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COMPACT MICROSTRIP ANTENNA FOR RFID APPLICATIONS

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Abstract—This work presents a planar antenna for Ultra-High-Frequency (UHF) Radio Frequency Identification (RFID) Tags to be applied on metallic surfaces. The proposed radiating structure consists of a short-circuited patch antenna designed with a fractal geometry, resulting in a very compact and cost effective Tag. Showing a very good platform tolerance, such a Tag is also suitable for application on different kinds of materials (metal, glass, etc.).

1. INTRODUCTION

In recent years, Radio Frequency Identification (RFID) systems have been gaining growing interest both from scientific and industrial communities. The capability to mark objects and people with passive transponders (Tag), in fact, allows the easy development of cost-effective and low-power-consumption wireless sensor networks (WSN) with undoubted benefits on applications ranging from logistics to healthcare, robotics, security, automotive, and many others [1–3]. In such a context, Ultra-High-Frequency (UHF) systems (see Fig. 1(a)), are generally preferred to the more consolidate High-Frequency (HF) and Low-Frequency (LF) ones, because they considerably guarantee longer communication distances. However, UHF-Tags have the disadvantage of being much more influenced by the material properties of the marked item (particularly severe are the effects of metals and lossy materials) as well as by the presence of objects in the near field zone of the Tag itself. Hence, the design of a platform-tolerant UHF-Tag, which is at the same time cost-effective and small-sized, is an open challenge driving research efforts [4–6].

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Among the many different design strategies, the use of microstrip antennas seems to guarantee the fulfilment of the above mentioned requirements. Indeed, patch antennas are intrinsically suitable for operating also on metallic surfaces; they allow the application of well-known size reduction techniques as well as a low-cost and large-scale realization [7–11].

In this work, a compact and cost-effective RFID Tag for metallic surfaces is presented. The Tag is designed in microstrip technology and takes advantage from the fractal techniques together with the use of appropriate shorting posts in order to significantly reduce the Tag size.

The paper is structured as follows: in Section 2, some details of the proposed patch antenna are given and its performance is compared with both traditional short-circuited and fractal patches. In Section 3, a systematic analysis of the Tag performance sensitivity, by varying both the ground plane dimensions and the mounting material properties, is presented and critically discussed. Finally some conclusions are drawn in Section 4.

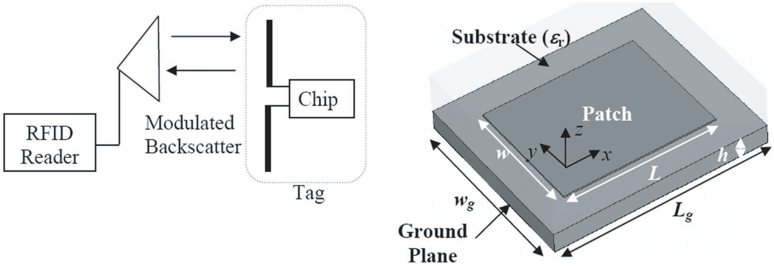
2. PROPOSED TAG ANTENNA

Microstrip antennas are the most common form of planar antennas [7–11]. The basic structure is illustrated in Fig. 1(b): a dielectric substrate is sandwiched between a square/rectangular radiating patch and a ground-plane (see Fig. 1(b)).

The antenna operating frequency is determined by L, whereas w fixes its radiation resistance. In order to have a broadside radiation with a good efficiency, the simplest design approach consists in setting L equal to $\lambda/2$ ([10]). Nevertheless, this resulting antenna is too large if used in some application fields, as for in the UHF-RFID.

In order to overcome this shortcoming, a large number of methods have been proposed; among these, a possible technique consists in short circuiting one of its radiating edges. This way, the physical length L which guarantees the desired broadside radiation is reduced of 50%, becoming $\lambda/4$ [10]. The consequences of this approach are a lower gain and a broader beam-width.

Another possible method to achieve a size reduction of the patch antenna, which has been more recently investigated, is based on the space filling property of fractal geometries. In particular, in [11] the use of the Koch curve in designing the non radiating edges of a $\lambda/2$ patch (w in Fig. 1(b)) has been investigated. This resulting structure shows a reduced size and a smaller bandwidth when compared to a standard rectangular patch.



(a) (b)

Figure 1. (a) RFID system operation. (b) Design parameters of a conventional rectangular patch antenna.

