DUALBAND WEARABLE UHF RFID ANTENNA

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Abstract

Based on a system study of the ability to use a commercial RFID system operating in 869 MHz band for the identification of moving sportsmen [1], TAG antennas has been recognized as one of the most sensitive component that affect the proper function of the whole system, especially in case when TAG antenna has to operate in the close vicinity of human body. Single and dual-band weareable patch antenna to cover European (869.5 – 869.7 MHz) and US (902 – 930 MHz) RFID bands that are not affected by the presence of human body has been designed, manufactured and measured. The specifics of the design are complex conjugate input impedance to the impedance of the chip used, application of technique to extent the operating band, using of the foam dielectric and conductive cloth. The properties of developed TAG antennas has been compared with meander dipole and patch test antennas in free space as well as in the close vicinity to the human phantom.

1 Introduction

Radio Frequency Identification (RFID) systems are employed in many applications areas, see [2]. Identification is currently performed with minimal velocity of movement of transponders. However, in the recent time the demand for RFID system for identification of fast moving objects (such as sportsmen in mass races) arisen. System study of the ability to use a commercial RFID system operating in 869 MHz band for the identification of moving sportsmen has been performed and described in [1]. This study pointed to that the standard commercial RFID system is not usable for aforementioned applications. As the main issues following system fadings has been specified: the multi-way propagation, the influence of readers and TAG antennas radiation pattern shapes, the TAG antenna detuning caused by the presence of a human body, the polarization losses and the shadowing of TAG antenna by another racer in the vicinity of the identified racer. To improve power balance of the system new type of tag antennas that are not affected by the presence of human body has been designed. Special care has been devoted to the size, weight and the choice of the fabric for the prototype development so that the antennas could be used as wearable antennas for sportsmen of mass races.

2 Test antennas

To be able to realize measurement of power budget by means of a spectral analyzer [1] and comparison of antenna parameters, two types of test antennas has been designed and manufactured. Both antennas have been provided with 50 Ω SMA connector. The radiation patterns of antennas has been measured in the free space and in the distance b in front of the human body phantom (a tank of 5 litres of salt water). The measurement of the antennas gain has been performed right on human chest.

2.1 Meander dipole test antenna

TAGs of standard RFID systems usually use shorted dipole-type antennas. To be able to analyze and measure the antenna properties in the vicinity of human body/phantom, prototype of meander line shorted dipole antenna has been designed and manufactured. The meander dipole has been made of conductive cloth, see Fig. 1 and 2.

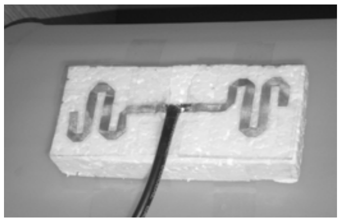

Fig. 1: Photograph of meander dipole test antenna placed in the distance b = 20 mm in front of the human body phantom

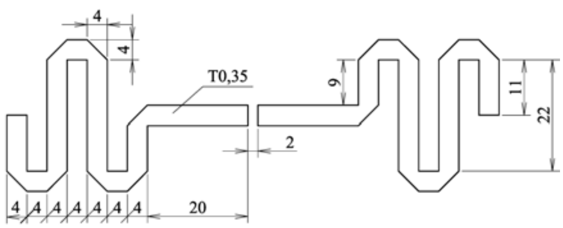

Fig. 2: Layout view of meander dipole test antenna

As for the main advantage of this antenna type, it is possible to mention relatively small dimensions (typ. 80 × 50 mm). Next advantages of this antenna type are a low profile (typ. 0.5 mm), a low weight and low manufacturing cost. This type of antenna with gain approx. 2 dBi could appear as usable for the mentioned above application. Unfortunately, the location of the antenna in the close vicinity of some objects (in the our case a human body is the object), cause the substantial detuning of its impedance matching. The measurement of the frequency detuning of the meander dipole antenna can bee seen in Fig. 3. This feature of dipole antenna results in a totally degrading of aforesaid benefits.

