Long Range RFID Position Estimation for Applications in the Health Care System

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***Abstract*— Localization of RFID devices are important tasks in numerous modern applications e.g. hospital management. The communication distance and therefore the ranging distance between base station and RFID sensor-tags is strongly limited by the maximum transmission power and the receiver sensitivity. A method based on passive SAW compressive receivers is presented to enhance the transmission distance for RFID tag ranging. The position estimation was done by active transmission of chirp pulses by the RFID sensor-tag and ToA and PoA measurements at the receivers.**

Keywords—radio frequency identification; position estimation; chirp; compressive receiver

I. INTRODUCTION

Radio Frequency Identification Tags (RFIDs) are common used in numberless applications like logistical product tracking, patient tracking in hospitals, electronic identification and access control as well as wireless sensor applications. Especially the use of RFIDs as passive or semi-passive RF-frontend makes them together with low power sensors very attractive for industrial or environmental monitoring as well as for enhanced hospital management [1]. The RFID concept is based on a near field inductive coupling between the RFID tag and the reader allowing only short communication distances and therefore a limited operation range for fully passive devices [2]-[3].

Together with its capability as sensor RF-frontend, RFID tags can be used for localization purposes where the actual position can be estimated from e.g. the received signal strength (RSS) [4]. Especially for passive tags this technique is imprecise due to scattering/multipath propagation and the need of several antennas or base stations. Other localization techniques based on phase of arrival (PoA) evaluation from the back scattered signal are more accurate but need more than one base station for reliable position estimation [5].

II. POSITION ESTIMATION OF RFID BASED SENSORS

Our concept for RFID position estimation based on time of arrival (ToA) is useful for semi-active devices which can be switched from a sleep mode into an active mode by a power-up signal enabling the tag to transmit a signal for ToA determination. For RFID wake-up a power-up signal must be transmitted from the base station to the tag, however, the transmission distance is limited by the transmitter power, the antenna gain/diameter and the input sensitivity of the tag. In common concepts, for energy saving, all components of the tag are powered down except a comparator input over which a wake-up interrupt can be released by an external signal [6]. Without active amplification on the tag, the amplitude of the power-up signal is proportional to the received field strength and the quality factor of the antenna. A substantial gain of the received power-up signal can be achieved by using a passive compressive receiver like a surface acoustic wave (SAW) signal matched filter on the RFID tag. An analog matched filter is a time invariant linear device. The response c(t) to a signal s(t) is c(t)=s(t)*h(t), the convolution of the signal s(t) with the impulse response h(t) of the device. In the receiver the signal is compressed in a main lobe of duration $1/B_c$.

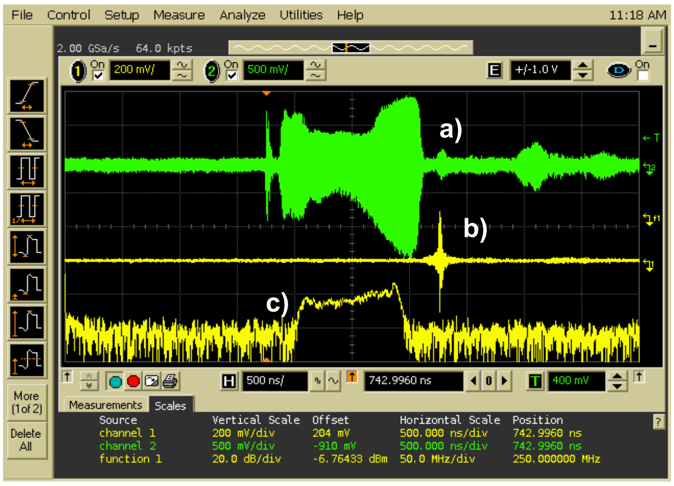

Fig. 1. Time signal of the **a)** transmitted chirp signal, **b)** compressed chirp pulse after the matched filter. **c)** Spectrum of the transmitted chirp signal.

