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On an approach to provide space diversity to an ultra wideband time hopping pulse position modulated wireless communication system

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On an approach to provide space diversity to an Ultra Wideband Time Hopping Pulse Position Modulated wireless communication system.

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by

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Abstract

The hypothesis question, which is addressed in this PhD dissertation, is how to use two transmission antennas in an Ultra Wide Band Time Hopping Pulse Position Modulation system to take advantage of space diversity in such a way as to not significantly degrade the communication link compared to using only one transmit antenna. In answering the hypothesis question, this dissertation proposes a novel technique, based on Space Time Spreading, to allow an Ultra Wideband Time Hopping Pulse Position Modulation system to obtain full advantage from space diversity using two transmit antennas and one receive antenna, showing how such a Multiple Input Multiple Output system is designed. This is achieved with the added advantage of transmitting the same two symbols simultaneously on each antenna link. This means that for the proposed system, should a fade occur on one of the two antenna links, the two symbols transmitted will still be received with a slight increased cost in average Bit Error Rate (BER) performance as Signal to Noise Ratio (SNR) or measured E_b/N_o is increased.

Results are first provided for wideband Space Time Spreading in the presence of Multiple Access Interference when using two, four and eight transmit antennas. A system is developed in simulation using modules provided by MATLABs Simulink program. It is then shown that using low correlation Wysocki spreading code set results in an improved BER performance compared to the more often used Walsh Hadamard spreading code set. A Simulink Ultra Wide Band Pulse Position Modulation Single Input Single Output system is developed and validated against published peer reviewed material. This is then modified to consider the use of Space Time Spreading in a Single Input Single Output system and it is shown that improved performance over an Ultra Wide Band Pulse Position Modulated Single Input Single Output is possible. It is also shown that this improvement allows the transmission of two symbols in the same time that the original system only transmits one symbol.

The thesis also investigates a system which uses two transmit antennas but a hard decision is made on a chip by chip basis. Its performance, compared to an equivalent Single Input Single Output comparable system, is suboptimal. It does, however, have the advantage that it sends two symbols in the same time that the equivalent Single Input Single output Ultra Wide Band Pulse Position Modulation system sends one, and its implementation is simpler to codify. Also, it has the feature that both symbols are sent simultaneously on each antenna link.

The simulator is then modified to make a hard decision after all chips of a spreading sequence for two antennas are received and it is shown that this system, in simulation and analysis, has a similar performance to that for a comparable Single Input Single Output system with the added advantage that both antenna links send the same two symbols simultaneously. It is further demonstrated in simulation and analysis that such systems can be affected by Multiple Access Interference. In addition, it is shown, using simulation, that the choice of spreading sequence set does have an impact on the average BER performance of the proposed Space Time Spreading Time Hopping Ultra Wideband Pulse Position Modulation system. The thesis finally proposes some extensions using the developed simulator which are outlined in future work.

Statement of Originality

I Peter James Vial swear that this thesis, where attribute is not given to others, is solely my work and my research and no others. I personally wrote all the code or made modifications to existing code where attribution is provided via the codes comments, developed the proposed systems and undertook all associated studies including the analysis of the proposed system.

Signed: Mr Peter James Vial

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Peer reviewed Publications of this thesis

[1] P. Vial, I. Raad, and T. Wysocki, "On the effect of adjacent sector Multiple Access Interference on Space Time Spreading Systems," *in Conference Proceedings of DSPCS'03,* Coolangatta, Queensland, Australia,pp. 543-548,December, 2003.

[2] P. J. Vial, I. S. Raad, and T. A. Wysocki, "On the Design and Validation of a Space Time Spreading System using Simulink," *in Conference Proceedings of the 14th International Czech-Slovak Scientific Conference Radioelektronika,* Bratislava, Slovak Republic,pp. 480-483,April, 2004.

[3] P. Vial, B. Wysocki, I. Raad, and T. Wysocki, "Space time spreading with modified Walsh-Hadamard sequences," *in Conference Proceedings of the Eighth IEEE International Symposium on Spread Spectrum Techniques and Applications,* Sydney, Australia,pp. 943-946,August, 2004.

