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UHF RFID Tag for Metal Containers

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***Abstract* — In this paper, we describe a passive UHF RFID tag for operating on various metal surfaces, primarily metal containers. The tag is designed is designed to cover both ETSI (865-870 MHz) and US (902-928 MHz) RFID bands and to provide both normal (boresight) and edge (lateral) reading capability with the read range of up to 7 m from normal direction and up to 4 m from lateral directions when mounted on metal. We describe the antenna structure, present modeling, simulation, and experimental data, and provide information on typical applications of this tag.**

***Index Terms* — Transponders, microstrip antennas, RFID**

I. INTRODUCTION AND MOTIVATION

There is a strong interest from automotive and other industries in tagging metal containers (including roll and freight) using passive RFID tags [1] which are cheap, contain no batteries and can be fully encapsulated for ruggedness and protection. The challenge in metal container applications is that in many practical cases the tags must be read not only from normal direction (boresight) but also laterally (from edges). For example, in a typical real-life application, a metal container (containing, for example, automotive parts) can have a tag mounted on the front or on the side surface (it is not known apriori) as illustrated in Figure 1.

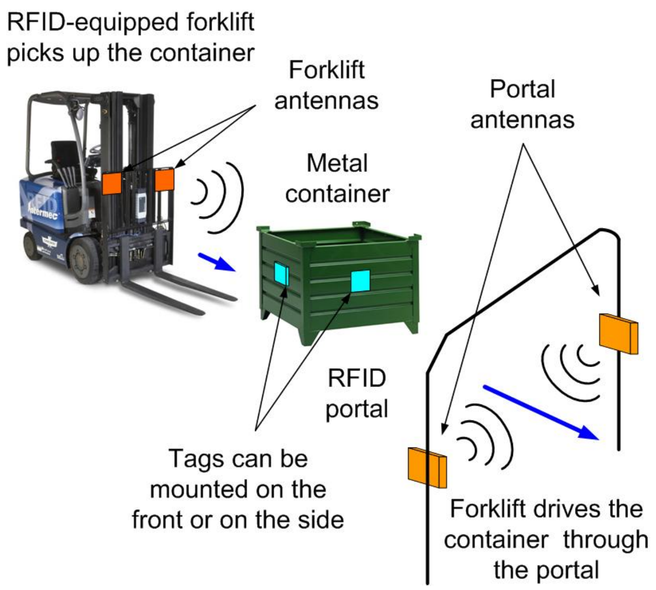

Fig. 1. Application scenario for metal container tag.

Such container often must be picked up by an RFID equipped forklift (which needs to read the container tag) and then must be driven through an RFID portal (which also needs to read the tag). In this scenario, the container tag must have good normal and edge reading capability as illustrated in Figure 2 (the tag polarization does not play a significant role here because both forklift and portal antennas are usually circularly polarized).

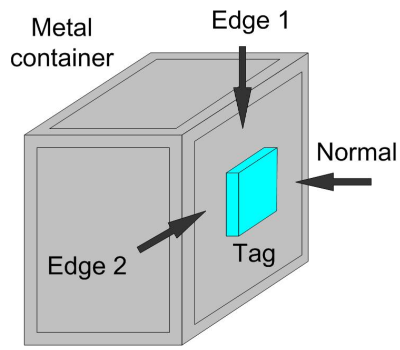

Fig. 2. Required normal and edge readings of the container tag.

Many passive UHF RFID tags for metal surfaces have been described in literature in recent years [2-26]. Those tags employed variations of microstrip patch antennas [2-13], PIFA antennas [14-17], slot antennas [18-19], their combinations [20-22], cavity backed antennas [23-24], dipole type antennas on spacers [25-28], etc. They were all designed for good read range on metal in the normal direction.

In this paper, we describe the tag which was specifically designed to achieve good read range in both normal and lateral directions when mounted on large metal surfaces such as automotive containers, which is the fundamental difference of this tag from previously described tags for metal. A significant advantage of such normal and lateral reading in practical use scenarios is that the tag can be read from different directions independently of the initial container orientation or tag location on it.