If the energy is assumed to be constant, the peak value of the autocorrelation function (ACF) after pulse compression $R_{ss}(0)$ is given by

$$R_{ss}(0) = \sqrt{T_c B_c} \quad (1)$$

The factor $T_c \cdot B_c$ is the gain in peak signal power due to impulse compression. It is equal to the enhancement of the peak signal-to-noise ratio (SNR) in the case of additive white Gaussian noise. In our application, for RFID wake-up, we have used chirp signals with a center frequency of 250 MHz, a bandwidth of B_c=80 MHz and a chirp duration of T_c=1 µs corresponding to a compressive gain of 19 dB (Fig.1).

The position estimation of a tag is done by sending a up-chirp signal for wake-up from the base station to the tag. On the tag a signal matched chirp filter delivers a compressed chirp pulse with the dedicated compressive gain of 19 dB, triggering an interrupt for wake-up of the RFID device. After wake-up the RFID tag starts a periodic transmission of down-chirp signals to the base station. The tag position estimation can be done in the base station by ToA together with PoA measurements at compressive chirp-receivers on different locations and subsequent triangulation (Fig.2).

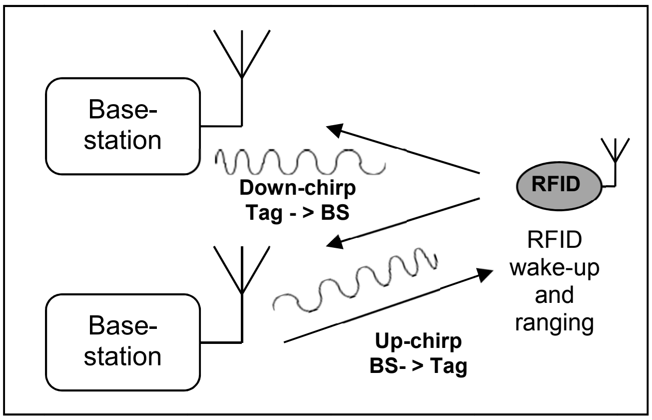

Fig. 2. Principle of the RFID-tag location estimation by chirp impulse ToA and PoA.

In Fig. 3 the compressed chirp pulses are depicted as a bandpass signal (Fig. 3a) with a center frequency of 250 MHz and after envelope demodulation (Fig. 3b). Rough position estimation can be done from the received compressed chirp signals after demodulation (Fig. 3b) where an additional better accuracy can be gained from the phase differences of the received bandpass signals at the receivers (Fig. 3a).

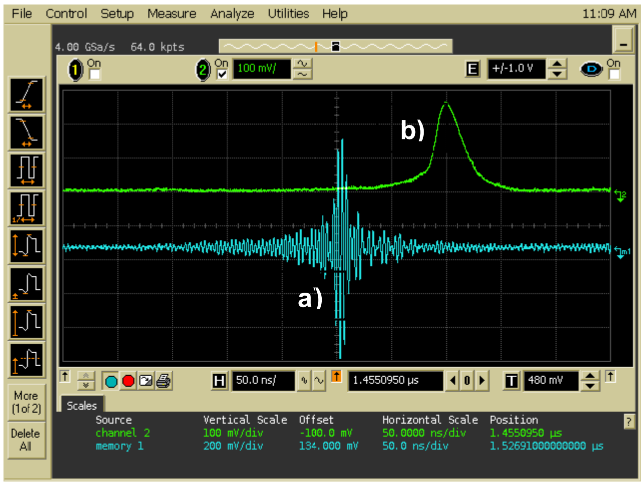

Fig. 3. **a)** Compressed chirp signal with center frequency of 250 MHz and **b)** compressed chirp signal after envelope detection.

CONCLUSION

A concept for long range position estimation of RFID tags is proposed. Utilizing a passive compressive chirp receiver a compressive gain of approximately 19 dB can be achieved. In hospitals RFID's are common used for patient as well as consumable identification. The shown method can be used for possible location and tracking of patients within the complete duration of hospitalization.

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