High Resolution Impulse Radio UWB Localization

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A new UWB ranging technique has been developed that outperforms the existing ones. A reduced-complexity version of this ranging technique can be flexibly implemented using FPGAs and hence it can be put on low-power silicon, which makes it a good candidate for high resolution localization and proximity ranging in wireless sensors based applications.

Ultrawideband (UWB) has been the focus of a big research effort recently. Due to its delay resolution proprieties, UWB exhibits good capabilities for short range communications in dense multipath environments. Among such capabilities, an important one is the ability of accurate ranging leading to accurate position localization. Indeed, the transmission of extremely short pulses (and hence large transmission bandwidth) resolve the multipath components, which enhance the ranging accuracy. A set of ranging techniques that can lead to accurate position are based on the estimation of Time of Arrival (ToA) of the UWB received signal.

Methods using Impulse Radio (IR) UWB can lead to ranging accuracy improvements over classical narrowband solutions. The susceptibility of obtaining such enhanced accuracy would depend on the used ranging method. Using an IR-UWB transmission scheme alone will not lead to reaching the performance bounds unless a suitable ranging method, that efficiently exploits the UWB transmission nature, is used.

Simple ranging algorithms (such as correlation based techniques and the leading edge ones) lead to a satisfactory ranging accuracy (in terms of the obtained ranging error and its closeness to the corresponding error lower bound) in propagation environments with high Signal to Noise Ratio (SNR) values but for situations where the SNR values are low, the obtained performance is not good. As SNRs in the normal indoor environments (e.g. Office, Residential, etc) are not always high, adequate ranging techniques for such propagation situations, need to be developed.

A high resolution IR-UWB ranging technique is proposed here. The main idea of the investigated approach is to exploit the Maximum Likelihood (ML) formulation applied on the UWB received signal in the frequency-domain, in order to estimate the ToA and then convert the obtained estimate of the first ToA component to a distance estimate. The developed technique relies on the exploitation of the UWB nature of the transmitted signal in combination with an efficient denoising procedure of the ML cost function. This joint combination leads to spectacular enhancement in the estimation of the ToA of the received UWB signal, which immediately results in improvement of the ranging error. Motivated by the good results obtained for the ranging technique, related reduced-complexity version [1], which can be flexibly implemented using FPGAs and hence be put on low-power silicon [2] were investigated. Such implementation is important in the sense that it can be envisaged for tiny sensing devices such as sensors and tags, which makes the reduced-complexity version of the ranging algorithm a good candidate for localization and proximity ranging in wireless sensors based applications.

For illustration purposes, a received UWB signal composed of IR Gaussian pulses with a centre frequency equal to 5.12 GHz is considered. Each pulse has a duration of 1 ns in a total burst length of 100 ns, which means a duty cycle equal to 1%. On the received IR UWB signal, a Fast Fourier Transform (FFT) of length equal to 128 is applied. The propagation environment is characterized by a five-ray channel with amplitudes equal to [0.6, 0.8, 0.6, 0.7, 0.5] and delays equal to [10 ns, 20.5 ns, 31 ns, 43.5 ns, 50 ns]. The developed ranging technique to estimate the vector of the channel delays is first applied and then only the first delay is kept that is converted to a distance estimate. Figure 1 illustrates the obtained performance in terms of standard deviation of the ranging error and compares it to the ranging error lower bound that can be reached and expressed here in terms of Cramer-Rao Lower Bound (CRLB). Clearly, using the developed ranging technique high resolution localization results are obtained.

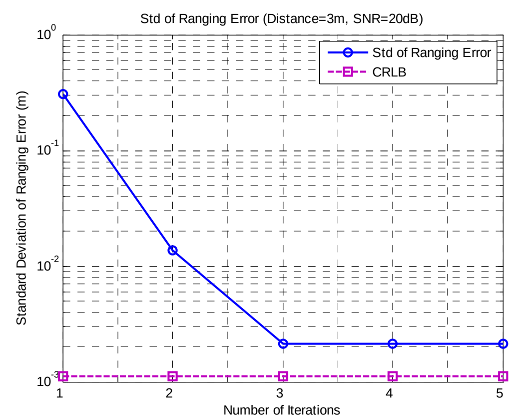

Figure 1: Standard deviation of the ranging error

[1] The reduced-complexity version of the ranging technique is under submission for a CSEM's patent application.

[2] An integration of the ranging technique in a UWB testbed being developed in the Swiss Federal Institute of Technology, Lausanne (EPFL), is under way.