IPI Removing by Using Reference Sign/N-ary Orthogonal Coded/Balanced TR-UWB Receiver for WPAN Based on Hadamard Matrix

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Abstract

IR UWB system has been proposed as a promising physical layer candidate for indoor wireless communications, because it offers very fine time resolution and multipath resolvability. Inter pulse interference (IPI) is one important challenge related to the transmit reference (TR) IR UWB receiver. In this paper, an attempt to completely remove the IPI problem in TR with increasing the data rate. This is achieved by using orthogonal codes generated from modified version of Hadamard matrix via the application of the reference sign technique, i.e., by modulating the reference pulse besides the already data modulated.

Keyword: Inter Pulse Interference Removing

1. Introduction

Transmit-reference (TR) schemes are considered a realistic candidate for impulse-based ultra-wideband (UWB) communication systems. Due to the narrow pulses employed in such systems, many multipath components can be resolved, and it is not efficient to estimate all of them. TR schemes side step channel estimation by transmitting a reference signal which undergoes the same distortion by the channel as the data signal. This provides an (unfortunately) noisy template [1].

In general, the data rate of the conventional TR system is limited by the multipath delay spread T_{mds}, because the inter-pulse distance T_d should be greater than T_{mds}, so as not to incur the interference between the reference and data pulses in a frame. To mitigate this inter-pulse interference (IPI) and boost the TR system's achievable information rate, a new signaling scheme is proposed.

Many literatures studied and focused on the IPI cancellation or mitigation using TR receivers with all its types.

In [2], the authors proposed *M*-ary orthogonal coded/balanced TR system in which the IFI can be avoided because the frame time can be prolonged due to *M*-ary signaling as far as the required data rate is. achieved. Based on this signaling approach, the IPI has been mitigated by using a pair of *balanced* matched filters, which subtracts out the overlap portion between multipath delayed pulses. The effective suppression of the IPI has been validated through the theoretical analysis and simulations in dense multipath. It has been shown that the use of proposed balanced TR can result in significant data rate increases even at a lower transmit power, compared to conventional TR. This proposed receiver is largely suffered from time jitter even for small time values. It is also too complex in terms of the number of matched filters used. In [3], the authors proposed balanced transmit reference (TR) system for ultra-wideband (UWB) communications. This proposed TR system is capable of properly eliminating the inter-pulse interference (IPI) between the reference and data pulses in multipath environments, with a low system complexity. In fact, it should be noted that the suboptimal receiver does not completely eliminate the IPI because of the non-linear cross-correlation performed prior to the IPI cancellation. In [4], the authors introduced *M*-ary orthogonal coded/balanced TR system in which the inter-frame interference can be avoided because the frame time can be prolonged due to *M*-ary signaling as far as the required data rate is achieved. Based on this signaling approach, the interpulse interference has been overcome jointly by using *balanced* matched filters, which subtracts out the overlapping portion between multipath-delayed tail of the reference pulse and subsequent information-bearing data pulse. It has been shown that their proposed TR system can result in significant data rate increases even at a lower transmit power; compared to conventional TR. They also addressed the receiver complexity issues and presented two suboptimal receiver structures. It is demonstrated that the suboptimal receivers still outperform conventional TR, with lower complexity than the optimal receiver. Finally, they compared the performances of their proposed TR system with that of conventional TR system in the presence of timing jitter and showed that, even when a large amount of timing jitter occurs, their proposed TR system with the suboptimal receiver still outperforms conventional TR. Also, it should be noted that the suboptimal receiver does not completely eliminate the IPI because of the non-linear cross-correlation performed prior to the IPI cancellation.

In this paper, a new IR-UWB-TR receiver is proposed based on Hadamard matrix namely Reference Sign/Orthogonal/Coded/Balanced/UWB TR scheme, to increase the information rate and improving the detection performance.

