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Performance of QAM MC-CDMA Higher Data Rates Transmission Systems in Impulsive Noise

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ABSTRACT: The effect of impulsive noise on the performance of multi carrier code division multiple access (MC-CDMA) systems and analyze the performance by examining the MC-CDMA system model in time domain. We have discovered that conventional Walsh-code based MC-CDMA is less robust to the presence of impulsive noise than the corresponding direct sequence (DS) CDMA and multi carrier modulation based (MCM) systems. Furthermore, it is demonstrated that the performance of MC-CDMA depends strongly on the selection of the utilized spreading codes. A modified MC-CDMA structure, called MC-SI-CDMA, is proposed and investigated in impulsive noise that employs sub carrier interleaving (SI) to reduce the cross correlation between the time domain MC-CDMA waveforms and the impulsive noise. Computer simulation results conducted to support our analysis indicate that the proposed MC-SICDMA system in impulsive noise.

Keywords: Direct sequence, Multi carrier modulation, QAM MC-CDMA, impulsive noise.

I. INTRODUCTION

MC-CDMA has become increasingly popular as a promising wireless access technique in wideband communication systems, mainly due to its high spectral efficiency, robustness to frequency selective fading and flexibility to support integrated applications [9], [13]. In MC-CDMA, the information symbols of individual users are spread in the frequency domain over a number of orthogonal sub carriers using pseudo-noise (PN) sequences. Most MC-CDMA receivers proposed previously are designed to be optimal or suboptimal under the Gaussian noise assumption. However, when the radio bandwidth becomes wider in order to meet the demands for higher data rates, the transmission performance may be seriously impacted by impulsive noise caused by vehicle ignitions, power lines, electrical equipment etc. In many physical channels, such as urban, indoor radio and underwater acoustic channels, the ambient noise is known through experimental measurements to be decidedly non-Gaussian due to the impulsive nature of man-made electromagnetic interference and a great deal of natural noise as well. Linear and nonlinear receivers for DS-CDMA system has been investigated in [1], [2]. The effects of impulsive noise for both MCM systems and single-carrier modulation (SCM) system have previously been analysed in [8], where the BER of orthogonal frequency-division multiplexing (OFDM) QAM based systems has been derived by varying impulse power and probability.

Robust detection of DS-CDMA and OFDM based signals under similar channel conditions has been studied and various nonlinear detection techniques have been investigated in [3]–[6], [15, 16]. The BER performance of MC-CDMA in the presence of impulsive noise and frequency-selective multipath fading has been investigated in [12] [7]. However, it was inconclusive that MC-CDMA systems are more robust to impulsive noise than the equivalent DS-CDMA as the performance was demonstrated in the presence of frequency-selective fading, thus, it was not evident that the gain obtained was due to robustness to impulsive noise or frequency selectivity. we will compare the performance of MCCDMA and DS-CDMA in-mixture impulsive noise model, which is widely used to model impulsive noise environments [1], [3], [15]. The theoretical analysis and simulation results evidently illustrate the conventional MC-CDMA is more sensitive to impulsive noise than DS-CDMA and OFDM. However, it is not ture that MC-CDMA structure fails in the presence of impulsive noise. Furthermore, we propose a modified MC-CDMA structure called MC-CDMA with sub carrier interleaving (MC-SI-CDMA), which outperforms DS-CDMA and OFDM in impulsive noise. interference has become a real problem, particularly because of the limited available bandwidth resources. As telecommunication systems rapidly grown, the interference among such systems is becoming increasingly serious, especially on industrial environments. Measurement of interfering signals is the initial and main step for realizing coexistence of these systems.

