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A LITERATURE REVIEW IN METHODS TO REDUCE MULTIPLE ACCESS INTERFERENCE, INTER-SYMBOL INTERFERENCE AND CO-CHANNEL INTERFERENCE

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ABSTRACT

This discussion will be primarily focused on the problem of jointly suppressing the different interferences such as Multiple Access Interference (MAI) and Intersymbol Interference (ISI), which are the limiting sources of interference for high data-rate wireless applications, as in wireless multimedia or Spread Spectrum Code Division Multiple Access. After describing the general problem of interference rejection in wireless communications, we present a signal subspace approach to blind joint suppression of MAI and ISI. Then, follows a discussion of a powerful iterative technique for joint interference suppression and decoding called Turbo multiuser detection that is especially useful for wireless multimedia packet communications. We also discuss space-time processing methods that employ multiple antennas for interference rejection and signal enhancement. These are not all the available methods, but the ones that we consider available to us in the near future. We will deal on; a) Co-Channel interference mitigation detectors, b) Partially suppression of MAI and ISI, c) MAI near–far resistance architecture, and d) Successive interference algorithms.

Keywords: Multiple Access Interference, Inter-Symbol Interference, Co-Channel Interference.

1. INTRODUCTION

It is anticipated that future-generation wireless communication systems will incorporate considerable signal-processing intelligence in order to provide advanced services such as multimedia.

In order to make optimal use of available bandwidth for these services and to provide maximal flexibility, many such systems will operate as multiple-access systems, in which channel bandwidth is shared by many users on a random access basis using protocols such as code division multiple access (CDMA) signaling. Moreover, in order to support the high data rates inherent in such services, ratios of bit rates to bandwidths will be pushed to their limits. In general, wireless channels can be very hostile media through which to communicate.

Physical impairments such as multiple-access interference, co-channel interference, multipath transmission, amplitude fading and dispersion due to limited bandwidth all contribute to make it difficult to transmit data reliably and quickly through wireless channels. Moreover, the dynamism resulting from user mobility and the above-noted random-access nature of mobile channels amplify the effects of these impairments and make them much more difficult to ameliorate. Solution to these difficulties lie in the use of advanced signal processing techniques and in this paper we present some of the recently developed methodologies for interference rejection that are especially useful for wireless multimedia communications.

1.1 CO-CHANNEL INTERFERENCE MITIGATION DETECTORS FOR MULTIRATE TRANSMISSION IN TD-CDMA SYSTEMS

Code Division Multiple Access (CDMA), is an example of a good proposal for the use of short sequences in a communication system, with the advantage of reducing the total processing load at the receiver end. Also CDMA promises data rates of the order of multiples Mbps as a requirement for future systems in which multimedia is supported.

This is particularly important in the case of mobile user terminals in which battery life is often a limiting factor in the success or widespread acceptance of the system.

The proposal of such a system for multi-cell applications has many advantages are inherent in to the technique of Spread Spectrum technology. They include multiple access, inherent frequency diversity and allowing a frequency reuse factor of one. However, to derive the advantages of spread spectrum while using short spreading sequences, several issues must be considered.

First, given the relative efficiency of conventional sequence matched correlator receivers, it is not possible to support many users if low bit error rates (BER) are required.

There are systems in which it is not possible to support more than one or two users. Hence, it is necessary to assume the design of a more efficient receiver structure than the matched filter. A single-user Linear Minimum Mean-Squared Error (LMMSE) Multiple Access Interference (MAI) suppression receivers is being design, which offers an improved single cell capacity without increasing the system complexity. This LMMSE receiver minimizes the interference by adapting to the cyclo-stationary nature of the MAI.

CDMA as a third generation of mobile system is proposed as a duplexing technique for high data rate applications and picocell coverage mode, which uses Time Division Duplex (TDD), and time slots to separate both the streams in the downlink and uplink as well. TDD allows for a large flexibility in data transmission rates due to the use of orthogonal codes for channelization.

Multirate transmission is relatively new in CDMA systems and a new topic for research in this area as receptors that could be used for such systems. The complexity of this receiver is very high and it must be able to detect the data carried by a subset of the active codes used in the current time slot. These active codes may be assigned to the same user as an intracell signal in the path from the base station to the mobile and modeled as if it were a synchronous CDMA system, where all code signals goes through the same propagation channel and possibly also experience a multipath. Hence the possibility that any signal coming from another cell in the downlink of interferer nature, can be described by the same structure as the intracell signal and all intercell signals will be considered true asynchronous signals to each other and also to the intracell one. At the base stations the use of specific scrambling sequences to mask every intracell beam which duration is a few symbols interval, makes up a window of observation which is considered to be statistically stationary.

An investigation is being done in reference to the use of a more complex type of mobile terminal in which the downlink group detection of the data carried by a group set of codes ranging from one to the totality of all active codes, and in which rejection of both the intra and intercell interference is taken into account. Instead, the focus in the co-channel interference mitigation work is done on all linear detectors based on zero forcing or Minimum Mean Square Error criterion in order to counteract the inter symbol interference by equalization and multiple access interference by interference mitigation.

