Limitations on the Read Range of UHF and Millimetre Wave Radio Frequency Identification

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INTRODUCTION

Since the introduction of low cost passive, i.e. batteryless, transponders in the end of 1990's, the radio frequency identification (RFID) at ultra high frequencies (UHF) has been adopted in many applications from logistics to road tolls collection and timing in mass sports events. The passive RFID transponder is powered by the RF signal from the reader device. The communication from the transponder to the reader is based on backscattering modulation. The integrated circuit in the transponder modulates the load of the transponder antenna, which is seen as a modulation of the scattered field.

In this paper, the read range of passive UHF RFID is analysed, and the usage of millimetre waves for RFID, or millimetre wave identification (MMID) [1], is discussed.

READ RANGE

The RFID system has two restrictions to the read range. The power transfer to the transponder can be described by the effective aperture A_e of the transponder and the modulated backscattered power by the radar cross section σ_m of the transponder [1],

$$
\begin{aligned}
A_e^m &= \frac{G_A \lambda^2}{4\pi}\left(1 - \frac{1}{2}\left[|\Gamma_1|^2 + |\Gamma_2|^2\right]\right), \\
\sigma_m &= \frac{G_A^2 \lambda^2}{16\pi}\left|\Gamma_1 - \Gamma_2\right|^2 .
\end{aligned} \tag{1}
$$

Here G_A is the gain of the transponder antenna, λ is the wavelength and $\Gamma_{1,2}$ are the Kurokawa power reflection coefficients between the antenna and its load, i.e. $\Gamma_{1,2} = (Z_{1,2} - Z_A^*)/(Z_{1,2} + Z_A)$, where $Z_{1,2}$ are the antenna loads in modulation states 1 and 2, and Z_A is the antenna input impedance.

Equations (1) can be used with the Friis equation and radar equation to calculate the power transferred from reader to the transponder P_{tag} and the scattered power received by the reader P_{rx}, which are presented in Fig. 1 as a function of distance d between the reader and the transponder. The horizontal line in the figure presents transponder and reader sensitivities, P_{tag}^0 = -20 dBm and P_{rx}^0 = -100 dBm, respectively. These are typical values in a state-of-the-art passive UHF RFID system. The read range of the passive UHF RFID is limited by the power transfer to about 10 m.

However, the architecture of the reader RF front end is critical, because the transmitted signal may couple a significant amount of noise to the receiver input, overpowering the faint reflection from the transponder and raising the reader sensitivity with tens of dB.

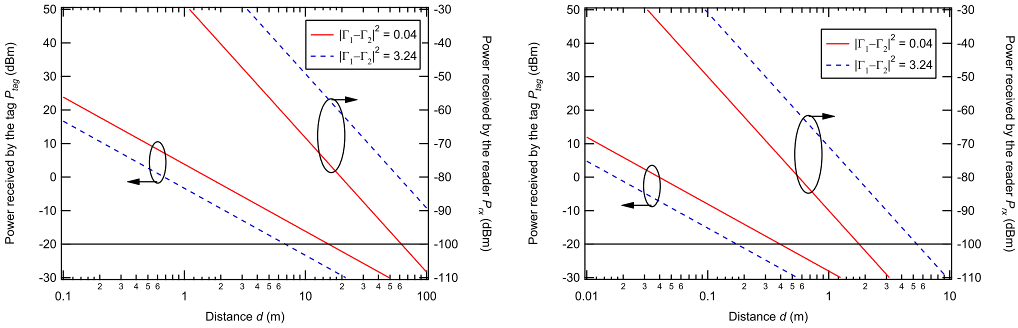

Figure 1: The limiting factors on the read range of RFID systems: UHF RFID at 869 MHz (left) and MMID at 60 GHz (right). Transmission power $G_{tx}P_{tx}$ = 33 dBm (erp) and G_A = 0 dBi. For UHF RFID, G_{rx} = 8 dBi, and for MMID, G_{rx} = 20 dBi.

Several designs, e.g. an adaptive RF front end in [2], has been suggested to provide high isolation between the transmitter and the receiver. In RFID, also matching ($\Gamma_{1,2}$ in (1)) in the transponder antenna may deteriorate the read range severely. The matching is affected by the antenna immediate surroundings, which vary from mounting platform to another.

Adopting millimetre waves for RFID provides smaller directive antennas for the reader and allows wider data band. In Fig. 1, the range of a passive MMID system is analysed. The passive MMID is feasible only in very low range due to inefficient power transfer, but enables wide data band, because received power P_{rx} is high compared to the reader sensitivity. Of course, smaller antennas with less directivity have to be used at low ranges to satisfy the far field criterion for Friis equation. Semipassive transponders, i.e. transponder with battery, would be limited by the scattered power, enabling a range of 5 m. The semipassive MMID has been experimentally verified to a range of 1 m in [1].

CONCLUSION

The read range of the passive UHF RFID is limited by the power transfer to the transponder to 10 m, provided the reader architecture eliminates the transmitter noise coupling to the receiver. The theoretical analysis of millimetre wave identification (MMID) opens two possible applications: 1) A passive mass memory with wireless wide data bandwidth access and range of a few cm; and 2) a semipassive transponder for e.g. sensor nodes, where densely located transponder can be separated from each other by the narrow beam of the reader antenna up to a range of 5 m. Another interesting possibility is that the automotive radars have all the hardware required for communication with MMID transponders, but probably active transponders should be used to enable longer range.

References

[1] P. Pursula, T. Vähä-Heikkilä, A. Müller, D. Neculoiu, G. Konstantinidis, A. Oja, and J. Tuovinen, "Millimetre Wave Identification — A New Short Range Radio System for Low Power, High Data Rate Applications", to be published in *IEEE Transactions on Microwave Theory and Techniques*, October 2008.

[2] P. Pursula, M. Kiviranta, and H. Seppä, "UHF RFID Reader with Active Reflected Power Canceller", accepted in *IEEE Microwave and Wireless Component Letters*, September 2008.