The Hadamard matrix H_n has $N = 2^n$ rows and $N_s = 2^n / 2$ columns. Each row can be treated as a specific symbol "ary" and hence there is N-ary system. Each ary can be transmitted using $2N_s$ frames. As a result, sending all the $2N_s$ columns of H_n for N-ary signaling is *impractical*, due to the following reasons:-

1. The information rate is decreased with increasing N_s.
2. The probability that the channel remains fixed for the entire symbol period is decreased as N_s increased.
3. By examining H_n, it becomes clear that the first row could not be used for IPI canceling, because it contains (-1s'), and hence H_n is orthogonal.
4.

2. Transmit-Reference

A conventional transmit-reference (TR) signaling carries bit information using the phase difference between the reference and data pulses occurring with fixed relative delay in a frame. The i^{th} bit's transmitted signal of conventional TR using bi-phase modulation can be written as [4]:

$$s_{tr}(t) = \sqrt{\frac{E_f}{2N_s}} \sum_{j=iN_s}^{(i+1)N_s-1} [w_{tr}(t - jT_f) + b_{\lfloor j/N_s \rfloor} w_{tr}(t + jT_f - T_d)] \quad (1)$$

where $w_{tr}(t)$ is the unit-energy transmitted pulse of duration T_p (also equal to one chip time T_c). T_f is the frame time to transmit a pair of reference and data pulses. Ns is the number of frames used to transmit one bit (symbol) information, and E_f here is defined as the frame energy. To avoid the inter-frame interference (IFI), it is assumed that $T_f \geq (T_c + T_d + T_{mds})$, where T_d is the relative time delay between the reference and data pulses, and is assumed to be an integer multiple of chip time ($T_d = \Delta T_c$), where Δ is an integer. T_{mds} represents the multipath delay spread. b_i is the i^{th} binary bit, taking on the values of {−1, 1} with equal probabilities, and $i = \lfloor j / N_s \rfloor$ denotes the integer part of j/N_s. Note that, to allow for multiple access (MA) a user specific time hopping sequence is employed to randomize the location of the pulse pair in each frame. However, since we focus more on information rate increase and performance improvement of a single-user TR system, we will not consider TH for simplicity [4].

As will be shown later, this signaling scheme, combined with our proposed *balanced* TR receiver, is effective against the IPI caused by the multipath. This enables us to realize higher data rate transmission than conventional TR by choosing $T_d < T_{mds}$, because the minimum frame time T_f for ensuring zero IFI can be reduced accordingly

3. Hadamard Matrices

Definition

A Hadamard matrix, $\mathbf{H}_n$, is a square matrix of order n = 1, 2. The elements of **H** are either +1 or –1 and $\mathbf{H}_n\mathbf{H}_n^T = n\mathbf{I}_n$, where $\mathbf{H}_n^T$ is the transpose of $\mathbf{H}_n$, and $\mathbf{I}_n$ is the identity matrix of order n. A Hadamard matrix is said to be normalized if all of the elements of the first row and first column are +1 [5].

Properties

Hadamard matrices have several interesting properties [5]:

• The determinant, $|\mathbf{H}_n| = n^{n/2}$, is maximal by Hadamard's theorem on determinants.

• A normalized $\mathbf{H}_n$ has n(n-1)/2 elements of –1 and n(n+1) elements of +1.

• For normalized Hadamard matrices of order 2 or greater, every row (except the first) or column (except the first) has n/2 elements of +1 and n/2 elements of –1.

• Any two rows or two columns are orthogonal.

• Every pair of rows or every pair of columns differs in exactly n/2 place

A Hadamard matrix may be transformed into an equivalent Hadamard matrix by any of the following operations:

• Interchanging any two rows or any two columns

• Multiplying any row or any column by –1

• Matrix transposes.

