Null Mitigation of Planar RFID Tag Antennas

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***Abstract*— Printed monopole and dipole antennas for RFID tags have inherent nulls in their radiation patterns. These nulls in radiation patterns limit tag reading even if a circularly polarized reader antenna is used. The paper presents ten various conventional and novel printed antennas to improve the nulls for maximum visibility of the tag. The investigation reveals that highest null improvement of 25 dB in monopole and 24.6 dB in dipole is possible using non-conventional monopole and dipole.**

Keywords: RFID tag antennas, antenna patterns

I. INTRODUCTION

Radio Frequency Identification (RFID) system is a new wireless data transmission and reception technique for automatic identification, asset tracking, security surveillance and many other emerging applications. A RFID system consists of three major components: a reader or integrator, which sends interrogation signals to a RFID transponder or tag, which is to be identified; a RFID tag, which contains the identification code; and a middleware, which maintains the interface and the software protocol to encode and decode the identification data from the reader into a mainframe or a personal computer. Fig. 1 illustrates a generic block diagram of the RFID system. Realizing the fact that the barcodes and other means for identifications and asset tracking are inadequate for recent demands, RFID technology has been influencing tremendously the world of logistics, supply chain managements, security access control, government services and many other applications areas. The RFID market has surpassed \$5 billion marks in 2007 and this growth is expected to be \$25 billion by 2017 [1] with its diversified emerging applications in all sectors like medicine and health care, agriculture, livestock, fishing industry, and retail chains. Today, RFID is being researched and investigated by both industry and academic scientists and engineers around the world.

Antennas play one of the most significant roles in Auto-ID procedure which comprises both the RFID tags and readers. Being the eyes for the electronic circuits, antennas communicate wirelessly with outer world via electronic circuits. Antennas also play significant role in link margin and signal purity of the whole system. These antennas increase the efficiency and overall performance of the system. Realizing the importance and significance of suitable candidate antenna elements for RFID tags, we have done a comprehensive design exercise of ten varieties of planar antenna elements. These antenna elements are conventional and new printed monopoles and dipoles antennas. All the designed antennas are optimized to 2.4 GHz for effective comparison. The prime objective of the investigation is to understand the limitation of the conventional antenna elements and how to improve their input impedance and radiation performance suitable for RFID tag applications [2, 3, 4].

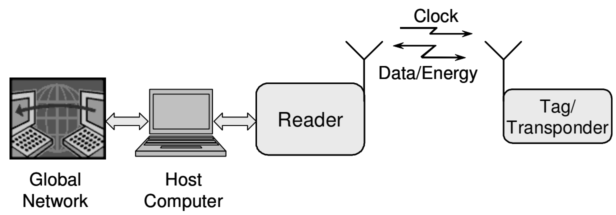


Fig. 1. RFID system block diagram.

The paper is organized as follows: firstly the overview of the RFID technology and importance of antenna in RFID are presented in section I. Importance of antenna form factors is presented in section II. Designs of 10 planar antenna configurations, their comprehensive analyses and comparison are shown in section III. The main focus of the exercise is to improve the RFID tag's visibility by improving radiation pattern nulls, hence reducing the blind spots of reading zones by making the antenna pattern as null free as possible. An improvement of as much as 25 dB null reduction is possible by modifying the conventional antenna elements. The input return loss and radiation patterns of each antenna element are presented. Finally the paper is concluded with an inference of the investigation in section IV Conclusion.

II. ANTENNAS FOR RFID

Antennas are spatial filters which interface the guided electromagnetic wave to and from the transceiver module via free space. Therefore, careful design of an antenna which maximizes the transfer of power from and to the electronics device is the prime concern of a designer. RFID tags and readers operate over a very wide range of frequencies starting from very low frequency (LF) of a few hundreds of KHz up to the millimeter wave region up to 60 GHz [2-7]. With the frequency rises from LF region to the microwave regions in GHz frequency bands matching of an antenna to the electronic device become more complicated. On the other hand, the RFID tag, with the appropriate form factor, must be attached to the object to be identified for the specific applications for identification and asset tracking.

The form factor of the RFID tag antenna is very important so that the suitability of the tag for the object will not affect the object's weight, forms, performance and longevity. Therefore, an antenna designer should observe the various factors such as antenna size, coverage, polarization and cost when deigning an antenna for RFID applications [2].