Taking advantage from the two above mentioned design approaches, the radiating structure here proposed consists of a short circuited fractal antenna, whose layout is shown in Fig. 2(d). Specifically, starting from a rectangular patch, two posts have been applied at one end of its feeding edge. Then a further size reduction has been obtained by using a second-order iteration Koch curve in designing the antenna non-radiating edges.

In Fig. 2, the layouts of the proposed short-circuited fractal antenna (Fig. 2(d)), of the conventional rectangular patch (Fig. 2(a)), of the fractal antenna (Fig. 2(b)), and of the short-circuited one (Fig. 2(c)) have been compared. The shown layouts are referred to a working frequency of about 866 MHz (EU standard for UHF-RFID applications) and to a standard and cost-effective FR4 substrate ($h = 1.6$ mm, $\varepsilon_r = 3.7$, a copper metallization of thickness $= 17\,\mu$m). In Fig. 3, for instance, the return loss of the four structures obtained through the planar full-wave simulator Ansoft Designer is reported. In particular, the advantage in terms of size-reduction of the short-circuited fractal antenna is clear. In fact, it has been calculated that its size reduction with respect to a rectangular patch antenna is 89.8%; whilst an 85.5% and a 45.8% size reduction is reached when the same structure is compared to the fractal and the short-circuited patch antennas respectively.

Finally, from the already mentioned Fig. 3 it is evident that, with respect to a conventional patch, the short-circuited fractal antenna exhibits a smaller bandwidth; however, such a bandwidth is larger enough to satisfy the UHF-RFID requirement (a few MHz).

Further details on the antenna performance will be given in the next section.

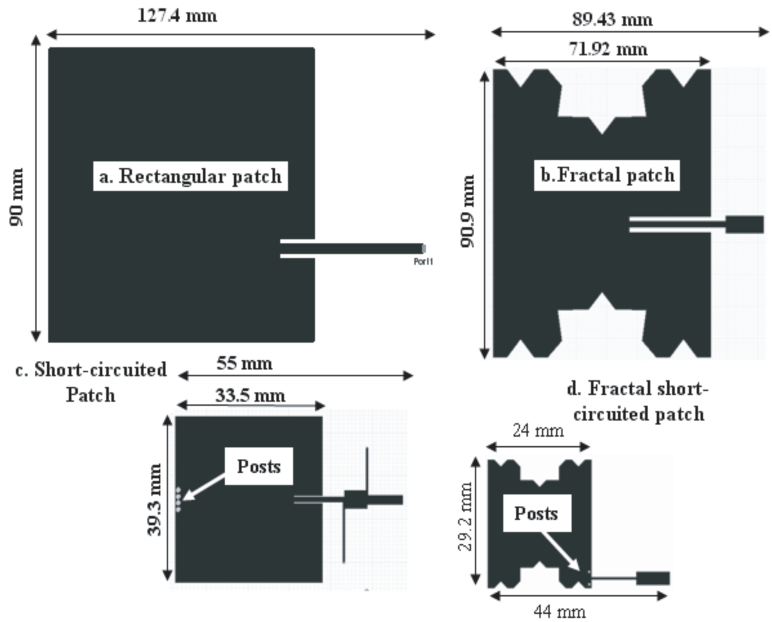


Figure 2. Layout comparison among: a rectangular (a), a fractal (b), a short circuited (c) and the proposed short-circuited fractal patch (d).

3. SENSITIVITY ANALYSIS OF THE ANTENNA PERFORMANCE

As stated in the previous section, results presented in Fig. 3 have been obtained by using the planar full-wave simulator Ansoft Designer, i.e., by assuming an infinite ground plane. In this section, the sensitivity of the antenna performance to the application surfaces and to the ground plane dimension will be investigated through different 3D Electromagnetic (EM) simulators. Specifically the simulators adopted are 4 commercial tools, namely the planar simulators Ansoft Designer and ADS-Momentum, both based on the Method of Moments, and the 3D simulators HFSS (High Frequency Structure Simulator) and CST-MS (Computer Simulation Technology-Microwave Studio) based respectively on the Finite Elements Method (FEM) and on the Finite Integration Technique (FIT).

