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Direct sequence modified time hopping PPM over ultra wideband S-V channel

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Abstract- **A three position Pulse Position Modulation (PPM) scheme is proposed for a Direct Sequence Time Hopping Ultra Wideband wireless communication system. The channel is based on the Saleh-Valenzuela model. We show that by adapting the Space Time Spreading technique to use three pulse positions in a single input single output system representing -2,0,2 an improvement in Bit Error Rate is achieved compared to sending the same bits using two pulse positions only. In addition, the bit access rate is doubled as two bits can be successfully sent in the same time using our proposed system.**

1.0 Introduction

Recently, in [1] Impulse-UWB (I-Ultra Wide Band) is described for distributed MAC (Medium Access Control) protocols. In this paper the authors describe a UWB (Ultra Wide Band) system which is applicable in the moderate range of pulse repetition interval (PRI) of between 1μs to 10μs. They suggest that this moderate range is an adequate representation due to the challenges that occur with intersymbol interference (ISI), increased frequency of pulses (need to meet United States of Americas' FCC (Federal Communications Commission) criteria) and increased magnitude of spectral lines with decreased PRI [1]. These authors go on to point out that, due to the channel characterization, advantage can be taken of the dead time between pulses, which can be interleaved with other sub-channels (as needed in a shared MAC media). This interleaving of channels allows us to consider a system which uses DS-TH-UWB (Direct Sequence-Time Hopping-Ultra Wide Band) in a similar way. This idea also is expressed in [2] which looked at a comparison of Orthogonal Transmit Diversity (OTD) and STS (Space Time Spreading) systems for IS-2000 (not a UWB based system).

In [3] they analyse PPM (Pulse Position Modulation) UWB orthogonal, overlapped and OOK (On-off keying) employing binary block coded modulation over a indoor multipath channel for a single user single input single output (SISO) system using MRC (Maximal Ratio Combining) at the Rake receiver. They show that the choice of interval and multipath used for individual re-combinations at the Rake receiver is up to the receivers choice and can be considered dependent of the channels characteristics for careful selection of the multipath as a function of location in time of other multipath relative to time shifts (for different pulse positions) and for width of a ultra wideband pulse (typically in nanoseconds). This further implies the importance of time between received pulses and their multipath. This concept is then further extended by applying the use of the STS code to the pulse position mechanism.

In our previous work [4][5], we have covered the development of STS systems in the presence of Multiple Access Interference (MAI) and the development of a PPM UWB simulation using MATLAB's Simulink. Here we combine these two systems across a SISO wireless link using simulation and show that in the presence of multipath and with perfect knowledge of the channel coefficients the Bit Error Rate (BER) performance normalized for energy per bit for a three position pulse position scheme, which we describe below, is equal or superior to the two position pulse position scheme when using DS-TH-UWB technique. Moreover, by doing so the data rate can be doubled as two bits of information can be transmitted in the same time slot instead of a single bit that can be sent using only a two position technique [5].

The inspiration for this technique, which we call Direct Sequence Modified Time Hopping Pulse Position Modulation was from our earlier work in building a STS Multiple Input Multiple Output (MIMO) system as first proposed in [6]. We simulated this in [7] and showed how Wysocki spreading codes can be used to reduce the effects of MAI in Multiple Access Direct Sequence Spread Spectrum systems [8].

This paper is organised as follows. In Section 2 we outline the simulation of the DS-TH-UWB two pulse position simulation. In Section 3 we propose how the two pulse position simulation can be modified to three pulse positions using the Space Time Spreading Technique proposed in [6] as applied across a SV (Saleh-Valenzuela) channel using UWB PPM. In Section 3 we compare the performance of the two systems using simulation in the presence of Gaussian noise and compare the Bit Error Rate versus measured energy per bit in the simulations. Section 4 concludes the paper and outlines further work.

