A Compact Broad-band UHF RFID Tag Loaded with Triangular SRR Arrays

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Abstract

A novel compact planar UHF RFID tag with a broadband operation and enhanced read range characteristics are presented. The structure of the tag consists of a T- matched dipole antenna whose arms are orthogonally loaded with Triangular SRR arrays. Triangular SRR arms loaded in the structure produce compactness and good impedance matching which are essential for maximizing the read range. The measured results show that the proposed tag shows the highest read range of 9.6 meters in the European UHF RFID band of 866 MHz and significantly good read range in the other UHF RFID bands in the 860-930 MHz range. Measured read range pattern over the azimuth and elevation angular ranges are also depicted.

1. Introduction

Radio Frequency Identification (RFID) technology is a leading automated wireless communication technology that has existed for the past few decades. RFID technology is much stronger than other automated identification systems in commercial long-distance identification. The main applications of RFID are in asset tracking, access control, logistics, product management, distribution network management and much more.

Any RFID system is a combination of three main components: the RFID tag, the RFID reader, a processing system that connects to the arbitrary record with tag recognition data. An RFID tag (transponder) contains an antenna and an integrated chip. Microchip stores information regarding the tagged object which is connected to the terminals of the antenna. Tag antenna plays an important role in RFID tag operations, particularly in passive RFID communication [1-2]. The RFID tag that works with the UHF band (860-960 MHz) is well accepted due to its smaller size, long reading range, and the better data rate. In passive RFID, the tag antenna receives a modulated RF signal from the reader. The integrated chip connected to the antenna terminals responds by varying its impedance and modulates the backscattered signals with respect to data stored in the chip. To maximize the performance of the tag, it is most essential to have a conjugate impedance match between the tag antenna and the integrated chip.

Many researchers have published several papers on the RFID tag antenna design and its performance. KVS Rao et al presented an overview of RFID tags that work on UHF-RFID band and its design requirements [3]. A tag must be compact in size, low profile, and simple in structure for comfortable use with low production costs. E. Perret et al discussed the design process of the RFID tag running on the UHF band [4]. Designing a small sized good read-range tag antenna is a challenge to antenna designers. Since the majority of antenna models are based on dipole structure, the dipole architecture has been widely adopted in tag antenna designs [5-7]. Miniaturizing the size of the tag antenna is a primary concern in the design of RFID tags because the tag size depends only on the antenna size.

Usually, the meandering and, folded dipole shapes are used to reduce the size of RFID tags [8-11]. Techniques like inductive coupling, T-matching are used in the design of UHF RFID tags for Conjugate impedance matching and better performance [12-14]. It is desirable to design an RFID tag with long reading range and wideband operation for commercial applications in the RFID field. Reducing the size of the tag along with broadband operations and substantially decent read range is a tough task and was tried by some researchers [15-17]. Split Ring Resonator (SRR) is a profound subject in the area of the electromagnetic field, and several researchers have investigated various applications of antenna design. In the SRR, two concentric metal rings are separated by a gap and split on these rings into the opposite sides. Recently SRRs are included in the RFID tag design to reduce the size of the Tag antenna [18-19].Designing a compact RFID Tag with good read range and broadband characteristics are suitable for the efficient deployment to small objects for the whole UHF band (860-960 MHz).

In this paper, we propose a novel compact UHF RFID tag with enhanced read range and broadband operating characteristics. The proposed model composed of a T-matched dipole antenna orthogonally loaded with Triangular SRR arrays. The design uses an orthogonal dipole with triangular SRRs which gives the good impedance matching and compact size. Tuning of the gap parameters of SRR structure gets good impedance characteristics and it increases the tag's read range to the broadband UHF band and enhanced the performance of the tag. The anticipated compact tag has a measurement of 38.58 x 38.58 x 1.66 mm^3 with a read range of 9.6 meters at 866 MHz and a broad bandwidth all over the entire UHF RFID bands (860-960 MHz).

