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A Review of Multiband UWB-OFDM in WPAN MIMO QAM

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ABSTRACT: Multiple-input multiple-output (MIMO) and orthogonal frequency division multiplexing (OFDM) stand as promising technologies to resolve bottlenecks in the traffic capacity of current and future high data rate wireless systems such as long term evolution (LTE), Wi-Fi, and worldwide interoperability for microwave access (WiMAX). Recently, the expansion of MIMO systems to employ multiple users (multi-user MIMO) has been a key topic of interest, mainly motivated by the need to recognize the network capacity enhancements resulting from the use of MIMO Technology. In Australia, it has proposed and implemented a novel and feasible system called the wireless broadband access" system using to allow multiple users to employ the same frequency at the same time in MIMO-OFDM systems. In MB UWB-based multi-user MIMO-OFDM, wireless broadband services with higher spectral efficiency can be enabled by employing multiple antennas at an access point to serve each mobile stations equipped with a single antenna.

Index Terms: Multiple-input multiple-output, MB UWB, WiMAX

I. INTRODUCTION

Ultra-wideband (UWB) radio has recently been popularized as a technology for short-range, high data rate communication and locationing applications The IEEE 802.15 standardization group, responsible for wireless personal area networks (WPANs), organized task group 3a to develop an alternative physical layer based on UWB signaling [2]. There were two main contenders for this standard: a frequency hopping orthogonal frequency-division multiplexing (OFDM) proposal known as *Multiband OFDM* and a code-division multiple access (CDMA) based technique. In this paper, we consider the proposed Multiband OFDM standard [3] (also recently standardized by the ECMA [4]). Multiband OFDM is a conventional OFDM system [5] combined with bit-interleaved coded modulation (BICM) [6] for error prevention and frequency hopping for multiple access and improved diversity. The signal bandwidth is 528 MHz, which makes it a UWB signal according to the definition of the US Federal Communications Commission (FCC) [1], and hopping between three adjacent frequency bands is employed for first generation devices [3]. Thus, the Multiband OFDM proposal is a rather pragmatic approach for UWB transmission, which builds upon the proven BICM-OFDM objective of this paper is to study the suitability and to analyze the (potential) performance of Multiband OFDM for UWB transmission. Furthermore, we propose system performance enhancements by applying capacity-approaching Turbo and Repeat-Accumulate (RA) codes and by using OFDM bitloading. These specific techniques were chosen because of their potential for improved system performance without requiring substantial changes to other portions of the Multiband OFDM system, nor requiring major increases in complexity. Since our investigations rely on the new UWB channel model developed under IEEE 802.15 [7], we first analyze this channel model in the frequency domain and extract the relevant statistical parameters that affect the performance of OFDM based transmission. In particular, the amount of diversity available in the wireless channel as a function of the signal bandwidth is examined.

As appropriate performance measures for coded communication systems, we discuss the capacity and cutoff rate limits of BICM-OFDM systems for UWB channels. In this context, since one limiting factor of performance in practical and especially in wideband.

II. MODULATION

A. Multiband OFDM Standard Proposal: In the proposed standard, the interleaved coded bits are mapped to quaternary phase-shift keying (QPSK) symbols using Gray labeling. After the optional spreading described above, groups of 100 data symbols are used to form OFDM symbols with N = 128 tones.

Bit-Loading: The UWB is considered time-invariant for the duration of many packet transmissions. For that reason, it is feasible to consider bit-loading algorithms to assign unequal numbers of bits to each OFDM subcarrier Channel state information is obtained at the transmitter, either by (a) exploiting channel reciprocity (if the same frequency band is used in the uplink and downlink as in the standard proposal), or (b) some form of feedback (which may be required even if the same frequency band is used, since reciprocity may not apply due to different interference scenarios for transmitter and receiver). We consider loading for higher data rates (without time or frequency spreading) using two different OFDM bit-loading schemes. We selected the algorithm of Piazzo [8] (which loads according to the uncoded BER) due to its low computational complexity, and the algorithm of Chow, Cioffi and Bingham (CCB) [2] because it loads according to the information-theoretic capacity criterion, as well as for its moderate computational complexity. The data rates and OFDM symbol structure of the Multiband OFDM proposal are maintained by loading each OFDM symbol with 200 bits. Each tone carries from 0 to 6 bits using Quadrature Amplitude Modulation (QAM) signal constellations with Gray or quasi-Gray labeling (note that 6 bit/symbol corresponds to 64-QAM, which is a reasonable upper limit for modulation on a wireless channel.