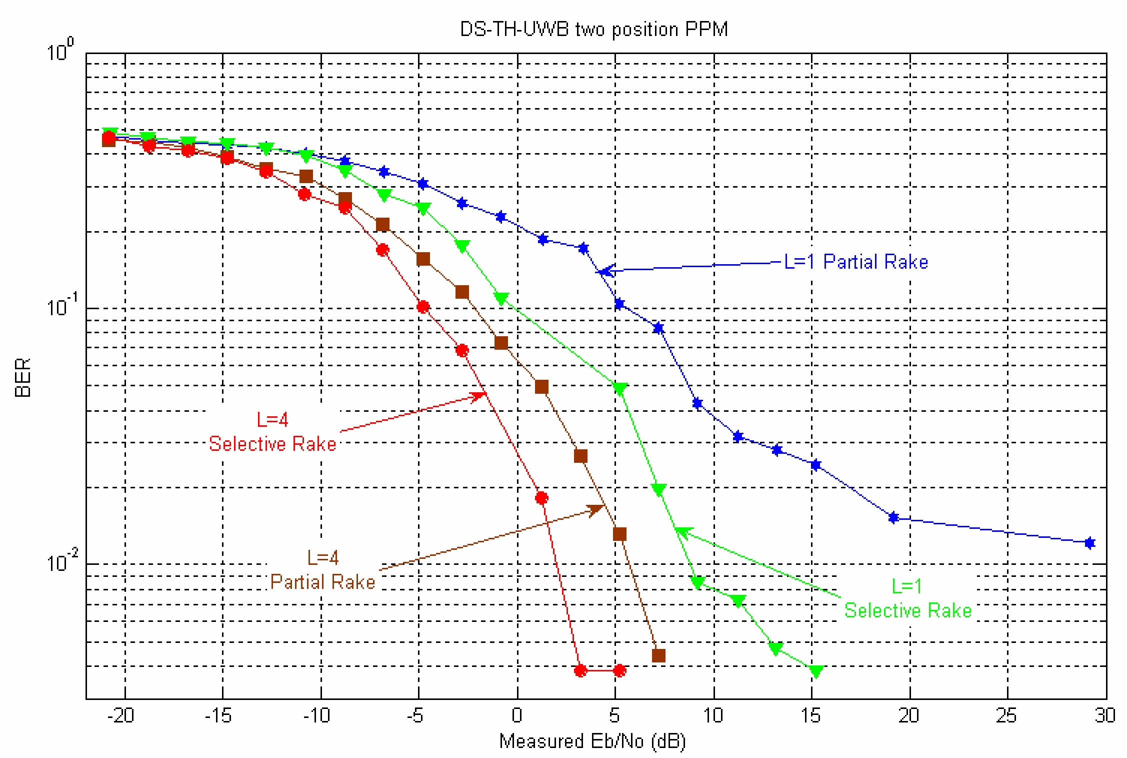

Figure 1: DS-TH-UWB simulations for two position PPM

2.0 DS-TH-UWB with Two pulse Positions

We constructed a Direct Sequence Time Hopping Ultra Wideband simulation[5] using MATLAB/ Simulink. We added a Direct sequence outer loop based on a simple thirty two bit Walsh-Hadamard code and a Time Hopping bit pattern. A frame with eight one hundred nano-second slot positions was defined where during one of these eight slots a Gaussian pulse (as illustrated in [5]) would be transmitted. A time hopping pattern was then superimposed on this to add further time dithering and hence smooth out the spectrum of our system. The Time hopping pattern chosen (purely randomly) was [6 0 5 3 6 4 5 3] and this was not varied during the simulations for either two or three pulse position modulation. To further elucidate, each frame was split into eight one hundred nano-second time frames. For the first such frame at the sixth slot a Gaussian UWB pulse was transmitted with a zero shift to represent a '0' and a one nano-second shift (delay) to represent a '1' (dependent on the value being transmitted and the Walsh-Hadamard spreading sequence). These shifts corresponded to those imposed in the simulations described in [5].

We assumed here that only the energy received at the demodulators' receiver was considered (as was done in [5]). Prior to generating the SV channel coefficients the received Gaussian pulses were ranked in order of strongest to weakest useful multipath. Usefulness was decided on whether there were any other significant multipaths in the near vicinity of the signal in time. The simulations were then conducted for the first useful ray (L=1, Partial Rake) and the best useful ray (L=1, Selective Rake), the first four useful rays (L=1, Partial Rake) and the best four useful rays (L=4, Selective Rake). The measured results are shown in Figure 1.