For this, a one bit data set can be transformed, using orthogonal codewords of two digits each, described by the rows of Hadamard matrix $\mathbf{H}_1$ as follows [6]:

Data set   orthogonal codeword set

Data set	orthogonal codeword set
0 1	$H_1 = \begin{bmatrix} 0 & 0 \\ 0 & 1 \end{bmatrix}$

To encode a 2-bit dataset, we extend the foregoing set both horizontally and vertically, creating matrix $\mathbf{H}_2$ [6]:

Data set   orthogonal codeword set

$$\begin{matrix} 0 & 0 \\ 0 & 1 \\ 1 & 0 \\ 1 & 1 \end{matrix} \quad H_2 = \left[\begin{array}{cc|cc} 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 \\ \hline 0 & 0 & 1 & 1 \\ 0 & 1 & 1 & 0 \end{array}\right] = \begin{bmatrix} H_1 & H_1 \\ H_1 & \overline{H_1} \end{bmatrix}$$

The lower right quadrant is the complement of the prior codeword set. The same construction rule can be used to obtain any $\mathbf{H}_n$. In general, a codeword set $\mathbf{H}_n$, of dimension $2^n \times 2^n$ can be constructed, from the $\mathbf{H}_{n-1}$ matrix as follows [6]:

$$H_n = \begin{bmatrix} H_{n-1} & H_{n-1} \\ H_{n-1} & \overline{H_{n-1}} \end{bmatrix} \quad \ldots \tag{2}$$

4. The Proposed TR Receiver based on Hadamard matrix

In this transceiver, we first construct the modified Hadamard matrix, and then design the transceiver system according to the new generating matrix.

Any Hadamard matrix H_n with dimension $(N \times N)$ can be constructed as follows:

$$H_n = \left[\begin{array}{c|c} H_{n-1} & H_{n-1} \\ \hline H_{n-1} & \overline{H_{n-1}} \end{array}\right]$$

H_n is orthogonal and has four quarters, each one is biorthogonal. In symbolic notations, this could be written as:

$$\sum_{k=1}^{N_s} v_{i,k}.v_{j,k} = \begin{cases} 1 & for \quad i=j \\ -1 & for \quad i=1, j=N_s/2-1 \\ 0 & for \quad elsewhere \end{cases} \tag{3}$$

Where N_s is the number of pulses used in TR receiver (N_s=N). $v_{i,k}$ and $v_{i,k}$ are the elements of Hadamard matrix. Hence we have:

$$H_n = \begin{bmatrix} v_{11} & v_{12} & \cdots & v_{1n} \\ v_{21} & v_{22} & \ddots & \vdots \\ \vdots & \vdots & \ddots & \vdots \\ v_{n1} & v_{n2} & \cdots & v_{nn} \end{bmatrix} \tag{4}$$

H_n can be divided into two halves, as:

$$H_n = \begin{bmatrix} Q_1 \\ \hline Q_2 \end{bmatrix} \tag{5}$$

For symbolic notation simplicity, and without lose of generality, the first half Q_1 could be written as:

$$Q_1 = H_{n-1} = \begin{bmatrix} v_{11} & \cdots & v_{1,n} \\ \vdots & \ddots & \vdots \\ v_{n/2,1} & \cdots & v_{n/2,n} \end{bmatrix} \tag{6}$$

with dimension (N/2 x N) …

Duplicate Q_1 in a second matrix to get the Q_1^* matrix. We need another way to distinguish between the two parts. Anyway, another column (N+1) is added to represents the sign of the reference pulse to get the generating matrix GM in the following form:

$$Q_1^* = \begin{bmatrix} v_{11} & \cdots\cdots & v_{1,n} \\ \vdots & \ddots & \vdots \\ v_{n/2,1} & \cdots\cdots & v_{n/2,n} \\ v_{11} & \cdots\cdots & v_{1,n} \\ \vdots & \ddots & \vdots \\ v_{n/2,1} & \cdots\cdots & v_{n/2,n} \end{bmatrix} \tag{7}$$

with dimension (N x N)

$$GM = \left[\begin{array}{ccc|c} v_{11} & \cdots\cdots & v_{1,n} & -1 \\ \vdots & \ddots & \vdots & \vdots \\ v_{n/2,1} & \cdots\cdots & v_{n/2,n} & -1 \\ v_{11} & \cdots\cdots & v_{1,n} & +1 \\ \vdots & \ddots & \vdots & \vdots \\ v_{n/2,1} & \cdots\cdots & v_{n/2,n} & +1 \end{array}\right] \tag{8}$$

with dimension (N x N+1) …

The RS-TR-TH receiver, shown in figure (1), is based on the generating matrix GM. The block (D) is the delay between the data and the reference pulses which is (T_d) in equation (1).

