# Design of a Microstrip-Line-Fed Inset Patch Antenna for RFID Applications

Nazish Irfan, Mustapha C. E. Yagoub, and Khelifa Hettak

***Abstract*—Radio Frequency Identification (RFID) systems, due to recent technological advances, have been used for various advantages in industries like production facilities, supply chain management etc. Since used in wide range of applications, RFID systems demand low cost and low profile antennas. Microstrip patch antenna offers a potential solution and therefore is a popular printed resonant antenna for narrow-band applications. In this paper, a 2.42 GHz inset fed patch antenna has been designed for RFID applications with a gain of 4.6772dB and a return loss of -21.0579 dB.**

***Index Terms*—RFID, antenna, reader, inset fed, gain.**

## I. Introduction

Radio Frequency Identification (RFID) is based on radio communication for tagging and identifying an object [1]. It consists of two blocks namely, RFID transceivers (readers) and RFID transponders (tags). A RFID tag consists of a small integrated circuit for storing information and an antenna for communication. A basic RFID system is based on wireless communication between a reader and a tag. RFID readers can read information stored in no line-of sight RFID tags in their vicinity and communicate it to central database system through wired or wireless interface [2]. Over the last few years, RFID has drawn a great deal of attention and it is now widely believed that RFID can bring revolutionary changes [3]. Indeed, applications of RFID systems include supply chain automation, security and access control, cold chain management (temperature logging) and identification of products at check-out points, to name a few. Some of the major retailors have already invested significantly in RFID and mandated their manufacturers to place tags on cases and pallets, which resulted in mass production of inexpensive RFID tags [4].

In recent years, more efforts have been made to implement RFID applications in inventory control and logistics management. RFID based system leads to significant reduction on processing time and labor as inventory in warehouses can be tracked more accurately in a simple, timely and more efficient manner. More importantly, RFID based system provides complete visibility of accurate inventory data, from manufacturer's warehouse, shop floors and brings opportunities for improvement and transformation in various process of the entire supply chain [5].

Integration of RFID systems with wireless sensors has broadened the scope of RFID applications. RFID tags can be interfaced with external sensors such as shock, temperature, and light sensors. Similar to wireless sensor networks, RFID systems can be deployed on-line instead of pre-installed statically [2].

RFID readers are transceivers which transmit and receive at the same time at the same frequency. To maximize read range, readers typically transmit with maximum allowable power using directional antennas with high gain. For proper decoding and detection of weak tag signals, good isolation between transmit and receive channels is very important [6]. Fig. 1 shows a typical RFID system.

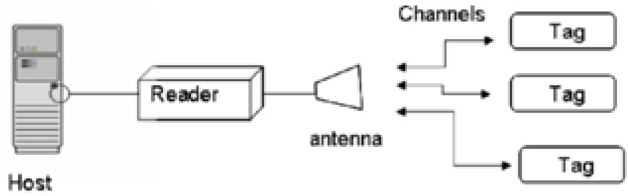


Fig. 1. Typical typical RFID system.

In a RFID system, the reader is at heart, a radio transceiver that communicates with tags. Many different varieties of reader antennas are available and the proper choice is often guided by the regional regulations for maximum allowable radiated power and antenna beamwidth. As per applications demand, RFID systems can use advanced antennas such as switched beam antennas, smart antenna arrays, etc. To reduce the size of the antenna and to achieve wideband, different techniques such as meandered ground plane, chip loading, feed modification, stacked shorted patch, slot-loading and teardrop dipole in an open sleeve structure have been reported [7]. Several frequency bands have been assigned to the RFID applications, such as 125 kHz, 13.56, 869, 902 - 928 MHz, 2.45 and 5.8 GHz [8]. According to ISO-18000 (International Standard Organization), the operated frequency range of the 2.45 GHz RFID band is 2400 - 2483.5 MHz, and the bandwidth is about 83 MHz, i.e. a narrow bandwidth compared to UHF RFID band of 860-960 MHz. The frequency of 2.4 GHz is higher than that of UHF RFID so the size of the tag antenna is smaller. Thus, the application of 2.45 GHz RFID system can be applied to the smaller objects and systems [6].