3.0 DS Modified-TH Pulse Position Modulation

While developing the Space Time Spreading simulation described in [7] it was observed that the values being sent per stream could be represented by -2, 0, or 2. These could correspond to three different time shifts in a UWB PPM scheme. At the computational expense of one extra shift in time within a slot (an extra nanosecond), we could send one symbol representing two chips of data instead of one and use the space time spreading demodulator described in [7] to demodulate the received signal. We do this with perfect timing and channel coefficients knowledge at the receiver. The receiver then makes a decision in the presence of noise as to which symbol has been transmitted by comparing the received signal with three possible received symbols but with no noise (as done in [5]).

The stream sent could be the summation of two bits multiplied by the 32 bit spreading sequence. If we then represent the individual chips of the spreading sequence by $c_1[j]$ and $c_2[j]$ where these are the two Walsh-Hadamard spreading sequences used in Space Time Spreading and j is the counter for the individual chips within that sequence which here is a integer in the range {1,2,..,32}. If b_1 and b_2 are the two bits to be transmitted across the UWB channel, then for the addition stream we have:

$$b_1c_1[j]+b_2c_2[j]=\begin{Bmatrix} 2 \\ 0 \\ -2 \end{Bmatrix} \quad for \quad j=1,...,32 \qquad (1)$$

While for the difference stream we have:

$$b_2c_1[j]-b_1c_2[j]=\begin{Bmatrix} 2 \\ 0 \\ -2 \end{Bmatrix} \quad for \quad j=1,...,32 \qquad (2)$$

Either of these streams can then be transmitted and demodulated at the receiver using the Space Time Spreader demodulation technique used in [7]. This means that one symbol now represents two bits instead of the one bit represented per symbol transmitted in Section 2.

Using the same UWB channels as described in Section 2 we conducted the simulations for the first useful ray (L=1, Partial Rake) and the best useful ray (L=1, Selective Rake), the first four useful rays (L=1, Partial Rake) and the best four useful rays (L=4, Selective Rake). The measured results are shown in Figure 2.

3.0 Comparison of DS-TH-UWB with DS-Modified-TH-UWB

We now compare the results obtained using the two pulse position UWB and the modified three pulse position UWB based on the Space Time Spreading technique. Figure 3 shows the modified and un-modified method developed in Section 3 and Section 2, respectively for the first useful arriving ray (L=1, Partial Rake). For the Measured Eb/No in the middle range the two methods appear to work nearly the same. For lower and higher measured Eb/No values the un-modified methods performance in terms of BER is superior. For this middle range of values for measured Eb/No it would be better to choose the modified method as two bits are sent in the same time taken to transmit one bit with the un-modified method with no loss in the BER.