Antenna configurations (form factors) for RFID tags are greatly influenced by the intended application and the frequency of operation. More complexity is added when considerations of contents and shapes of items on which tags must be affixed come into play. As for an example, dipole and monopole antennas are being omnidirectional radiators interact with liquids and metals [8]. A patch antenna being a radiator with a high front to back ratio (F/B) could be a good solution to this problem. Based on the frequency of operation the tag can be classified as low frequency (LF), high frequency (HF) and Ultra High Frequency (UHF) and Microwave tags [2]. A comprehensive classification can be found in [9]. In the following section different varieties of UHF and microwave RFID tag antennas developed in Monash University's RFID Research Group are presented.

III. Printed Antennas for RFID Tags

Fig. 2 shows ten different microstrip monopole and dipole configurations. Usually circularly polarized (CP) reader and tag antennas [4] are used to make RFID system orientation insensitive so that tags can be read in any orientation and position. However, due to the inherent nulls of the conventional tag antennas the CP radiation does not help. In this regard, the main objective is to improve the nulls of the antennas so that the reader can have the maximum visibility of the tag. To fulfill the requirement, the conventional tag antennas are modified by bending the monopoles and dipoles in various forms so that the current distribution on the antenna's effective aperture is multi-directional. The outcome is the improvement of nulls. The ten antennas are designed using CST Microwave Studio and all of them are optimized to resonate at 2.4 GHz. The antennas are placed on FR4 substrate having 1.6mm height.

As can be seen in Fig. 2, the simplest generic antenna is a printed monopole with a finite ground plane on a dielectric substrate. This antenna generates an omnidirectional radiation pattern with deep nulls along its axis in the order of 30 dB. This null can be improved by bending the monopole at the center by 90° so that the current on the conducting strip is bi-directional. The resultant radiation pattern is an omnidirectional radiation pattern with much improved null in the order of only 5 dB as shown in Fig. 3(b). This bending also enjoys the compactness of the design by harnessing the electronics of the RFID ASIC chip and other associated circuitry including the batteries for semi-passive and active RFID tags. Similarly, a conventional printed dipole antenna has an omni-directional radiation pattern with a null in the order of 29.6 dB along its axis as shown in Fig. 4(b). By bending the two microstrip arms by 90° in U-shape (co-bent), 90° in S-shape (opposite-bent) and > 90° in obtuse U-shape, the null can be improved by maximum of 18.6 dB along the axis of the antenna as shown in Fig. 4(b). The co-bent and opposite-bent dipole both has null at 17 dB and opposite-bent dipole has lowest null at 11 dB.

Besides bending of dipoles, conventional dipole is also modified in four different ways. Butterfly dipole, flying bird dipole, folded dipole, and saw tooth dipole as shown in Fig.2. The radiation pattern of these non-conventional dipole antennas is compared with conventional dipole antenna in Fig. 5(b). While butterfly dipole antennas generates almost an ideal isotropic radiation pattern with null at 16 dB, the saw tooth antenna has a null in the order of 29 dB. The flying bird dipole having two-stage V-shape bends in opposite direction produces almost null free radiation pattern having null at 8 dB. However, folded dipole has lowest null of all designed dipoles at 5 dB. The investigation on printed folded dipole can be found on [10].The impedance bandwidth, null value and directivity of all designed antenna is shown is Table 1. We can see that bent-monopole gave 25 dB null reduction compared to conventional monopole and Folded Dipole gave highest null reduction of 24.6 among other modified dipoles. The directivity of the antenna is not affected much because of the modifications. The return loss curve shown in Fig 3(a), 4(a) and 5(a) shows that all the antennas resonate at 2.4 GHz. Hence, the performance of antenna is not affected because of the modification performed on conventional antenna. Furthermore, the advantage of these modified and bended antennas is also in its compactness and usage of less real estate in the actual circuit compared with its other counterparts besides having null reduction.