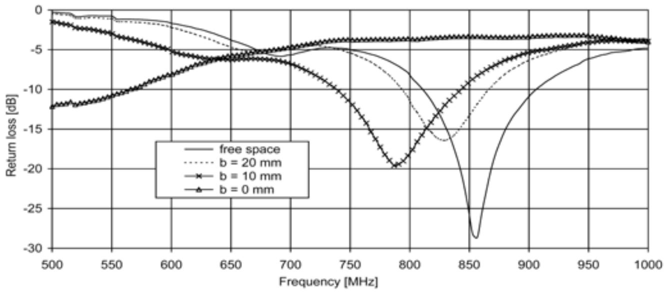

Fig. 3: Measured return loss of planar meander dipole test antenna as parameter of distance *b* from human body phantom

The similar effect is evident in case of antennas radiating patterns. Radiating patterns seeing at Fig. 4 has been measured in the free space and in the distance *b* in front of the human body phantom. The radiating patterns are normalized to maximum of new patch antenna radiation pattern (paragraph 3).

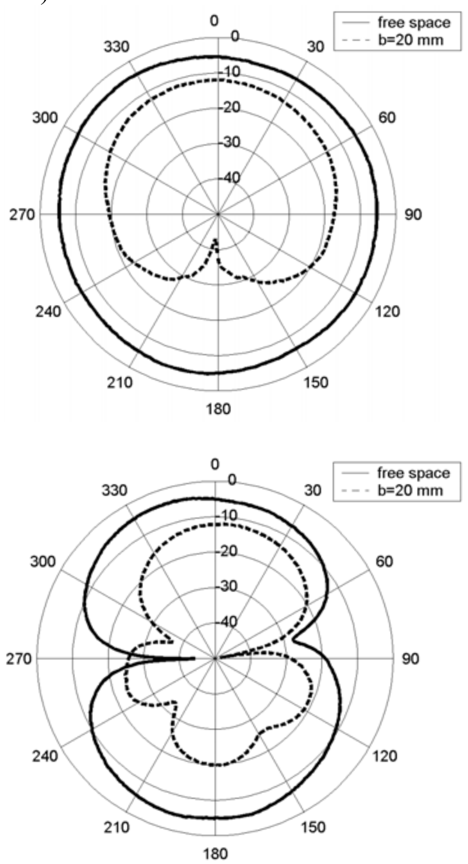

Fig. 4: Measured radiation patterns of meander dipole in free space and in distance *b* in front of human body phantom, a) E-plane, b) H-plane, normalized to maximum of new patch antenna radiation pattern (paragraph 3)

2.2 Patch test antenna

An antenna with a metallic ground plane seems to be the best solution of the described above issues. Metallic ground plane significantly increases front-to-back ratio of antenna thereby it reduce the influence of a pad material to the antennas parameters. Fig. 5 shows the insignificant influence of a pad locating in the distance *b* in front of the patch type antenna.

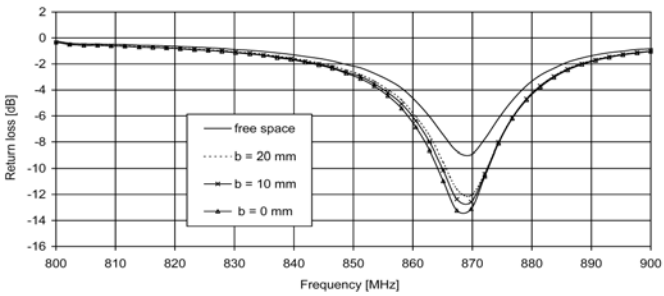

Fig. 5: Measured return loss of patch test antenna as parameter of distance *b* from human body phantom

However, because the RFID system operates at the frequency 869 MHz, we dash against two another problems. Firstly, the basic patch resonant frequency corresponds to $\lambda/2$ and therefore, at UHF frequencies the patch antennas cannot be extremely small. Second problem is relatively low antenna efficiency when relative patch height h/λ_0 decreases bellow 0.01, see Fig. 6.

