UHF RF Identification Distance in Indoor Areas

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***Abstract*—UHF RFID read range tests have been performed with a novel electrically small low-profile TAG antenna equipped with an artificial-like surfaces providing very good immunity against the influence of a near human body. The RFID system equipped with this antenna has been tested for the detection of a person in indoor and outdoor areas within 869 MHz band and reached read range up to 9 m.**

***Index Terms*—identification, loop antenna, RFID, TAG antenna.**

I. Introduction

Recently, applications of RFID systems have been more and more extended on monitoring and identification of persons, both within indoor and outdoor areas. These applications concern, for example, monitoring of employees in offices working with sensitive information, in large factories or power plants, personnel in army storehouse, supervisors in prisons, or long distance runners at checking gates or generally in access systems. In all these cases it can be important to identify a person on distance of several meters without necessity to take care or perform any action. These can be ensured by RFID systems operating on electromagnetic wave coupling mechanism where radiation efficient TAG antennas can be developed. This can be ensured starting from UHF RFID frequency band.

Behavior and functionality of any UHF and microwave RFID system based on electromagnetic wave coupling mechanism depend substantially on wave propagation effects and on corresponding reader-TAG and TAG-reader power budgets and on identification range of passive UHF (860 – 930 MHz). Propagation of electromagnetic waves between the reader and TAG antennas is influenced by several effects, namely by interference of direct and reflected rays, by waveguide effects, by mutual shadowing among persons in the irradiated area and by possible tilt of identified persons.

II. RFID System Desription

For the identification range tests a standard commercial RFID system [3] operating in the 869 MHz band was used. The main parameters of the system can be seen in Table I.

TABLE I
Standard UHF RFID system parameters from [3]

System components	**Parameter**	**Values**
	Operational frequency	869.5 ÷ 869.7 MHz
Reader	Transmitted power	24.7 ÷ 36.0 dBm
	Receiver sensitivity	-64 dBm (200 pW)
	Identification rate	70 s^{-1}
Chip	Sensitivity	-6.9 dBm (200 µW)
	Impedance (measured)	76-j340 Ω
	Conversion loss	approx. 20 dB

A novel TAG antenna [4] has been developed and used for the measurements. The antenna is depicted in Fig. 1 and its parameters follow.

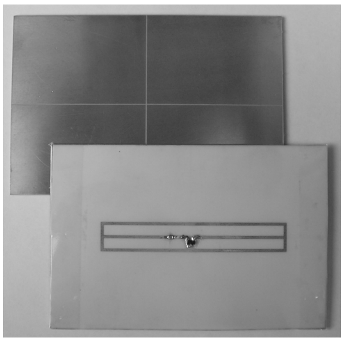

Fig. 1 Photograph of the designed prototype of the loop antenna closely spaced over a patch array surface at the distance d_1 = 0.24 mm, d_1/λ_0 ~ 0.0007 which is situated over the grounded dielectric slab, with the height d_2 = 1.58 mm, d_2/λ ~ 0.0046.

Antenna efficiencies and gain simulated and measured in free space and on a human body agar phantom can be seen in Table II.

TABLE II
Efficiency and Gain of loop antenna from Fig. 1

	Radiation efficiency [%]	Antenna efficiency [%]	Directivity [dBi]	Gain [dBi]
Simulated, free space	53	39	5.3	1.3
Measured, free space	68	38	5.0	0.8
Measured, on phantom	70	33	5.4	0.6

The measured radiation pattern of the loop antenna fed by the coaxial cable shows an approx. 15° tilt caused by the non-perfect symmetrization, see Fig. 2. This tilt is not expected to be present in the case of the TAG antenna-chip connection.

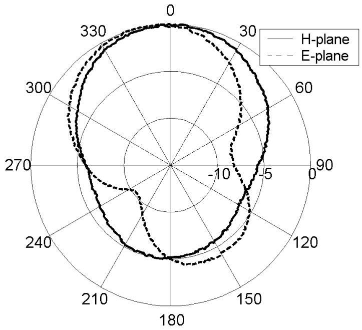

Fig. 2 Radiation pattern of the new TAG antenna measured in free space.

The antenna total size including the patch array is equal to 70 x 105 x 1.82 mm (relative size is 0.2 x 0.3 x 0.005 λ_0 at 869 MHz). The RFID TAGs, with these dimensions, can be used as standard identification badges.

III. MODELING

Simulation of the power budget in indoor and open area was performed for identification distance prediction.

A. Open area

In case of open areas, evaluations of reader-TAG and TAG-reader power budgets can be performed relatively simply by means of the analytical two-ray path-loss model [1].