TABLE I: CHARACTERISTICS OF VARIOUS PRINTED ANTENNAS FOR RFID TAG APPLICATIONS

Antenna Type	10-dB RL BW	Null	Directivity
Monopole	316	30	2.07
Bent-Monopole	235	5	1.89
Dipole	393	29.6	2.18
Obtuse-bent Dipole	301	11	1.96
Opposite-bent Dipole	362	17	2.07
Co-bent Dipole	356	17	2.03
Butterfly Dipole	79.23	16	2.05
Flying Bird Dipole	106.88	8	1.9
Folded Dipole	36.98	5	1.9
Saw-tooth Dipole	341	29	2.08

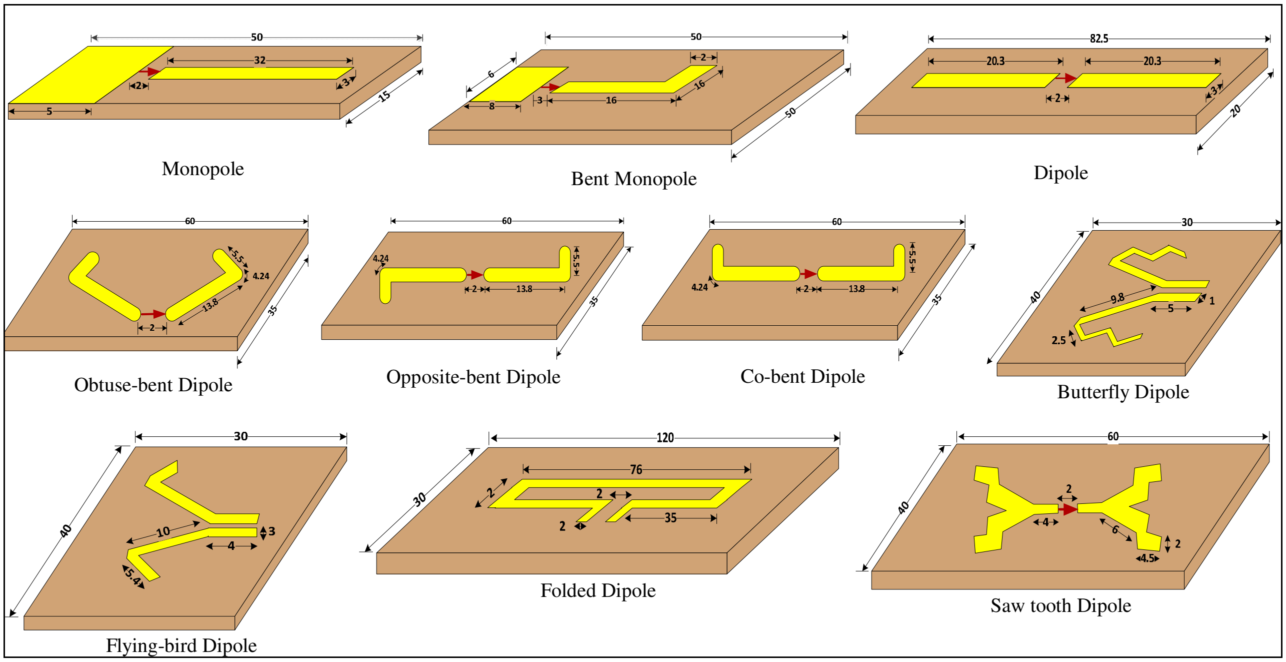
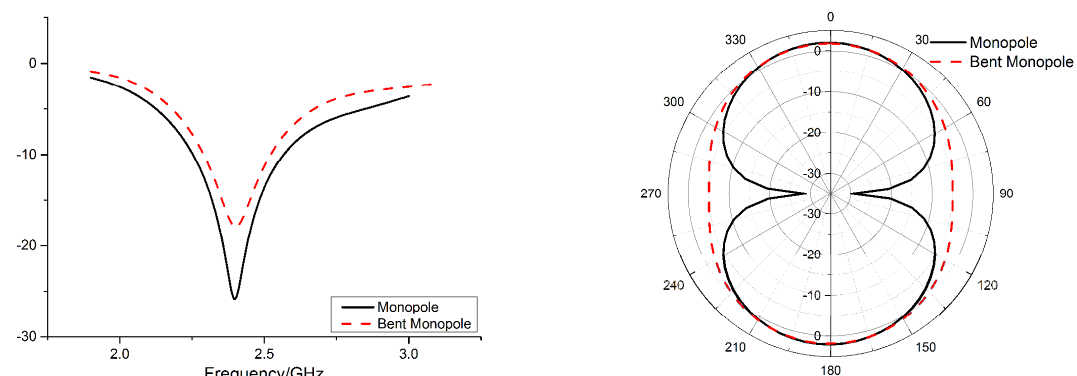