For the receiver design we rely on the fact that detection performed by a Mobile Terminal Station (MTS) can always exploit explicit knowledge concerning all the intracell codes currently assigned to a time slot, because the codes destined to a specific MTS are notified by the use of a control channel, meanwhile the others are determined by processing the middle of the packet. Therefore, this observation model always includes a "structured" description of the intracell signals. Consequently, the direct intracell mitigation feature is always set "on," while different options for co-channel interference suppression will be always available.

A statistical description of the intercell interference allows for the use of low complexity receivers by augmenting their capacity to deal with non gausssian background noise which characterizes both inter and additive white Gaussian noise. Then the mobile station can realize the mitigation of both inter and intracell interference.

Basically in this scheme, the receivers identify a tunable complexity of the signal of two components. A structured part as the most significant for detection or rejection as interference and the non structured part treated as Gaussian noise which is only statistically described. The receivers are linear and non complex using the ZF code and Minimum Mean Square Error criterion to counteract simultaneously both ISI and MAI. The proposed receivers are grouped into two families: (1) the first family of receivers restore separation of users by mitigating both ISI and MAI simultaneously; (2) the second family attempts to restore the orthogonality of the codes by simply equalizing the common channel (to eliminate ISI) and relies on a conventional detector for user separation. A relevant sliding window algorithm synchronized with the symbol rate of the slowest data stream is proposed and its fine structure is illustrated. Multiple access interference is not totally rejected.

1.2 A METHOD TO PARTIALLY SUPPRESS ISI AND MAI FOR CDMA WIRELESS NETWORK

In this method ISI and MAI are partially suppressed for CDMA. This is an alternative method to combat both, ISI and MAI by the method of advanced multiuser detection. This method introduces a modification to the carrier waveform. It reduces the cross correlation between users and can be applied to any CDMA scheme. Figure 1 shows a Spread Spectrum Communication system.

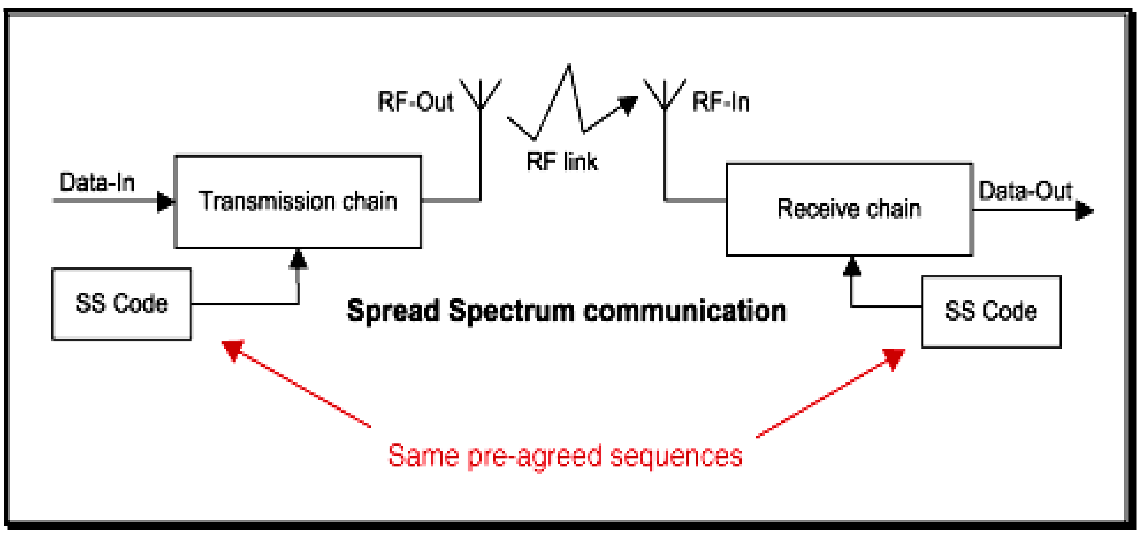

Figure 1: Spread Spectrum Communication Scheme

This method is very useful when applied in a Wireless Local Area Network for high speed data transmission and hyperlan standards that operate or will be operating on industrial scientific medical bands where data integrity is a concern. Present moment multimedia require data rates of several Mbps and due to dispersion caused by multipath propagation as well as the presence of strong industrial radiators jammers as microwave ovens, door and windows sensors, medical appliances and other users, the CDMA signal is exposed to a severe bit error rate degradation. This in band jammers, as any other channel of the same wireless Local Area Network that is acquired by means of CDMA access, can block the communication. Also, as the transmission is blocked more power is required to reestablish the link.

Cancellation of the interference in CDMA is possible if all users utilize orthogonal signals but due to time delay and the near–far effects between the base station and the mobile the signal that the user receives cannot be considered orthogonal causing MAI which is severe for very short spreading sequences.

When the spreading codes are short length, this adds to the effects of multipath propagation provoking that the transmitted symbols can interfere one with the others.

These kind of problems called MAI are very severe for short spreading sequences. Also this type of codes combined with multipath propagation can cause severe problems of ISI. These two problems, ISI and MAI can be fought with advanced multiuser detection but at the mobile terminal the receiver must be of great complexity in its design. An alternative approach to mitigate ISI and MAI is by a substantial cut in auto and cross correlation among the multipath signals and among the users. Then, by introducing a modification into the waveform ISI and MAI can be reduced, but not totally.