We start our analysis by using CST-MS to investigate the effects on the proposed Tag-antenna performance of a ground plane with finite dimensions. The results achieved by using the time domain

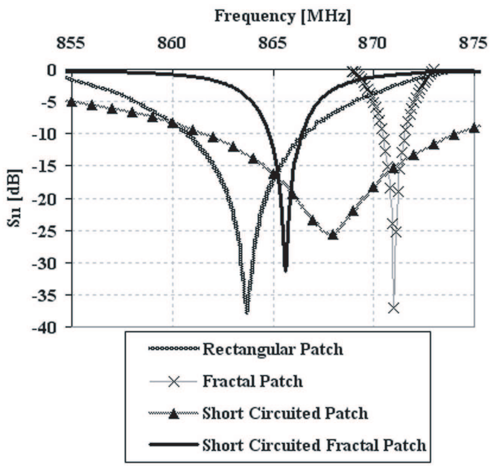


Figure 3. Return loss amplitude of the antennas whose layout is given in Fig. 3 (results calculated with the planar full-wave simulator Ansoft Designer).

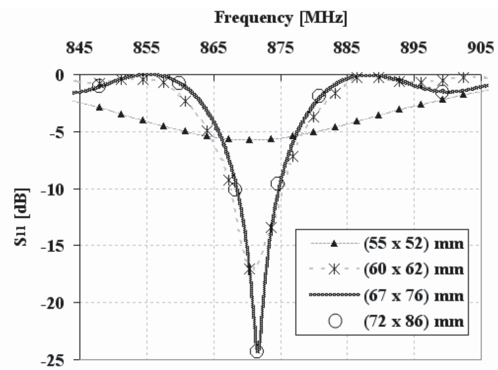


Figure 4. Amplitude of the proposed tag-antenna return loss for different values of the ground plane dimensions (w_g, L_g) as calculated by CST-MS.

solver of CST-MS are showed in Fig. 4 and resumed in Table 1. It is evident that good values of the S_{11} parameter have been obtained for a ground plane of dimensions greater than 67 mm along $x(w_g)$ and than 76 mm along y (L_g). In order to verify this result, the antenna with a ground plane of dimensions (67×76) mm has been also simulated with HFSS; the corresponding S_{11} amplitude is reported

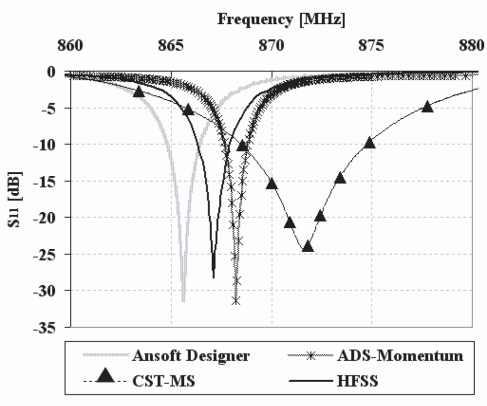


Figure 5. Comparison among the S_{11} parameters calculated with different commercial full-wave simulators for the proposed antenna with a ground plane of dimensions (67×76) mm.

Table 1. Ground plane with finite dimensions: CST-MS simulation results summary.

Ground Plane Dimensions (mm)		*S_{11} Amplitude Minimum (dB)*	*Resonance Frequency (MHz)*
w_g	L_g		
55	52	−5.72	870.4
60	62	−17.84	870.4
67	76	−24.31	871.62
72	86	−24.38	872.36

in Fig. 5 and is compared with the one calculated by using CST-MS, Ansoft Designer and ADS-Momentum simulators: all simulators calculate a resonance frequency in the range [865.63 MHz, 872 MHz] and a return-loss smaller than −24 dB. A prototype of the antenna has been also realized and its photograph is showed in Fig. 6 along with the corresponding S_{11} parameter. From measurements it can be observed that the antenna exhibits a resonance frequency equal to 864 MHz and a return loss of about −20 dB. The slight difference between simulated and experimental data is substantially due to our not yet optimized process for the realization of the posts.

As for the antenna radiation parameters, Fig. 6 shows the 3D polar plot of the far field calculated by HFSS for the antenna with a ground plane of (67×76) mm. We carry on our analysis by investigating the antenna application on metallic surfaces; the corresponding results are illustrated in Figs. 6–8. More specifically, Fig. 7 refers to the antenna with a ground plane of dimensions (67×76) mm. It is evident that with respect to the free-space case the antenna return loss remains substantially the same, whereas the radiated field exhibits a smaller retro-lobe (see Fig. 6).