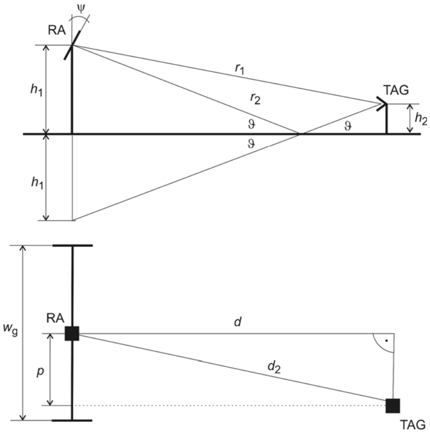

Fig. 3 Configuration of the two-ray model a) side-view b) top-view, with the following parameters: h_1 height of the reader antenna (denoted here RA), h_2 height of the TAG antenna, r_1 direct ray length, r_2 reflected ray length, d_2 ground plane distance between reader and TAG antennas, p reader and TAG antenna axis offset.

B. Indoor

Within indoor areas (typically corridors) a path-loss can be also influenced by reflection from surrounding walls causing so called waveguide effects. Attenuation of a received power $P(r)$ is here proportional to the distance from transmitter r by the term $(1/r)^n$ where n stands for a slope or path-loss exponent affected by the geometry of the corridor and electrical properties of the ground and roof floors, and side walls [2]. Inside corridors the path-loss exponent reaches values lower then in free space, i.e. from the interval $< 1; 2 >$. In this case, modeling of electromagnetic wave propagation is more complicated due to the multiple reflections, diffractions around vertical wedges, and the shadowing of walls and usually some form of a semi-analytical or numerical approach must to be used. For modeling of path-loss in a long test corridor a ray tracing method was used. The method takes into account all propagation paths whose fulfill the following criterions: up to 6 reflections, up to 2 diffractions, up to a total number of 6 interactions with a combination of max. 6 reflections and max. 2 diffractions. Particular ray tracing model uses coherent superposition and includes real radiation pattern of the reader antenna. Radiation pattern of receiving antenna has been considered omnidirectional. Results show that waveguide effects in the corridor can increase received power in expected identification distance by constructive summation of direct, reflected and diffracted rays compared to open area. Increased received power results in increased identification range in corridors compared to open areas. In closed rooms resonant effects and both constructive and destructive summation must be expected.

IV. IDENTIFICATION RANGE TESTS

In order to evaluate the read range, several test configurations have been measured: the TAG fixed at a person's chest in the height of 1.25 m in open area and in 4 m wide corridor; see Fig. 4.

a) b)

Fig. 4. Photograph of test configurations: a) a person with a chest-fixed TAG in an open area, b) a person with a chest-fixed TAG in a 4 m wide corridor

The received power P_{rTAG} at the TAG position and the received power $P_{rREADER}$ at the reader antenna position were calculated according to the two-ray model. In addition, they were compared with both the TAG chip and the reader sensitivity, see Fig. 5 and Fig. 6. In the range where P_{rTAG} and $P_{rREADER}$ exceed the sensitivities of the chip and the reader, a successful identification can be expected. The results of the read range of the test configurations are presented in Table III.