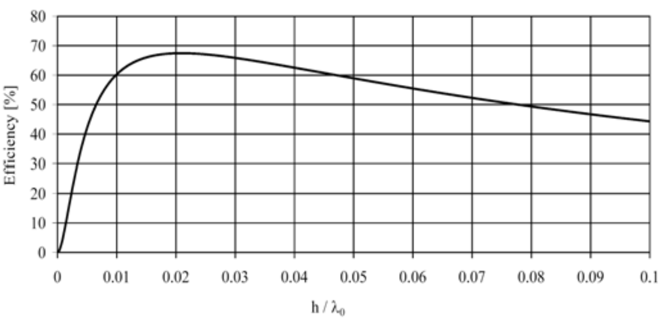

Fig. 6: Radiation efficiency of rectangular patch antenna with side ratio W/L = 1.5 and ε_r = 1.29 versus relative thickness of substrate h/λ_0, according to the reference [4]

For the identification of the racers, the patch layout size does not necessarily represent the major problem, since the TAG antenna can be integrated, for example, into racer number label. Moreover, the patch antenna can be fabricated on a foam dielectric and it is possible used for the creation of both the ground plane metallization and the top plane radiating patch a conductive cloth. Antenna created on a foam dielectric has minimal weight and it is possible to increase the antenna profile. Therefore, also problem of low efficiency can be dispose.

Nevertheless as the testing patch type antenna used for measurements has been designed and manufactured quarter-wavelength performance of patch antenna, see Fig. 7 and 8.

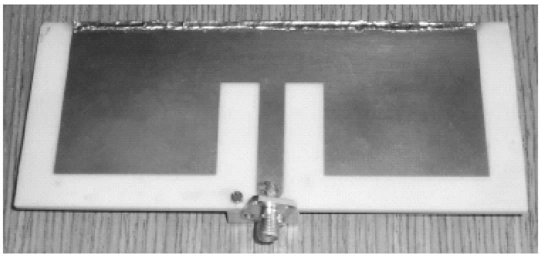

Fig. 7: Photograph of quarter-wavelength patch test antenna

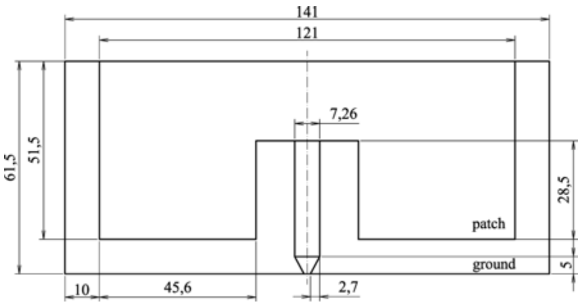

Fig. 8: Layout view of quarter-wavelength patch test antenna

Antenna has been made on 3 mm dielectric substrate (GIL GML 1000, $\varepsilon_r = 3.05$, tgδ ~ 0.003). Patch outer dimension are 141 × 61.5 mm. Relatively high dimensions and weight are acceptable for measuring purposes.

3 New RFID patch antenna

From the system point of view [1] demands on new TAG antenna result. As the TAG antenna is terminated with a chip of input impedance $Z_{chip} = 76 - j340\ \Omega$ its input impedance Z_{in} must be conjugate matched, see Fig. 9. Next requirements are satisfactory antenna gain (about 3 dBi) and broad hemispherical radiation patterns. Other requirements were specific with the nature of transponder "carriers" (sportsmen in mass races). The transponder antennas must be very light, flexible, must have a low profile and "reasonable" layout dimensions. As a matter of course the antenna must have minimal influence of a human body (or any other pad – e.g. a metal case) on antenna parameters.

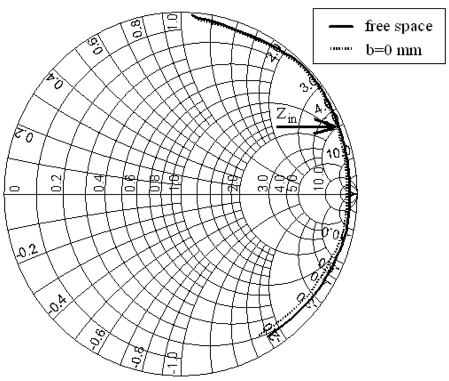

Fig. 9: Measured input impedance of new RFID patch antenna as parameter of distance *b* in front of a human body

According to the previous paragraph, the new patch antenna [5], see Fig. 10 and Fig. 11, was fabricated on the foam dielectric (G3 9568 foam $h = 4.8$ mm, $h/\lambda_0 \sim 0.014$, $\varepsilon_r = 1.29$) using a conductive fabric.