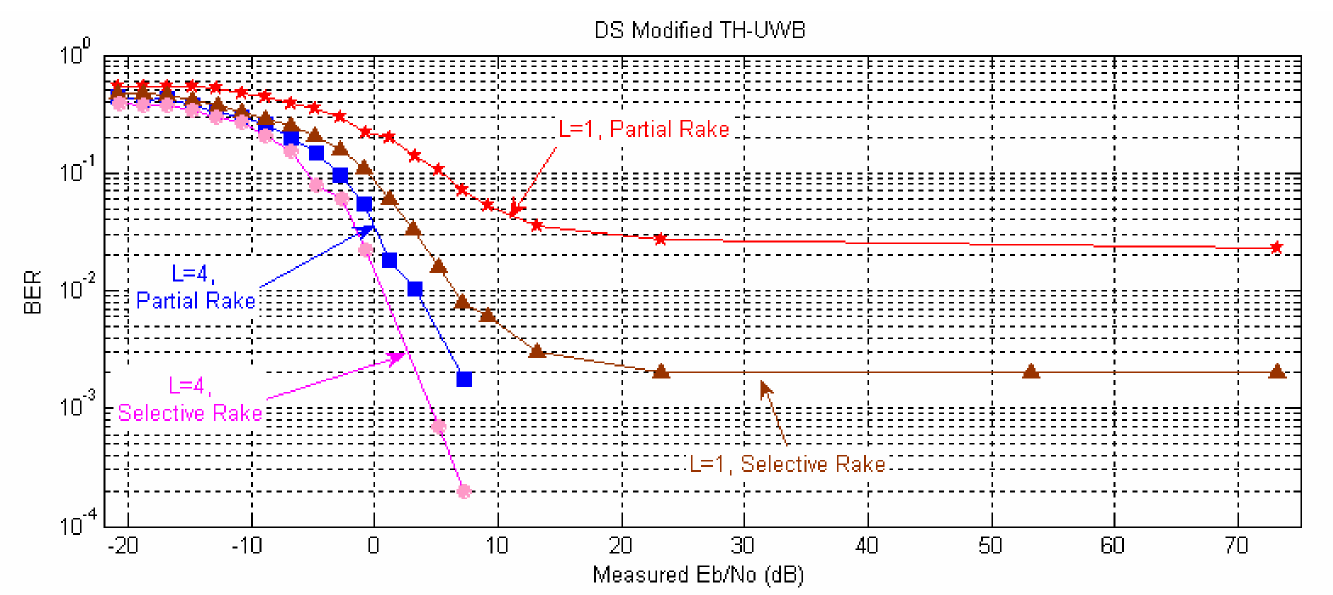

Figure 2: DS Modified-TH-UWB simulations for three position PPM

Figure 4 shows the modified and un-modified method developed in Section 3 and Section 2, respectively for the first four useful arriving rays (L=4, Partial Rake). We now see a significant improvement in the modified methods performance over the un-modified methods performance in terms of BER. For low values of measured Eb/No the modified method has a slightly better performance than the un-modified method. For higher values of measured Eb/No there is a significant improvement of BER over the unmodified method, for example at a BER of 0.03 there is approximately a 3dB difference in measured Eb/No between the two methods.

Figure 5 shows the modified and un-modified method for the best arriving ray (L=1, Selective Rake). The modified method shows significant improvement in BER over the un-modified method for all values of measured Eb/No. Once again a more significant improvement is seen for higher values of Eb/No than lower. This contrasts with Figure 3 where the two techniques performed in a similar manner for the middle set of Eb/No values. For the case of selective rake this performance improvement clearly favours the modified method.

Figure 6 shows the results for the two methods when the best four arriving rays are used (L=4, Selective Rake). Once again there is significant improvement in the BER for the same measured Eb/No, which improves as the measured Eb/No increases.

4.0 Conclusion

We have modified the simulation described in [5] to include Direct Sequence and Time Hopping. We have then proposed to modify this technique using the sum or difference approach described in space time spreading which we term DS-Modified-TH-UWB. We found that for three out of the four studies conducted DS-Modified-TH-UWB performed with a better BER than DS-TH-UWB at the same measured Eb/No values in our simulation. In the case where there was no performance advantage we showed that for middle values of Eb/No the systems performed similarly. Even in this case, the added advantage higher data rate would warrant usage of the DS-Modified-TH-UWB method.

In our future work we will consider the effect of Multiple Access Interference (due to the same hopping pattern being used) in Direct Sequence Ultra Wideband scenario and investigate if Wysocki codes can mitigate MAI as was found in [8].