Numerous works have studied the impact of impulsive interference into multiple modulation schemes but they have not performed real measurements [1]. The main objective in this thesis is to develop three different measurement setups to test the performance of multiple modulation schemes under certain interference. Two types of noise models are generally used to describe noise interference. These models include the Gaussian noise and the non-Gaussian noise (impulsive noise). Actual wireless systems are designed to work under certain signal to noise ratio, considering This noise as Additive White Gaussian Noise (AWGN). However impulsive interferences have different statistical properties than AWGN and consequently their impact into the communication system is different too. The man-made environment, and much more of the natural one as well, is basically impulsive, that can drastically degrade the performance of the systems that are usually assumed to operate effectively against background noise. The requirement to combat the interfering noise to improve the quality of any communication system, requires to parameterize the interference noises in a statically way. For high quality communications, is required a low BER that it is not always obtained, in some cases due to impulsive noise. But we cannot fight only the impulsive noise, in order to get a realistic noise model it should be a combination of the both noises, Gaussian and Non-Gaussian, where Middleton's class A model is the one that fits better with most of Non-Gaussian noises [2]. The main parameter of the Gaussian model is the average noise power a across the channel. The Gaussian probability density function and a constant power spectral density characterize this model. In the other hand, impulsive noise is completely random and has an unpredictable power and cannot know when it is going to occur. The only way to get statistical information about it is doing measurements in a specific place and characterizing it [3].Gaussian noise is defined as noise with some particular statistical properties. This noise has a probability density function as a normal distribution, also known as Gaussian distribution. That means that the power of the noise is Gaussian distributed. An specific case of this noise, and the noise we are going to work with, is Additive White Gaussian noise, which besides of that, the values of the noise in two different times are statistically independent and uncorrelated, what makes it appear broadband [4]. This kind of Gaussian noise does not represent a problem, while the power of the wanted signal is higher than this noise.

Impulsive noise, is non-stationary and is compounded by irregular pulses of short duration and signifier energy spikes with random amplitude and spectral content, this is why impulsive noise is considered the main cause of burst error occurrence in data transmission causing a temporary loss of signal. Therefore is essential to know the statistical nature of impulse noise in order to be able to evaluate its impact on a communication system. These pulses are made by 2 main causes, ambient electromagnetic interferences (storms), natural electromagnetic interference, or errors on telecommunications systems, man-made. impulsive noise is a sequence of pulses characterized by three of those parameters: the pulse amplitude, the time-duration of the pulse, and the time between consecutive pulses.

A. Impulsive Noise

The present data detection in direct sequence spread-spectrum multiple-access non-Gaussian channels.This issue arises in practical situations because many physical channels in which multiple-access communications is applied are known to be decidedly non-Gaussian. With reference to a synchronous system, the optimum (in the maximum likelihood sense) multi user detector is derived, and its performance is analyzed and compared with that of several suboptimum detectors. The AWGN model has been an appropriate model in previous studies, since the focus there has been on the mitigation of the most severe noise source - the MAI. However, as increasingly practical techniques for multi user detection become available, the situation in which practical multi pleaccess channels will be ambient-noise limited can be realistically envisioned. In the single-user context, it is well known that non- Gaussian noise can be quite detrimental to the performance of conventional systems based on the Gaussian assumption, whereas it can be beneficial to performance if appropriately modeled and ameliorated. we study the issue of non-Gaussian ambient noise in the multi user context by adopting the discrete-time model obtained by considering the sequence fQrng in (2). This discrete-time model is convenient since non-Gaussian ambient noise can be studied by representing the noise in the sequence fQrng as a sequence of independent and identically distributed complex random variables with a non-Gaussian distribution. Performance gain (more than 10dB in some cases) over Gaussian-optimal techniques in multiple-access channels when the ambient noise is impulsive.

However, this gain is achieved with a significant penalty on complexity, in that the standard low-complexity multi user detectors are not easily modified to account for non-Gaussian ambient noise. A compromise in complexity can be achieved by applying a two-stage detector, in which tentative bit decisions are madeby the linear decorrelator, and then these decisions are refined by maximizing likelihood within a fixed Hamming radius of the decorrelator outputs As part of a larger project to assess the risk associated with the deployment of wireless equipment in electricity substations the BER performance of IEEE 802.11b and IEEE 802.11a in the presence of impulsive noise has been investigated. Middleton class A noise model is used to simulate impulsive noise environment and Simulink is used to simulate the WLAN physical layer. The observed degradation in performance is compared with that due to additive white Gaussian noise. Deployment of wireless communications equipment in electricity substation for monitoring, control and surveillance applications offers significant potential benefits over wired communications in terms of convenience, flexibility and cost [1, 2]. Typically wireless transceiver designs are based on the assumption that noise is additive, white and Gaussian (AWG) [3]. These transceivers perform fine in normal environments (where optimum reception can be achieved with Gaussian channel assumption) but their applicability in noise intensive electricity substation environment is not risk free and needs thorough investigation [4]. Partial discharges and sferic radiation are major sources of impulsive noise, in electricity transmission substations and if the risks of deploying wireless communications equipment are to be properly assessed the impact of such impulsive processes requires thorough evaluation [5]. Broadly speaking, man-made interference can be intelligent' where the interfering signal carries meaningful information or unintelligent where the interfering signals carries no information. The latter includes Partial discharge switching transients and combustion engine ignition noise. This work deals with unintelli interference having impulsive characteristics which may dominate close to a source of PD. Seminal work [6, 8] focussing on the realisation of a tractable analytical model for combined man-made and natural radio noise serves following purposes: a. It provides a realistic and quantitative description of man-made and natural electromagnetic (EM) interference, It guides experimental protocols for the measurement of such interference,