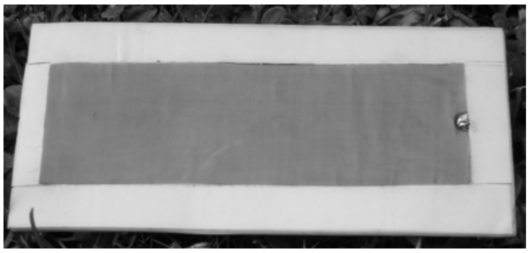

Fig. 10: Photograph of transponder new patch antenna with chip

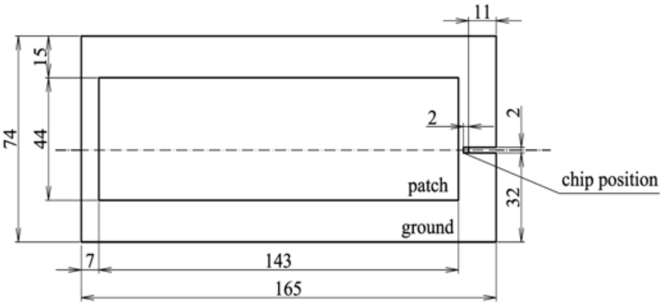

Fig. 11: Layout view of transponder new patch antenna

The new RFID patch antenna provides promising parameters compared to the test ones. Table 1 compare power gain of the antennas measured really on human chest. To be able to see influence of the frequency de-tuning, measurements have been realized for several values of distance from a human body (parameter *b*). The gain of new RFID patch antenna with non-50 Ω input impedance has been corrected (due to the presence of mismatch loss) so that the presented value is valid when antenna operate to conjugate matched chip impedance.

Antenna type	G [dBi]
Meander dipole test antenna, free space	2.2
Meander dipole test antenna, *b* = 20 mm	-5.72
Patch test antenna, free space	-3.02
Patch test antenna, *b* = 10 mm	-1.12
Patch test antenna, *b* = 0 mm	-0.12
New RFID patch antenna, free space	6.3
New RFID patch antenna, *b* = 0 mm	5.0

Tab. 1: Measured gain of new RFID patch antenna in comparison with test antennas

The similar comparison is possible to perform in case of antennas radiating patterns. This confrontation has been performed for the meander dipole and the new patch antenna. The meander dipole antenna radiating patterns can be seen in Fig. 4, which is placed in paragraph 2 – Test antennas.

The patch antenna patterns can be seen at Fig. 12. Both radiating patterns has been measured in the free space and in the distance b in front of the human body phantom and they are normalized to maximum of the new patch antenna radiating pattern.

