Loop feed Meander-line Antenna RFID Tag design for UHF band

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Abstract

A loop feed meander-line Antenna (LFMLA) RFID tag on a relatively low dielectric constant substrate operates on the European UHF band 865-868 MHz is presented. The tag modeling is analyzed using two different electromagnetic simulator HFSS and CST. A prototype tag antenna is constructed and measured for validation .The input impedance of the proposed antenna is verified against the simulated data results, the measured and simulated results are found to be in good agreement. The compact size tag antenna shows excellent impedance matching to the typical input impedance of a RFID integrated circuit chip and a significant improvement in reading range up to 5 meters.

1. Introduction

Radio Frequency Identification (RFID) is referred to as the Automatic Identification System. It comprises a tiny silicon (CMOS) microchip and a tag antenna [1]. A subject is scanned by a reader and the information corresponding to the tag is stored in the database running on a host computer. The key part of the system is antenna, enable the tag or reader to transmit and receive the data , the RF energy transmitted from the reader is normally required to power the circuit in the tag, so the passive tag antenna design is required, thus, avoiding the needs for the battery. There is a challenge to achieve an excellence impedance matching between tag antenna and the tag integrated circuit (IC). That is, in order to realize the maximum transmission efficiency using RF power induced from the antenna, the reactance part of the tag antenna output impedance has to be designed and optimized to be the complex conjugate impedance of that of the IC .In the last few years, many compact size RFID tags have been demonstrated successfully [2] in the literature. In addition, the RFID tag flexibility and the low-cost implementation. Currently, RFID applications widely used in different industries such as animal tracking, access control, toll collection, security, and radio astronomy [3]. RFID is a promising and powerful technology; there is an opportunity for this technology to grow rapidly in different fields' based upon the build scenarios.

In this paper, loop feed meander-lined Antenna (LFMLA) RFID tag was investigated, operating at UHF band (860-960 MHz), but executed the European UHF band standard 865-868 MHz .The meander-line loop feed antenna is simple in the printed micro-strip's structure and it is more popular because of the low profile and low cost of production. A Higgs IC [4], designed to follow EPCglobal Class-1 Gen-2 standardizations [5], was used for the tag IC whose input impedance was found to be 13-j140 Ω at 867 MHz [6].

2. Antenna design

The geometrical configuration of the proposed compact LFMLA RFID tag is shown in Fig. 1, which shows the antenna structure and specific dimensions. The proposed design is composed of two paralleled strips, equal-spaced meander lines, and the vertical lines acts as storage of electric energy and resistance loss, and the horizontal lines control the radiation resistance [6]. As can be seen in Fig. 1, the two paralleled strips which were analyzed with perfectly electrically conducting, two narrow strip lines around IC chip as a loop feed. The loop feed antenna has transmission-line current between all strip lines, which also have radiation coupling. The loop feed meander-lined Antenna is printed on Alron "foam clad" dielectric substrate with relative permittivity of εr= 1.1, to provide some design flexibility [7].The key designing for the RFID tags is required to be characterized to achieve optimum conjugate impedance with respect to the tag IC input impedance: The purpose of design is

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operating at the European UHF RFID band with 3 MHz bandwidth and resonant at a center frequency of f_c = 867 MHz.

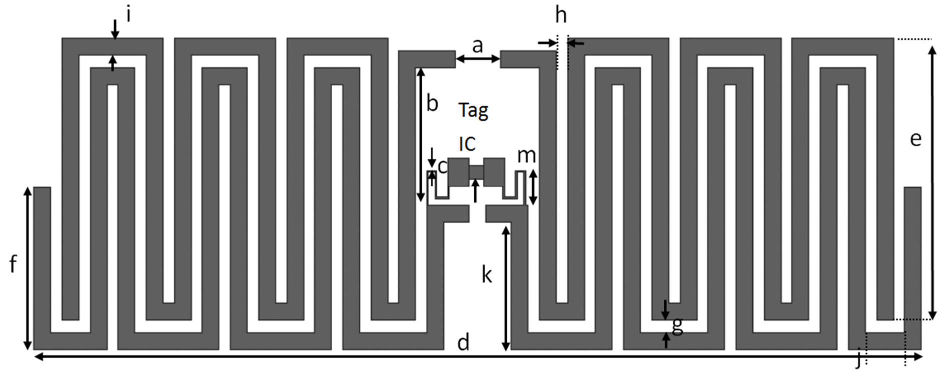

Figure1: The Geometry of the loop feed meander line antenna RFID tag design.

It can be found in design process that the antenna input impedance or matching can be optimized by changing antenna length (*e*) and by different the space between lines (*h* and *g* – chosen to be equal). For the proposed RFID tag design, the loop feed designing plays a vital role in controlling the resonant frequency.