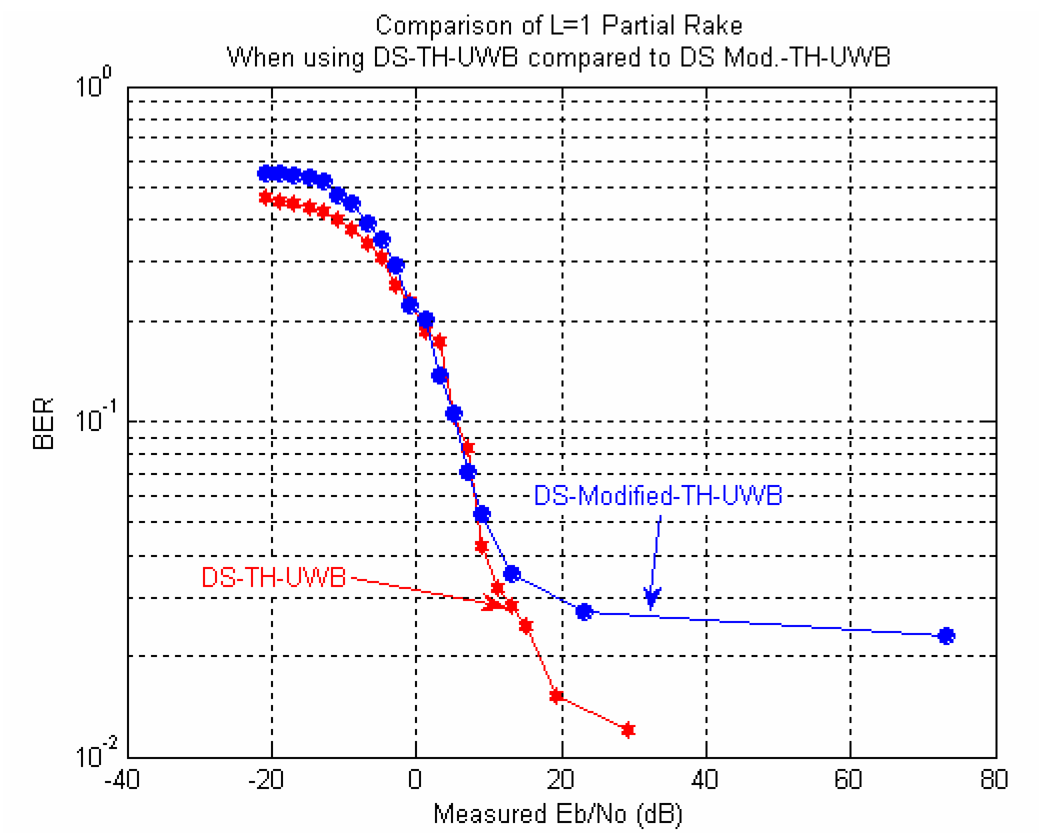

Figure 3: Comparison of L=1 Partial Rake using DS-TH-UWB and DS-Modified-TH-UWB

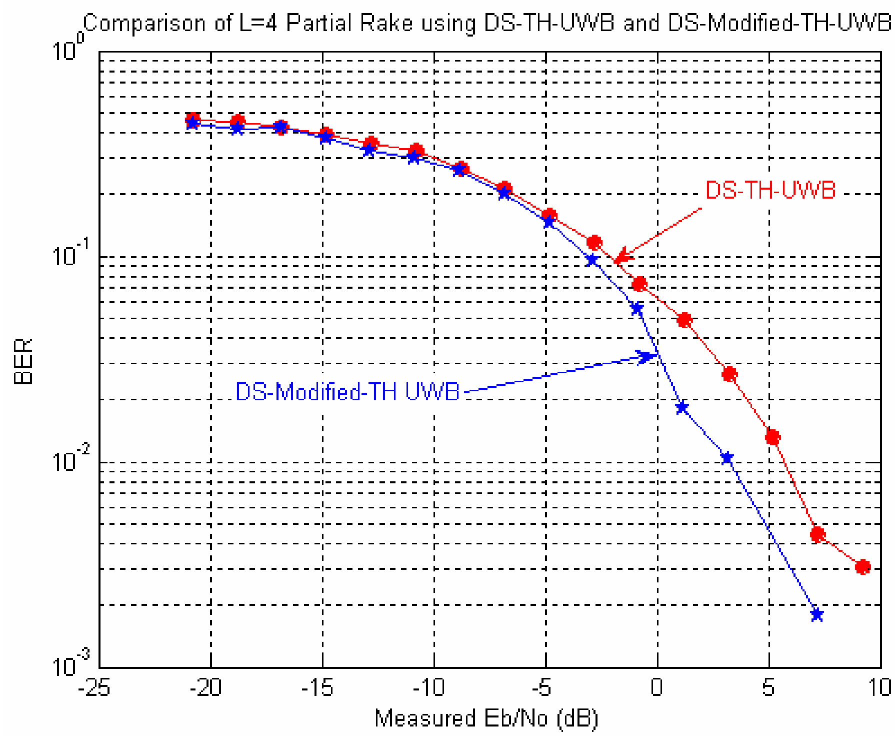