This tag has been commercialized [29] and is currently used in many applications, such as automotive containers, large metal containers, postal roll cages, and metal drums.

II. Tag Design and Simulation

The tag antenna is a coplanar waveguide-fed microstrip circular patch structure shown in Figure 3. It has two resonant frequencies, defined by complex conjugate matching between the antenna impedance and the chip impedance, which enable the tag's wideband performance.

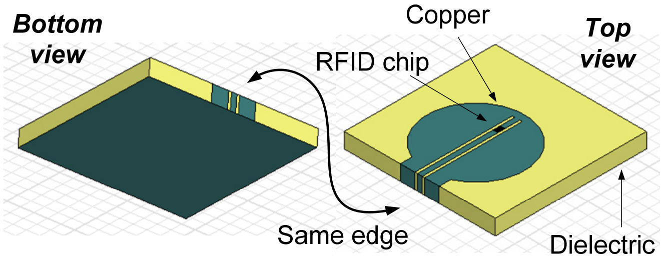

Fig. 3. Tag structure (general view).

For engineering purposes (simplicity, reliability, cost) it was decided to construct a tag antenna using a flexible inlay (1 oz copper on 2 mil PET) wrapped around a rectangular piece of the dielectric (high density polyethylene, HDPE, dielectric permittivity 2.5) as shown in Figure 4. This tag antenna was then inserted into the rigid plastic body made of Lexan 945 material (dielectric permittivity 2.7).

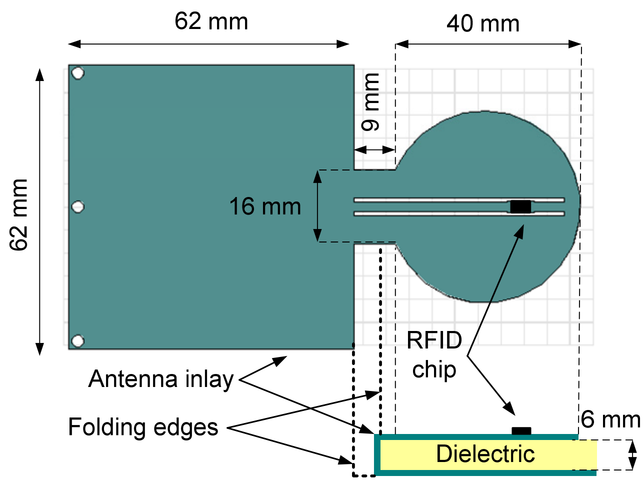

Fig. 4. Tag inlay and dimensions.

We used a UHF Gen2 RFID chip G2XM by NXP [28] in TSSOP package with approximate sensitivity of -12.6 dBm and a measured packaged chip impedance Zc = 26 − j 150 Ohm at 900 MHz [31]. The antenna was designed using electromagnetic simulation tool *Ansoft HFSS* which allowed us to calculate antenna gain, impedance, and proper matching to the RFID chip. The simulations were carried out for the case when the tag was encapsulated and then mounted on 30 cm x 30 cm sheet of metal as shown in Figure 5. Simulated antenna gain pattern for this case (at 900 MHz) and impedance vs. frequency are shown in Figures 6 and 7.

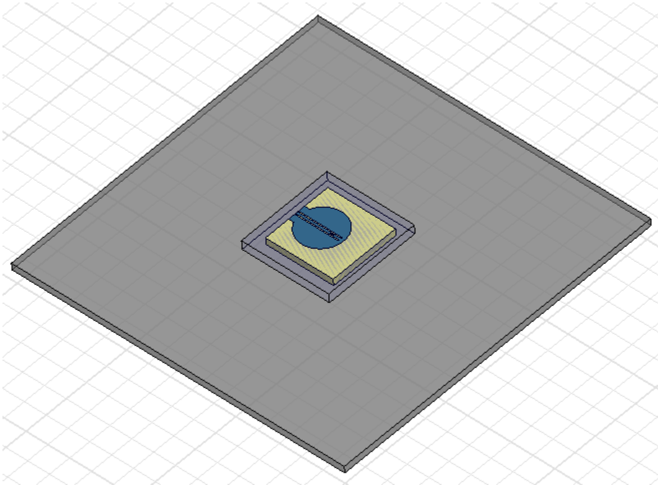

Fig. 5. Geometry used in HFSS simulations: encapsulated tag placed on 30 cm x 30 cm sheet of metal.