[4] P. Vial, B. Wysocki, and T. Wysocki, "An Ultra Wideband Simulator Using MATLAB / Simulink," *in Conference Proceedings of DSPCS'05 & WITSP'05,* Noosa Heads, Queensland, Australia, December, 2005.

[5] P. Vial, B. Wysocki, and T. Wysocki, "Direct Sequence Modified Time Hopping PPM over Ultra Wideband S-V Channel," *in Conference Proceedings of the 5th Workshop on the Internet, telecommunications and Signal Processing (WITSP'06),* Hobart, Tasmania, Australia,December, 2006.

[6] P. Vial, B. Wysocki, and T. Wysocki, "Optimal receiver for Space Time Spreading across a Time Hopping PPM over Ultra Wideband Saleh-Valenzuela MIMO Channel," *in Conference Proceedings of the International Conference on Signal Processing and Communication Systems, 2007 (ICSPCS '2007),* Gold Coast, Queensland, Australia,pp. 56-61,December, 2007.

[7] P. Vial, B. Wysocki, and T. A. Wysocki, "Non-optimal receiver for space time spreading across a Time Hopping over Ultra Wideband PPM," *in Conference Proceedings of the third International Symposium on Communications, Control and Signal Processing, 2008 (ISCCSP 2008),* Malta,pp. 990-993,March, 2008.

Submitted to Journal for peer reviewed Publication

P. Vial, B. Wysocki, M. Ros, T.A. Wysocki, and D. Stirling, "On the effect of Multiple Access Interference in a Space Time Spreading Time Hopping PPM UWB System", submitted to IEEE Transactions on Wireless Communications on the 5th of February 2009.

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List of Abbreviations

AWGN	Additive White Gaussian Noise
BER	Bit Error Rate
BPSK	Binary Phase Shift Keying
BS	Base Station
CDF	Cumulative Distribution Function
CDMA	Code Division Multiple Access
CFO	multicarrier offsets (carrier frequency offsets)
CSI	Channel State Information
DS	Direct Sequence
DSP	Digital Signal Processing
FCC	Federal Communications Commission
FET	Field Effect Transistor
FFT	Fast Fourier Transform
FH	Frequency Hopping
H-R	Hurwitz-Radon
ICI	Inter Carrier Interference
IEEE	Institution of Electrical and Electronic Engineers
IFFT	Inverse Fast Fourier Transform
ISDN	Integrated Services Digital Network
ISI	Inter-symbol Interference
IS-OFDM	Interference Suppressing OFDM
I-UWB	Impulse based Ultra Wideband
LAN	Local Area Network
MAC	Medium Access Control
MAI	Multiple Access Interference
M-ALOHA	Multi-channel ALOHA
Mcps	Mega chips per second
MFSK	M-ary Frequency Shift Keying
MIMO	Multiple Input Multiple Output
MMRC	Maximal Ratio Receiver Combining
MOFDM	Multiband OFDM
M-PSMA	multi-channel pulse sense multiple access
MRC	Maximum Ratio Combining

MS	Mobile Station
MUI	Multiple User Interference
NLOS	Non Line of Sight
OFDM	Orthogonal Frequency Division multiplexing
OFDMA	Orthogonal Frequency Division Multiple Access
OOK	On-off keying
OTD	Orthogonal Transmit Diversity
PA	Power Amplifier
PAM	Pulse Amplitude Modulation
PAPR	Peak to Average Power Ratio
pdf	probability density function
PG	Processing Gain
PPM	Pulse Position Modulation
PRF	Pulse Repetition Frequency
PRI	Pulse Repetition Interval
PSK	Phase Shift Keying
QPSK	Quadrature Phase Shift Keying
RTW	Real Time Workshop (from MATLAB/Simulink)
SDMA	Space Division Multiple Access
SER	Symbol Error Rate
SINR	Signal in Noise Ratio
SISO	Single Input Single Output
SNR	Signal to Noise Ratio
ST	Space Time
STS	Space Time Spreading
SV	Saleh-Valenzeula
TH	Time Hopping
UWB	Ultra Wideband
WCDMA	Wideband Code Division Multiple Access
WSN	Wireless Sensor Network