Antenna Design for Compact RFID Sensors Dedicated to Metallic Environments

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Abstract

In this paper, the design and simulation of a Radio Frequency Identification (RFID) antenna is presented. The antenna is designed in order to maintain a small size while operating on metallic surfaces. This RFID antenna with an appropriate chip is intended to be used as RFID sensor. The RFID tags designed for metallic environment have to overcome certain drawbacks regarding the effects of metal to the performance of the antenna. These effects are being addressed in this work and certain solutions are explored. Finally the results of the simulation of the antenna are presented to evaluate the performance of the antenna.

1 Introduction

Towards the era of Internet of Things (IoT) and 5G networks, where billion of devices will be interconnected, a great demand on small, cheap and passive sensors has been emerged. One of the potential candidates to realize the IoT plan is the RFID technology. The RFID sensors can have a very small size; operate passively while harvesting power from the ambient electromagnetic field as well as maintaining a very low cost. In order for the ambitious plan of IoT to be realized, a vast amount of sensors are required to be deployed in urban and non-urban environments. These environments can vary greatly, from agricultural fields to cities infrastructures, airports and big industries. Many of these environments can be harsh for establishing a communication between the sensor and the receiver, creating the need for sensors capable of communicating effectively in harsh environment. More specifically, metallic environment can affect critically the antenna characteristics which can lead to communication loss. Thus, special consideration should be taken into the design of a dedicated sensor operating in such harsh metallic environments [1].

The design of antennas for RFID tags, dedicated to operate on metal surfaces, has been quite a research topic with a variety of publications [2-4]. Different techniques have been used in order to achieve good performance on metal surfaces such as the use of antennas with ground plane [5] and the use of electromagnetic bandgap (EBG) structures [6] as well as classic designs i.e. planar inverted-F antennas (PIFA) [7]. In this paper a small size RFID antenna with a ground plane is being presented. The antenna design is based on an elliptical PIFA design presented in [8] with slightly bigger dimensions. The main differences lay on the ease of realization, since a shortening wall is not included and a series of slits have been added for better tuning of the antenna. In addition, the overall thickness of the antenna has been increased in order to increase the distance between the radiating patch and the ground aiming to achieve higher value of gain. The proposed design is intended for realizing a passive RFID sensor with the usage of an RFID chip with sensing capabilities.

2 Antenna Design

The introduction of a metallic surface underneath a current fed antenna generates an equal surface current with opposite phase, which results in the cancellation of the radiation in the far field. This phenomenon causes degradation in the radiation efficiency and consequently a reduction in the gain of the antenna. Also this affects greatly the adaptation of the antenna to the chip. To overcome this problem, the presented antenna is designed with a ground plane while the radiation patch was placed as far as possible from the ground plane using a substrate with thickness of 5.08 mm. Also, for size reduction, a high permittivity substrate was used (Rogers RT6010LM) with permittivity 10.3 and a capacitive feed to supply the antenna. Moreover, on the radiating patch a series of slits were used to control the resonance frequency of the antenna in the European band (865-868 MHz) by controlling the overall path of the current through the patch.

According to the Fig.1(a), the layers of the antenna are: the first, top layer where there is the radiating patch; the second layer where there is the capacitive feed; and the third bottom layer where the ground plane and the chip area are located. Between the first and second layer, a substrate core with thickness 5.08 mm is intervened, while for the second and third layer there is a substrate core with thickness 2.54 mm. At the bottom of the structure, a Polytetrafluoroethylene (PTFE-teflon) substrate with thickness of 1 mm is added for mechanical support and for covering the chip from contacting the mounting surface. Moreover, two via have been added, one (through via) connecting the radiating patch with the chip while the other (blind via) connects the feed plane with the chip.
The proposed antenna is realized to be connected to SL900A RFID chip from AMS, which is equipped with an integrated temperature sensor. This particular chip has also external ports for connecting a variety of sensors, as thermistors, strain sensors, accelerometers etc. The input impedance of this chip is (31-j×320) Ohms and the nominal power-on sensitivity of the chip is -15 dBm for battery assisted power (BAP). For passive mode operation the power-on sensitivity is approximately -8 dBm.

3 Antenna simulation and results

The presented design was simulated in the CST Microwave Studio on a metallic surface with size 180 × 180 × 1 mm. The S11 were optimized with the appropriate tuning of the slits in order to match the EU band for RFID operation. The S11 simulation results are presented in Fig. 2 where the reference input impedance is not the typical 50 Ohms but the input impedance of the chip (31-j×320) Ohms).

Figure 2. Antenna S11 simulation on metallic surface. The values of S11 are: -9 dB at 865 MHz and -11 dB at 868 MHz

The directivity and the gain of the antenna are presented in Fig. 3. It can be seen that the directivity of the antenna is quite high since the metallic surface acts as a reflector increasing the directivity of the antenna.

Figure 3. (a) the gain and (b) directivity simulated. The maximum gain is 0.809 dB and the maximum directivity is 6.25 dBi

The theoretical read range was then calculated, considering a reader with the maximum allowed power output according to the EU regulations (3.28 W effective isotropic radiated power, EIRP), perfect polarization match, chip sensitivity -8 dBm and for the respective S11 parameters. The maximum value of reading range can go up to 4.1 m at the EU band.

4 Conclusion

The presented antenna is designed for realizing an RFID tag capable to accommodate sensing functions for operation in metallic surfaces. The goal of this RFID antenna is to maintain a small size while presenting a good performance mainly in a metallic environment. This design in currently under realization process and in the near future measurements of the realized antenna will be available in order to validate the current design.
References


