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ABSTRACTS (PH D THESIS)

Study on Accurate Ranging and Positioning System with UWB-IR Technology

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In this work, a low-power UWB-IR transceivers for wireless sensor networks as well as wireless positioning systems were developed.

We first explained conventional positioning methods with radio signals in Chapter 2, followed by presentation of the proposed TOA/TDOA hybrid relative positioning system based on UWB-IR technology. The proposed system design reduces the complexity of the system infrastructure when compared to the conventional TDOA systems and also reduces the number of wireless transmissions in a positioning sequence compared to conventional TOA systems. In particular, the proposed method eliminates the need for accurate synchronization among the APs and the target nodes. Additionally, it enables node-position detections with less number of access points compared to the conventional methods leading to low communication overhead at the target nodes. Through computer simulations, we confirmed that the proposed method can achieve better performance compared to the conventional TOA method with the same number of transmissions from the target node. These results validate that the proposed TOA/TDOA hybrid relative positioning system can detect the position of the target nodes with a better accuracy compared to the conventional TOA systems and with less access points compared to the conventional TDOA systems.

In Chapter 3, a novel design of the impulse-based DS-UWB system for low-power wireless applications such as wireless sensor networks was discussed. The proposed system is based on direct-sequence impulse radio with low duty cycle that enables energy efficient precise positioning. We propose several schemes in order to realize a low-cost and low-power coherent-based UWB-IR transceiver with features such as differential encoding, 2-step spreading at the transmitter, PRF sampling and initial acquisition with a combination of a serial search method and a MF method at the receiver. This system has potential to realize a lower-power transceiver LSI by reducing the sampling rate and the complexity of the digital signal processing. Towards the end of this chapter, we showed link budget calculation to conclude that our proposed system can provide enough performance for long range communications.

Chapter 4 discussed detailed system specifications of the proposed system along with simulation as well as measurement results. First of all, we investigated the permissible implementation loss of each block by considering deteriorating factors of the receiver. As a result, we found out that the total implementation loss can be within the link margin of 10.7 dB. We then performed computer simulations in which all the deteriorating factors were incorporated. The results showed that the target performance was satisfied even in the worst case conditions.

Finally, we developed a test bed and confirmed that our developed system satisfied the target performance of 250-kbps and 30-m communication. As the conclusion of this investigation, the experimental results support the feasibility of our proposed system, which has a potential to realize a lower power transceiver LSI and precise positioning systems.

Chapter 5 explained the developed UWB-IR receiver with an accurate TOA measurement capability for ranging/positioning systems for wireless sensor network applications. The developed system provides a simple architecture for coherent-based receivers and was designed to allow for transceiver implementation in a general 0.18-micrometer CMOS technology. For a rapid initial acquisition and low complexity of the coherent-based receiver, a combination of the serial search method with multiple-step search for the pulse-synchronization and the matched filter method for the code-synchronization was proposed. Furthermore, a first-path-detection algorithm that enables accurate measurements of the arrival time of the first-path signal in a multipath environment was presented. This algorithm also utilizes a combination of the serial search method for the pulse synchronization and the characteristics of the matched filters for the code synchronization as well as the initial acquisition scheme discussed above. The proposed approach can reduce both the speed of analog digital converters in the receiver and the amount of memory required to estimate received waveforms for the first-path detection.

Furthermore, the proposed system allows 20-ppm frequency error of transceiver's clocks by utilizing a characteristic of coherent-based transceivers. These features enable a ranging-capable transceiver with simple, low-power, and low-cost implementation.

Furthermore, full UWB transceiver chips and modules for ranging and positioning systems with the proposed algorithms were developed. A highly-precise ranging system with the developed modules was set up and used to test the proposed algorithm. The experimental results verified that (i) the proposed algorithm achieves ranging accuracy of 18.5 cm on an average in a closed space, and (ii) the developed transceiver has a good enough receiver sensitivity to enable 30-m distance communications. These performances are thought to be sufficient enough for systems used in real sensor network applications.

Finally, the TOA/TDOA hybrid relative positioning system based on UWB-IR technology was developed. As discussed in Chapter 2, the system reduces the complexity of the system infrastructure compared to conventional TDOA systems, and reduces the number of wireless transmissions in a positioning sequence compared to conventional TOA systems. In particular, the system can eliminate the need of accurate synchronization among the APs and the target nodes. The proposed system was then implemented with the developed UWB transceivers. The measurement results cofirmed that the developed TOA/TDOA hybrid system can detect the relative positions of target nodes with a measured-distance accuracy of 0.31 m and a measured-angle accuracy of 8.6 degrees under the condition that the distance between two APs are 4 m. It also achieves a measured-distance accuracy of 0.18 m and a measured-angle accuracy of 16.2 degrees under the condition that the distance between two APs is 1 m. These results support that the developed system has positioning capability even when the distance between APs is shorter than the distance from the APs to the target node.

The presented research and development work is one of the earliest work in the world which realizes UWB-IR ranging/positioning systems with in-house single-chip UWB-IR transceivers in CMOS technology. We believe this research work can be a promising solution for realizing current and future ubiquitous societies.