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Editorial

Ultra-Wideband Communication Systems: Technology and Applications

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Ultra-wideband (UWB) signals are defined to have a bandwidth of at least 500 MHz and/or a relative bandwidth of more than 20%. A signal with such a large bandwidth has some very unique properties like resistance to small-scale fading, good resolution for ranging and geolocation, and resistance to narrow-band interference. These signals can be used for transmission of extremely high-speed data or low-rate data with a large spreading factor.

UWB communications have been investigated since the early 1990s, following the pioneering work of Win and Scholtz at USC. A major milestone for UWB deployment was the decision of the frequency regulator in the USA, the FCC (Federal Communications Commission) to allow unlicensed operation of UWB transmission subject to certain restrictions in the emission mask of the power spectral density. In essence, the FCC allowed intentional emissions in the frequency band between 3.1 and 10.6 GHz with a power spectral density of −41.3 dBm/MHz. This value agreed with the already existing regulations for unintentional emissions from electronic devices in that frequency range. Regulations in other countries were much slower in the making. Japan allowed UWB transmissions in the 3.1–4.8 and 6–10 GHz bands only in late 2006. A key requirement of the Japanese regulations is that, for frequencies between 3.1–4.8 GHz, UWB transmitters must employ "detect and avoid." In other words, it is the duty of a UWB transmitter to detect a possible victim device and cease transmissions that might disturb such a device. Until 2010, the band between 4.1 and 4.8 GHz is exempt from this DAA requirement. European regulations are scheduled to be issued in the next years and are anticipated to be similar to the Japanese regulations.

High-speed communications based on UWB were originally envisioned by the IEEE 802.15.3 standardization group, which tried to establish a standard for short-range communications with rates in excess of 100 Mps. Though standardization within IEEE 802.15.3a failed, and the group ultimately dissolved, two major proposals for high-speed UWB communications emerged and were standardized by industry groups: multiband-OFDM (later-on adopted by the WiMedia Alliance and the European Computer Manufacturing Association, as standard ECMA 369/369), and a direct-sequence CDMA approach adopted by the UWB Forum.

Products based on UWB will soon appear on the market. The first application will be wireless USB (universal serial bus). The USB Implementers Forum (USB-IF) has introduced certified wireless USB based on the WiMedia multiband-OFDM radio platform. Other vendors have developed wireless USB products based on the UWB Forum radio platform, which are already available to customers.

This special issue includes eight papers on various UWB topics. The first paper by Zhang et al. discusses interference mitigation techniques for coexistence of the various UWB radio platforms which will be available on the market. The paper clearly shows that both radio systems are severely degraded by interference from the other systems. It is also shown that the interference is asymmetric due to the heterogeneity of the two systems. A goodput-oriented utility-based transmit power control (GUTPC) scheme is proposed to partly overcome the interference problem. The feasible condition and the convergence property of GUTPC are investigated, and the choice of the coefficients is discussed for fairness and efficiency.

In the second paper by Wang et al., the multiband-OFDM radio system is further improved by turbo trellis coded modulation (TCM) and QAM modulation. In this new coding scheme, a TCM code is used as the inner code and a simple parity-check code is employed as the outer code. The new system is shown to provide a much improved spectral efficiency and is able to provide 1.2 Gps which is 2.5 times better than the WiMedia Alliance system. The authors identify several essential requirements to achieve the high rate transmission, for example, frequency and time diversity and multilevel error protection.

In the third paper by Pekka Pirinen, an outage analysis is presented for lognormal fading channels and square-shaped cellular configurations. Statistical distributions for link distances in single cell and multicell configurations are derived. Cochannel interference induced outage probability is used as a performance measure. The probability of outage varies depending on the spatial distribution statistics of users (link distances), propagation characteristics, user activities, and receiver settings. Numerical results show the strong dependence of outage probability on the link distance distributions, number of rake fingers, and path losses.

Ranging using noncoherent receivers enabled low-cost implementation but interference can be detrimental to range accuracy. The fourth paper by Sahinoglu and Guvenc develops a method that performs nonlinear filtering on received signal energy to mitigate multiuser interference (MUI). It is suitable for noncoherent ranging receivers, and it is tested with time-hopping and direct sequence impulse radio ultrawideband signal waveforms. Simulations conducted over IEEE 802.15.4a residential line of sight ultrawideband multipath channels indicate that nonlinear filtering helps sustain range estimation accuracy in the presence of strong MUI.

In the fifth paper by Tiziano Bianchi and Simone Morosi, frequency domain detectors for impulse radio UWB schemes are studied. Two different detection strategies based on either the zero forcing (ZF) or the minimum mean square error (MMSE) criteria have been investigated and compared with the classical rake receiver, considering two scenarios where a base station transmits with a different data-rate to several mobile terminals in an indoor environment characterized by severe multipath propagation. The results show that the MMSE receiver achieves a remarkable performance, especially in the case of highly loaded high data-rate systems.

The sixth paper by Badaroglu et al. analyzes the impact of CMOS technology scaling on power consumption of UWB impulse radios. It is shown that the power consumption of the synchronization constitutes a large portion of the total power in the receiver. A traditional technique to reduce the power consumption at the receiver is to operate the UWB radios with a very low duty cycle on an architecture with extreme parallelism. On the other hand, this requires more silicon area and this is limited by the leakage power consumption, which becomes more and more a problem in future CMOS technologies. The proposed quantitative framework allows systematic use of digital low-power design techniques in future UWB transceivers.

The seventh paper by Djapic et al. considers blind synchronization schemes in asynchronous UWB-based networks which are based on the impulse radio transmitter reference scheme. UWB transmission schemes with short bursty packets require a fast synchronization algorithm that can accommodate several asynchronous users. Exploiting the fact that a shift in time corresponds to a phase rotation in the frequency domain, a blind and computationally efficient synchronization algorithm that takes advantage of the shift invariance structure in the frequency domain is proposed in this paper. Integer and fractional delay estimations are considered, along with a subsequent symbol estimation step. This results in a collision-avoiding multiuser algorithm, readily applicable to a fast acquisition procedure in a UWB adhoc network.

The eighth paper by Gezici et al. considers optimal and suboptimal finger selection algorithms for MMSE rake receivers for impulse-radio UWB systems. The optimal finger selection problem is formulated as an integer programming problem with a nonconvex objective function. The objective function is then approximated by a convex function and the integer programming problem is solved by means of constraint relaxation techniques. The proposed algorithms are suboptimal but they perform better than the conventional finger selection algorithm. A genetic algorithm-(GA-) based approach is also proposed, which is based on the direct evaluation of the objective function and can achieve near-optimal performance with a reasonable number of iterations.

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Arne Svensson was born in Vedåkra, Sweden, on October 22, 1955. He received the M.S.EE, the Dr. Ing., and the Dr. Techn. degrees from the University of Lund, Sweden, in 1979, 1982, and 1984, respectively. Currently he is with the Department of Signal and Systems at Chalmers University of Technology, Gothenburg, Sweden, where he was appointed Professor and Chair in Communication Systems in April 1993 and Head of department from January 2005. Between 1987 and 1994, he was with Ericsson in Mölndal, Sweden. His current interest is wireless communication systems with special emphasis on physical layer design and analysis. He is a coauthor of *Coded Modulation Systems* (Norwell, MA: Kluwer Academic/Plenum, 2003). He has also published 4 book chapters, 34 journal papers/letters, and more than 150 conference papers. He received the IEEE Vehicular

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