MUI MITIGATION IN TH-IR-UWB SYSTEM BASED ON THREE-STAGES-DECISION UNITS RAKE RECEIVER[+]

تسكين تداخل المستخدمين في نظام الحزمة العريضة جدا باستخدام مستقبل نوع راك بثلاث مراحل لوحدات القرار

Hamid M.Farhan [*]

Abstract:

Due to enormous growth of Wireless Personal Area Network (WPAN) service, the need of a new engineering technique that can transmit high data rates arises. With its wide bandwidth, Ultra Wideband (UWB) has the potential to offer much higher capacity than the current narrowband system. In this research, a new Rake receiver for a pulse based UWB communication system is proposed in a multipath channel environment to mitigate the multi-user interference (MUI). The conventional Rake receiver is capable to mitigate the MUI to a certain limit because it contains only one decision unit. The proposed Rake receiver is based on modifying the conventional Rake receiver in order to mitigate the MUI by using three-stages-decision unit. The results are illustrated by using Matlab program that validate the proposed Rake receiver. Theperformance of the proposed Rake receiver is evaluated using a Partial Rake (PRake). The Bit Error Rate (BER) performance of the proposed Rake receiver is improved as compared with the conventional Rake receiver.

Keywords :WPAN, UWB, MUI,Rake,PRake and conventional Rake

المستخلص:

ازدادت الحاجه الى تقنيه هندسيه جديده والتي يمكنها ان ترسل , WPANبسبب النمو الهائل لشبكات الــ والذي له الامكانيه لارسال سعة بيانات اعلى بكثير من انظمة UWBبيانات ذات سعة عاليةجدا. وهذا النظام هو الــ يعتمد على كشف رقاقه (نبــضه) Rake الحاليه. تم في هذاالبحث اقتراح نظام استقبال نوع Narrowbandالــ التقليدي قــادر علــى تــسكين Rakeومن ثم تحويلها الى مقررين. ان مستقبل الــ Rakeلوحدها في اصابع الــ المقترح مستند على تعديل مستقبل Rake الى حد قليل لانه يحتوي على وحدة قرار واحده فقط. ان الــ MUIالــ الى حد كبير وذلك باستعمال وحدات قرار المراحل الثلاثه. MUIالتقليدي لكي يكون قادرا على تسكين Rakeالــ ان MUIتوكد قوة المستقبل المقترح لتسكين الــMatlabان النتائج التي تم الحصول عليها باستعمال برنامج الــ الجزئي . وبينت النتائج التي تم الحصول عليها بان المستقبل Rakeاداء المستقبل المقترح تم فحصه باستخدام الــ التقليدي. Rakeمقارنة بالــ BERالمقترح ابدىاداء افضل من ناحية انجاز قيم منخفضة لنسبة خطأ القطعه

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[*] Assist.Lec.\ college of Electrical and Electronic Techniques

Introduction :

From Shannon's formula for the capacity Cin bit/s in Additive White Gaussian Noise (AWGN), the capacity of the UWB system occupying bandwidth BW, as a function of the Signal to Noise Ratio (SNR) at a distance d between the transmitter and receiver is given by [1]:

$$C(d) = BW \log_2 (1 + SNR(d)) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

The function SNR (d) represents the effect of path losses on the transmitted signal. It can be seen that UWB systems offer their greatest promise for very high data rates for high BW.
UWB system covers a large spectrum and interferes with existing users and narrow band services [2]. In order to keep this interference to the minimum, a spectral mask was specified for different application which show the allowed power output for specific frequencies. In Figure (1), the spectral mask for indoor UWB system is shown. A large contiguous bandwidth of 7.5 GHz is available between 3.1 GHz and 10.6 GHz at maximum power output of -41.3 dBm/MHz.

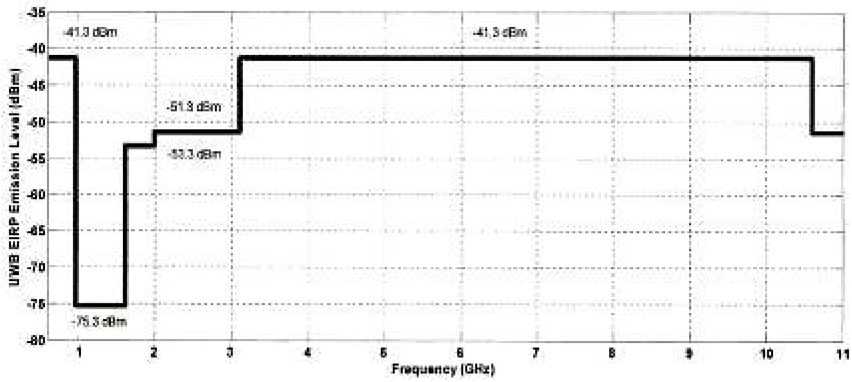

Figure (1): The spectral mask for indoor UWB systems [2]

In [3], the authorproposed a detection method that was independent of the power of different signal included in the Impulse Radio UWB (IR-UWB). That detection method will work well in the absence of power control where the conventional detection method fails.He called it Power Independent Detection (PID) method.

