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A Comparison of energy efficiency for UWB Modulations

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In a fully connected world, wireless communication users request more and more access to high data rates. Usually, this demand comes at the cost of consuming more electrical energy which is limited in battery operated systems and can generate some environmental problems. To deal with these problems, researchers created a concept called “green communication” [1] to improve the energy efficiency of the communication system and also optimize the communication networks.

Ultra Wideband (UWB) is a technology that offers the ability to create efficient energy and low complexity communication systems at reduced cost. Researchers explored various subjects related to energy efficiency from system design to network protocols. In [2] the authors presented an energy-efficient low complexity pulse generator for UWB system in CMOS technology. Authors in [3] proposed a low power UWB transmitter in CMOS with all digital pulse generator and binary phase modulator operating in the FCC low frequency band 3.1-4.5 GHz. Reference [4] introduced and analyzed an efficient energy adaptive transmission protocol called ATP-UWSN for UWB wireless sensor networks (WSNs). They showed that this protocol adapts the error-control code rate and the spreading code length to match the channel state information (CSI) and reach the optimum transmission parameters. In [5] the authors consider an energy-aware and link-adaptive strategy for UWB WSNs to introduce different routing metrics. Reference [6] took advantages of the positioning capabilities of UWB to propose an energy efficient routing algorithm. This algorithm is developed to search for energy efficient routes with respect to the quality of service (QOS) of the system.

In this work, we propose an analytical model to analyze and compare the total energy consumption of some well-known UWB modulations. Three modulations will be compared; Pulse Amplitude Modulation (PAM) which uses two different amplitude levels to modulate the data bits, Pulse Position Modulation (PPM) which uses a shift in time to modulate the data bits and finally Pulse Shape Modulation which uses two orthogonal waveforms to modulate the data bits. Our analytical model is based on the work presented in [7]. It considers the transmission power, the transceiver's circuitry power consumption and time slot duration. To calculate the transmission power for each modulation in a UWB 802.15.3a channel [8], we use the probability of error superior bounds for UWB channel with high and low degree of fading introduced in [9]. To calculate the transmitter's power consumption and the receiver's power consumption, we consider realistic hardware UWB components. The value of the time slot is computed from the length of the sequence to transmit, the system bandwidth and the duty cycle (the ratio of the frame duration and the pulse duration in UWB systems). Since in a UWB system an optimal duty cycle makes the system more energy efficient, we started our simulations by depicting the total energy consumption for the three modulations versus the duty cycle. This enabled to determine the optimal time slot. After identifying the optimal time slot, we plotted in Fig.1 the total energy consumption for the three modulations against a distance range between 1 m and 10 m (10 m is the maximum distance supported in UWB). We obtained that PAM is more energy efficient than PPM and PSM and that PSM is the least energy efficient modulation. In a second step, in Fig. 2, we compared the total energy consumption versus a path-loss coefficient range between 2 m and 6 m. We still obtained also that PAM outperforms PPM that is also more energy efficient than PSM. We concluded that PAM is the modulation to choose in a system that requires a low energy consumption and low complexity receiver (PAM uses a non-coherent receiver).

Figure 1: Total energy consumption vs distance

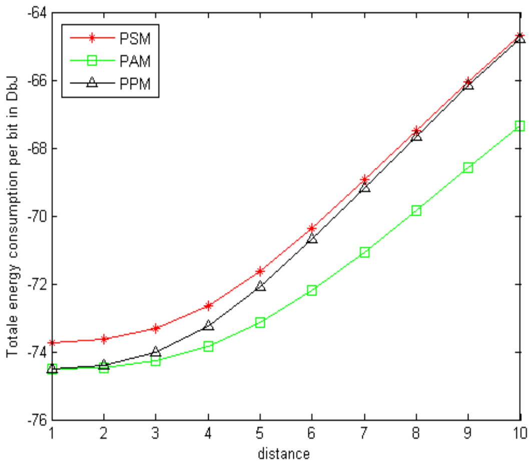
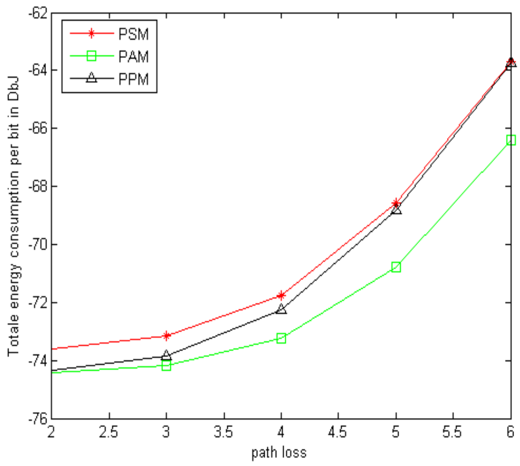


Figure 2: Total energy consumption vs path-loss



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