Tutorial #2

Ultra Wideband (UWB) and Its Applications to the Industry and Automotive Environments

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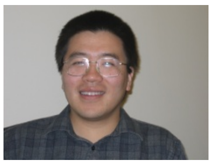

Instructor: Hong Nie received his Ph.D. degree with specialization in wireless communications in 2004 from the University of British Columbia, Vancouver, BC, Canada. He is currently an assistant professor at the Department of Industrial Technology, the University of Northern Iowa, Cedar Falls, IA, USA. His research interest includes UWB technology for wireless sensor transceivers, advanced wireless transceiver architectures for sensors in industrial environments, and industrial applications of wireless sensor networks.

Highlight: This tutorial will provide audience with an overall but yet deep introduction to the principles, fundamentals and state-of-art of ultra wideband (UWB) radio technologies and their applications. The interested topics that will be addressed in this tutorial are various UWB modulation technologies, transceiver design and optimization of UWB based sensors, channel model for UWB radio under various environments, UWB system performances and the applications of UWB to customers, industry and automotive.

Abstract: UWB systems are wireless systems which transmit signals across a much wider frequency spectrum than conventional wireless systems. According to a definition given by the US Federal Communications Commission (FCC), the radio signal of a UWB system has either a bandwidth of at least 20% of its center frequency, or a -10 dB bandwidth which exceeds 500MHz. The UWB systems were originally used for radar, sensing, military communications and some niche applications. In February 2002, the FCC issued a Report and Order allowing license-free access to the 0-960 MHz and the 3.1-10.6GHz frequency bands for data commutations, radar, and other applications, as long as the power spectrum density (PSD) of the radio frequency (RF) signals transmitted by the UWB systems satisfies the indoor and outdoor spectral masks set by the FCC. This new regulation has sparked great research and development interest from both academia and industry in the UWB systems and their potential applications such as high date-rate consumer electronics, and low power and low complexity wireless sensor networks.

Typically, there are two different approaches to generate RF signals with ultra wide bandwidth: the multi-band CDMA or OFDM approach for high-data-rate (20Mbs or greater) applications, and the impulse radio (IR) approach for low-data-rate applications. The IR UWB approach transmits pulses or pulsed waveforms with very short duration, which is usually on the order of nanoseconds or even shorter. Because those short-duration pulses can be transmitted without a carrier, the IR UWB systems have the advantages of low complexity, low power consumption, and good time-domain resolution allowing for location and tracking applications. With all these advantages, the IR UWB approach has

been selected by the IEEE 802.15.4a standard as the alternative PHY for the IEEE 802.15.4 standard "in providing communications and high precision ranging/location capability (1 meter accuracy and better), high aggregate throughput, and ultra low power; as well as adding scalability to higher data rates, longer range, and lower power consumption and cost."

Nevertheless, transmitting short-duration pulses also introduces a critical problem in the transceiver design for the IR UWB systems. In multipath environments, especially in non-line-of-sight environments, the received IR UWB signals consist of many resolvable multipath components (MPCs), the number of which is much higher than that in any other wireless systems. Generally, for the received signals with multiple resolvable MPCs, the Rake receiver can effectively capture the signal energy spread among those MPCs by assigning each MPC a detecting finger. However, in order to precisely match the amplitude, phase, and delay of a specific MPC, an individual set of channel estimation, multipath acquisition, and tracking operations are required for each detecting finger. Consequently, the system complexity of the Rake receiver becomes unacceptably high when the number of detecting fingers is large.

In this tutorial, with the above-described multipath problem as a key problem to solve, I will present in detail the following four technical subjects related to the transceiver design for the IR UWB systems: i) the IEEE 802.15.4a multipath models for the potential applications of IR-UWB systems in various environments such as body-area networks and general indoor and outdoor settings (including residence, office complex, agricultural areas, farms, and industrial operation rooms and workshops); ii) general IR UWB modulation schemes such as pulse position modulation and pulse amplitude modulation; iii) the existing IR UWB transceiver technologies, including Rake receiver, selective Rake receiver, differential detection transceiver, transmitted reference transceiver, frequency-shifted reference transceiver, and code-shifted reference transceiver; and iv) future development tendency for the IR UWB transceiver technologies