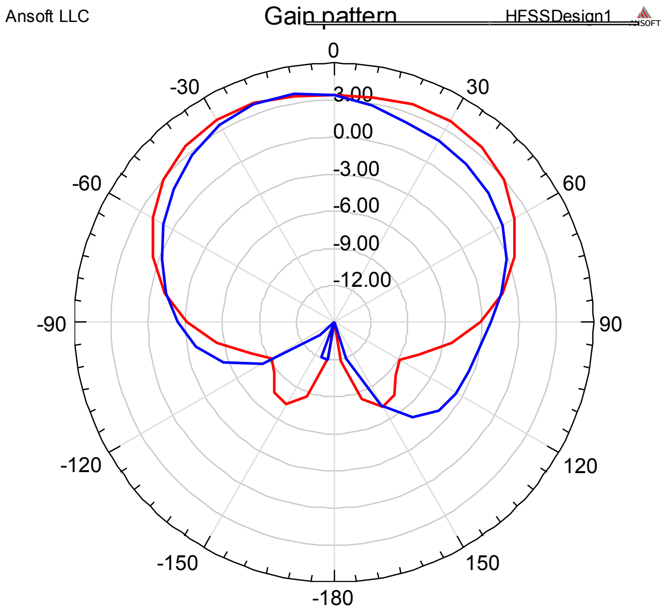

Fig 6. Simulated gain pattern (E-plane, red color, and H-plane, blue color) at 900 MHz. The scale is in dB.

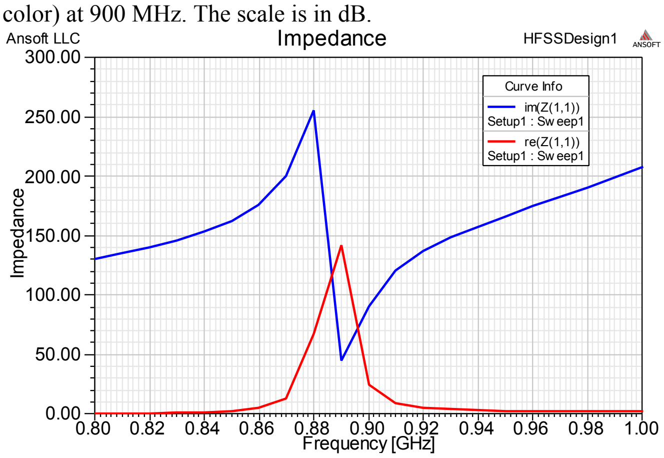

Fig 7. Simulated complex antenna impedance vs. frequency.

III. PROTOTYPES AND EXPERIMENTAL DATA

Several prototypes of the tag were made and tested. The final prototype of the tag insert (the inlay wrapped around the dielectric) is shown in Figure 8. The RFID IC in TSSOP package is soldered directly onto the inlay.

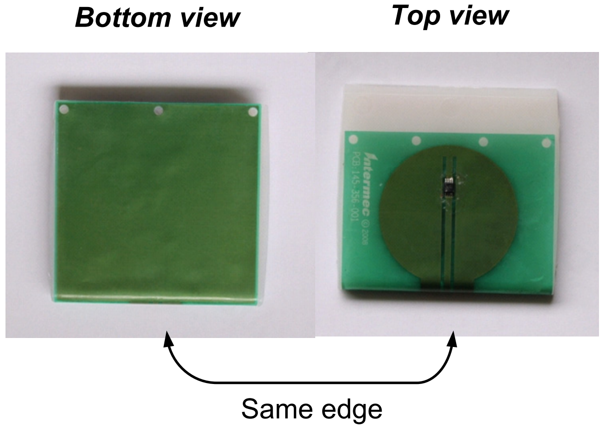

Fig. 8. Photograph of the tag prototype made with the inlay wrapped around the dielectric.

