

Position Estimation of RFID based Sensors using Surface Acoustic Wave Devices

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Abstract—A lot of all-day products are equipped with radio frequency identification (RFID) tags to enable a wireless identification, payment etc. For a lot of applications, especially for sensor based applications, location information of the RFID based sensor tag would be helpful. In this paper an accurate and robust method for position estimation of RFID tags based on time of arrival (ToA) calculation of a transmitted broadband spread spectrum signal is described. The used spread spectrum waveforms are broadband chirp signals which are generated by passive surface acoustic wave devices (SAW). The performance of RFID position estimation under additive white Gaussian noise (AWGN) conditions was simulated.

Keywords—RFID tags; position measurement; chirp modulation; surface acoustic wave devices; correlation.

I. INTRODUCTION

Radio frequency identification devices (RFIDs) are used in numerous applications like wireless sensors. For advanced applications the actual position and the tracking of RFID tags is from importance. Therefore for battery operated devices a method for RFID position estimation with low power consumption is needed.

The principles of position estimation of RFID devices can be separated into two groups. First, the RFID device is detected by its ID response if it is powering up in the vicinity of a base station. If a RFID device is supplied with energy from an external device, the standard ISO/IEC 14443 [1] defines that the RFID's ID will be periodically transmitted. Based on this principle, the position of a RFID device can be roughly estimated from the maximum transmission distance of the base station [2]-[4]. A second principle for position estimation is given by base station connected to a directional antenna. RFID tags are located on known position and if the base station irradiates one of the RFID tags, it powers up and transmits its ID. From the angle of the directional antenna and the known position on the RFID tags, the position of the base station can be estimated [5][6]. This principle is commonly used for moving objects like robots. In general, the performance of position estimation can be improved by using the received signal strength (RSS) as an additional indicator [7]-[9].

II. SYSTEM DESIGN

In this study, a principle for wireless position estimation of RFID devices based on time of arrival (ToA) and phase of arrival calculation of a transmitted broadband spread spectrum signal is described (Figure 1).

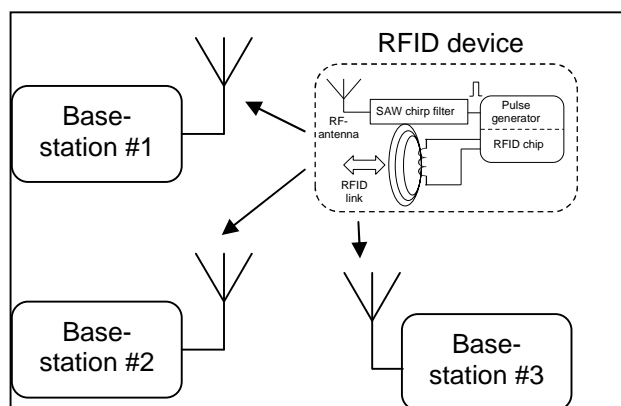


Figure 1. Transmission of linear chirp signals for ToA measurement.

The used spread spectrum waveforms are broadband chirp signals which are generated by passive surface acoustic wave devices (SAW). The impulse response of the used SAW filters is a linear chirp signal with center frequency $f_0=250\text{MHz}$ and a bandwidth of $B=80\text{MHz}$ (Figure 2). The chirp signal is generated by exciting the SAW chirp-filter with a short pulse which is delivered by the RFID unit on the tag. To transmit a powerful chirp signal from the RFID tag to the base stations a pulse generator based on an avalanche transistor was developed. With this method, high energy pulses with rise times below 3ns are generated for exciting the SAW chirp filter. The chirp signal is transmitted via a RF antenna to RFID base-stations which are located within the transmission range.