1.3 A Method For MAI Mitigation And Near Far Resistance Architecture For Global Navigation Satellite System Receivers

MAI, multipath and near–far effects are three important factors that strongly influences the performance of a CDMA system. Advanced digital signal processing algorithms and high level complexity multidetector receivers prove to be useful for mitigation on these effects however ISI and MAI remains as a problem not totally solved.

In spite off an extensive development in Direct Sequence CDMA based communications, the classical relation matched filter receiver structure is still used and it will be in use for several years. Either way, MAI is inherent to Spread Spectrum and near far problems will always arise. This interference is the result of the random transmission delays between the transmitted signals which is inherent to this mobile systems making it impossible to design Pseudo Noise codes (PN codes) completely orthogonal.

If the number of transmitters remain small the level of MAI also remain small but as they increase the level of MAI also increases degrading the reception quality. MAI is conventionally treated as White Gaussian noise.

When the power of the signals being transmitted arrive at the receiver is different one to the others, near far problems occur. Therefore, the stronger signal will jamm the weakers. This is widely considered due to the different distance that each transmitter is to the receiver.

For satellite transmissions, no serious near far problem arises due to distance since they are roughly at the same range and the signals arrive at the receiver with the same level.

However due to the mode in which the receiver is tracking the PN code, the near far effect can not be avoided or compensated because the acquisition band if a tracking loop that works in acquisition mode, is larger than any Doppler shift, which has been designed for fast acquisition. Hence it is necessary to further research in near far effects, multiple access interference and multipath resistance for satellite systems.

High level complexity receivers named multidetector receivers for multiple access mitigation, near–far and multipath resistance are not on demand and low cost receivers with optimal performance which are capable to operate where most consumers live, will require an affordable new technology that offers these features. Therefore multidetector receivers are not the solution for MAI at the present moment.

1.4 Successive Interference Cancellation Algorithms for Downlink W-CDMA Communications

A method for interference cancellation is an algorithm named successive interference cancellation. Successive intracell interference cancellation (IIC) is a practical scheme for increasing the capacity of Wideband CDMA systems (W-CDMA) at the mobile unit. No prior knowledge of users' spreading codes or even their spreading factors are required for interference cancellation. A new term, effective spreading code, has been introduced which is defined as the interfering user physical code as seen by the desired user within the desired user symbol duration. The mobile receiver estimates the effective spreading codes of the interfering users regardless of their spreading factors using Fast Walsh transform (FWT) correlators (instead of the regular correlators) and uses this information to suppress the intracell multiuser interference.

There are at least three different interference-suppressing techniques studied at the present moment: subtraction; combined interfering signal projection; and separate interfering signal subspace projection. The complexity of the proposed techniques is low compared to conventional interference cancellation techniques. For a W-CDMA system and the IMT-2000 vehicular channel model, a capacity increase of up to 150% of the original (without IIC) system capacity is shown.

The third generation (3G) cellular mobile communications systems will support several kinds of communication services, including, e.g., voice, images, and even motion picture transmission.

Therefore, the users will be transmitting their information signals using different data rates and their performance requirements will vary from application to application. W-CDMA with variable spreading factor and multicode modulation as a multirate scheme is emerging as one of the air interfaces for the 3G mobile communications systems. The high and different user data rates and the large number of users together with multipath dispersive fading channels cause severe intercell and intracell multiuser interference. Fundamental investigations have demonstrated huge potential capacity and performance improvements as a result of using multiuser detection at the expense of increasing complexity of optimum structures.

In general, a major problem with multiuser detectors and interference cancellers is the maintenance of simplicity. Even the sub-optimal linear detectors require considerable complex processing.

There are several algorithms for interference cancellation for CDMA systems. However, most of these algorithms are designed for the uplink. For uplink interference cancellation, it is assumed that the receiver knows all the spreading codes. This assumption is not true for the downlink where the mobile unit only knows its own spreading code. Furthermore, the complexity of the interference cancellation algorithms proposed up to date is very high. For the downlink, since interference cancellation has to be performed at a hand-held battery-operated terminal, cost and power consumption are of great concern. The focus here is on the downlink communications. At the present moment a successive intracell interference cancellation mobile receiver is proposed.

This receiver estimates the interfering users' effective spreading codes and uses them to suppress the interference on the received signal.

Some researchers are trying to estimate the interfering user actual spreading code and then use it in the cancellation process using different ways, either by equalization idea or by subtractive cancellation, etc. (very few are dealing with variable spreading factor case). This is to say that the effective spreading code of the interfering user as seen by the desired user within the desired user symbol duration belongs to the Walsh Space seen by the desired user. Better this estimation process is combined with the interference cancellation to get a code estimate after every iteration. Therefore a better cancellation and better performance is achieved. Three different techniques have been considered in the canceller: subtraction, combined interfering signals projection, and separate interfering signals subspace projection.

We should notice that total interference cancellation is not achieved. Therefore a residual level of interference is present.

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