This paper presents the design and simulation of an inset fed patch antenna. The antenna is designed at resonant frequency of 2.425 GHz and was intended for RFID applications.

The remainder of this paper is organized as follows: Section II briefly presents the proposed microstrip patch antenna design. Section III summarizes the antenna simulations and results and finally Section IV concludes the proposed work.

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## II. Antenna Design

### A. Microstrip Patch Antennae

Microstrip antennas, in recent years, have been one of the most innovative topics in antenna theory and design. The basic idea of microstrip antenna came from utilizing printed circuit technology not only for the circuit component and transmission lines but also for the radiating elements of an electronic system. They are used in wide range of modern microwave applications because of their simplicity and compatibility with printed-circuit technology. It is easy to manufacture and either as stand-alone elements or as elements of arrays.

A microstrip antenna in its simplest form consists of a rectangular (or other shapes such as circular, triangular …) on top of a substrate which is backed by a ground plane [9]. Fig. 2 shows a typical microstrip patch.

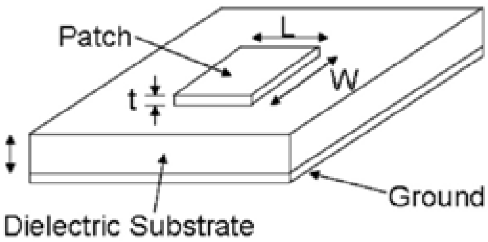


Fig. 2. Typical microstrip patch.

There are various types of feeding methods available for patch antennas. In general, the microstrip antenna is fed either by strip line or coaxial line. In either case, electromagnetic energy is first guided along the feed line to the region under patch, which acts like a resonant cavity with open circuits on the sides. Some of the energy leaks out of the cavity and radiates into space, resulting in antenna. There is another form of non-contracting feed available, called aperture coupled. The aperture coupled feed eliminates feed-line radiation and also allows thick substrate as probe reactance is not an issue.

Microstrip antennas radiate a relatively broad beam broad-side to the plane of the substrate. Thus the microstrip antenna has very low profile, and can be fabricated using printed circuit techniques. This implies that the antenna can be made conformable and potentially at low cost.

In microstrip antennas, linear and circular polarizations are possible with simple feed. They can easily be used to fabricate dual-frequency and dual-polarization antennas. Some other advantages include easy fabrication into linear or planar arrays, and easy integration with microwave integrated circuits [10], [11].

Some of the disadvantages of microstrip antenna configurations include narrow bandwidth, spurious feed radiation, poor polarization purity, excitation of surface waves, limited power capacity, and tolerance problem.

In microstrip antennas, the dielectric and conductor losses can be large for thin patches resulting in poor antenna efficiency. Sensitivity to environmental factors such as temperature and humidity are also an issue with microstrip antennas.

However, narrow bandwidth disadvantage of patch antenna turns out to be advantage for RFID reader as RFID applications do not need much bandwidth because antenna rejects the signals that are out of the band and accordingly increases the quality factor [12].

### B. Design Principles

In modern communications, low cost and low profile antennas are demanded. Microstrip patch antenna due to its conformal nature and capability to integrate with the rest of the printed circuitry satisfy those requirements. In antenna design feeding mechanism plays an important role. Coaxial probe feeding is sometime advantageous for applications like active antennas, while Microstrip line feeding is suitable for developing high gain Microstrip array antennas [13].

In general, patch antennas have the length of half-wave structures at the operation frequency of fundamental resonant mode. Since the fringing field acts to extend the effect length of patch, the length of the half-wave patch is slightly less than a half wavelength in the dielectric substrate material. Approximate value for the length of a resonant half-wavelength path is given by [14].

$$L = 0.49\frac{\lambda}{\sqrt{\varepsilon_r}} \tag{1}$$

where, $\lambda$ is the free-space wavelength and $\varepsilon_r$ is the substrate dielectric constant.