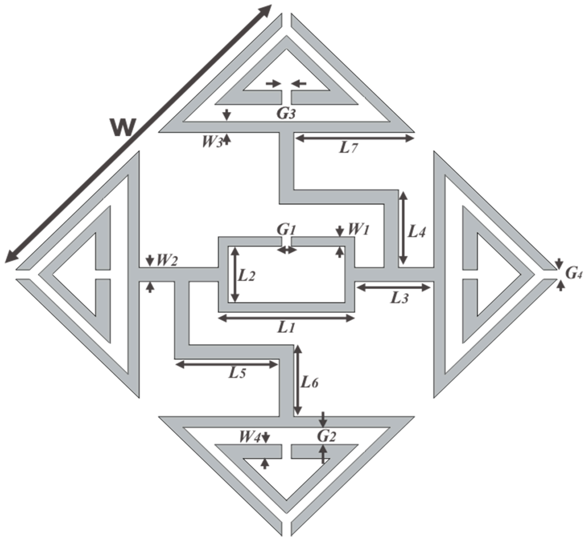

Figure 1: Geometrical structure of the proposed RFID tag

2. RFID Tag Antenna modeling and testing

Geometrical structure of the triangular SRR loaded UHF RFID tag is shown in figure 1. CST Microwave studio is used to get the design and simulation of the tag antenna. The proposed tag antenna consists of a T-matched dipole with orthogonally loaded triangular SRR arrays. Each SRRs section contains two triangular rings separated by a gap and each ring has split into the opposite sides. The orthogonally connected triangular SRRs produce an inductive and capacitive loading in the structure. The inductive loading produced by the length of the triangular rings and capacitive loading produced by the gap between the rings and gap on the rings. The inductance of the orthogonally loaded SRRs in the arms of the dipole is much greater than the conventional meander line sections used in the tag antenna design. This makes the SRRs particularly useful for designing compact UHF RFID antennas.

Currently, various types of RFID chips of different vendors are available in the market, So it is critical to design an antenna that matches the tag chips with different input impedances. Tuning on the design parameters provides size miniaturization and proper impedance matching with the tag chip and the antenna. To get optimized parameters for a specific design, properly tune the antenna parameters along with a T-match circuit using the CST microwave studio. Several parameters such as the slit widths (G_3,G_4) of the triangular SRRs and the gap between the split rings (G_2) are the important parameters which can effectively tune the properties of the tag due to its capacitive effect. All the RFID tag antenna and their optimized parameters are labeled in figure 1 are listed in Table 1. Optimized parameters have a significant effect on the performance and size of the antenna. The length of the dipole in the design is smaller than the traditional dipole and overall size of the tag antenna is reduced.

Table 1: Dimensions for the proposed antenna

Parameters	Value	Parameters	Value
L_1	14mm	W_1	1mm
L_2	6mm	W_2	1.5mm
L_3	8.13mm	W_3	1.13mm
L_4	8.25mm	W_4	1.48mm
L_5	10.75mm	G_1	1mm
L_6	7.63mm	G_2	1.83mm
L_7	12.4mm	G_3	1mm
w	38.58mm		

Alien Higgs-3 RFID chip of impedance 27-j211Ω at 866 MHz is mounted on the terminals of the antenna. The minimum threshold power required to power up the microchip is -18dBm. The input impedance of the proposed antenna must be the conjugate impedance of the RFID chip (27+j211Ω) for optimum power transfer between the antenna and the chip and maximize the effective read range. T- Match network incorporated in the design is used to get the conjugate impedance matching between the antenna and chip. The parameter variations of the antenna structure and its effects are studied through the simulated results.

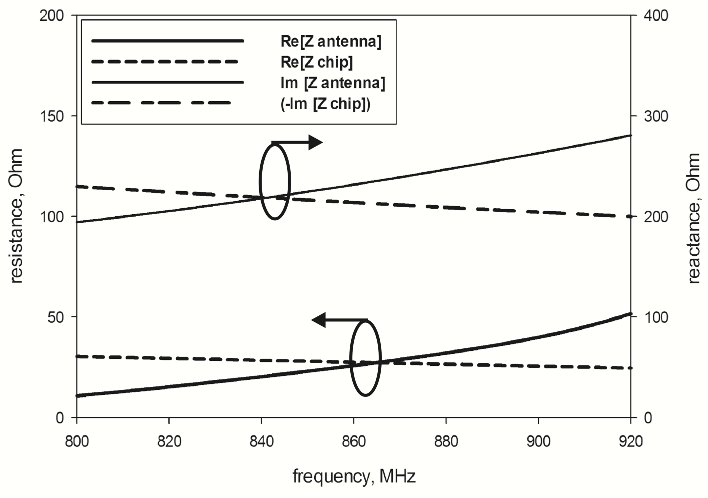

Figure 2: Variations of the real and imaginary part impedance with frequency for the suggested tag antenna along with the chip impedance

The variations of simulated input impedance characteristics of the intended tag antenna with frequency are indicated along with that of the RFID chip in figure 2. It is explainable from the graph that simulated input impedance of the projected antenna at 866 MHz with a real-part impedance value of 27 Ω and an imaginary part value of 235 Ω. The simulated impedance values of the proposed antenna are at close conjugate matching to the chip impedance of 27-j211 Ω. These results indicate that the designed antenna has a good impedance matching with the microchip and it's essential for a good design.