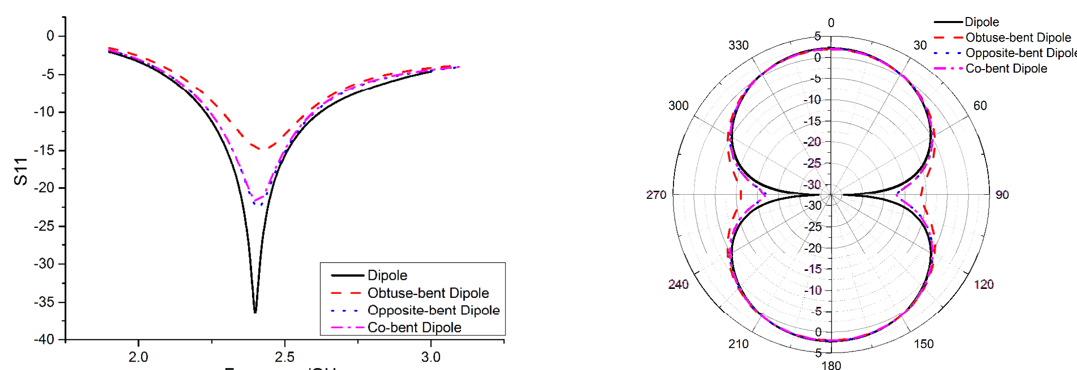
Fig. 2: Various printed RFID tag antenna.



(a)

(b)

Fig. 3 (a) Simulated return loss vs frequency and (b) Radiation pattern of monopole and bent monopole



(a)

(b)

Fig. 4 (a) Simulated return loss vs frequency and (b) Radiation pattern of dipole, obtuse-bent dipole, opposite-bent dipole, and co-bent dipole

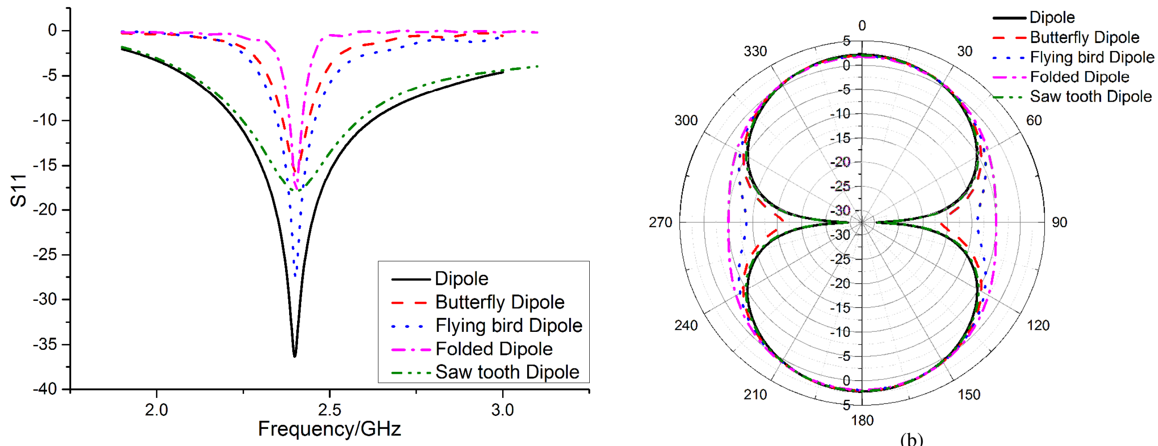


Fig. 5(a) Simulated return loss vs frequency and (b) Radiation pattern of dipole, butterfly dipole, flying bird dipole, folded dipole, and saw tooth dipole

IV. Conclusion

A comprehensive study of ten varieties of conventional and new monopole and dipole antennas for RFID tags have been presented in terms of their input return loss, radiation patterns and gain. The important design aspects for the RFID tag antennas are their configurations, frequency and applications. The desirable antenna pattern for an ideal tag is a null free isotropic radiation patterns with maximum visibility to a RFID reader. The designed antennas have shown null reduction along with its size compactness. In this paper only CST simulated results are produced, analyzed and synthesized. The fabrication of the designed antennas and the verification of the simulated result with the measured result will be our future work.

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