On the other hand, its important to notice that the proposed receiver has low complexity as compared with the one proposed in [4] as shown in Figure 2.

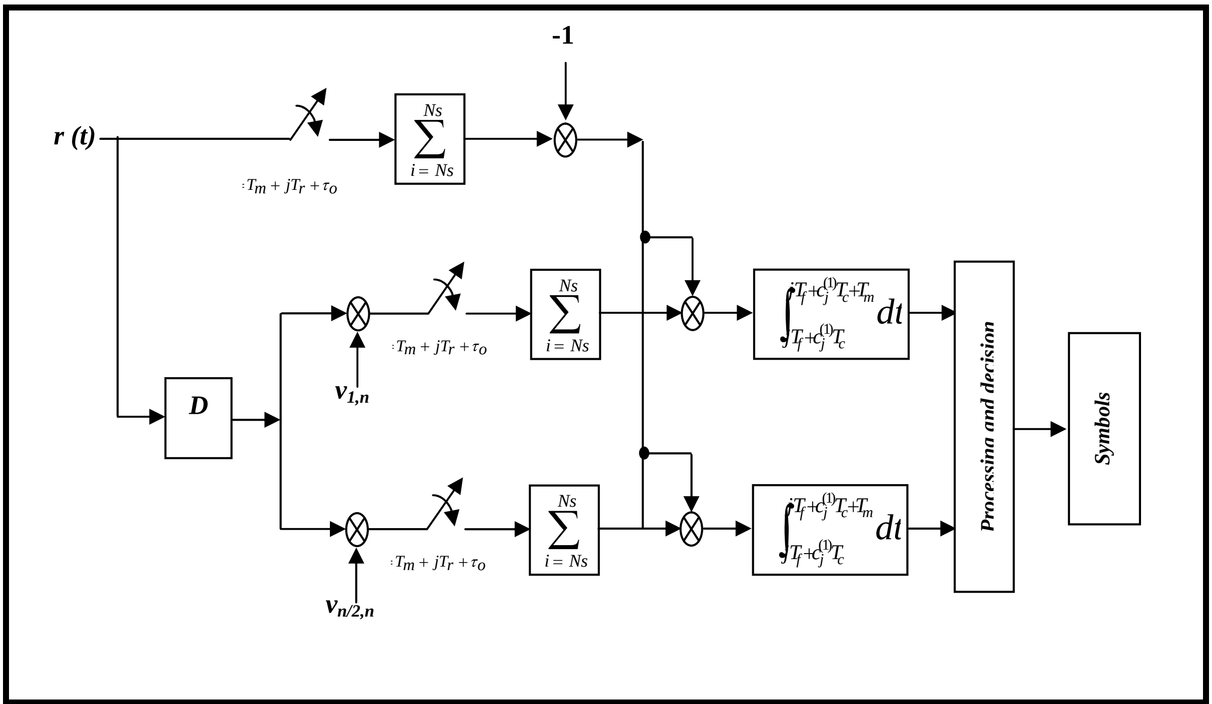

Figure (1) : The Proposed RS-TR-TH- Receiver

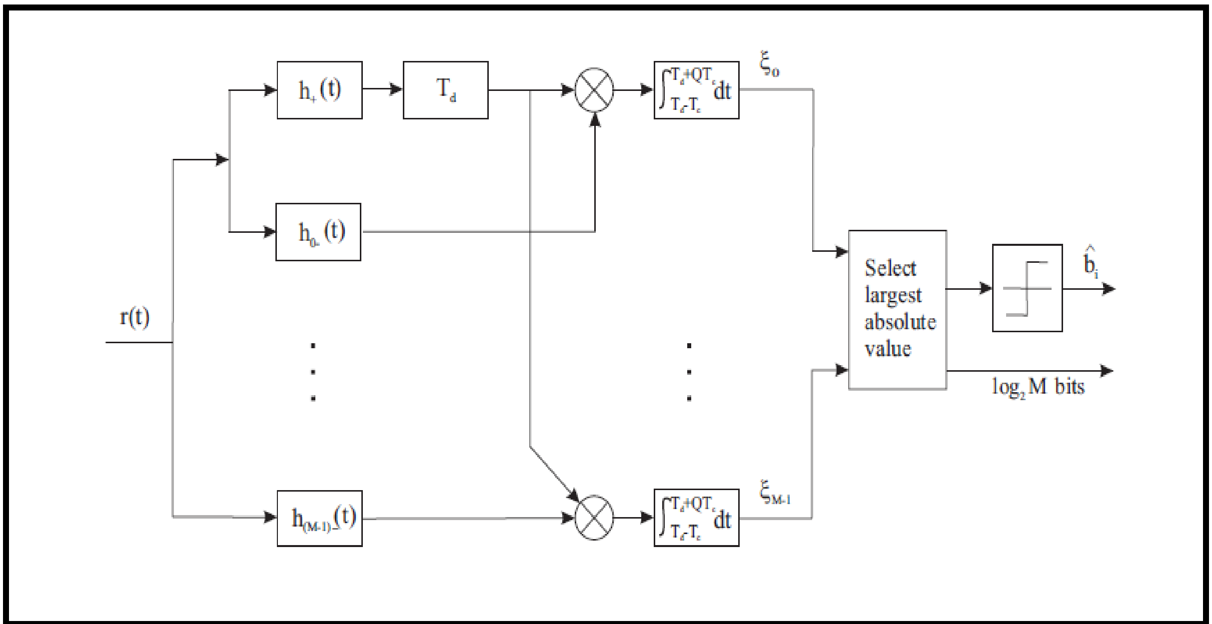

Figure (2) : Optimal receiver structure for M-ary Orthogonal coded/balanced TR system [4]

5. Simulation Results

In the simulation, and in order to not permit the ISI and IFI to occur, the RMS delay spread of the channel T_{rms} was set to 25 nsec, and a non-LOS WPAN CM3 channel has been used because of a dimension of 10m WPAN was used. The second derivative of a Gaussian pulse is used as a received pulse,

$$w(t) = \left[1 - 4\pi\left(t/t_n\right)^2\right]\exp\left[-2\pi\left(t/t_n\right)^2\right]$$

because it's easy to generate with a time normalization factor of t_n = 0.2877 ns has been used. The shaping factor for the pulse is 0.15 ns in order to get an UWB system. To get many samples in the receiver, the continuous-time signals of the receiver have been simulated by sampling at $f_s = 1/T_s$ = 100 GHz.

For 200 CM3 channel realization the channel is truncated at only 100 bins in order not to accommodate higher noise. In order the paths must be resolvable at the receiver inputs, the bin time of the channel is chosen to be 0.5 nsec and the pulse width was chosen to be 0.5 ns. 1000 symbols were used in the simulation.

The number of frames in each symbol is varied between 4 and 8. The delay between pulses is chosen to be 10, 20, 30 and 40 bins. The number of hopping is chosen to be 50. Also, in order to separate the users and not to let ISI and IFI to occur, the frame time is chosen to be 250 chips.

The simulation of the proposed receiver and the performance results are implemented in Matlab 7.4. Figures (3, 4, and 5) show the comparison results between the proposed receiver that we called N-ary for simplicity and the receiver proposed in [4] that is called M-ary for N_s = 8, 16 and 32. It's very obvious that the obtained BER for our proposed receiver is much lower than that obtained for the receiver in [4].

Moreover, a very large degradation in the performance of the receiver in [4] is shown because there is no perfect removing for the inter pulse interference, i.e., there is a residue IPI remain in the detection process affects on the perfect estimation of symbol in the last stage.

A very important issue is noticed in the performance that is the BER for the proposed receiver is zero for higher E_f/N_o, especially for higher values of N_s.