Various analytical approximated approaches may be used to meet the initial design requirements. In this work, we have used transmission line model. All the dimensions of the patch antenna is calculated based on equations (2)-(5) [15]. The width is given by

$$w = \frac{c}{2f_0}\sqrt{\frac{2}{\varepsilon_r + 1}} \tag{2}$$

where, $f_0$ is the resonant frequency of the patch antenna, c is free-space velocity of light. The effective dielectric constant for the case of (w/h > 1) is given by

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{w}\right]^{-1/2} \tag{3}$$

The extension of patch length due to fringing effects can be determined by

$$\frac{\Delta L}{h} = 0.412\frac{(\varepsilon_{eff} + 0.3)\left(\frac{w}{h} + 0.26\right)}{(\varepsilon_{eff} - 0.258)\left(\frac{w}{h} + 0.8\right)} \tag{4}$$

The effective length of patch after taking into fringing effect can be calculated by

$$L = \frac{c}{2f_0\sqrt{\varepsilon_{eff}}} - 2\Delta L \tag{5}$$

### C. Patch Antenna Configuration

The 2.45 GHz is taken as a resonant frequency of the Microstrip patch antenna. Rogers Duroid material has been selected for the substrate with dielectric constant 2.2. The height of substrate is kept at 0.8mm.

In inset fed microstrip patch antenna the location of feed determines the antenna input impedance. Therefore, to achieve 50Ω impedance, we the inset length (y0) as shown in Fig. 3 by using the relation

$$R_{in}(y = y0) = R_{in}(y = 0)\cos^2\left(\frac{\pi}{L}y0\right) \quad (6)$$

where $R_{in}(y = 0)$ is the input impedance at the leading radiating edge of the patch and $R_{in}(y = y0)$ is the desired input impedance (50 Ω). The antenna has three layers or three blocks: first for the radiating plate, second for the microstrip line, and third for the substrate.

After optimization, we got improved results at patch length of 41.21mm and width of 48.4mm. The inset feed length was optimized to 12.5mm. The feed line, a 50 Ω transmission line, is directly connected to the port.

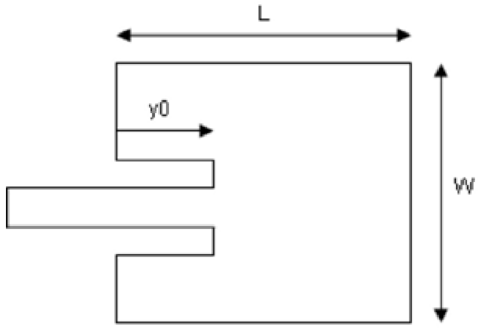


Fig. 3. Typical inset fed microstrip patch antenna.

The ground plane is specified by an electrically conducting boundary condition. An air box has to be specified as defined into model open space, so that the radiation from the structure is absorbed and not reflected back. The airbox should be a quarter-wavelength long of the wavelength of interest in the direction of the radiated field [15]. For proposed work air box of length 71.21mm, width 19.625mm and height of 43.6575mm was taken. Lumped port was taken as the excitation port. Fig. 4 shows the proposed antenna design.

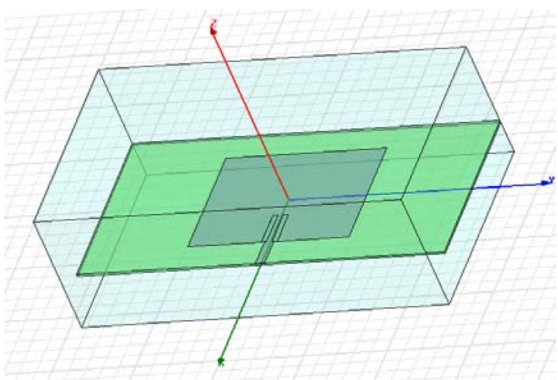

Fig. 4. Proposed microstrip patch antenna.

## III. Simulation and Results

Initially simulation was performed using analytically computed antenna parameters (2)-(6). Guided by the initial simulated results, an optimization of the antenna parameters was performed to obtained satisfactory results. As shown in Fig. 5, the obtained input return loss ($S_{11}$) is equal to -21.0579 dB. Similarly, Fig. 6 shows the antenna gain and Fig. 7 presents the radiation pattern of proposed antenna. Figure 8 gives the far field radiation pattern of the proposed antenna at 2.42 GHz. Table I shows the antenna parameters obtained after simulation.

