applications is the antenna gain. The greater is the gain, greater will be the directivity. This design has produced a gain of 4.75 dB as shown below in figure 5.3.

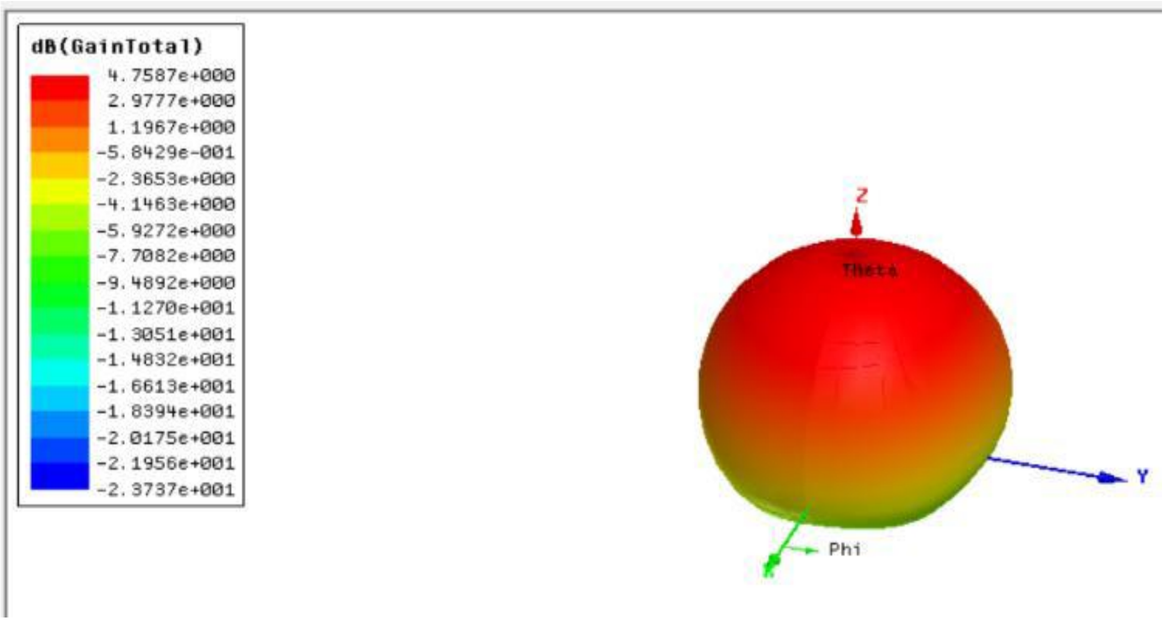

Figure 5.3: Gain for MSPA design 1

5.1.2 Antenna Design 2

Microstrip patch antenna has been designed with a rectangular patch of length 27.3mm and width 38mm on Fr4 epoxy substrate. The material assigned to ground plane and patch is conducting copper material. Inset feeding is used and the antenna is excited using lumped port. To this, a single rectangular slot of length 1.55mm and width of 4.65mm has been introduce exactly to the side opposite to the feedline as shown in the figure 5.4.

