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SUPPERSSION OF INTERFERENCE IN ULTRA WIDE BAND SRAKE RECEIVERS USING IMPULSE RESPONSE

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ABSTRACT

A new promising technique adopted by 4G community is Ultra-Wide Band (UWB) technology, which offers a solution for high bandwidth, high data rate, low cost, low power consumption, position location capability. One type of UWB communication is impulse radio. The Rake receiver used for spread spectrum is considered a very promising candidate for UWB reception, due to its capability of collecting multipath components. Ultra Wide Band signals occupy such a large bandwidth; they operate as an overlay system with other existing narrowband (NB) radio systems overlapping with their bands. In order to ensure a robust communication link, the issue of coexistence and interference of UWB systems with current indoor wireless systems must be considered. Bit error rate (BER) performance study for different data rates over different UWB channel models are analyzed using proposed receiver models. Suppression of Narrowband interference in WLAN has been studied intensively to remove Inter Symbol Interference (ISI). The performance of SRAKE receiver in presence of NBI is almost over the 10^{-1} BER floor. So it is concluded that multipath is reasonably high for Channel Model 2 (CM2), Channel Model 3 (CM3) and Channel Model 4 (CM4) channel models, but this model is sufficient to eliminate interference.

Keywords:
Impulse response, RAKE Receiver, SRAKE Receiver, Ultra wideband Technology

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1. INTRODUCTION

A traditional UWB technology is based on single band systems employing carrier free or impulse radio communications. Impulse radio (IR) refers to the generation of a series of impulse like waveforms, each of duration in the hundreds of picoseconds. This type of transmission does not require the use of additional carrier modulation and is a baseband signal approach. UWB technology provides high data rate with low power spectral density due to modulation of extremely short pulses within 3.1 to 10.6 GHz. The very low transmission power and the large bandwidth enable an UWB system to co-exist with narrowband communication systems illustrated in Fig.1. Although UWB communication offers a promising solution in an increasingly overcrowded frequency spectrum, mutual interference due to coexistence with other spectrally overlapping wireless system degrades the performance of both systems. The interference caused may jam the UWB receiver completely. In this Gaussian doublet pulses are used because they are more skewed at the center.So, this pulse can carry data with higher data rates. Using this pulse the problem of pulse generation and pulse shaping can be solved.

In 1993, H.F. Engler [1] wrote prolifically on the electromagnetic of UWB about the area of high-power baseband pulse radiation, the new methods for generation and radiation of Ultra wideband signals. M. Ressler et. al [2] discussed the basic phenomenology of impulse radar, specifically the propagation effects of targets . Ultra-wide bandwidth signal propagation experiment in a rural terrain to characterize the outdoor UWB signal propagation channel is

indicated in [3] and [4]. The UWB research focused more on communication methodology and commercial short-range wireless applications such as wireless LAN and home entertainment. Some general properties of ultra-wideband (UWB) communications systems such as the importance of fractional bandwidth in ultra-wideband pulse design and identifying the characteristics of UWB technology in order to make it an attractive solution for indoor wireless networks is discussed in [5] and [6]. D. Cassioli, M.Z.Win and A.F. Molisch first applied a statistical model for the UWB indoor channel. The main goal of this work was to develop an understanding of the indoor UWB propagation channel, including the time-of-arrival, angle-of-arrival and level distributions of a collection of received signals [7]. They concluded that the power delay profile can be well modeled by a single exponential decay with a statistically distributed decay-time constant. According to Electromagnetic Compatibility (EMC) reports submitted to FCC, the narrowband interferences (NBI) expected by the UWB receivers are computer motherboard of emission level 42.7dBm at 1.9 GHz, IEEE 802.11b at centre frequency 2.4 GHz, network interface card (NIC) of emission level 49.8dBm at 3.75 GHz, LAN switch of 44.3dBm at 3.75 GHz, peripheral component interconnect (PCI) card for a personal computer 3.75 GHz and IEEE 802.11a (WLAN system) at centre frequency 5.25 GHz etc [8].
D. Cassioli, M.Z. Win and A.F. Molisch first applied a statistical model for the UWB indoor channel [9], [10].

UWB signal spreads over a large bandwidth of several gigahertz and hence coexists with other narrowband systems. Thus it may cope with the narrowband interference (NBI) using their high processing gain. However, due to low transmission power, it is anticipated that even this large processing gain is not sufficient to suppress high levels of NBI. In many cases, the power of NBI is a few tens of dBs higher than both the signal and noise power. Hence, if such interference is not suppressed properly, the UWB receiver may be jammed and the system performance degrades. Investigation of UWB system using realistic channel models is to be carried out of performance improvement through interference suppression. NBI suppression techniques using Rake receiver for UWB system needs to be analysed.