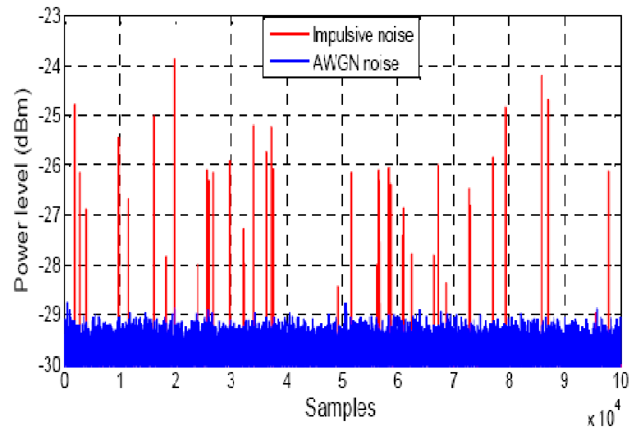

Fig. 1. Impulsive noise and Gaussian noise, power levels.

II. MC-CDMA SYSTEM MODEL

With the increasing demand for broadband multimedia services in wireless cellular networks, packet switching multi code-code division multiple access (MC-CDMA) is considered to be a suitable multiple access technology to support multimedia traffic by assigning multiple spreading codes to each user [1]. Packet switching for wireless transmission makes it possible to achieve a high statistical multiplexing gain for better radio resource utilization. Due to the heterogeneity and bursty nature of multimedia traffic, a flexible packet scheduling scheme, which can efficiently accommodate multimedia traffic, is desired. The order of packet transmission for multimedia traffic has a great impact on the efficiency and performance of wireless systems. The uplink call admission region of an MC-CDMA system is statistically defined as the number of calls of all traffic classes with different transmission and performance requirements that can be supported simultaneously. The call admission region can be enlarged by decreasing the cell size. However, shrinking the cell size will increase handoff rate during the call holding time. In a network supporting multimedia services, the increased handoff rate makes it difficult to guarantee the service requirements in a new cell agreed upon at call setup time. If a handoff is unsuccessfully executed, the connection of an ongoing call is forced to terminate. It is important to maintain service continuity of an ongoing call from a user's perspective. Many schemes have been proposed to prioritize handoff calls over new calls.

In channel reservation schemes [2], a fixed amount of the channel capacity is reserved exclusively for handoff calls. Fixed channel reservation has the risk of increasing new call blocking probability. To decrease the probability of handoff call dropping and at the same time to keep the new call blocking probability as low as possible, dynamic channel reservation schemes based on user mobility are developed [3,4]. However, these schemes only consider homogeneous voice traffic. In Refs. [5,6], multimedia services are introduced where resources are reserved a Frequency Division Duplex/MC-CDMA (FDD/MC-DMA) system, in which the uplink and downlink use different frequency bands to provide frequency isolation, so there is no interference between the uplink and downlink transmissions. The network structure has two tiers. The first tier is a mesh connection of MSCs, which connect the wireless sub-networks with the backbone network. An MSC collects status information of all its serving BSs and performs CAC and handoff management based on traffic characteristics,