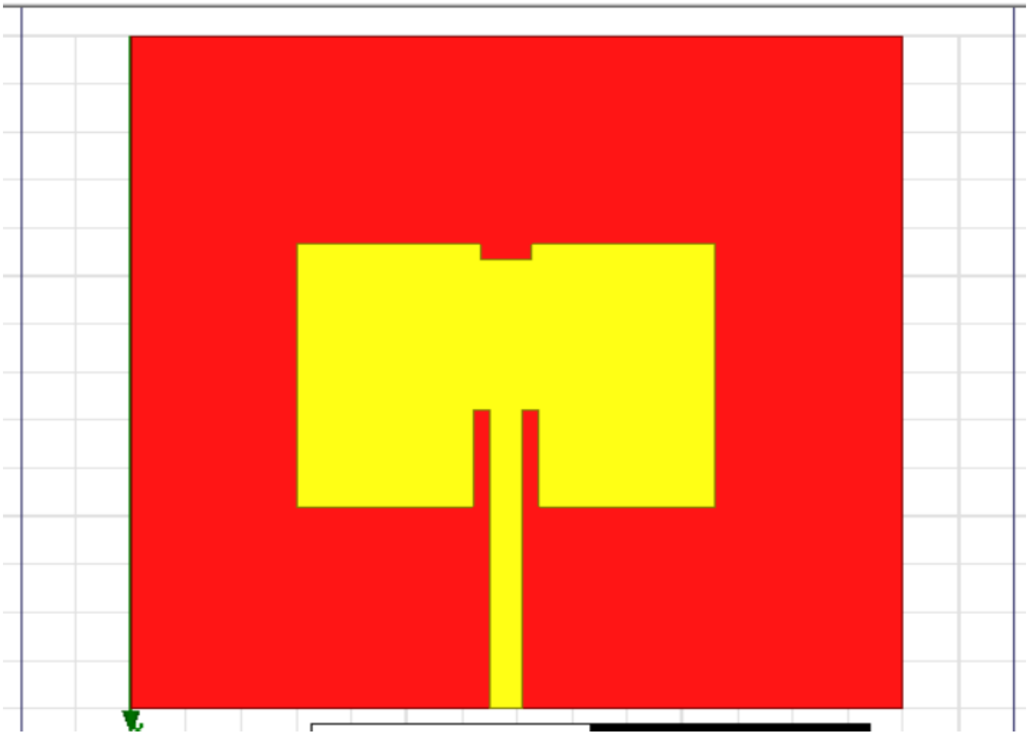

Figure 5.4: MSPA design 2 (one rectangular slot)

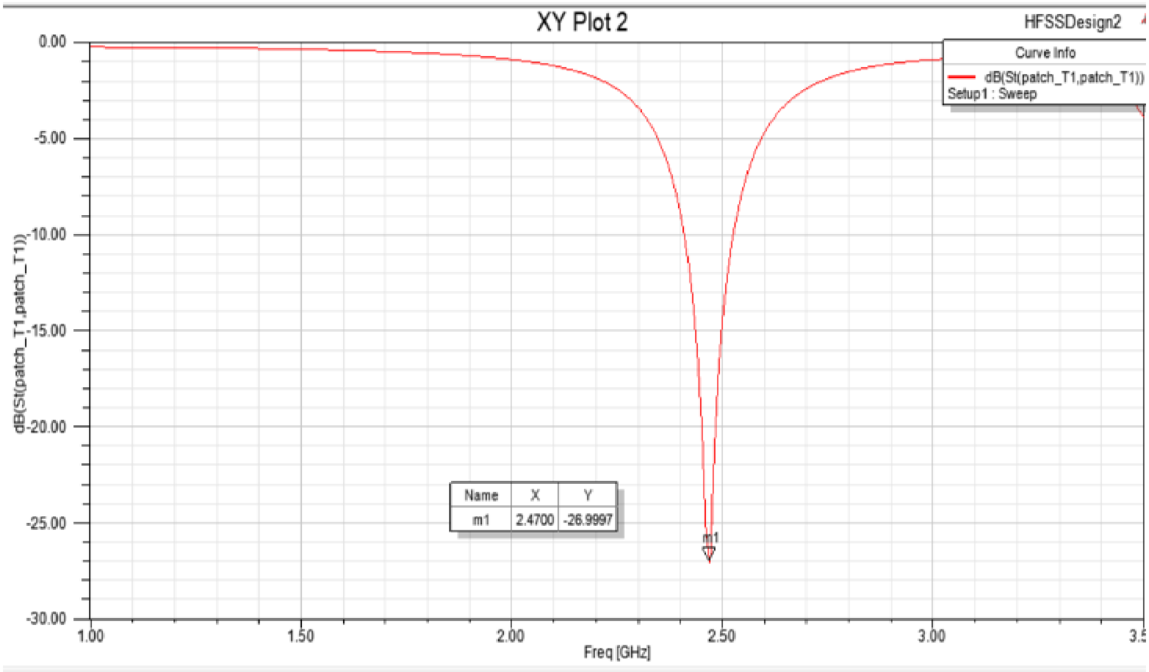

Figure 5.5: Return Loss (S11) for MSPSA design 2

This MSPSA design 3 with one rectangular slot has produced a return loss (S11) of -26. dB, which is also well below the nominal S11 value of -10 dB at 2.45 GHz resonant frequency as shown above in figure 5.5. We have to note that though the return loss is slightly increased when compared to design 1, this value of S11 is also optimal for the required application.

