

A Long Range UHF RFID Tag for Metallic Objects

Manoel Vitório Barbin¹, Michel Daoud Yacoub¹, and Silvio Ernesto Barbin²

¹Communications Department, Faculty of Electrical and Computing Engineering
University of Campinas, Brazil

²Telecommunication and Control Engineering Department, Polytechnic School of Engineering
University of São Paulo, Brazil

Abstract— The performance of passive UHF RFID tags, commonly available in the market, is significantly degraded when they are placed near a conducting surface. A possible solution to overcome this problem is to design tags based on PIFA (Planar Inverted F Antenna) the performance of which is less sensitive to the presence of objects in its surroundings. This ability is mainly due to the existence of a ground plane inherent to its structure. In this paper, a PIFA is utilized in the design of a passive tag that can be used to identify metallic objects with medium to large dimensions. A new type of antenna feeder is presented with a slot in the radiating element where the RFID IC is attached. The maximum range of utilization, covering all licensed RFID UHF bands (860 to 960 MHz), is in excess of 8 m, according to simulations using a MoM based software, verified by practical measurements. Further results from simulation and measurements show that the tag can also be used attached to other materials with good performance.

1. INTRODUCTION

The identification of objects by radio waves or RFID (Radio Frequency Identification) is a technology where a tag is attached to an object and its information read by a remote processing system. Although it is not a new technology, its use has shown steady growth in recent years. Currently, RFID is identified as one of the main enabling technologies of the future Internet, the Internet of Things (IoT).

Operating in the ISM frequency bands, RFID systems have different characteristics depending on the frequency band used. In UHF (Ultra High Frequency) band, RFID systems using passive tags are considered as a solution with good performance to identify objects at distances ranging from a few centimeters to several meters.

However, the distance of identification depends on the material that the object is made [1]. For example, metals are materials which can significantly degrade the performance of UHF RFID systems by reducing the distance of identification.

Several solutions for tags have been developed in order to make them, as far as possible, insensitive to the presence of metal [2–4]. Some different types of antennas are proposed, among which are those with a ground plane inherent in its structure, such as the microstrip antenna and the PIFA (Planar Inverted-F Antenna) [5–16].

In this paper we present the design of a passive RFID tag in UHF based on a PIFA for identification of metallic objects. The main usage of the tag is to identify objects with medium or large dimensions such as containers, plates and pipes often found in industrial environments and storage warehouses.

In order to attach the RFID IC for antenna, a slot on the radiating element of the PIFA was developed. The effect of the slot on the resonant frequency of PIFA was analyzed. Moreover, the presence of the slot introduces an inductance that is used for impedance matching between IC and antenna.

Electromagnetic simulations and measurements indicate a good tag performance in a wide frequency band, which covers the main RFID UHF operation bands in the world.

2. TAG ANTENNA DESIGN

Figure 1 shows the geometry of the proposed UHF RFID tag antenna. Basically, it is an air filled PIFA where a slot is implemented on the radiating element.

To determine the behavior of the resonance frequency of the PIFA for this form of feeder, an analysis was performed using results of simulation on IE3D [17], varying the width of the short plate W/L_1 , the height of the radiating element H/λ_0 and the length of the slot L_S/L_1 . The resonant frequency f_1 was normalized to $f_0 = 900$ MHz.

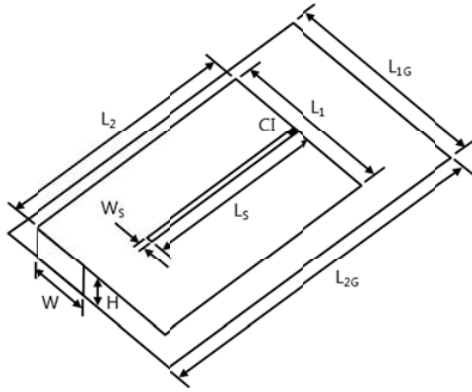


Figure 1: Geometry of tag PIFA.