III. UWB CHANNEL MODEL

For a meaningful performance analysis of the Multiband OFDM proposal, we consider the channel model developed under IEEE 802.15 for UWB systems [7]. The channel impulse response is a Saleh Valenzuela model modified to fit the properties of measured UWB channels. Multipath rays arrive in clusters with exponentially distributed cluster and ray interarrival times. Both clusters and rays have decay factors chosen to meet a given power decay profile. The ray amplitudes are modeled as lognormal random variables, and each cluster of rays also undergoes a lognormal fading. To provide a fair system comparison, the total multipath energy is normalized to unity. Finally, the entire impulse response undergoes an "outer" lognormal shadowing. The channel impulse response is assumed time invariant during the transmission period of several packets (see [7] for a detailed description). Four separate channel models (are available for UWB system modeling, each with arrival rates and decay factors chosen to match a different usage scenario. The four models are tuned to fit 0-4 m Line-of-Sight (LOS), 0-4 m non-LOS, 4-10 m non-LOS, and an "extreme non-LOS multipath channel", respectively. The means and standard deviations of the outer lognormal shadowing are the same for all four models. The model parameters can be found Multiple-antenna technology is a rich area of research. Whether for future military wireless networks, soldier radios, autonomous sensors, or robotics, the demand for improved performance may be met with multiple-antenna communication links and the advanced technology making those links effective. Lincoln Laboratory is investigating multiple-input multiple-output (MIMO) techniques to improve the robustness and performance of wireless links. Here, the term multiple-input multiple-output refers to the use of an array of antennas for both transmitting and receiving. MIMO approaches show promise of enabling better wireless communications because they mitigate problems inherent in ground-to-ground links, which are the most common links used by wireless devices, including cell phones and WiFi. Typically, ground-to-ground links are not line of sight. The electromagnetic waves transmitted from the antennas bounce around the environment in a complicated fashion and end up at the receiver coming from multiple directions and with varying delays. The multi-band OFDM system is an OFDM solution proposed for the UWB WPAN physical layer standard [5]. In that proposal, the whole available ultra wideband spectrum between 3.1-10.6 GHz is divided into several sub-bands with smaller bandwidth. Figure. 1 shows the band planning for the multi-band OFDM system. In each sub-band a normal. In the current proposal, there are four groups of 3-band systems to support 4 independent piconets. The main difference between the multi-band OFDM system and other narrowband OFDM systems is the way that different sub-bands are used in the system.

The transmission is not done continually on all sub-bands. Rather, it is time multiplexed between different bands in order to use a single hardware for communications over different sub-bands.