3. Simulation, results and discussion

A LFMLA configuration (see Fig. 1) was proposed in order to achieve a tag design with compact size at UHF band. Moreover, a paralleled strip line arrangement was used to enhance the impedance bandwidth for the presented design. The geometry configuration of the optimal antenna was found with the software of High Frequency Structure Simulator (HFSS) and the optimum parameters are listed in Table 1. The return loss at 867 MHz is 36.85 dB (see Fig. 2) and the input impedance of the optimal tag antenna was found to be 14-j138.5 Ω (see Fig. 3)

Table 1 Geometrical specification of the loop feed meander line antenna RFID tag design.

a	3.2mm	*g*	0.9mm
b	9.8mm	*h*	0.9mm
c	0.1mm	*i*	1.2mm
d	63.2mm	*j*	2.8mm
e	19.8mm	*k*	9mm
f	11.5mm	*m*	2.5mm

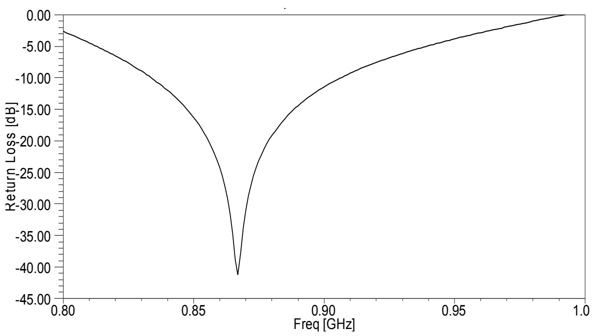

Figure 2: Simulated RFID tag antenna return loss.

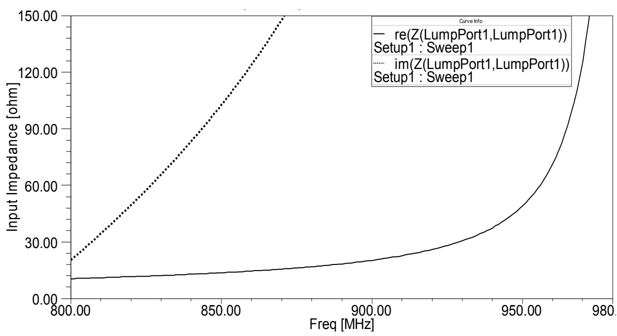

Figure 3: Simulated RFID tag input impedance.

For the LFMLA RFID tag verification, the performance of the proposed optimal tag antenna was evaluated and validated with the CST Microwave Studio software: simulated results of the antenna input impedance from 800 MHz to 1000 MHz were analyzed. The prototype antenna also measured by Network Analyzer. So these three comparative input impedance locus were plotted on a Smith Chart (see Fig. 4). This shows that the simulated input impedance achieved at 867 MHz was found to be 11.5-j84 Ω (using CST) and was 14-j138.5 Ω using HFSS. The results show fairly good agreement by the two software packages, and the measured results also can match the simulated locus. The prototype tag antenna was fabricated and tested, because the proposed design has a symmetrical structure, the measured input impedance of the antenna could obtained using mirror image theory, only half of the antenna, operating as a monopole over a very large square ground plane in the measurement, where each lateral length of the ground plane is greater than 3λ (wavelength in free space) [6]. The measured result of input impedance is shown in Fig. 4, in which it is also compared to two calculated values obtained from the two different EM simulators.

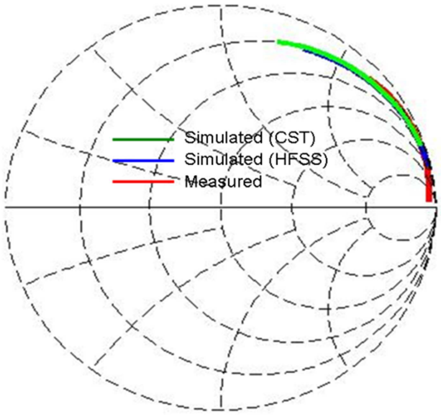

Figure 4: Comparison of input impedance on Smith Chart

The radiation patterns in the E-plane (z-x plane) and H-plane (z-y plane) at 867 MHz were studied and the corresponding normalized results are presented in Fig 5. The radiation pattern of the proposed antenna is an omnidirectional radiation pattern in the H-plane and doughnut shape pattern in the E-plane with linear polarization. The maximum antenna gain was found to be about 1.5 dBi and 1.4 dBi for z-y and z-x planes, respectively.