As a result, the proposed receiver in this work is completely removing the IPI besides a very high bit rates are obtained

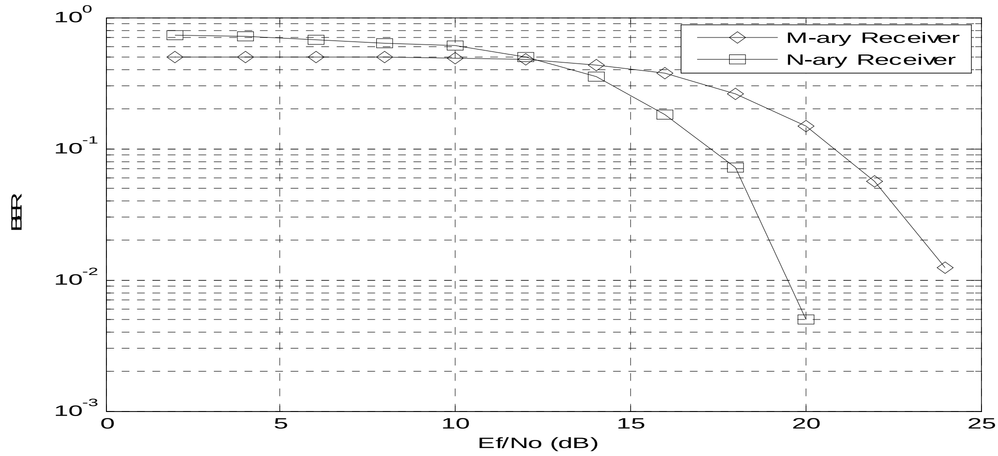

Figure (3) : The BER for the proposed receiver and the receiver in [4] for Ns = 8

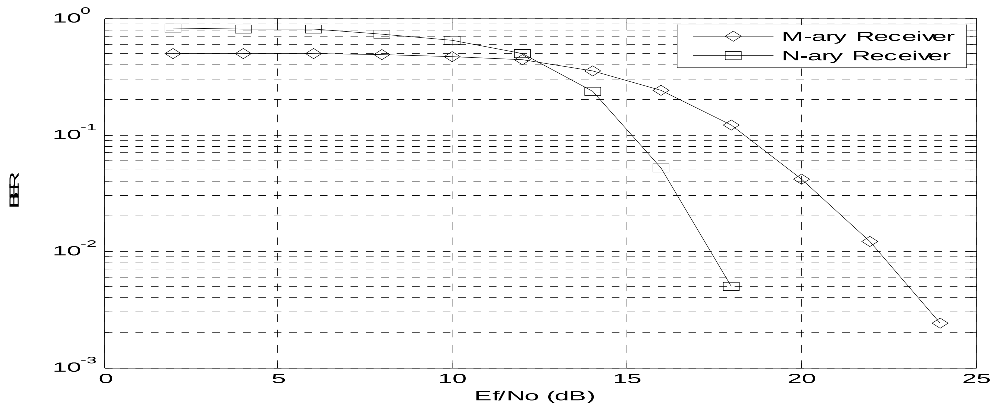

Figure (4) : The BER for the proposed receiver and the receiver in [4] for Ns = 16