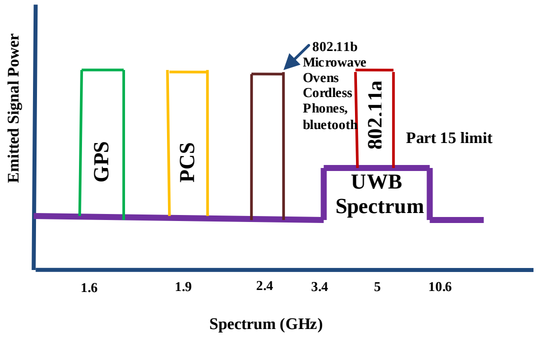

Fig. 1:- Spectrum of UWB and existing narrowband systems

2. UWB CHANNEL MODEL

The accurate design of channel model is a significant issue for ultra wideband WPAN communication system [10]. Large-scale models are necessary for network planning and link budget design and small-scale models are necessary for efficient receiver design. The most famous multipath UWB indoor channel models are tap-delay line Rayleigh fading model, Saleh and Valenzuela (S–V) model and Δ-K model. The S–V channel measurement shows that the multipath components are arriving in a cluster form. The different paths of such wide band signal can rise to several multipath components, all of which will be part of one cluster. The arrival of multipath components is modeled by using Poisson distribution and thus the inter arrival time between multipath components is based on exponential distribution. The multipath arrival of UWB signals are grouped into two categories: cluster arrival and ray arrival within a cluster. This model requires several parameters to describe indoor channel environments. Ray arrival rate is the arrival rate of path within each cluster. The cluster arrival rate is always smaller than the ray arrival rate. The amplitude statistics in S–V model are based on lognormal distribution, the power of which is controlled by the cluster and ray decay factor. Indoor channel environments are classified as CM1, CM2, CM3, and CM4 following IEEE 802.15.3a standard [11].

2.1 Channel parameters

- CM1 describes a line-of sight (LOS) scenario with a maximum distance between transmitter and receiver of less than 4m.
- CM 2 describes the same range as of CM1, but for a non-line-of sight (NLOS) situation.
- CM 3 describes a NLOS medium for separation between transmitter and receiver of range 4-10m.
- CM 4 describes an environment of more than 10m with strong delay dispersion, resulting in a delay spread of 25ns with NLOS medium **.**

3. UWB RAKE RECEIVER STRUCTURE

The robustness of UWB signals to multipath fading [12] is due to their fine delay resolution, which leads to a high diversity order once combined with a Rake receiver. Rake receivers are used in time-hopping impulse radio systems and direct sequence spread spectrum systems for matched filtering of the received signal. The receiver structure consists of a matched filter that is matched to the transmitted waveform that represents one symbol and a tapped delay line that matches the channel impulse response [13]. It is also possible to implement this structure as a number of correlators that are sampled at the delays related to specific number of multipath components; each of those correlators is known as rake finger. The Rake receivers are of three types. The All-Rake (ARake) receiver captures all most all the energy carried by a very large number of different multipath signals. To reduce the rake complexity, a partial combining (called PRake) is used as partial combining of the energy, which combines the first arriving paths out of the available resolved multipath components. Selective combining (called SRake) is a suboptimum Rake receiver. A UWB Rake receiver structure is shown in Fig 2

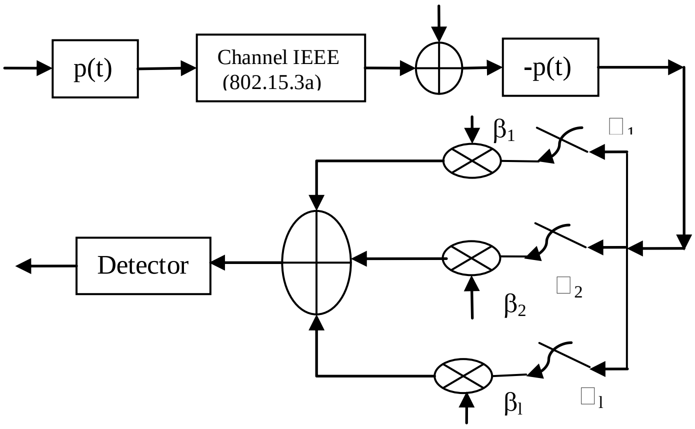

Fig.2 UWB Rake receiver model

For a single user system, the continuous transmitted data stream is represented as

$$s(t) = \sum_{k=-\infty}^{+\infty} d(k)p(t-k.T_s) \qquad [1]$$

where *d(k)* are stationary uncorrelated Binary Phase Shift Keying (BPSK) data and *Ts* is the symbol duration. The UWB pulse *p(t)* has duration *Tuwb (Tuwb < Ts).*

The channel impulse response is given by

$$h(t) = \sum_{i=0}^{M} h_i\, \delta(t-\tau_i) \qquad [2]$$

M is the total number of paths in the channel.