In [4], the author presented a simple chip discrimination technique for use with IR that significantly improves BER performance for a linear correlation receiver with large near-far power ratios. An analytical model was developed that estimates the BER performance for binary Pulse Position Modulation(PPM) IR for varying Signal-to-Interference (S/I) power ratios and discrimination thresholds.

In[5],the author proposed a simple way to modify the Rake receiver in order to totally remove the residual interference that occurs at the output of the Rake receiver when realistic multipath propagation channel is considered even if a large guard time interval was used.

Rake Receiver Construction:

The basic version of the conventional Rake receiver-Figure (2)-consists of $L_r$correlators (Fingers) where each of the fingers can detect the signal from one of the Multipath Components (MPCs) provided by the channel. The output of the fingers are appropriately weighted and combined to reap the benefits of multipath diversity [6].

It is obvious that the Rake receiver make one decision over allthe number of pulse per symbolN_s.So it is convenient to call this receiver by Bit Decision (BD)Rake receiver, where each correlator correlates the received signal with a template, then summing the output inMaximal Ratio Combining (MRC)scheme. The summed signal is called and summed again for $N_s$pulses,after that a single decision device decides the estimated bit.

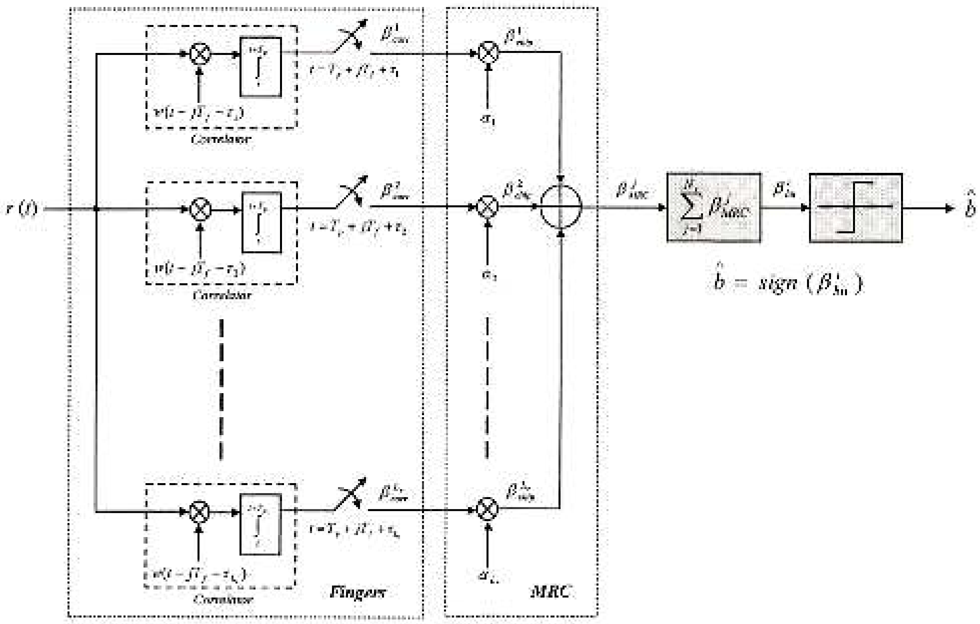

Figure (2): The conventional Rake receiver [6]

Signal Model for Rake Receiver:

A Binary Phase Shift Keying (BPSK)with Time Hopping (TH) IR-UWB system is considered with $N_u$users, in which the transmitted signal from user v is represented by [7]:

$$S_{tx}^{(v)}(t) = \sqrt{E_p^{(v)}} \sum_{j=-\infty}^{\infty} b_{\left[\frac{j}{N_s}\right]}^{(v)} W_{tx}\left(t - jT_f - c_j^{(v)}T_c - \tau_0^{(v)}\right) \qquad \ldots\ldots(2)$$

where $w_{tx}(t)$ is the transmitted UWB pulse, $E_p^{(v)}$is the pulse energy of user v,$b_i^{(v)} = \{+1,-1\}$ is the binary information symbol transmitted by user v,$\left[\frac{j}{N_s}\right]$denotes the integer part of$\frac{j}{N_s}$ and $\tau_0^{(v)}$ represents v^{th}users reference delay relative to the first user caused asynchronous transmission where, $0 \le \tau_0^{(v)} \le T_f$. In order to allow the channel to be many users and avoid catastrophic collision, a TH sequence$\{C_j^{(v)}\}$, where $C_j^{(v)} \in \{1,2 \ldots, N_c\}$, is assigned to each user, and N_c is the number of frame's chips. This TH sequence provide an additional time shift of $C_j^{(v)}T_c$ second to thej^{th} pulse of the v^{th} user and $T_f= N_cT_c$. Also, in some cases, $T_f=T_h+T_g$ is assumed, where $T_h=N_hT_c$ is the frames hopping time and T_g is the guard time to decrease ISI. N_h is the number of hop position in T_h (number of chips in T_h) [5].

The $S_{tx}^{(v)}(t)$ is transmitted through the IEEE 802.15.3a WPAN indoor multipath channel. This channel is modeled as a linear, time-varying filter which is time-invariant over a $T_f$duration with impulse response for user v, $h^{(v)}(t)$ and has a certain T_{mds} value. The IEEE 802.15.3a multipath model for user v consists of the following discrete time impulse time response:

$$h^{(v)}(t) = \sum_{l}^{L} \alpha_l^{(v)} \delta(t - \tau_l) \ldots\ldots (3)$$

where$h^{(v)}$ is the v^{th} user's channel impulse response and $\tau_{l=lT_c}$.

At the receiver side, the receiver is assumed to be completely synchronous with the transmitter, i.e, all the path delay τ_l **for** $1 \leq \square \leq L$ are known to the receiver. Moreover error free channel estimation is considered, that is, the receiver estimates the path amplitudes α_l s with no error.

However, the number branches (fingers) of the Rake receiver is assumed to be limited to $L_r \leq L$. The received signal is [8]:

$$\mathrm{r(t)} = \sum_{v=1}^{N_u} h^{(v)}(t) S \bigotimes_{tx}^{(v)} \square(t) + n(t) \qquad \ldots\ldots\ldots (4)$$

where$n(t)$ is the AWGN with spectral density N_o. The receiver signal can be expressed as:

$$r(t) = \sum_{v=1}^{N_u} \sqrt{E_p^{(v)}} \sum_{j=-\infty}^{\infty} b_{\left[\frac{L}{N_s}\right]}^{(v)} \sum_{l=1}^{L} \alpha_l^{(v)} w_{tx}\left(t - jT_f - c_j^{(v)}T_c - \tau_0^{(v)}\right) + n(t) \ldots\ldots (5)$$

wherew_{rx}(t) is the received unit-energy UWB pulse ,which is usually modeled as the derivative of w_{tx}(t) due to the effects of the receiving antenna.

<u>Output of the BPSK Matched Filters</u>

The received MPCsare considered to arrive in successive bins. Each bin has duration ofT_c .Therefore $\tau_{l2} - \tau_{l1} = (l_2 - l_1)T_c$ [5].

Since there are $L_r$matched filter output,so, $L_r$template waveforms there be matched on the signal from the first (desired)transmitter. The template signals for the incoming signal can be expressed as:

$$S_{temp}^{(1)}(t) = \sum_{l=1}^{L_r} w_{rx}\left(t - jT_f - c_l^{(1)}T_c\right) \ldots. (6)$$

The template signal for the l^{th}fingeris given by:

$$S_{temp,l}^{(1)}(t) = w_{rx}\left(t - jT_f - c_i^{(1)}T_c\right) \ldots .(7)$$

For the i^{th} information symbol of user 1, the output of l^{th}Rake finger β_{corr}^{l} is :

$$\beta_{corr}^{l} = \int_0^{T_p} r(t).S_{temp,l}^{(1)}(t)dt \ldots \ldots .(8)$$

The quantity before the MRC β_{chip}^{l} is expressed as:

$$\beta_{chip}^{l} = \alpha_l^{(1)}.\beta_{corr}^{l} \ldots \ldots \ldots .(9)$$

The quantity after the MRC β_{MRC}^{j} of the first $L_r$paths is expressed as:

$$\beta_{MRC}^{j} = \sum_{l=1}^{L_r} \beta_{chip}^{l} \ldots \ldots \ldots (10)$$