Figure 4: Comparison of L=4 Partial Rake using DS-TH-UWB and DS-Modified-TH-UWB

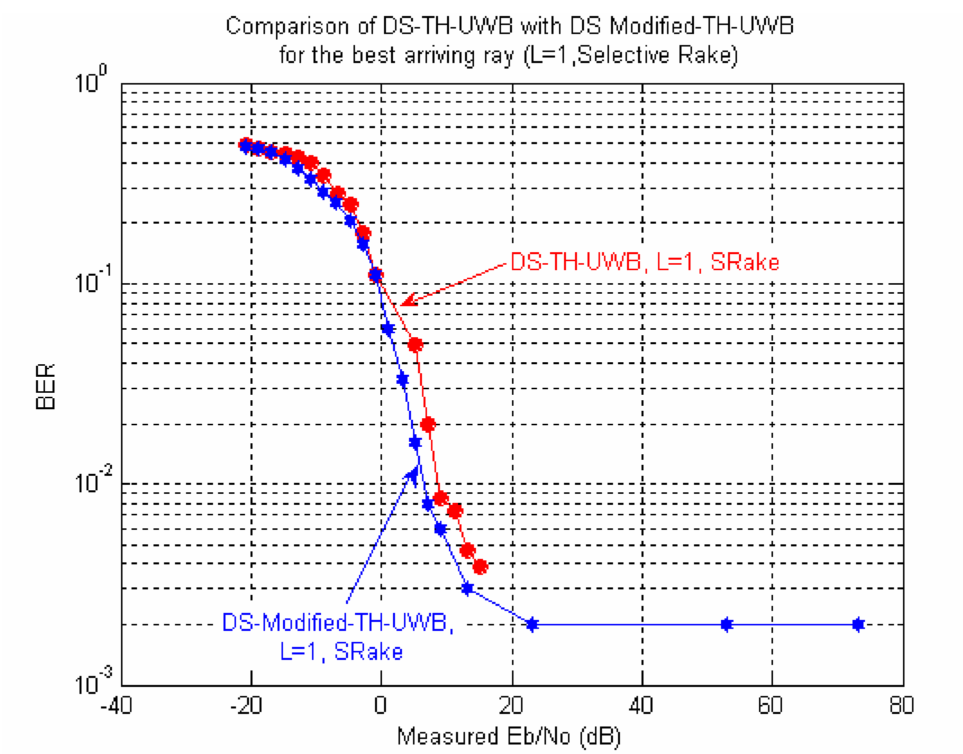

Figure 5: Comparison of L=1 Selective Rake using DS-TH-UWB and DS-Modified-TH-UWB

