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On diversity improvements for ultra wideband communication systems

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On Diversity Improvements for Ultra Wideband Communication Systems

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by

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To my beloved wife Kristina,
my parents, my sister, and my loving family.

Abstract

The wireless communications arena consists of a wide range of products and services, each with a specific target market and approach. Having characteristic advantages and disadvantages, all attempt to increase their market share through diversification and innovation. Ultra wideband (UWB) is a recent entry into the commercial short-range communications world, differentiated by its sparse spectral profile and low peak power emissions. Being unlicensed and capable of operating simultaneously with conventional communication systems, it has seen considerable attention by both industry and academia.

This thesis explores diversification improvements available for UWB systems, explicitly through orthogonal user multiplexing schemes, channel equalization, and forward error correction. A review of this communication method is presented, considering its technical evolution and standardization.

Multi-user sequencing is researched with regard to a time hopped UWB architecture. The successful adoption of UWB into commercial devices greatly depends upon the development of efficient user access mechanisms. A comparative analysis of varied time, frequency, and direct sequence hopping codes is presented in terms of their performance, diversity, and computational requirements. It is shown that for low user utilization levels, short periodicity deterministic codes attain a similar performance to randomly generated sequences. However, within a fully utilized system deterministic codes slightly out-perform short length random sequences.

The application of multiplexing codes to UWB chip level interleaving is also examined. Interleaver performance is compared when designed through long length random codes versus design through deterministic hopping sequences, exemplifying similarities between the approaches.

A unique approach to sequence analysis is introduced, developing a set of state probabilities for pulse separations generated by each multiplexing code. Providing insight into optimal code design procedures, this separation profile is employed in the closed-form derivation of intersymbol and multi-user interference expressions. These formulations adopt a transmitter-side equalization process, with comparisons against a receiver-side approach presented. Derivations are based upon an analysis of transmission overlaps, together with the probabilities of each overlap. A close alignment against a simulated UWB system is evident for varied system parameters, exemplifying numerous properties of each equalization measure.

Despite diversification efforts to improve communication procedures, data errors are an unavoidable consequence of operation across a wireless medium. Forward error correction is researched within this dissertation for both binary and a non-binary encoding. Utilizing a transmitter-side equalization scheme, conventional binary turbo decoding is considered at the binary data level. Also, non-binary turbo decoding is applied to combine data encoding and user multiplexing stages. This latter method presents an innovative means of time hopping code generation. A comparative analysis of each technique against a simulated performance is given for both single- and multi-user scenarios, together with observations on the multi-user interference effects of signals employing forward error correction. A performance improvement for scarcely populated systems was evident, although a binary turbo scheme is shown to achieve optimal performance in high traffic systems. The mapping scheme required for non-binary encoding is evaluated in terms of random generation and design through deterministic coding schemes. Truncated orthogonal codes are shown to achieve a performance gain for higher turbo iteration levels, also having the advantage of simpler design.

Wireless communications are inherently subject to numerous signal degradations. With its revolutionary and unlicensed communication approach, UWB has emerged as a formidable contender in the wireless arena. Having an array of error mitigation techniques, including orthogonal user multiplexing, channel equalization, and advanced error correction, it prevails as a high rate and low power consuming system for the modern world of telecommunications.

Statement of Originality

This is to certify that the work described in this thesis is entirely my own, except where due reference is made in the text.

No work in this thesis has been submitted for a degree to any other university or institution.

Signed

Keni Popovski
23rd October, 2008

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List of Abbreviations

AC	Autocorrelation
ARake	All-RAKE
AWGN	Additive White Gaussian Noise
BEC	Backward Error Correction
CC	Cross-Correlation
CDMA	Code Division Multiple Access
DS	Direct Sequence
DS-CDMA	Direct Sequence Code Division Multiple Access
DS-UWB	Direct Sequence Ultra Wideband
EIRP	Effective Isotropic Radiated Power
FCC	Federal Communications Commission
FEC	Forward Error Correction
FR	Frame Repetition
GGA	Generalized Gaussian Approximation
ICM	Interleaved Coding-Modulation
ICTH	Interleaved Convolutional Time Hopping
IFFT	Inverse Fast Fourier Transform
ISI	Intersymbol Interference
LOS	Line Of Sight
LSE	Least Square Error
MAP	Maximum A Posteriori
MBOA	Multi-Band OFDM Alliance
MB-OFDM	Multi-Band Orthogonal Frequency Division Multiplexing
MHP	Modified Hermitian Pulses
ML	Maximum Likelihood

MSE	Mean Square Error
MUI	Multi-User Interference
NLOS	Non-Line Of Sight
OFDM	Orthogonal Frequency Division Multiplexing
PAM	Pulse Amplitude Modulation
PCTH	Pseudo Chaotic Time Hopping
PPM	Pulse Position Modulation
PRake	Partial-RAKE
PSD	Power Spectral Density
RF	Radio Frequency
RMS	Root Mean Squared
RSC	Recursive Systematic Convolutional
RX	Receiver
S-B-S	Symbol-By-Symbol
SGA	Standard Gaussian Approximation
SISO	Soft-Input-Soft-Output
SOVA	Soft-Output Viterbi Algorithm
SRake	Selective-RAKE
TCM	Trellis Coded Modulation
TH	Time Hopping
TH-UWB	Time Hopped Ultra Wideband
TR	Time Reversed
TTCM	Turbo Trellis Coded Modulation
TX	Transmitter
UWB	Ultra Wideband
WLAN	Wireless Local Area Network
ZCZ	Zero Correlation Zone