Then, the decision statistic $\beta_{bit}^{i}$for i^{th} bit for N_s frames is expressed as:

$$\beta_{bit}^{i} = \sum_{j=1}^{N_s} \beta_{MRC}^{j} \ldots \ldots \ldots (11)$$

Andfinally, the estimated bit $\hat{b}$ is given by sign(β_{bit}^{i})

<u>The Proposed Rake Receiver:</u>

In a multi-user scenario, MUI in the TH-IR-UWB system must be considered, in which a larger number of users in the system causes a higher probability of collision. It has been found that per-chip pulse distortion affects the system performance through the matched filter [9].

In multi-access multi-piconet WPAN IR-UWB system with concurrent transmission, the conventional Rake detection receiver becomes inefficient, especially if there isn't any power control.

The proposed Rake receiver makes three decisions over all N_s where each correlator correlates the received signal with a template, then summing the outputs in maximum ratio combining scheme. The summed signal collected and summed again for N_s pulses, after that a single decision device decides the estimated value. The final decision unit is placed to decide the estimated bit according to the number of frames $N_f$for assigned for each symbol. In other words, the proposed receiver, summing all the chips that contained in a certain frame for all the frames of the current symbol and then making a final decision to decide the estimated bit.

This proposed Rake receiver minimizes the MUI due to different interferers signal powers that constitute catastrophes in the conventional Rake receiver.

In other words the proposed Rake receiver structure is suboptimal in terms of minimizing the probability of transmission error in detecting the information sequence in the presence in of MUI. The proposed Rake receiver is shown in Figure (3).

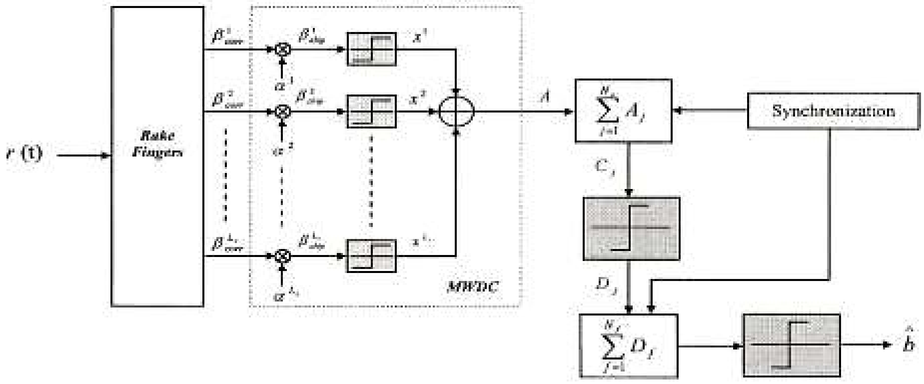

Figure (3): The proposed Rake receiver

Simulation Results and Discussion:

The general block diagram of the IR-UWB indoor physical layer communication system investigated and programmed in this paper is shown in Figure (4) with IEEE 802.15 a indoor multipath channel and IR-UWB Rake receiver.

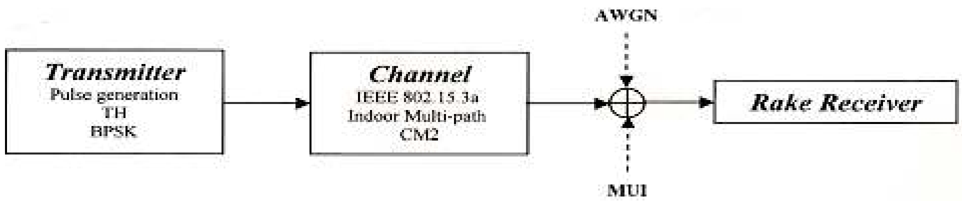

Figure (4): IR-UWB communication system used in this paper

The main system parameters that are used in this research are shown in Table (1).

Table (1): Simulation Parameters

Parameter	*Symbol*	*Value*
Sampling period	T_{sam}	***0.03 ns***
Pulse duration	T_p	***0.45 ns***
Chip time	T_c	***0.35 ns***
Pulse shaping factor	τ_{sf}	***0.13 ns***
Channel bin duration	T_m	***0.45 ns***
Channel duration	T_{mds}	***30 bins***
Number of pulse per symbol	N_s	***6***
Total number of users	N_u	***5***
Number of bits generated by the source	-----	***40000 bit***
Number of PRake fingers	L_p	***4***

BER Performance with Single User:

It's the time now to discuss the performance of the proposed receiver as compared with the conventional receiver with N_s =4, N_u=1, and T_g=30 chips. In Figure (5), the proposed receiver has best performance, hence it achieved about $0.2*10^{-5}$ BER at S/N of -2 dB. This is because there is no MUI, so the proposed receiver dose not wastes the detected pulse energy in the decision units.