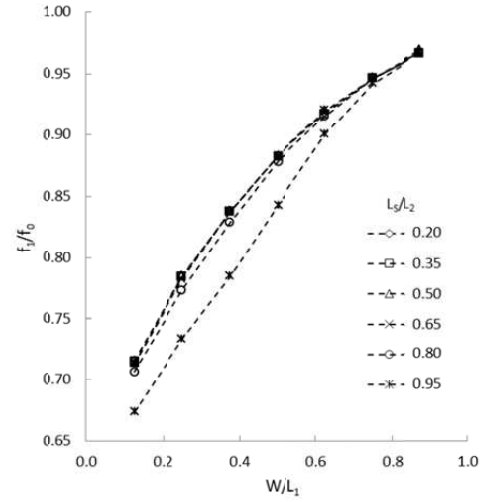


Figure 2: Resonant frequency of the PIFA versus width of the short plate.

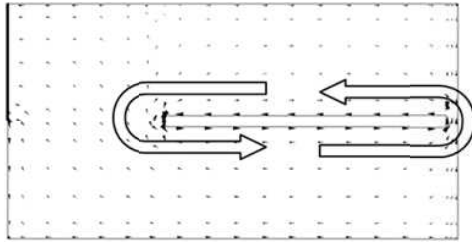


Figure 3: Current distribution on radiating element of the PIFA with slot.

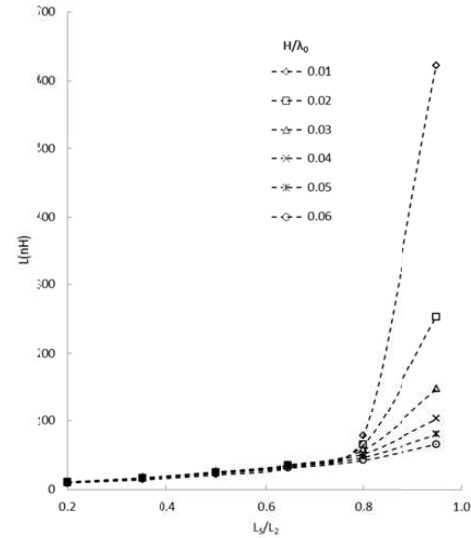


Figure 4: Inductance arising from the slot on the radiating element of the PIFA.

Figure 2 shows the behavior of f_1/f_0 in function of W/L_1 for $H/\lambda_0 = 0.02$. The curves are parameterized for L_5/L_2 . It is observed that for $L_5/L_2 \leq 0.80$ the resonant frequency of the PIFA is substantially independent of the normalized length of the slot.

Figure 3 shows the current distribution around the slot. It suggests that the slot introduces an inductance that can be used for impedance matching of the IC and antenna. This effect was also analyzed by the simulation results.

The analysis was performed by varying L_5/L_2 , W/L_1 and H/λ_0 . Figure 4 shows the variation of the inductance L in function of L_5/L_2 for $W/L_1 = 0.05$. The curves are parameterized for H/λ_0 . It is observed that for $L_5/L_2 \leq 0.75$, the inductance is practically independent of the height of the radiating element of the PIFA.

From the results of the analysis above, the PIFA was designed and mounted using the RFID UHF IC HiggsTM4 packaged in a JEDEC MO-283 Variant AA Strap from Alien Technology LLC [18]. Table 1 shows the final dimensions of the antenna after the simulation on the IE3D. The PIFA was constructed using a copper sheet with thickness of 0.55 mm. The IC was attached to antenna using silver conductive glue.

Table 1: Final dimensions of the tag antenna.

Description	Value (mm)
Length of ground plane (L_{G2})	80
Width of ground plane (L_{G1})	50
Length of radiating element (L_2)	64
Width of radiating element (L_1)	43.6
Height of radiating element (H)	6.1
Width of short circuit plate (W)	23.8
Length of slot (L_S)	49.7
Width of slot (W_S)	1.8
Thickness of copper plate	0.55

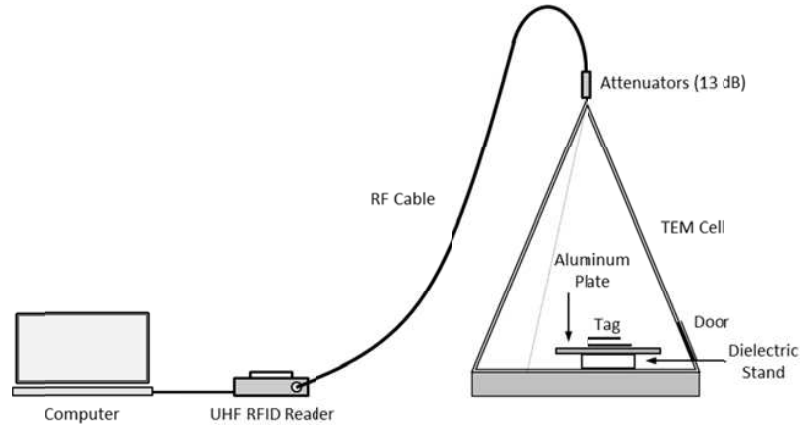


Figure 5: Setup for measurement of tag reading range.