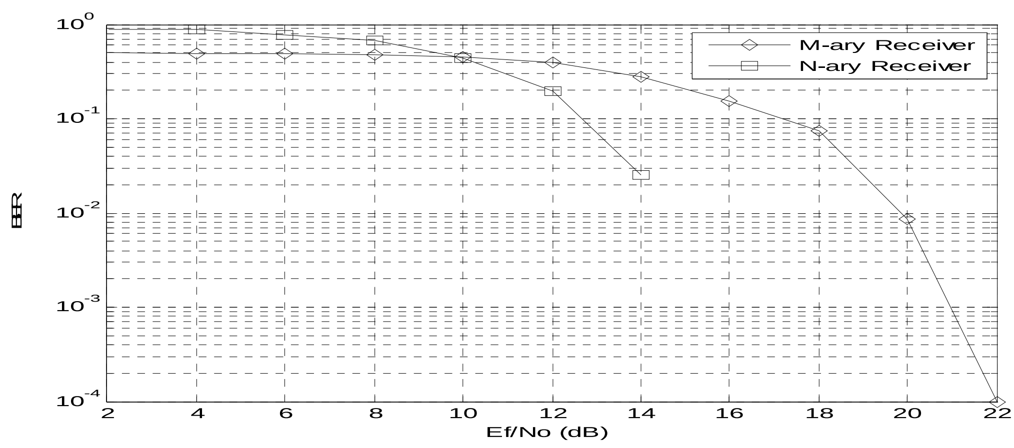

Figure (5) : The BER for the proposed receiver and the receiver in [4] for Ns = 32

Conclusions

The RS/TH/Orthogonal/Coded-Balanced UWB TR receiver structure was proposed and simulated. Its performance was evaluated and compared with the one proposed in [4]. The results showed that the proposed UWB TR system can completely remove the IPI occurred in TR schemes due to the smaller delay between the reference and data pulses. On the other hand, a high bit rate was obtained because of the large reduction in frame time T_f. From the complexity view, the proposed receiver was not complex due to the using of only one delay value between the reference and data pulses.

References

1. Quang Hieu Dang and Alle-Jan van der Veen, "***Resolving Inter-Frame Interference in a Transmit-Reference Ultra-Wideband Communication System***", ICASSP, pp. (481-484), 2006.
2. Dong In Kim and Tao Jia, "*M-ary Orthogonal Coded/Balanced UWB Transmitted Reference System* ", Proceedings of IEEE International Conference on Communications, Vol. 12, pp. (5552-5557), Istanbul, June 12-15, 2006.
3. Tao Jia and Dong In Kim, *"Multiuser Performance of Balanced UWB Transmitted-Reference System in Multipath* ", Proceeding of IEEE Globe Com. Conference, pp. (1-10), 2006.
4. Dong In Kim and Tao Jia, "*M-ary Orthogonal Coded/Balanced Ultra-wideband Transmitted-Reference Systems in Multipath*", IEEE Transactions on Communications, Vol. 56, No. 1, pp. (102-111), Jan 2008.
5. Don Torrieri, "***Principles of Spread-Spectrum Communication Systems***", Springer Science & Business Media Inc., 2005.
6. David Tse and Pramod Viswanath, "***Fundamentals of Wireless Communication***", Cambridge University Press, 2005.

ازالة التشويش بين النبضات لمستلمات الحزمة الواسعة جدا المعتمدة على تقنية ارسال المرجع ومصفوفة هادمارد للشبكات الشخصية اللاسلكية

صالح القرعاوي – الجامعة التكنولوجية

الخلاصة:

تم اقتراحَ نظام (***IR-UWB***) كمرشّحَ للطبقةِ الفيزياوية للإتصالاتِ اللاسلكية للشبكات الداخلية القصيرة (WPAN)، بما يمتاز به من مميزات تتعلق بَعْرض قرار وقتِ رفيعٍ جداً وحلول متعدّدة الطرق. يعتبر التشويش بين النبضات (IPI) كأحد التحديات المهمّة في المستلمات نوع (***TR- IR UWB***) والتي تتعلق بتقنية ارسال المرجع (***TR***) . في هذا البحث ، محاولة لإزالة مشكلةِ التشويش بين النبضات (IPI) بالكامل لنوع المستلمات التي تستند على تقنية ارسال المرجع وبزِيَاْدَة في سرعة ارسال البيانات. يمكن الحصول على هكذا انجاز بإستعمال الرموزِ المتعامدةِ (Orthogonal Codes) المتولّدة مِنْ النسخةِ المُعَدَّلَةِ مِنْ مصفوفةِ هادمارد عن طريق تطبيق تقنيةِ إشارةِ المرجع، وبمعنى آخر: . ، بتَنظمين نبضةِ المرجع اضافة الى تضمين البيانات.

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