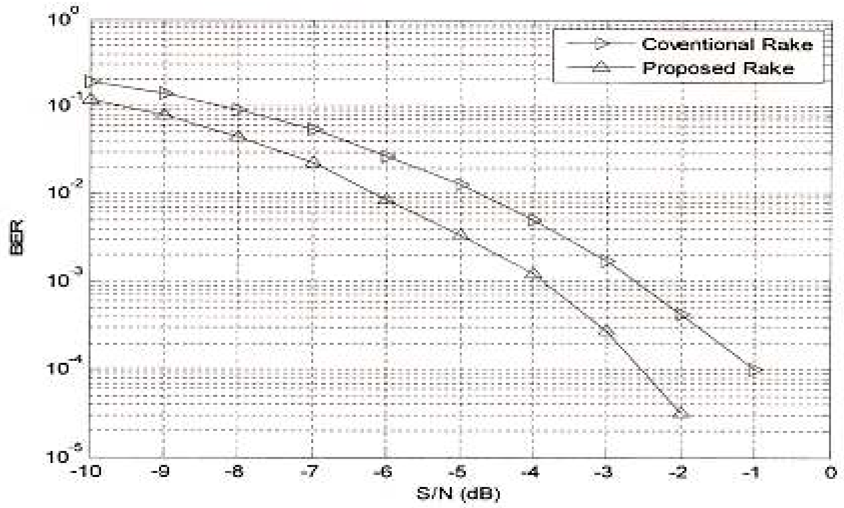

Figure (5): Average BER achieved as a function of S/N for N_u = 1

BER Performance with MUI:

The proposed receiver has simulated again in the presence of MUI for N_s=6, N_u=7,and PT_{int}=-80 dBm/Hz. Figure (6) shows the performance of PRake for T_g=50 chips. It's clearly noticed that the degradation in the BER values for the proposed receiver as compared with Figure (5) due to the MUI.But,the proposed receiver is still outperformed the conventional Rake receiver especially for S/N beyond-2dB due to the techniques applied to it in the previous section.It's also clear from Figure (6) that the two receivers exhibit hard effect on the BER performances.

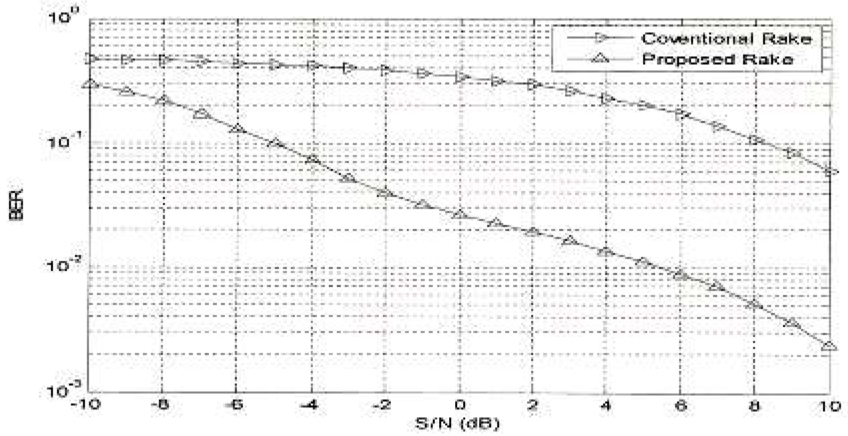

Figure (6): Average BER achieved as a function of S/N for N_u = 5

Conclusions:

The objective of this paper is to design and investigate the performance of a new multi-user WPAN IR-UWB Rake receiver. The performance was evaluated in the presence of MUI, indoor dense multipath IEEE 802.15.3a CM2,andAWGN.The proposed UWB Rake receiver is capable of mitigating the MUI to a certain level.The propose UWB Rake receiver makes a three decision on asingle chip and as a result enhances the BER performance. Therefore, it outperforms the conventional Rake receiver. The results show that the proposed receiver has a good BER result as compared with the conventional Rake receiver.In other words, it can be concluded that the three-stages-decision technique is a good candidate for MUI mitigation.

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