TABLE I: Antenna Parameter Obtained After Simulation.

| SN | Antenna parameters | Values |
|---|---|---|
| 1 | Gain | 4.6772 dB |
| 2 | Peak directivity | 5.0792 |
| 3 | Radiation efficiency | 91.858 % |
| 4 | Bandwidth | 84MHz |

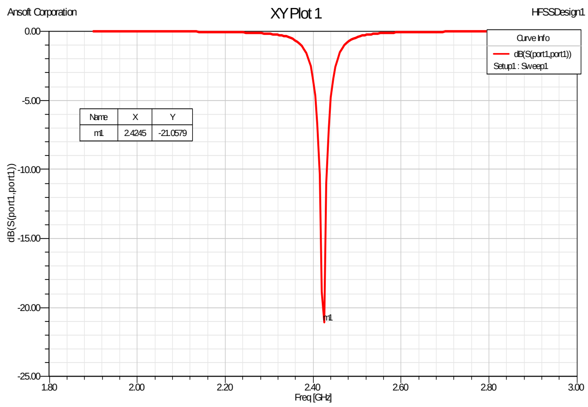


Fig. 5. Return loss (S11) plot for proposed patch antenna

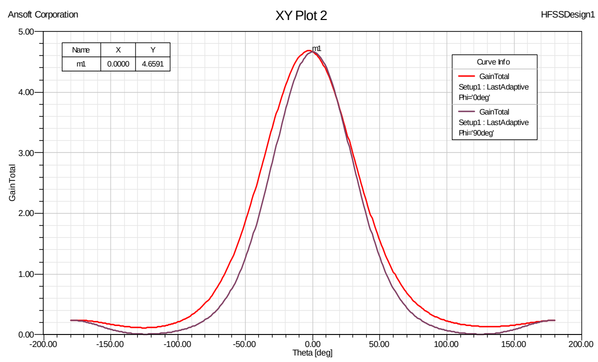


Fig. 6. Gain plot for proposed patch antenna

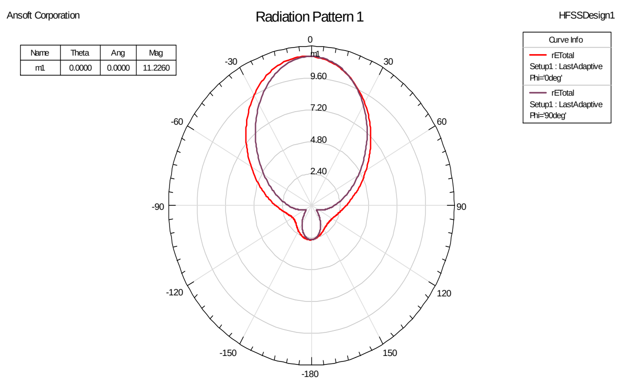


Fig. 7. Radiation pattern for proposed patch antenna.

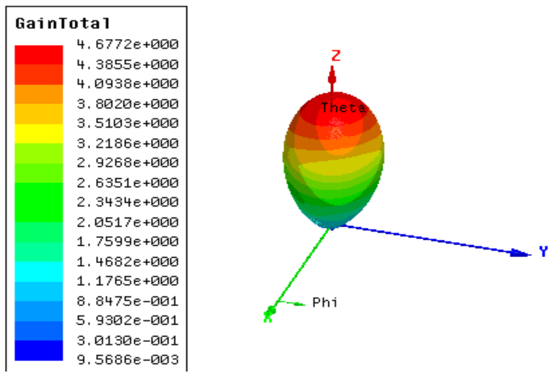


Fig. 8. Far field radiation pattern for proposed patch antenna.

## IV. Conclusion

An inset fed microstrip patch antenna was designed and simulated at resonant frequency of 2.42. An input return loss of -21.0579dB and a gain of 4.6772dB were obtained. The proposed design has simple design structure and can easily be constructed at low cost. The proposed antenna design can be a good solution for many RFID applications such as warehouse, supply chain automation etc.

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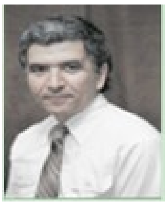

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