Different patterns of sub-band switching can be chosen in order to support more piconets operating in the same environments. the structure of a multi-band OFDM transmitter and receiver. The system looks like a normal consumptions. These considerations motivated a shift in UWB system design from initial Single-band radio that occupies the whole allocated spectrum in favor of Multi-band design approach [4]. Multi-banding consists in dividing the available UWB spectrum into several sub-bands, each one occupying approximately 500 MHz. By interleaving symbols across different sub-bands, UWB system can still maintain the same transmit power as if it was using the entire bandwidth. Narrower sub-band bandwidths also relax the requirement on sampling rates of ADCs consequently enhancing digital processing capability. Multiband-OFDM (MB-OFDM) [5] is one of the promising candidates for PHY layer of short-range high data-rate UWB communications. It combines Orthogonal Frequency Division Multiplexing (OFDM) with the above multi-band approach enabling UWB transmission to inherit all the strength of OFDM technique which has already been proven for wireless communications (ADSL, DVB, 802.11a, 802.16.a, Multiband Orthogonal Frequency Division Multiplexing (MB-OFDM) approach using UWB signals with short duration of pulses provide unique advantages in short-range high data rate wireless applications which include easy penetration through obstacles, high precision ranging and low processing power. In this paper a performance study on MB-OFDM is attempted for high data rate ultra wideband (UWB) WPAN physical layer standard according to modulation techniques such as QPSK, 16-QAM, 64-QAM etc. Different multipath components in the UWB channels are characterized by different delays and attenuation. The channel models chosen in simulation of MB-OFDM UWB communication system are standard IEEE 802.15.3a UWB channels considering realistic multipath resolution and operating frequencies. In this research different amplitude fading statistics for UWB channel are analyzed. The BER performance of MB-OFDM UWB on modified UWB channel models are investigated through simulation study. It is observed that QPSK modulation for the MB-OFDM UWB system performs better than 16-QAM and 64-QAM in the CM3 (NLOS) and CM4 (NLOS) channel environment. The challenge of reliable communication over a wireless Rayleigh flat-fading channel using multiple transmit and receive antennas. Since modern digital communication systems employ signal sets of finite cardinality, we examine the use of the quadrature amplitude modulation (QAM) constellation to approach the capacity of this channel.

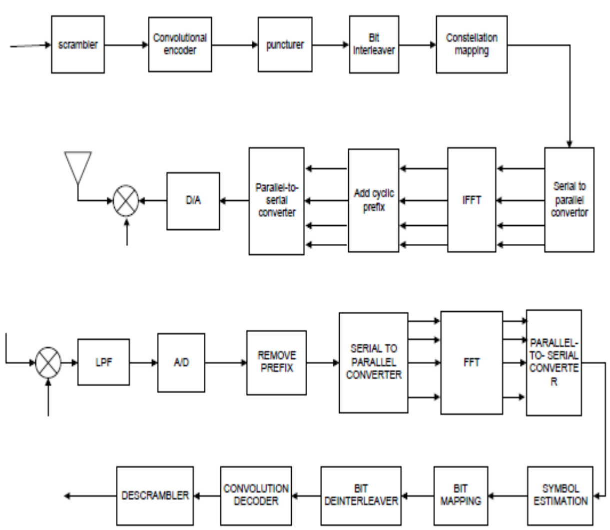

Fig. 1. Multi-band OFDM transmitter and receiver.

By restricting the channel input to the M-QAM subset of the complex-plane, the maximum achievable information rate ($C_{M\text{-}QAM}$) is strictly bounded away from the channel capacity (C). We utilize a modified version of the Arimoto-Blahut algorithm to determine $C_{M\text{-}QAM}$ and the probability distribution over the channel input symbols that achieves it. of this optimization procedure numerically indicate that the optimal input symbol distribution factors into the product of identical distributions over each real dimension of the transmitted signal. This is shown to vastly reduce the computational complexity of the optimization algorithm. Furthermore, we utilize the computed optimal channel input probability mass function (pmf) to construct capacity approaching trellis codes. These codes are implemented independent across all antennas and symbol dimensions and, if used as inner codes to outer low-density parity check (LDPC) codes, can achieve arbitrarily small error rates at signal-to-noise ratios very close to the channel capacity $C_{M\text{-}QAM}$. Examples are given for a 2-transmit/2-receive antenna (2 times 2) system Multiple Input Multiple Output (MIMO) uses multiple antennas at both the transmitter and receiver side. In recent times the demand for the use of MIMO systems has increased due to its capability of robustness against Multipath fading and increasing the Spatial Multiplexing Gain and Spatial Diversity Gain.Orthogonal Frequency Division Multiplexing (OFDM) is one of the best digital modulation schemes, where signal is divided into number of narrow band channels to obtain spectral efficiency and minimizing the Inter Symbol Interference (ISI). Thus, combining MIMO and OFDM technologies will improve spectral efficiency, link reliability and spectral gain. In this paper, MIMO and OFDM techniques are combined to improve the transmitter performance. Software reference model for 4x4-MIMO-OFDM Transmitter for wireless communication system is designed and modeled in MATLAB as well as the same is implemented in C language. The evaluation of Bit Error Rate (BER) and Signal to Noise Ratio (SNR) performance of the OFDM technique combined with Alamouti Space Time Block Codes (STBC) based on two modulation schemes namely QPSK and 16 QAM over AWGN channels is carried out. The developed system model is implemented in C and performance comparison & optimization are carried out using Real View Development Suite (RVDS) by considering different ARM cores. Performance metrics such as Mean Square Error (MSE) and Peak Signal-to-Noise Ratio (PSNR) are computed for 4x4-MIMO-OFDM transmitter system and performance of whole system is analysed for QPSK and 16 QAM modulation techniques. BER for QPSK is 10-2.6 and BER for 16 QAM is 10-1.5 dB at a fixed SNR of 10 dB. System developed in C is analysed in RVDS. Profiling results shows that ARM cortex family provides better performance in terms of number of cycles estimated to execution of code and code coverage when compared with lower versions of it. The number of estimated cycles in ARM Cortex A9 is reduced by 8.5% when compared to ARM 1136. The work can be further enhanced by using massive MIMO in place of conventional MIMO.