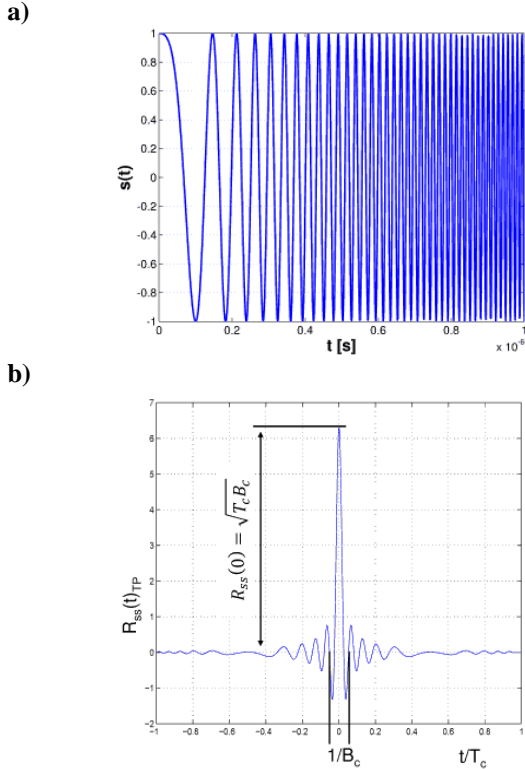


Figure 2. a) Linear frequency modulated signal (chirp signal), b) compressed chirp signal after matched filter detection (autocorrelation function ACF).

The RFID is not continuously in the active mode but will normally be set in the low-power sleep state and powered up only at scheduled time points or on request by a received wake-up signal. After wake-up, the RFID unit starts a periodic transmission of chirp signals to receivers within the transmission range. To gain a high signal to noise ratio (SNR) at the receiver a signal matched filter having the time inverse impulse response of the transmitted signal is used which generates in the matched filter case the chirp-autocorrelation function at the output with a compression gain proportional to the time-bandwidth product of the chirp (Figure 2b).

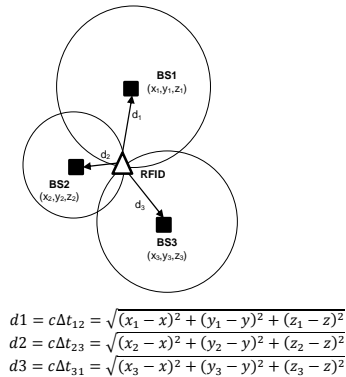


Figure 3. Trilateration principle for 3D RFID position estimation.

The position estimation is done by trilateration [1-3] where the time of arrival differences of the chirp signals at the receivers is calculated (Figure 3). If the position of more than one RFID tag should be estimated, each RFID transmits its unique code for separation. The coding of the transmitted chirp signals is done by pulse position modulation where the chirps are located in different time slots.

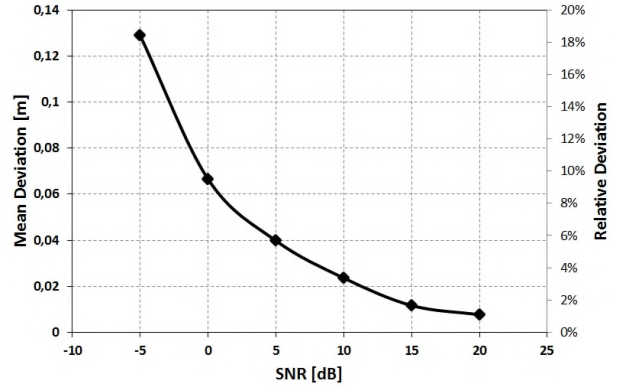


Figure 4. Mean accuracy of the RFID position estimation under AWGN conditions. N = 100.

The localization accuracy of the proposed method was determined under the assumption of an AWGN (additive white Gaussian noise) transmission channel where the received signal is corrupted with noise. The accuracy of position estimation based on chirp signals under LOS conditions is mainly given by the peak amplitude of the chirp ACF and the noise on the transmission channel. The simulation results for the accuracy of position estimation for different SNR values are depicted in Figure 4. It is shown that for SNR values above 10dB the position can be estimated with an error below 2%.

III. CONCLUSION

An accurate and power-saving principle for wireless position estimation of RFID devices was proposed. For correlative signal processing with a high immunity against interference in the transmission channel, linear chirp signals for locating RFID devices are used. The signal generation is carried out on the RFID tag by triggering a SAW-based chirp filter with short and broadband pulses. Several simulations of the chirp-based position estimation method under AWGN conditions underlie the accuracy and robustness of the proposed principle. Further simulations will be done under AWGN and indoor situations. The proposed position estimation principle should also be compared to different existing methods.

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