III. ZERO-FORCING MIMO

The downlink transmission of a wireless communication system antennas transmit independent information to a subset of users, each equipped with a single antenna. The Shannon capacity of this MIMO broadcast channel (MIMO-BC) can be achieved difficult to implement in practice. Motivated to study simpler transmission techniques, we focus on a linear precoding technique based on the zero-forcing (ZF) algorithm. In contrast to the typical sum power constraint (SPC), we consider a per-antenna power constraint (PAPC) motivated both by current antenna array designs where each antenna is powered by a separate amplifier and by future wireless networks where spatially separated antennas transmit cooperatively to users. We show that the problem of power allocation for maximizing the weighted sum rate under ZF with is a constrained convex optimization problem that can be solved using conventional numerical optimization techniques. For the special case of two users, we find an analytic solution based on waterfilling techniques. For the case where the number of users increases without bound, that ZF with PAPC is asymptotically optimal in the sense that the ratio of the expected sum-rate capacities between ZF with PAPC and DPC with SPC approaches one. how the results can be generalized for multiple frequency bands and for a hybrid power constraint. Finally, we provide numerical results that show ZF with PAPC achieves a significant fraction of the optimum DPC sum-rate capacity in practical design for the multiple-input single output (MISO) multiuser broadcast channel is an important problem in modern wireless communication systems. The main difficulty in this channel is that coordinated receive processing is not possible and that all the signal processing must be employed at the transmitter side. From an information theory perspective, the capacity region of this channel was only recently characterized [1]. From a signal processing point of view, there are still many open questions and there is ongoing search aimed at finding efficient yet simple transmitter design The most common linear precoding scheme is zero-forcing (ZF) beamforming. It is a suboptimal approach that attracted considerable attention since there are computational difficulties even within the class of linear precoding strategies. For example, we are not aware of any efficient techniques for maximizing throughput using linear beamforming. Instead, ZF is a simple method which decouples the multiuser channel into multiple independent subchannels and reduces the design to a power allocation problem.

IV. MMSE DETECTION OF MULTICARRIER CDMA

Minimum mean-squared error (MMSE) detection of multicarrier code-division multiple-access (CDMA) signals is investigated. The theoretical performance of two different design strategies for MMSE detection are compared. In one case, the MMSE filters are designed separately for each carrier, while in the other case the optimization of the filters is done jointly. Naturally, the joint optimization produces a better receiver, but the difference in performance to be substantial. The multicarrier CDMA performance is then compared to that of a single-carrier CDMA system on a frequency-selective fading channel. A mechanism is then developed to track the channel fading parameters for all the users' signals so that joint optimization of the receiver filters is possible in a time-varying channel. the performance of this The minimum mean square error combining (MMSEC) scheme performs best among various equalization and combining schemes for downlink MC-CDMA. However, it is also most computationally complex to realize as it involves coefficient for MMSEC based on reduced-size Multicarrier code division multiple access (MC-CDMA) is a technique that combines direct sequence (DS) CDMA with orthogonal frequency division multiplexing (OFDM) modulation. It is one of the candidate technologies considered for the 4th generation wireless communication systems [1]. MC-CDMA transmits every data symbol on multiple narrow band sub carriers and utilizes cyclic prefix to absorb and remove inter-symbol interference (ISI) arising from frequency selective fading.

As it is unlikely for all sub carriers to experience deep fade simultaneously, frequency diversity is achieved when the sub carriers are appropriately combined at the receiver. In [2] and [3], it is shown that MC-CDMA outperforms the conventional DS-CDMA and two other forms of CDMA with OFDM modulation, namely MC-DS-CDMA and multi tone CDMA. Several combining techniques have been proposed for MCCDMA systems, namely orthogonality restoring combining (ORC), equal gain combining (EGC), maximal ratio combining (MRC) and minimum mean square error combining (MMSEC) [4]–[7]. Furthermore, there are two MMSEC variants, "MMSEC per carrier" and "MMSEC per user" [8]. The latter is the scheme that is considered in this paper as it performs best among all schemes mentioned above [4], [5], [8]. For simplicity of notation, it is referred as MMSEC hereafter. MMSEC performs best compared to all other schemes mentioned above, however, it is also most computationally complex to realize as it involves the matrix inversion operation of a large complex matrix. a way to reduce the matrix inversion dimension for calculating the MMSEC equalizer coefficient for downlink MC-CDMAr MMSE channel estimator [9], [10] and DSCDMA detector [11], [12 For downlink transmission, all user signals are synchronously combined before transmission, hence they experience the same channel fading. Similar to an OFDM system, as long as the length of the cyclic prefix is equal to or larger than the maximum delay spread of the channel, ISI can be eliminated,