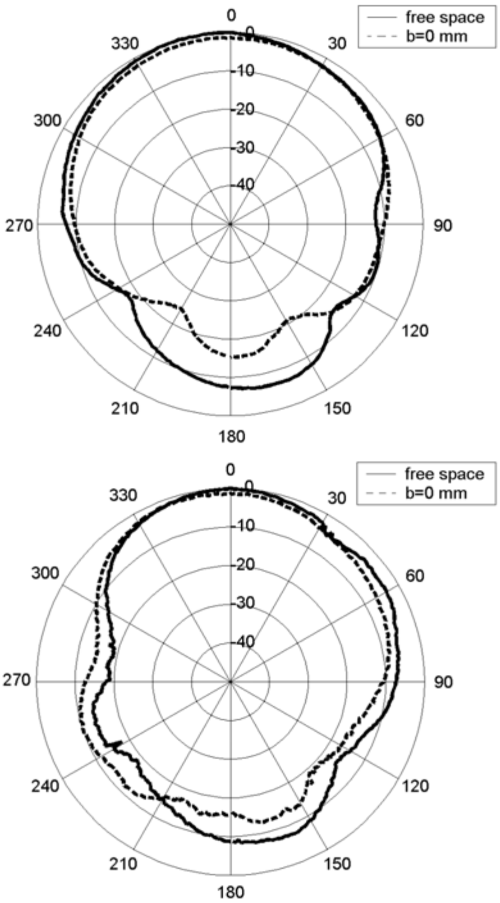

Fig. 12: Measured radiation patterns of new patch antenna a) E-plane b) H-plane

The new patch antenna fulfill above mentioned properties. The ground plane dimensions are 165 × 74 mm. Considering the antenna has been designed and realized on the basis of the foam dielectric, the relatively large dimensions are acceptable. Its weight is approximatelly 20 g. The measured purged of unmatching gain of the antenna placed on a human body is 5.0 dBi. The parameters of the realized antenna prototype have been consulted by sportsmen and organizers of mass races from the "wearablity" point of view and have been found acceptable.

4 Dualband RFID patch antenna

The described above antenna operate with good parameters in European RFID band (869.5 – 869.7 MHz). To be able to use it in US RFID band (902 – 930 MHz) too, the original antenna has been modified by two notches [4], see Fig. 13 and 14. The demands on the antenna remain the same as in the previous case. The antenna must be very light, flexible, and above all it must have minimal influence of a pad on antenna parameters. The prototype of the dualband RFID antenna has been manufactured from the same materials as the previous type. The antenna weight is about 20 g too. The ground plane dimensions are 155 x 74 mm.

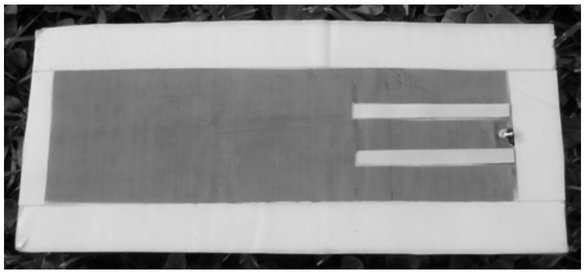

Fig. 13: Photograph of transponder dualband patch antenna with chip

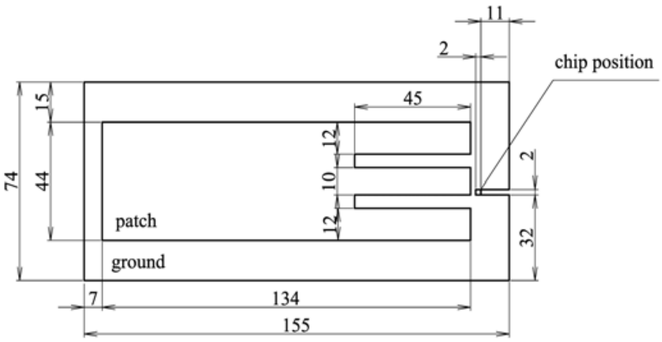

Fig. 14: Schematic view of transponder dualband patch antenna

IE3D simulation and measurement of antenna has been performed in free space and in a distance $b = 0$ mm from the human body phantom. In required band (869.5 – 930 MHz) it has been achieved matching better than -12 dB to the chip impedance ($Z_{chip} = 76 - j340\ \Omega$), see Fig. 15. Minimal influence of the human body phantom over the frequency de-tuning of the antenna is evident, too. It is possible to suppose similar behavior in case of any others type of a pad (e.g. a metal case).

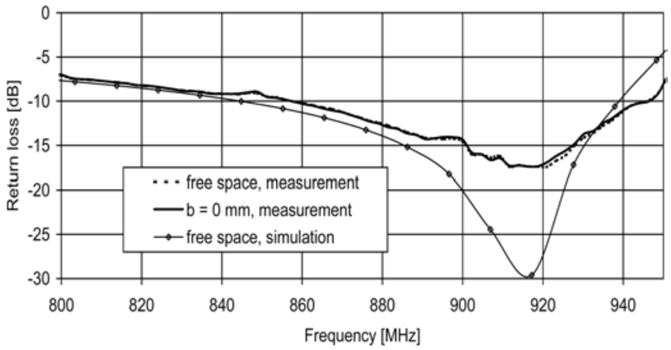

Fig. 15: Dualband patch antenna return loss in face of the chip impedance ($Z_{chip} = 76 – j340\ \Omega$) as parameter of distance b in front of a phantom