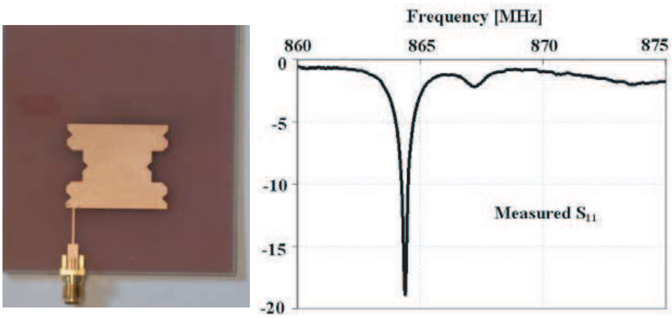


Figure 6. Photograph of the realized antenna and corresponding measured scattering parameter; the dimensions of the ground plane are (67×76) mm.

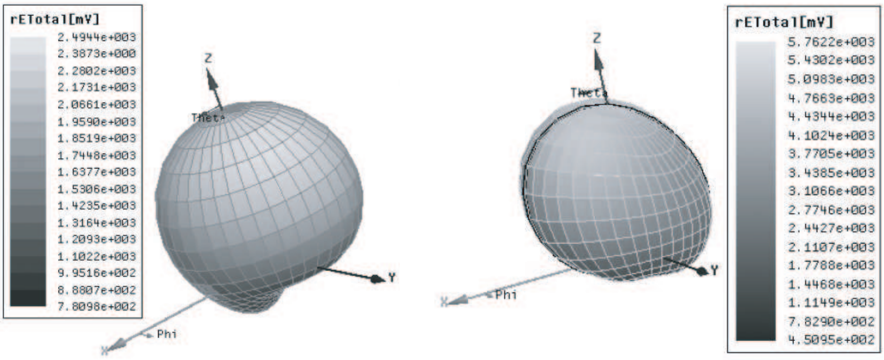


Figure 7. Normalized far-field and radiation parameters for the proposed tag-antenna as calculated by HFSS: antenna in free space (on the left) and antenna applied on a $(200 \times 200 \times 2)$ mm metal plate (on the right). The dimensions assumed for the ground plane are (67×76) mm.

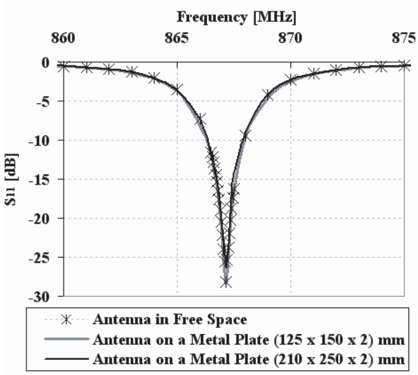


Figure 8. Proposed tag-antenna on a metallic platform: S_{11} parameter calculated with HFSS for different dimensions of the metallic surface; the ground plane dimensions have been assumed equal to (67×76) mm.

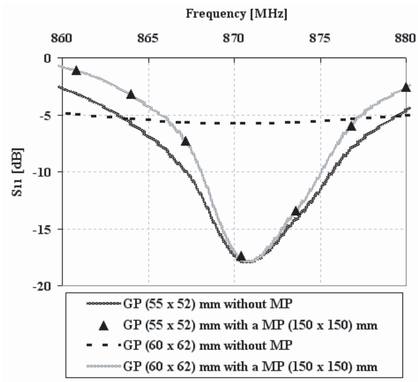


Figure 9. S_{11} parameters calculated for different values of the antenna ground plane: comparison between antenna in free space and antenna applied on a metallic plate. Reported results have been obtained with CST-MS.

As for the case of a smaller ground plane, the results calculated by using CST-MS are given in Fig. 8; it can be observed that the antenna application on a metallic plate results in smaller values of the S_{11} parameter and, de facto, in an improvement of the antenna performance.

4. CONCLUSION

A compact Tag-antenna for UHF-RFID applications has been presented. The proposed radiating structure is a patch antenna which takes advantage from the joint use of short circuiting posts and fractal geometries. This way, a size reduction of 89.8% has been obtained with respect to a conventional rectangular patch. The sensitivity of the antenna to the ground plane dimensions and to the application on metallic surfaces has been investigated; reported results demonstrate that the proposed antenna is well suited for application on any type of platform. It is worth underlining that, in line with the low-cost requirement of RFID Tags, the antenna has been designed on a standard FR4 substrate and can be realized with conventional Printed Circuit Board (PCB) techniques.

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