UWB ranging in passive UHF RFID: proof of concept

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A proof of concept for ultra-wideband (UWB)-based ranging in passive UHF RF identification (RFID) is presented. The proposed method uses the tag's backscatter modulation and thus does not require processing of the UWB signal by the tag. It is evaluated using measurements in an indoor environment similar to a warehouse portal in terms of channel impulse responses. The ranging accuracy is comparable to classical UWB ranging and thus inherently robust to multipath propagation.

Introduction and motivation: Even though passive UHF RFID is now a widespread technology, reliable positioning is a feature that is not yet available. Foremost in the list of reasons for this are the need to keep the tag simple (power consumption, costs) and the bandwidth limits of the UHF RFID frequency bands. As a consequence, currently used ranging methods are based on narrowband parameters such as return link phases [1], which rely on a very dominant direct path in multipath environments. Channel measurements in a warehouse portal [2] have shown that UHF RFID channels are typically dominated by the indirect (non-line-of-sight, NLOS) paths and not the direct line-of-sight (LOS) path. This leads to large errors and biased estimates in narrowband ranging methods, which in general cannot extract the LOS signal (see [2]). It is well known that ultra-wideband systems are able to overcome this problem and are thus able to provide accurate ranging in dense multipath environments. A related FMCW-based ultra-wideband ranging method has recently been published [3].

Discussion of ranging method: Setup description: The proposed method augments conventional passive UHF RFID by adding a UWB radar system. The radar system operates in parallel to the UHF system, see Figs. 1 and 2. As in conventional UHF RFID systems, tag power supply and communication is performed by the UHF reader and protocol. The radar setup emits an ultra-wideband signal, which is reflected by the tag during normal operation. Separation from the generally time-variant environment (decluttering) is performed by detecting the backscatter modulation in the received UWB signal. This modulation in the UWB frequency range can for example be achieved by creating a second match of chip and antenna impedance in the UWB band or by using two distinct antennas and modulation transistors for UHF and UWB.

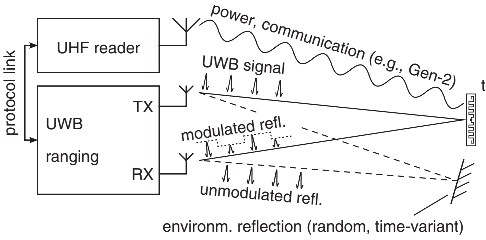

Fig. 1 *Basic principle of operation*

UWB radar determines tag range during normal tag operation by detecting shortest path that shows modulation

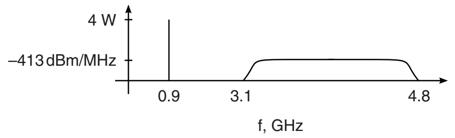

Fig. 2 *Example spectrum*

Parallel operation of conventional UHF RFID at 900 MHz and UWB radar in UWB frequency band

It is important to note that the tag does not process the UWB signal in any way except for backscattering it during normal operation. Thus the system requires only minimal changes in tag design and does not require any power supply by the tag. As the UWB transmitter and the receiver are within the same unit, coherent processing of the UWB signal can be achieved without the complexity of synchronisation.

Range detection: The radar base station uses estimates of the channel impulse response (CIR) over time to estimate the range to the tag. During modulation, the tag essentially switches between match (little reflection) and mismatch (large reflection). As a consequence of this backscatter modulation, the tap of the CIR that corresponds to the shortest path to the tag and many subsequent taps (multipath propagation on the return link) will show the modulation. This can be detected by evaluating the time-variance of each component of the CIR over time. The protocol link to the reader ensures that the tag reply is known to the UWB radar and thus can be used for the detection of the backscatter modulation in the CIR.

Proof of concept: This concept has been evaluated in the frequency range 3–6 GHz using time-variant transmission coefficient measurements between TX and RX antennas by a network analyser. The measurements were taken in an enclosed room (approx. 3 × 6 m) with steel-reinforced concrete floor and walls, reflective windows, and large metal surfaces on walls and ceiling. This makes it a relatively dense multipath environment. The channel TX → tag → RX fits classical short-range wireless indoor channel models with K-factors in the range of 0 dB and RMS delay spreads in the range of 20 ns. This is comparable to the inside of a warehouse gate with metal reflectors [2].

As UWB-band antennas matched to the chip are not yet available, the modulation was emulated by measuring match and short independently using omnidirectional UWB patch antennas. Time-variant transmission coefficient measurements using a standard UHF tag have confirmed that the modulation is detectable using this setup if the antenna is matched to the chip. We have also confirmed that passive backscatter modulation above 3 GHz is feasible during normal tag operation using an NXP UCODE G2XM chip attached to an omnidirectional UWB antenna [2]. However, as chip and antenna are not matched for this setup, the modulation is too unstable and weak to be detectable by the NWA setup. Therefore manual switching between short and match has been chosen for this evaluation.

Range estimates were taken at several positions in this room; the channel impulse responses were estimated out of 30000 modulation cycles for each position. The power-delay-profiles (PDP) for a position with a path length TX → tag → RX of 2.8 m are presented in Fig. 3. The upper plot shows the difference between the PDPs for matched and unmatched states. Note that the difference between the delay-profiles in this plot has been amplified for better visibility. The lower plot shows the extraction of this difference (not amplified). As can be seen, the profiles start to differ at the shortest path to the tag.

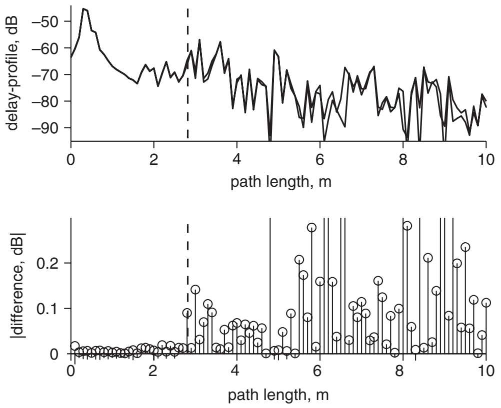

Fig. 3 *Measured PDP for matched/unmatched modulation state (top) and extracted differences (bottom)*

Note that difference in upper plot has been increased by factor of 20 to increase visibility; lower plot shows true difference

Conclusions and discussion: We have presented a proof of concept for UWB radar based ranging in conventional UHF RFID. The system does not require any processing of the UWB signal by the tag or synchronisation at the RF level. Ranging accuracy can be expected to be similar to coherent ultra-wideband ranging. The ranging method relies on the ability of the tag to reflect signals with sufficient modulation depth in an ultra-wideband frequency range. Commercially availably UHF RFID chips are only designed for operation in frequency ranges up to 2.5 GHz (e.g. UCODE HSL). Additional research is required to assess the feasibility of ultra-wideband matching of an antenna to state-of-the-art UHF RFID chips in the frequency range above 3 GHz. This might prove a nontrivial task owing to the power- and frequency-dependence of the chip and modulation impedance. Integrating a second modulation transistor on the chip that short-circuits a UWB antenna port might be a feasible alternative here: as the power levels in the UWB band are very low and the tag power supply is maintained by the UHF link, the UWB modulation transistor can be built as a very small structure and completely short-circuit a perfectly matched impedance for modulation. This switching between (close to) ideal loads would ensure an optimal modulation depth and match the measurements presented in this Letter.

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