The comparison of the RFID patch antennas power gain can be seen in Tab. 2. The gain has been measured in free space and in the distance b = 0 mm in front of the human chest. The measurements have been performed at three frequencies (the Europe RFID band – 869 MHz and the lower and upper edge of the US band – 902 MHz or 930 MHz) in case of the dualband antenna.

Antenna type	G [dBi]
New patch, free space, f = 869 MHz	6.3
New patch, b = 0 mm, f = 869 MHz	5
Dualband patch, free space, f = 869 MHz	3.5
Dualband patch, b = 0 mm, f = 869 MHz	2.8
Dualband patch, free space, f = 902 MHz	5.5
Dualband patch, b = 0 mm, f = 902 MHz	4.2
Dualband patch, free space, f = 930 MHz	5.9
Dualband patch, b = 0 mm, f = 930 MHz	4.9

Tab. 2: Comparision of measured gains of both RFID patch antennas

Normalized radiating patterns can be seen in Fig. 16. Measurement of the radiating patterns has been performed in free space and in the distance b = 0 mm in front of the human body phantom at frequency 869 MHz.

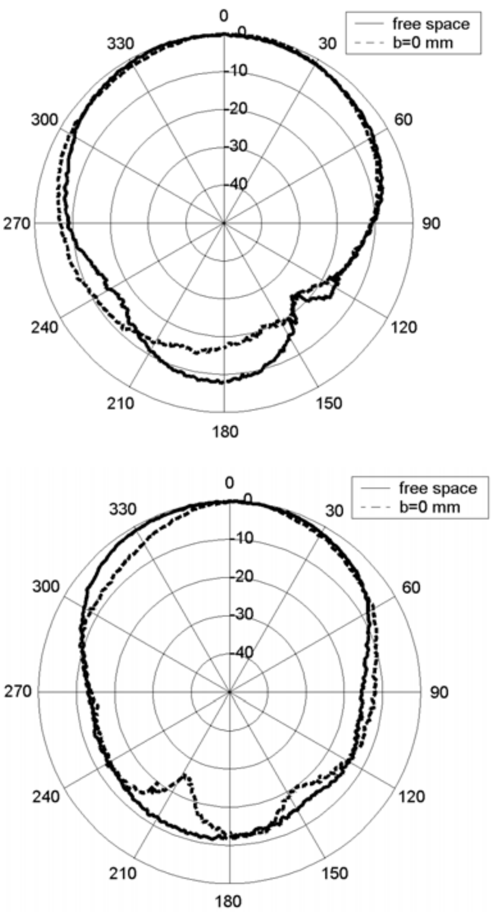

Fig. 16: Measured radiation patterns of dualband patch antenna a) E-plane b) H-plane, normalized to maximum of radiation pattern

5 Conclusion

In the recent time the demand for RFID system for identification of sportsmen in mass races arisen. The study of ability to use a commercial UHF RFID system has been performed and described in [1]. Result of this work leads to the necessity to design a new transponder antenna with independent parameters on the presence of a human body (or a other pad – e.g. a metal case). As the best candidate on the TAG antenna appears of patch-type. Such an antenna has been designed and examinated. In comparison to the original shorted dipole-type antenna, the gain of the new patch transponder antenna placed on a human body is more than 10.5 dBi higher. In other words the antenna parameters fulfil demands of a wearable antenna. The demands have been consulted of sportsmen and organizers of mass races.

To cover both European and US RFID bands broadband antenna (869.5 – 930 MHz) has been designed and measured. The antenna parameters are similar to in the previous case. The antenna gain is dependent on operating frequency. In the case of antenna position in the human body vicinity it vary from 2.8 dBi at 869 MHz to 4.9 dBi at 930 MHz. Further this antenna fulfil demands of a wearable antenna.

Acknowledgements

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