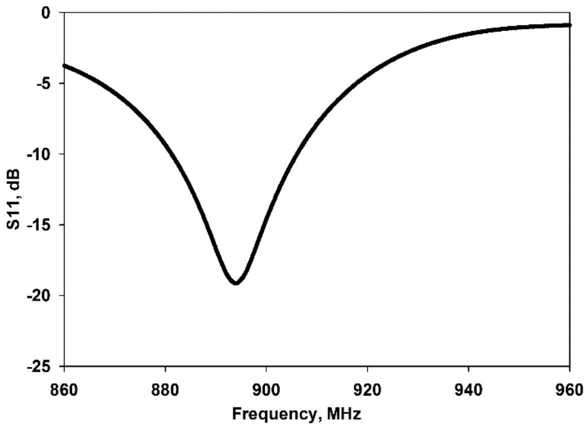

Figure 3: variation of return loss with frequency for the proposed tag antenna

The replicated return loss of the proposed tag antenna is shown in Figure 3. The variation of return loss with frequency for the SRR loaded dipole tag antenna when the port impedance is equal to the microchip impedance and which is presented in the graph. It can be noticed that the tag antenna resonates at 866 MHz and a half-power bandwidth (return loss below -3 dB) of the proposed tag antenna is 61 MHz (863-924 MHz). It is enough to covers almost all the UHF RFID band (860-960 MHz).

Next step is to fabricate the antenna using optimized parameters. A small RFID tag conjugately matched its impedance with RFID chip is usually desirable for a printed RFID tag on a single surface. The designed compact broadband tag antenna is built on a single side square FR4 substrate with a relative permittivity $\varepsilon_r = 4.3$ and a loss tangent of 0.002, and a thickness of 1.6 mm. Figure 4 shows the photograph of the fabricated model. The size of the prototype is 38.58x38.58x1.6mm and each element in the model printed on the single conducting plane.

The maximum reading range is the most important factor in evaluating a tag antenna. A conjugate impedance matching among the tag antenna and the chip is really important to power up the chip and effective read range. The passive RFID chip of impedance 27-j211Ω mounted on the prototype RFID tag chosen was the Higgs-3 by Alien Technologies. The minimum threshold power required to power up the RFID chip is -18dBm.

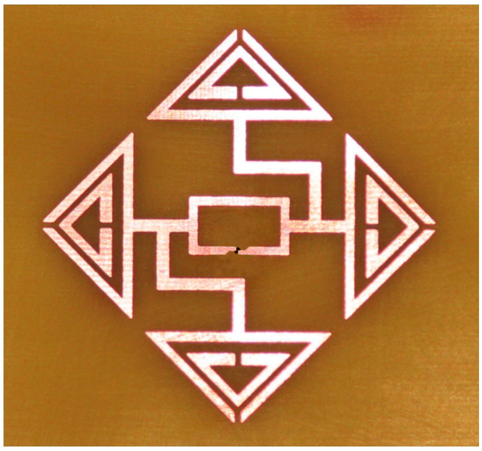

Figure 4: Photograph of the fabricated prototype RFID tag antenna

Measuring the read range of the fabricated prototype and ascertain how well it performed is very important. STA IR0507E reader with an RF power of 30 dBm and receiver sensitivity of -80 dBm associated to circularly polarized antennas are prepared for measuring the read range. The read range measurement was carried out in open space. Tag attached to a platform that can be moved to different azimuth and elevation angles to determine the maximum reading range of the tag.

3. Results and Discussions

The measured read range with frequency along the bore-sight for the proposed RFID tag operating in the UHF band is shown in figure 5. From the results, we can see that the proposed tag operated in the European UHF RFID band (865-867 MHz) and has a measured read range of 9.6 meters. In the North American (902-928 MHz) and Chinese (920.5-924.5 MHz) UHF RFID bands, the read range gets slightly decreased but exhibits appreciably good read ranges. However good range read is obtained in almost entire UHF RFID band for the proposed RFID tag. The proposed tag is suitable for global deployment.