IV. DESIGN AND SOLUTION PROCEDURES

A basic 4X4 MIMO OFDM's transmitter block diagram is shown in Figure 2. Here 4x4 is of the form NxM where N is the number of antennas at the transmitter side and M represents the number of antennas at the receiver side. The block diagram shows different blocks, namely the FEC coder, used to control the error over the channel.

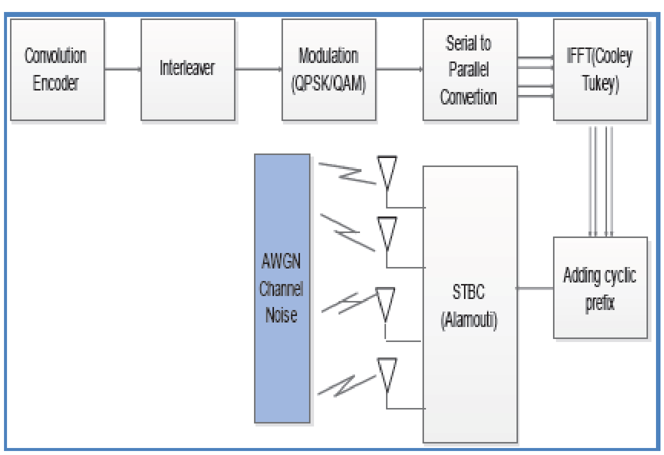

Fig. 2. Block Diagram of MIMO-OFDM Transmitter System.

The Bit Inter leaver block is used to logically reorder the data. The Mapper block uses Quadrature Amplitude Modulation (QAM), used which is followed by serial to parallel converter. After converting the Signals into parallel data all the data from the different sub carriers are added to get the OFDM signal using the IFFT block. Finally after adding cyclic prefix the signals are up converted to RF and are transmitted through the antennas. Modulated symbols are split into four sequences of s0, s1, s2 and s3 symbols. Corresponding index value from each sequence is arranged in the form of 4x4 code matrix or STBC matrix. Code matrix X is multiplied with channel matrix H and mixed with AWGN noise to obtain the signal.

V. CONCLUSION

In this paper, IEEE 802.16eMB UWB MIMO-OFDM PHY the PHY layer performance under frequency selective channel. The implemented PHY layer supports all the modulation and coding schemes as defined in the specification. used to compare the performance of different modulation and coding scheme under AWGN and multipath fading channel. It is observed that the lower modulation and coding scheme provides better performance with less SNR, accept for schemes employing rate 3/4 codes have noticeable degradation compare to other schemes under multipath fading. Results showed that under frequency selective fading channel it is more important to have a coding scheme that have higher error correction capability, than having modulation that is more tolerate to the noise. The design of MB UWB MIMO OFDM transceiver system based on simulation has been described in this paper where FFT algorithm and several types of modulation schemes has been implemented in this system in order to analyze the effect of modulations.

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