Comments and Replies

Comments on "Antenna Design for UHF RFID Tags: A Review and a Practical Application"

Yuri Tikhov

In [1], the authors discuss the generic design process for passive UHF Radio Frequency IDentification (RFID) tag antennas. The attempt to formulate the key universal criteria for the tag antenna design looks really interesting. In this connection the most important characteristic of every UHF RFID system is a read range r—the maximum practical distance between an interrogator base station (reader) and a transponder (tag). Accordingly, the basic considerations are focused on the read range formula given in [1] as (1)

$$r = \frac{\lambda}{4\pi}\sqrt{\frac{P_t G_t G_r \tau}{P_{\rm th}}} \tag{1}$$

where λ is the wavelength, P_t is the power transmitted by the reader, G_t is the gain of the reader antenna, G_r is the gain of tag antenna, $P_{\rm th}$ is the minimum threshold power necessary to provide enough energy feeding for the tag chip, and τ is the power transmission coefficient due to the impedance mismatch between tag antenna and chip. Indeed, the far-field formula (1) is correct subject to assumption that polarization of reader antenna and the polarization of tag antenna are perfectly matched. But in fact, the polarization mismatch is essential in most RFID applications.

The point is that in the majority of applications the tag is allowed to appear in almost arbitrary position in the field of the reader antenna. Actually in [1] authors mention the problem of tag orientation, but just in the specific context of a directivity pattern. However, the polarization issue becomes also critical. And the polarization of the tag antenna is usually linear because of pre-required small size of the tag. In such situation the only way to fulfill a system requirement is to use circularly polarized reader antenna. Thus, a sacrifice of 3-dB power loss due to polarization mismatch between circularly polarized reader antenna and linearly polarized tag antenna overcomes the problem of tag orientation. This is why nowadays the major vendors (such as [2]–[5] and many others) offer mainly circularly polarized reader antennas.

At the same time the linearly polarized antennas are also available in the market for limited RFID applications. In the case of linearly polarized both reader and tag antennas, the substantial polarization misalignment may cause severe power loss which in its turn can potentially lead even to fault of RFID system at all.

Therefore, considering polarization issues, in order to avoid overestimation of the read range the formula (1) needs revisions. Definitely, in the most conventional case of circular-to-linear polarization mismatch the read range r should be $(1/\sqrt{2})$ times shorter. In the case of linear-to-linear polarization mismatch the decay factor is a function of the variable misalignment angle. The chart in [1, Fig. 3] should be corrected accordingly.

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The author is with the Samsung Advanced Institute of Technology, Suwon 440-600, Korea (e-mail: tikhov@sait.samsung.co.kr).
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Besides, it is worth mentioning that formula (1) is invalid at near-field distances between reader and tag. And the near-field situation can frequently happen in practical UHF RFID application scenario.

Regardless of above-mentioned inaccuracy, the qualitative value of the work [1] can be definitely very helpful for designers of passive UHF RFID tags.

References

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Reply to "Comments on 'Antenna Design for UHF RFID Tags: A Review and a Practical Application'"

Pavel V. Nikitin and K. V. S. Rao

The first issue raised by Dr. Tikhov in his Comments [1] is missing polarization mismatch factor in (1) of our work [2]. We agree that polarization mismatch is an important factor in communication links [3]. We also would like to point that (1) gives the *maximum* distance in free space at which RFID reader can detect the backscattered signal from a given tag which implies that both reader antenna and tag antenna are oriented towards each other in the direction of maximum gain and their polarizations are matched. To make (1) more general, one can indeed include in it both the polarization efficiency p (which accounts for polarization mismatch) and the dependence of antenna gain on the angles (θ, φ). The modified read range equation would then be given by

$$r = \frac{\lambda}{4\pi}\sqrt{\frac{P_t G_t(\theta,\varphi) G_r(\theta,\varphi) p \tau}{P_{\rm th}}}. \tag{1}$$

In the most general case, both reader and tag antenna are elliptically polarized with mutually tilted major axis of the polarization ellipses which lie in the planes perpendicular to the direction of propagation. The polarization efficiency p can be expressed as [4]

$$p = \frac{1 + \rho_1^2 \rho_2^2 + 2\rho_1\rho_2 \cos(\vartheta_1 - \vartheta_2)}{(1+\rho_1^2)(1+\rho_2^2)} \tag{2}$$

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The authors are with the RFID Intellitag Engineering Department, Intermec Technologies Corporation, Everett, WA 98203 USA (e-mail: pavel.nikitin@intermec.com; kvs.rao@intermec.com).
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where $\rho_1 e^{j\vartheta_1}$ and $\rho_2 e^{j\vartheta_2}$ are the complex polarization ratios of the reader antenna and the tag antenna. The absolute value ρ of the antenna polarization ratio is related to the antenna axial ratio A (measured in decibels) as

$$A = 20 \log \left| \frac{\rho + 1}{\rho - 1} \right|. \tag{3}$$

There are several special cases of interest for RFID applications. When both antennas are linearly polarized and oriented with a misalignment angle ϕ, the polarization efficiency is $p = \cos^2 \phi$. When the reader antenna is circularly polarized and the tag antenna is linearly polarized, the polarization efficiency is $1/2$ which decreases the read range by $\sqrt{2}$ as correctly pointed out by Dr. Tikhov.

Dr. Tikhov also mentions that (1) is invalid at near-field distances. We agree with that but would like to emphasize again that (1) gives the *maximum* distance at which RFID reader can read the tag in free space. In most UHF RFID systems, this distance extends well into the far-field zone. This is reflected in the very form of (1) which uses Friis free-space transmission formula valid only in the far-field region [5]. While some tag application scenarios involve near-field tag scanning, it can be expected that in most cases the tag which can operate in the far field should receive more than adequate power to operate when brought closer to RFID reader antenna into the near field. Hence, the read range of most UHF RFID tags is determined by the tag performance in far field.

We would like to thank Dr. Tikhov for his valuable Comments [1] which helped to clarify some aspects of our work [2] and make it more useful for tag antenna designers and other RFID community.

REFERENCES

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