V. RESULTS

A. BER performance of the conventional MC-CDMA system In this section, the theoretical performance and computer simulation results are presented. 4-QAM modulation is employed for all investigated systems. For MC- and DS-CDMA systems, 32-chip Walsh codes and 31-chips Gold codes are used, respectively, while for MCM based systems the size of FFT is 32. Furthermore, the parameters of impulsive noise are set to _=0.01 and κ=100. Fig.4 illustrates BER performance versus signal-to-noise ratio (SNR) Eb/N0, where Eb is the energy transmitted per information bit and N0 is the one-sided noise power spectral density. For comparison purposes, both theoretical performance and simulation results of the linear receivers for SC, MCM, DS-CDMA and MC-CDMA in impulsive noise are plotted. It can be seen that the computer simulation results match the theoretical analysis perfectly. The DS-CDMA system has same performance as the MCM system which are superior to both SCM and MC-CDMA systems. Furthermore, it is worth noting that the performance of the MC-CDMA system provides the same performance as SC system when the 2nd Walsh code is employed. In other words, the MC-CDMA system is not robust to impulsive noise. The performance of MC-CDMA employing the 4th Walsh code and Gold codes are presented as well. Although the performance of MC-CDMA system is improved approximately 5 dB by employing Gold codes rather than Walsh codes, it is observed that DS-CDMA system is superior to MC-CDMA with at least 1 dB gain in SNR at a BER level of 10−3.

VI. FUTURE WORK

The increasing requirements for future wireless applications, MC-DS-CDMA may be considered as the most important for 4G wireless systems. This system has the ability to incorporate very large bandwidths without sacrificing equalization complexity. The long symbol duration is effective at mitigating ISI, and adaptive modulation or frequency diversity can be used to provide protection against destructive fades.

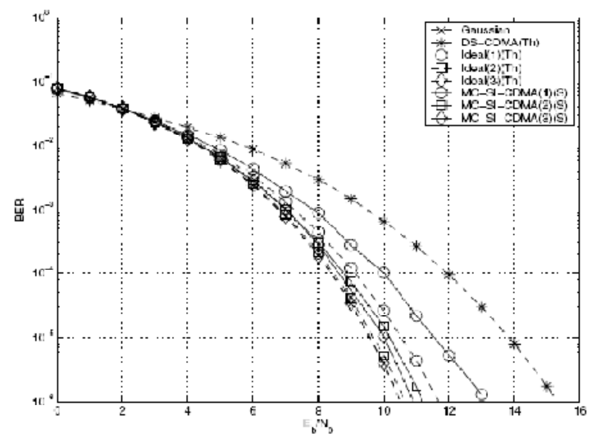

Fig. 2. Performance comparison over impulsive noise channel with _ = 0.01, *κ* = 100 between MC-SI-CDMA system with several interleaving factors *L*s, where (Th) stands for theoretical performance and (S) stands for simulation results. case(1): employing *L* = 10; case(2): employing *L* = 100; case(3): employing *L*=1000.

Though we have studied about the principles of CDMA and MC DSCDMA we haven't implemented the channel estimation techniques as in the case of OFDM. But the same can be carried out using pilot and implicit training sequence techniques to optimize the equalizer performance. Also lies the feasibility study of Multiple Input Multiple Output (MIMO) OFDM systems. In this study we have discussed about Single Input Single Output (SISO) OFDM systems. MIMO OFDM can be implemented using multiple transmitting and receiving antennas which is an interesting work of future.

VII. CONCLUSION

We considered the effect of impulsive noise on the performance of MC-CDMA based system. Analysis was performed by viewing the system model in time domain. PSK, ZF technique MC-CDMA is less robust to impulsive noise than DS-CDMA and MCM systems. Furthermore, it was shown that the performance is highly related to the selection of the spreading codesemployed. A modified MC-CDMA structure, called MC-SICDMA, was proposed and investigated in impulsive noise. Computer simulation results were conducted to support our analysis perfectly. Moreover, it was demonstrated that the proposed MC-SI-CDMA system in impulsive noise can provide a performance improvement of 2.5 dB at BER = 10^{-3} compared with the DS-CDMA system.

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