The received signal first passes through the receiver filter matched to the transmitted pulse and is given by:-

$$r(t) = s(t) * h(t) * p(-t) + \hat{n}(t) * p(-t) \qquad [3]$$

Where *p* (*-t*) represents the receiver matched filter and *n* (*t*) is the Additive White Gaussian Noise (AWGN) with zero mean and variance *No /2.*

Also, *m* (*t*) = *p* (*t*) * *p* (*-t*)

and

$\hat{n}(t) = n(t) * p(-t)$

Combining the channel response with the transmitter pulse shape and the matched filter

$$\breve{h}(t) = p(t) * h(t) * p(-t) \qquad [4]$$

The Rake combiner output at time *t* = *n.Ts* is

$$y[n] = \sum_{l=1}^{L} \beta_l v(n.T_s + \tau_l') + \sum_{l=1}^{L} \beta_l \hat{n}(n.T_s + \tau_l') \qquad [5]$$

4. UWB SRAKE RECEIVER STRUCTURE IN PRESENCE OF NBI

The UWB systems must cope with NBI using their high processing gain. However, due to very low transmission power, it is not sufficient to suppress high levels of NBI, which are typically from nearby narrowband radio systems having a bandwidth up to a few MHz. In many cases, the power of NBI is a few tens of dBs higher than both the signal and noise power.

The NBI signal is modeled as a traditional single carrier Binary Phase Shift Keying (BPSK) modulated waveform, given by

$$i(t) = \sqrt{2P_l}\cos(w_0\, t + \theta) \sum_{p=\infty}^{\infty} g_k\, z(t - kT_s - \tau_s)$$
[6]

Where, P_1 is average transmit power of the narrowband waveform. $\omega_0 = 2\pi f_0$ is carrier frequency of the narrowband waveform. θ is the random phase of the carrier. g_k are the randomly modulated BPSK symbols and T_s is the symbol period, τ_s is a random delay uniformly distributed in [0, T_1] and z(t) is the baseband wave form shape. UWB Rake receiver model considering NBI is shown in Fig.3

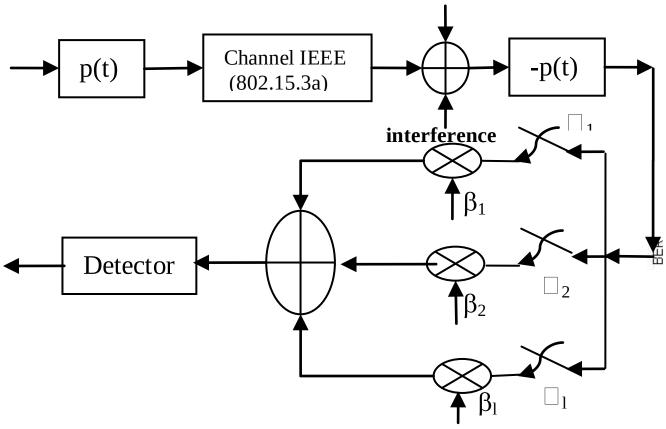

Fig.3:- UWB SRAKE receiver model in presence of NBI

The received signal passes through the receiver filter matched is given by

$$r(t) = A(t) * h(t) * p(-t) + n(t) * p(-t) + i(t) * p(-t)$$

Interference coexisting with the same system generates extra signal which can't be easily detected at the output. If such interference is not properly suppressed, then this will jam the receiver and the system performance degrades.