The tag insert shown in Figure 8 was encapsulated inside the rugged plastic package as shown in Figure 9.

Fig. 9. Photograph of the final encapsulated tag.

The package is capable of withstanding extreme temperatures and hazardous exposures. The tag can be mounted on metal surfaces using screws, rivets, or adhesive tape. The assembled tag dimensions are 9.45 cm x 7.2 cm x 1 cm. For more specification details, see [29].

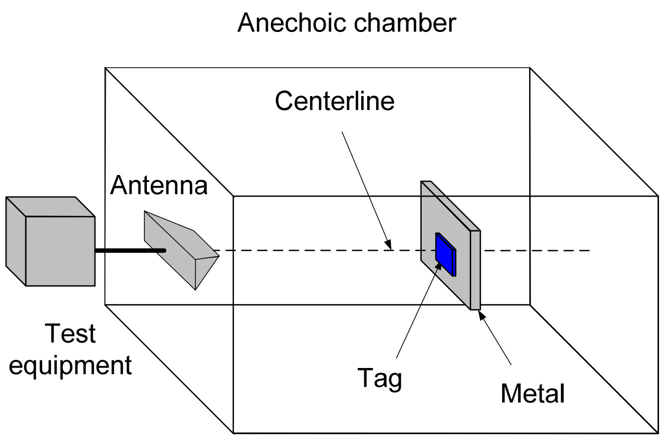

Fig. 10. Experimental setup for measuring the read range of the tag on metal (normal and lateral) for 4 W EIRP.

Tag read range was measured in anechoic chamber for the tag mounted on metal sheet (30 cm x 30 cm) using National Instruments PXI RF LabView based test system [30] with the setup shown in Figure 10. The reader antenna was linearly polarized (6 dBi gain), and the distance between the tag and the reader antenna was 1 m. Figure 11 presents experimentally measured read range data (normal and lateral directions) compared with HFSS simulations, which were in good agreement (sufficiently accurate to perform practical tag design iterations). Figure 12 illustrates reading directions (normal, edge 1, and edge 2) relative to the tag and the reader antenna.

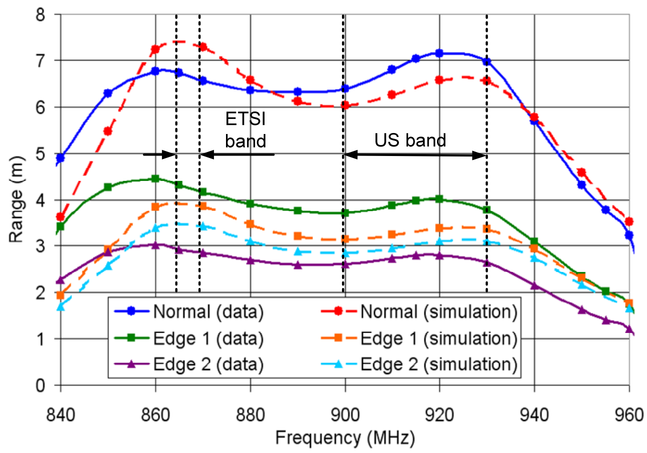

Fig. 11. Experimental read range of the tag on metal (normal and lateral) for 4 W EIRP (two RFID bands, ETSI and US are shown).

Fig. 12. Illustration of the tag reading directions using handheld RFID reader with linearly polarized antenna.

VI. Summary and Conclusions

In this paper, we described a passive UHF RFID tag for metal containers based on microstrip circular patch. The tag is wideband (covers both ETSI and US bands) and is designed to provide both normal (boresight) and edge (lateral) reading capability with the read range of up to 7 m from normal direction and up to 4 m from lateral directions when mounted on metal. The tag has been commercialized and is currently being used in many applications.

Acknowledgements

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