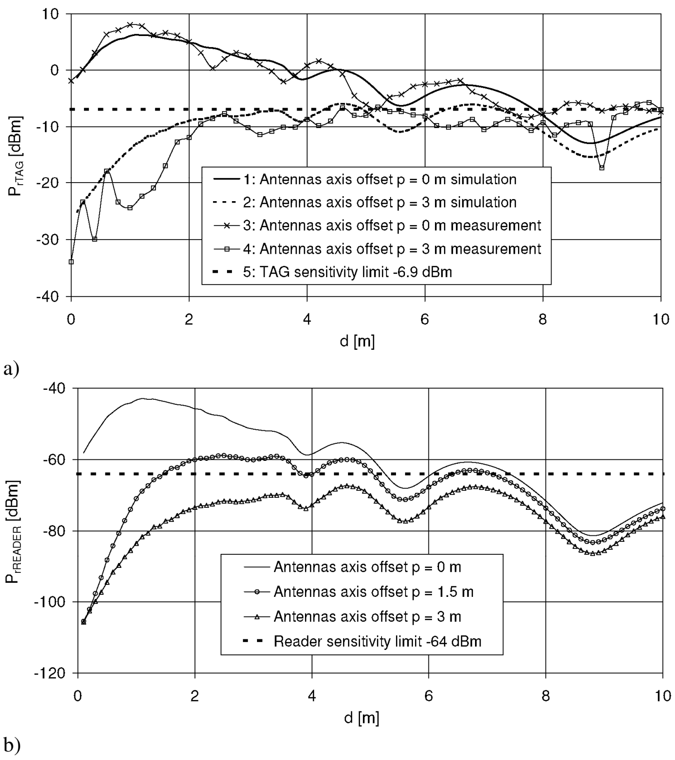

Fig. 5. Simulation and measurement (two-ray model) received power P_{rTAG} (a) and $P_{rReader}$ (b) versus distance d ($P_t = 35.4$ dBm, $h_1 = 2.5$ m, $h_2 = 1.25$ m, $\psi = 30°$) in open area

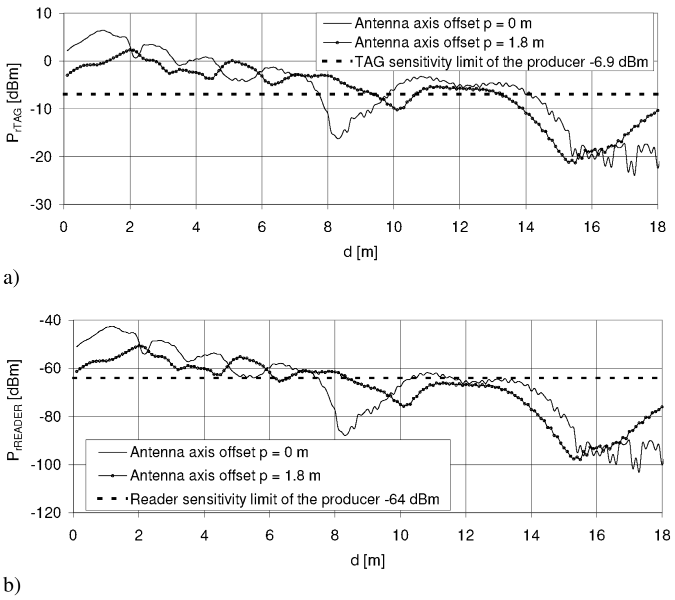

Fig. 6. Simulated (3D ray tracing) received power P_{rTAG} (a) and $P_{rReader}$ (b) versus base antenna distance ($P_t = 35.4$ dBm, $h_1 = 2.5$ m, $h_2 = 1.1$ m, $\psi = 30°$) in case of persons identification in corridor.

TABLE III

MEASURED MAXIMUM IDENTIFICATION DISTANCE OF TEST CONFIGURATIONS

Position of TAG antenna at person chest	Reader and TAG antenna axis offset p [m]	Reach of correct identification d_{max} [m]
open area	0	9
	1	6.5
	2	4
	3	unreliable ident.
4 m wide corridor	0	9
	1	8
	1.8	8

V. CONCLUSION

The performed RFID read range test with the electrically small TAG antenna provide a qualitative guess of the read range distances within the UHF RFID band. The read range up to 9 m has been achieved in open areas in the reader antenna axis. On the other hand, in case of the corridor the read range reaches 8 m for all antennas axis offsets. In this case, the waveguide effect in the corridor gives rise to a positive interference resulting in the increased read range.

For the implementation of the UHF RFID technology, the influence of the propagation effects (e.g. the multi-path propagation), waveguide effects (such as shadowing in case of the presence of a large amount of identified persons) must be carefully taken into account.

ACKNOWLEDGMENT

This work has been conducted at the Department of Electromagnetic Field of the Czech Technical University in Prague and supported partly by the Grant Agency of the Czech Republic project No. 102/08/1282 "Artificial electromagnetic structures for miniaturization of high-frequency and microwave radiation and circuit elements" and by the Grant Agency of the Czech Republic project No. 102/08/H018 "Modeling and simulation of fields".

REFERENCES

[1] Švanda, M.; Polívka, M., Hudec, P.: Application of the UHF RFID system for the identification of sportsmen in mass races, In: *Proceedings of the European Microwave Association*. Vol. 3, No. 4 (December, 2007), pp. 295-301, Edizioni Plus - Universita di Pisa, ISBN 88-8492-324-7.

[2] Digital Mobile Radio towards Future Generation Systems, COST 231 Final Report, Brussels, 1996

[3] http://www.trolleyscan.com, 2006

[4] Švanda, M., Polívka, M. : Novel dual-loop antenna placed over patch array surface for UHF RFID of dielectric and metallic objects. *Microwave and Optical Technology Letters*, march 2009, ISSN 0895-2477