5. PERFORMANCE DEGRADATION OF UWB SYSTEM IN PRESENCE OF NBI

SRake receiver in UWB system performance in absence and presence of NBI is studied and found that NBI deteriorates the system performance. Here SRake with both 3 and 5 rake fingers is considered. An NBI with signal to interference ratio (SIR) of 15dB is added to the channel model

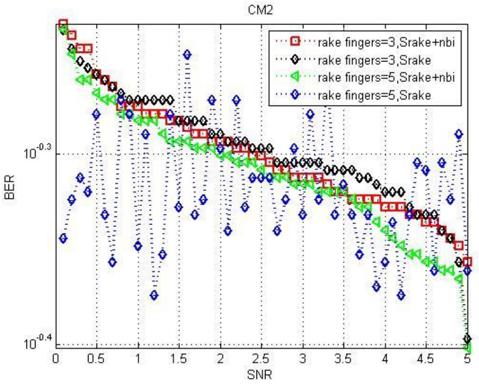

Fig.4.1:- Performance of SRake receiver for CM2 channel model

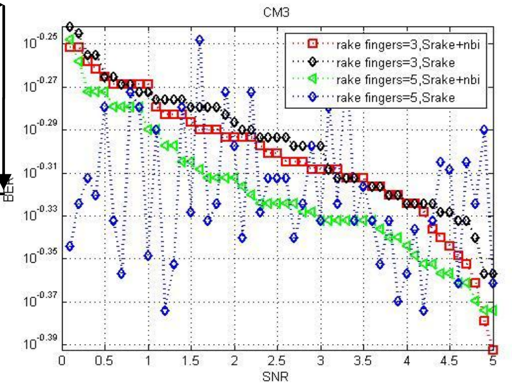

Fig.4.2:- Performance of SRake receiver for CM3 channel model

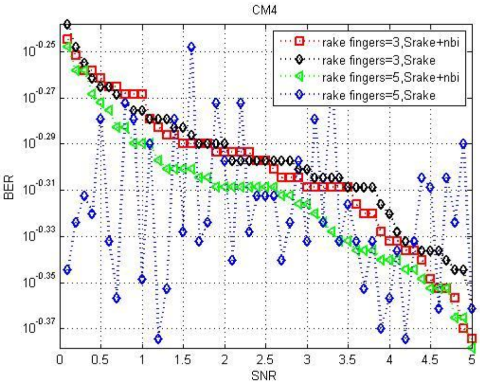

Fig.4.3:- Performance of SRake receiver for CM4 channel model

The time dispersiveness of the UWB pulse causes a considerable portion of the symbol energy to appear as a part of the following symbol, leading to inter-symbol interference. In the simulations, a second order derivative of the Gaussian pulse, which satisfies the FCC limitations regarding the transmission bandwidth, is used. The coherence bandwidths of CM3 and CM4 simulation are 10.6 MHz and 5.9 MHz respectively. The data rate is chosen to be 200 Mbps resulting in symbol duration of 5 nsec. The simulation is performed at 100.8 GHz sampling rate. With increase in rake fingers the performance of SRAKE receiver increase. When the number of rake fingers is increased to 5, degradation in performance is noticed in CM2, CM3 and CM4 NLOS channel medium as shown in Fig.4.1, Fig.4.2 and Fig.4.3. As shown in all the figures, at SNR=5dB, UWB SRake receiver BER passes from $10^{-.25}$ to $5 \times 10^{-.36}$ for 3 number of rake fingers and from $0.2\times 10^{-.268}$ to $5 \times 10^{-.38}$ for 5 number of rake fingers under the effect of NBI. From this value it can be concluded that as we increase the number of rake fingers the strength of the signal is very high. So, more number of signals can be accommodated in that range with interferening with each other, as this range is mostly used for communication. Therefore ISI can be minimized.

The performance of SRake receiver in presence of NBI is almost over the $10^{-.5}$ BER floor. So, the receiver structure cannot mitigate NBI and hence the performance deteriorates. So it is concluded that multipath is reasonably high for CM2, CM3 and CM4 channel models, but this model is sufficient to eliminate inter symbols interference. So, the problem of inter symbol interference in UWB can almost be eliminated.

6. CONCLUSION

A new promising technique adopted by 4G community is ultra-wideband technology which offers a solution for high bandwidth, high data rate, low cost, low power consumption, position location capability, resilience to multipath fading etc. But due to regulation by FCC emission mask, UWB coexistence in WPAN environment become a sensitive issue and interference to other narrowband systems is of primary concern. Although, the pulse design methods meet FCC spectral mask properly and well suppress the single narrowband interference. A conventional type of UWB communication is impulse radio, where very short transient pulses are transmitted rather than a modulated carrier. The Rake receiver used for spread spectrum is considered to be a very promising candidate for UWB reception, due to its capability of collecting multipath components. For high data rate and short range, the receiver combats NBI interference by taking advantage of the Rake receiver. The Srake receiver structure used above is able to eliminate interference interference.

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