Also, this design has produced a total gain of 4.89 dB as shown below in figure 5.6. It can be seen that the gain has improved from 4.75 dB to 4.9 dB when compared to design 1 while the return loss remains nearly the same.

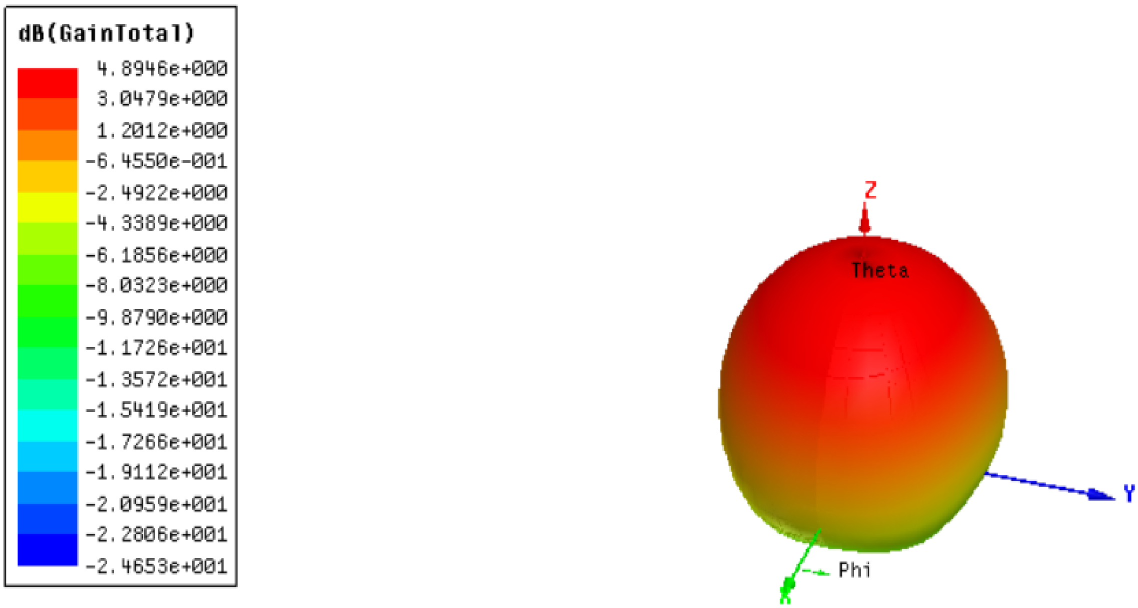

Figure 5.6: Gain for MSPSA design 2

5.2 Results and Analysis

The microstrip patch (MSPA) design 1 provides a gain of 4.75 dB, and a return loss (S11) of -28.6 dB while the microstrip patch slot antenna (MSPSA) design 2 have achieved a total antenna gain of 4.9 dB and a return loss (S11) of -27 dB at 2.45 GHz for a patch length of 27.3mm and width of 38mm. The most important parameter for an antenna used for RFID applications is that it must have relatively good gain as higher is the gain, higher will be the directivity. Thus, it is clear that though the results produced by the antenna in design 1 are good, introducing one slot technique as seen in design 2 has further improved the antenna gain.

Table 6.1: Antennas performance comparison

DESIGN	RETURN LOSS	GAIN
Design 1	-28 dB	4.75 dB
Design 2	-27 dB	4.9 dB

CONCLUSIONS

It can be seen from the results that both designs of microstrip patch antenna have produced results that are good enough for the targeted application but, the gain of the antenna being the much important factor here, it is clear that design 2 of microstrip patch antenna having a single rectangulat slot has improved gain when compared to patch antenna design 1, having no slots.

Also, we have to note that though the return loss for design 2 is slightly increased when compared to design 1, this value of S11 is still optimal for the required application as it is much below the minimum requirement of -10 dB.

Hence, it can be concluded that the microstrip patch slot antenna (MSPSA) with a single rectangular slot as shown in design 2 has produced the most optimized results at the required 2.45 GHz resonant frequency and therefore, it can be used in a microwave tags (also known as SHF tags) for RFID applications.

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PAPER PUBLICATION DETAILS

Our paper titled “**Novel Design of Microstrip Patch Antenna for RFID Applications**” has been sent for possible publication in **ICTACT Journal on Communication Technology**. The paper has been assigned an ID: IJCT/4197 by the journal and is to undergo a plagiarism checking process and then peer blind review process to proceed with the publication.