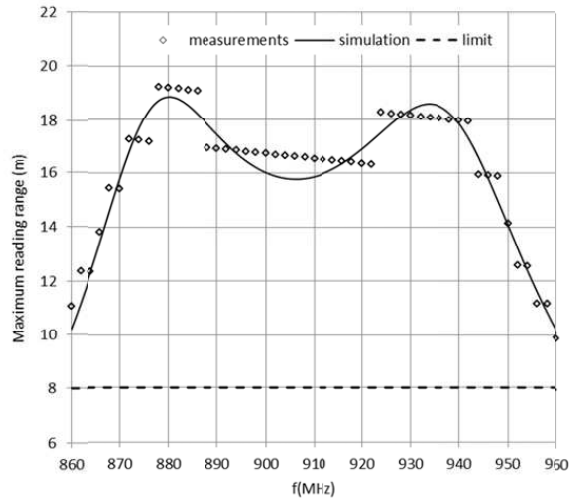


Figure 6: Maximum reading range with the aluminum plate under the tag.

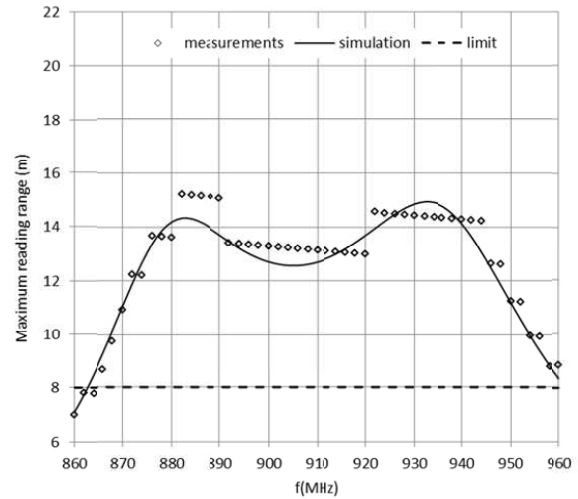


Figure 7: Maximum reading range without the aluminum plate.

3. MEASURED AND SIMULATED PERFORMANCE RESULTS

The performance of the tag was analyzed by the maximum reading range. From the results of simulation on IE3D, the minimum antenna gain is 2 dBi and the maximum VSWR is 3.5 over all band. The half power beamwidth of the antenna is 180 degrees in the elevation pattern. The reading range was calculated and compared with measurements.

Figure 5 shows the measurement setup. In this figure, the RF output power of the reader can

be controlled in 1 dB steps, from 11 dBm to 30 dBm. The tag was arranged on an aluminum plate with dimensions $150\text{ mm} \times 150\text{ mm} \times 1\text{ mm}$. This plate was also considered in the simulation of the antenna.

Considering the total setup loss, from the output of the reader to the point where the tag was placed inside the TEM Cell [19], the equation below was derived for equivalence with a free space performance of the tag where d is the maximum reading range in the free space in meters, L_{at} is the attenuation factor for the RF output power in dB, and f is the frequency in MHz.

$$d = \frac{3005.5}{f} 10^{(L_{at}/20)}$$

Figure 6 shows the maximum reading range calculated and obtained by measurements. The limit of 8 m is also shown in this figure.

The aluminum plate was removed from the simulation and measurement setup. Again, the maximum reading distance was determined. Figure 7 shows the maximum reading distance for this condition. The limit of 8 m is also shown.

4. CONCLUSION

A UHF RFID tag for metallic objects using a PIFA as a radiating device has been designed and tested. A different type of RF feeder for the PIFA, namely, a slot in the radiating element, was presented to couple the RFID IC to the antenna. The length of the slot was used to impedance matching the IC to the antenna. Good performance in terms of maximum reading distance was obtained for all licensed RFID UHF bands (860 to 960 MHz).

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