In further measurements, the position of the reader remains constant and position of the tag attached movable platform changes according to the elevation and angular ranges. Variations of the read range with different elevation and azimuth angles are measured and the variation are presented in figure 6a and 6b. It is evident from the figure 6a the measured read range of the compact broadband RFID tag are remains constant in the elevation angular range from -20^o to $+ 20^o$ and beyond 20^o the read range falls off on either one side of azimuth angular ranges.

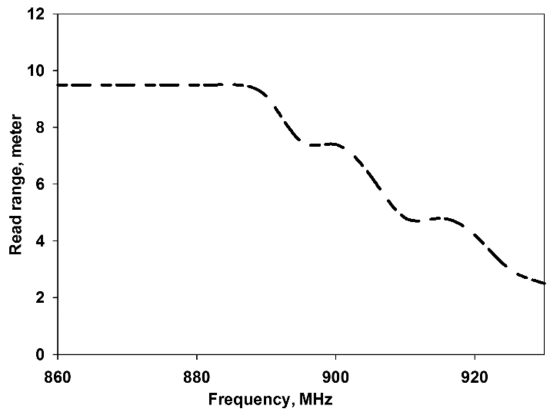

Figure ***5:*** Measured read range differences with frequency for the projected RFID tag at bore-sight with $\theta=0^o$, $\phi=0^o$

Variation of the measured read range with azimuth angle is plotted in figure 6b. The maximum reading range is 9.6 meters with limited angular ranges and then decreases rapidly on either side of the bore sight reaching a minimum of 4.5 meters at 90^o. However the proposed tag functioning in complete UHF RFID band and shows good read range features above the elevation and azimuth angular ranges.

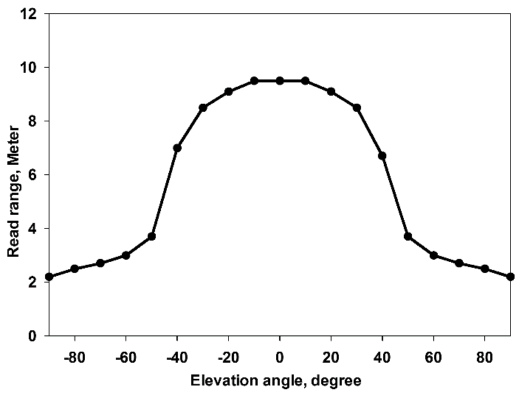

Figure 6a: Measured variations of reading range versus Elevation angle with $\theta=0^o$ for the RFID tag at 866 MHz

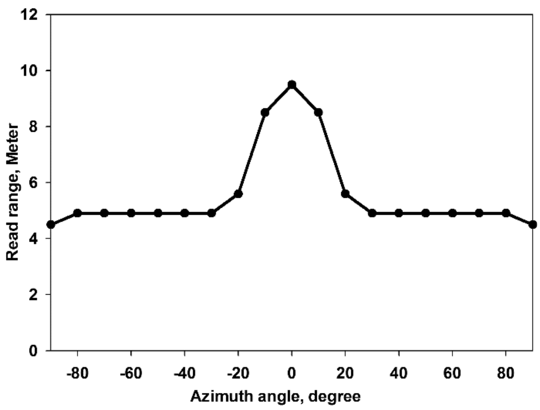

Figure 6b: Measured variations of reading range versus Azimuth angle with $\theta=0^o$ for the RFID tag at 866 MHz

Table 2: comparison of read range and size of the proposed RFID tag with some reported RFID tags

Model	Max Read range	Size	Frequency
Model 1 Ref no.15	3 m	80X 80 mm	840-960 MHz
Model 2 Ref no.17	2.8 m	26.4 X 24 mm	915 MHz
Model 3 Ref no.18	5.48 m	55.54mm X 11.91 mm	920 MHz
Model 4 Ref no.19	7 m	55mmX 19.5 mm	866 MHz
Proposed tag	9.6 m	38.5mmX 38.5mm	866 MHz

Table.2 presents the comparison of read range and size of the proposed model with the reported RFID tag models mentioned in the reference of papers. It can be seen that the proposed tag is relatively small in size and provides enhanced read range performance compared to the reported works.

4. Conclusion

A novel compact UHF RFID tag with broadband operations and enhanced read range characteristics are presented. The proposed model consists of a T-matched circuit with triangular SRR arrays to fulfill the conjugate matching and compact size. The proposed RFID tag exhibits a read range of 9.6 meters in the European UHF RFID band of (866MHz) and with good read range in all other UHF RFID bands. The broadband features of the proposed tag are appropriate for requests for worldwide deployment. The tag displays good read range features over the entire elevation angular ranges and over a wide azimuth angular ranges.

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