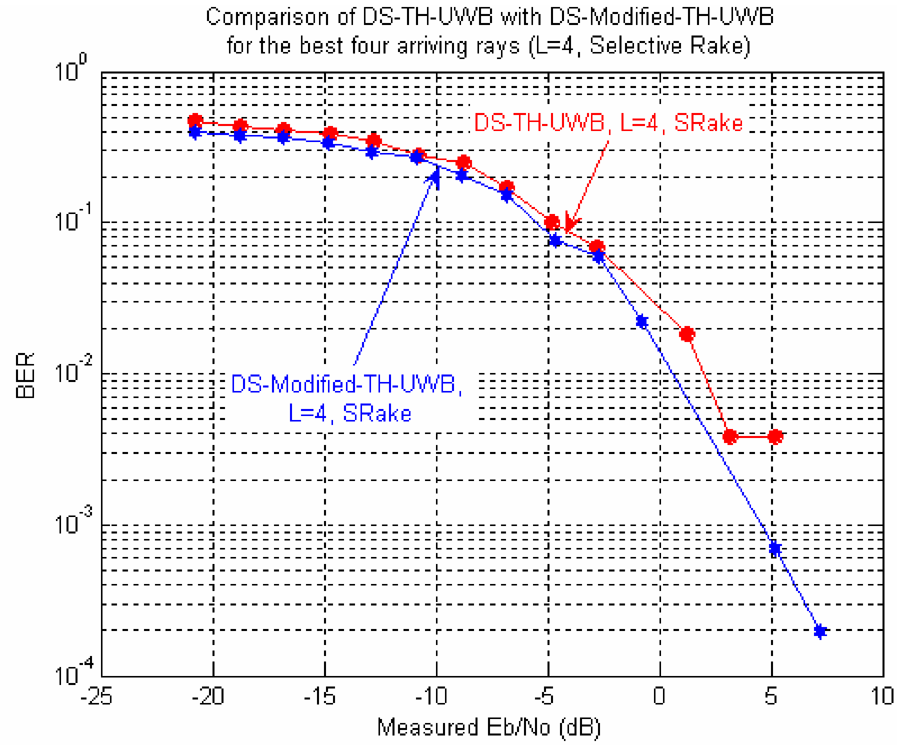

Figure 6: Comparison of L=4 Selective Rake using DS-TH-UWB and DS-Modified-TH-UWB

5.0 References

[1] July 2006, August, N.J and Dong Sam Ha, "Operation, system architectures, and physical Layer design considerations of distributed MAC protocols for UWB", IEEE Transactions on Microwave Theory and Techniques, Volume 54 Issue 7, pp. 3001- 3012

[2] September 2004, Robert A Soni and R Michael Buehrer, "On the Performance of Open-Loop Transmit Diversity Techniques for IS-2000 Systems: A Comparative Study", IEEE Transactions on Wireless Communications, Volume 3, Number 5, pp. 1602-1615

[3] IEEE Conference on Communications, Choi, J.D and Stark, W.E., "Performance analysis of RAKE receivers for ultra-wideband communications with PPM and OOK in multipath channels", 28 April-2 May 2002, pp. 1969 - 1973 vol.3

[4] DSPCS'03, Coolangatta Queensland, 8-11th of December, Peter James Vial, Ibrahim Raad, Tad Wysocki, "On the effect of adjacent sector Multiple Access Interference on Space Time Spreading Systems"

[5] DSPCS05'& WITSP'05, Noosa Heads, Queensland, 18-21st of December, Peter Vial, Beata Wysocki, Tad Wysocki, "An Ultra Wideband Simulator Using MATLAb/Simulink"

[6] Bertrand Hochwald, Thomas L Marzetta, Constantinos B Papadias, “A Transmitter Diversity Scheme for Wideband CDMA Systems
Based on Space-Time Spreading”, IEEE Journal on selected areas in communications, Vol 19, No 1, January 2001, pp. 48-60

[7] Radio Elektronica, Bratislava, Slovak Republic, Peter Vial, Ibrahim Raad, Tad Wysocki, "On Design of a STS channel using Simulink", 27-28 April 2004

[8] 2004 IEEE International Symposium on Spread Spectrum Techniques and Applications, P Vial, B J Wysocki, I Raad, T Wysocki, "Space Time Spreading with Modified Walsh-Hadamard Sequences", Sofitel Wentworth Hotel, Sydney, Australia, 30th August - 2 September 2004

[9] 1979, Geramita & Seberry, "Orthogonal Designs: Quadratic Forms and Hadamard Matrices", Marcel Dekker, Inc. New York and Basel, ISBN 0-8247-6774-8

[10] 2004, Di Benedetto & Giancola, "Understanding Ultra Wide Band: Radio Fundamentals", Prentice Hall Communications Engineering and Emerging Technologies Series, ISBN 0-13-148003-0

[11] 2004, Oppermann, Hamalainen, linatti, "UWB: Theory and applications", Wiley, ISBN 0-470-86917-8

[12] 2001, Proakis, "Digital Communications", fourth edition, McGraw-Hill, ISBN 0-07-118183-0

[13] 1999, Liberti & Rappaport, "Smart Antennas for wireless communications: IS-95 and Third Generation CDMA Applications", Prentice Hall Communications Engineering and Emerging Technologies Series, ISBN 0-13-719287-8

[14] 2000, Rooyen, Lotter, Wyk, "Space Time Processing for CDMA Mobile Communications", Kluwer International Series in Engineering and computer science, Kluwer Academic Publishers, ISBN 0-7923-7759-1

[15] 1996, Golub & Loan, "Matrix Computations", Johns Hopkins University Press, ISBN 0-8018-5414-8

[16] 1998, Sergio Verdu, "Multiuser Detection", Cambridge Press, ISBN 0-521-59373-5