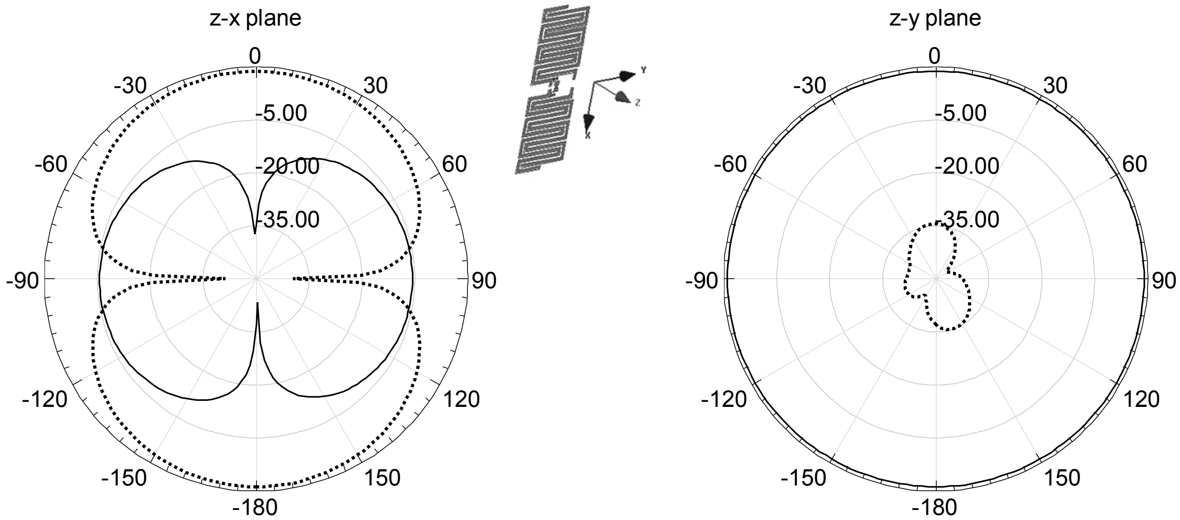

Figure 5: Radiation patterns of the proposed antenna for 867 MHz in: (left) z-x plane; (right) z-y plane, where'- - -' measured E_θ and '———' measured $E\phi$.

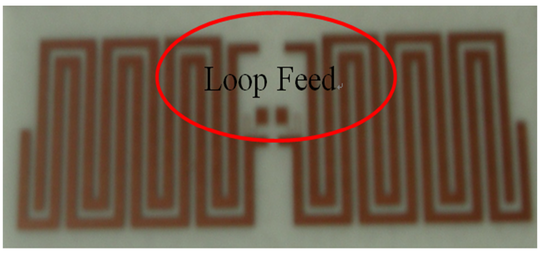

Figure 6: The prototype for loop feed meander-lined Antenna RFID tag

The present foregoing simulated results are quite well suited for practical implementation of this tag antenna (see Fig. 6). These encouraging results could lead to further practical investigation of the maximum detection distance of the RFID reader using the proposed tag design and the commercial Alien Technology UHF tags [4]. Therefore, the measured readable distance was found to be up to 5 meters (see Fig. 7), which is close to the calculated distance of 5.5 meters [4]. It shows that the distance of the practical prototype RFID tag achieved 5 times longer distance than the non-loop feed tag antenna [6].Furthermore, the measured results also shows a good matching with the calculated results.

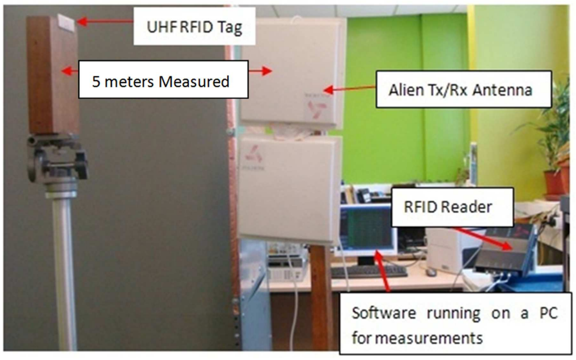

Figure 7: The reading distance was measured in RFID system.

4. Conclusions

A linear polarized RFID tag antenna based on a paralleled meander line has been presented. The antenna was shown to have a dipole radiation pattern [8], achieving maximum reading distance over the maximal range of angles. The antenna can be matched to the complex impedance of a tag chip directly, and the required bandwidth characteristics can be obtained by properly adjusting the characteristic impedance of the incorporated transmission lines. The simulated performance for the proposed design was compared with two different electromagnetics software simulators. The results presented a good input impedance matching, as required by the Higgs IC, and 5 meters reading distance has been achieved. The obtained results are acceptable for practical implementation in RFID tag antennas using at UHF band.

5. Acknowledgments

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