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A Review On Interleave Division Multiple Access In Underwater Comminication

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***Abstract* - This paper outlines a multiple access technique which exploits the interleaving as only means of user separation instead of by different signatures as in a conventional code division multiple-access (CDMA) scheme. It examines a very simple iterative chip-by-chip multi-user detection strategy for spread spectrum communication systems. The given scheme can achieve near single user performance in situations with very large numbers of users while maintaining very low receiver complexity. This technique shows that high performance can be maintained in multi-path environments. IDMA inherits many advantages from CDMA, such as diversity against fading and mitigation of the worst-case user interference problem. A low-cost iterative chip-by-chip multi-user detection algorithm is also described with complexity independent of the user number and increasing linearly with the path number.**

Keywords - IDMA, CDMA, Underwater communication

I. INTRODUCTION

Since from the last few years, technologies have taken rapid growth to provide new methods and products for wireless communications. The ability to communicate with people on the move has evolved because of Guglielmo Marconi first demonstrated radios ability to provide continuous contact with ships sailing the English channel and since then new wireless communications methods and services have been adopted by people all over the world.

A. First Generation (1G) Wireless Communication Systems:
The 1G system is characterized by the fact that they are all based on the analog technologies. Some representatives of 1G cellular system are the Advanced Mobile Phone System (AMPS) in USA, Nordic Mobile Telephone (NMT) in Scandinavia and the Total Access Communication System (TACS) in UK [1]. They are designed to carry voice transmission only. In these systems, each user has a unique frequency band. This multiple-access technique separates the signals of different users in frequency domain, which is called frequency-division multiple-access (FDMA).
The introduction of 1G systems, the worldwide mobile market experienced annual growth rates of 30% to 50% and there are nearly 20 million subscribers by 1990 [2]. Later, due to rapid advancement in technologies based on market demand, it has led to the second-generation (2G) of digital stage with time division multiple access (TDMA) and code division multiple access (CDMA) schemes, and now it has stepped into the third-generation (3G) with eye on fourth-generation (4G) of broadband stage .

B. Second Generation (2G) Wireless Communication Systems:
The 2G cellular systems are all based on the digital technologies. The most popular 2G standards include three time-division multiple-access (TDMA) standards and one code-division multiple access (CDMA) standard. The Global System for Mobile communications (GSM) is the first operated digital cellular system based on TDMA, whose commercial operation began in 1991 in Europe. The other two TDMA based standards are Interim Standard 54 (IS-54) in North America and Pacific Digital Cellular (PDC) in Japan. The only CDMA based 2G cellular standard is Interim Standard 95 (IS-95). Since the mid 1990s, the cellular communications industry has witnessed explosive growth. There are more than 600million cellular subscribers worldwide in late 2001 [3]. Most of today's cellular systems belong to 2G.
The representatives of 2G systems i.e. Interim Standard-95 (IS-95) system and the Global System for Mobile Communication (GSM), have been widely deployed throughout the world. The IS-95 system, developed in United States of America, is mainly based on code-division multiple-access (CDMA) scheme while GSM system, developed in Europe, is mainly based on time-division multiple-access (TDMA) scheme.

C. Third Generation (3G) Wireless Communication Systems :
Due to lots of technological changes and market oriented demands, mobile communication technology has entered in 3G stage. The 3G standards have been developed specially to support high-rate data services such as high-speed internet access, video stream and high quality image transmission. The distinctive features of 3G systems in comparison to 2G systems are inherited with technology of packet-switched high-rate data transmission along with voice services. Specifically, CDMA2000, a representative of 3G systems, builds on the packet-switched technology along with increased data transmission rate, and backward compatibility with original CDMA standards. It is employed primarily in North America and some parts of Asia. Another qualified 3G candidate, wideband CDMA (WCDMA) is referred as an evolution of the GSM technology, including

aspects of TDMA and CDMA2000 for global accessibility. The time-division synchronous CDMA (TD-SCDMA) is mainly developed by the Datang Group, China, building on the original CDMA standard to deliver multimedia data, considering its largest user base in its own country.

D. Fourth Generation (4G) Wireless Communication Systems:

Even before 3G systems were being deployed, researchers started the investigations on possible techniques for 4G systems. The explicit 4G standard is still not confirmed. In June 2003, ITU approved the recommendation ITU-R M.1645 “Framework and overall objectives of the future development of IMT-2000 and systems beyond IMT-2000” [4]. The document states the capabilities as well as possible technologies for 4G systems. Important features of 4G wireless systems include:

- 4G needs to support data rates of up to 100 Mbps for high mobility such as mobile access and up to 1 Gbps for low mobility such as local wireless access.
- 4G uses of packet-based architectures which will offer increased system security and reliability, intersystem mobility and interoperability capabilities.
- 4G satisfies future requirements for universal wireless network that will provide high data rates and a seamless interface with a wire line backbone network.

The 3G and beyond systems have been developed to serve people's daily work and life, and to satisfy their demands. The ultimate user needs reliable, cheaper, secure, and low-delay voice & data services anytime and anywhere. The additional features of the future wireless communications include high-speed data and broadband transmission for huge user base, along with global mobility, & scalable quality of service (QoS) for both operators and subscribers. The above features are imposing technical challenges on system design and stimulate various researches to work on topics related to capacity, complexity and performance of the communication systems [6, 7].There are also other research topics highly related to the physical layer in wireless systems including optimum channel coding, detection, and diversity mechanisms etc. For immediate solutions of above problems, near-capacity-achieving forward error correction (FEC) codes are developed to enhance power efficiency while improved detection algorithms are designed to enhance the reliability or bit-error rate (BER) performance. Diversity techniques have been proposed to increase spectral efficiency and diversity for accommodating more users and mitigating fading. The new horizons on above discussed topics have emerged as “hot cake” for researchers all over the world.

2. RELATED WORK

E.calvo et al, Motivated by finding reduced complexity versions of the maximum-likelihood (ML) detector for highly distorted underwater channels, a multiuser detection (MUD) algorithm for joint data detection and channel estimation based on the cyclic coordinate descent method is proposed. Assuming that the data symbols are available, they are used to estimate the channel responses, which, in turn, are used to refine the symbol estimates.
Adaptive estimation is performed using minimum mean square error as the overall optimization criterion. The receiver is implemented in a multichannel configuration, which provides the array processing gain necessary for many of the underwater acoustic channels. The complexity of the detection algorithm is linear in the number of receive elements and it does not depend on the modulation level of the transmitted signals. The algorithm has been tested using real data obtained over a 2-km shallow-water channel in a 20-kHz band, demonstrating good results [1].

Hao He et al, Covert communications are conducted at a low received signal-to-noise ratio (SNR) to prevent interception or detection by an eavesdropper, and successful detection in this particular area heavily relies on the processing gain achieved by employing the direct-sequence spread-spectrum (DSSS) technique. If covert communications take place in underwater acoustic (UWA) environments, then additional challenges are present. UWA channels are time-varying in nature, which could preclude accurate channel estimation at low SNR. Furthermore, UWA environments are frequency-selective with long-memory channels, which impose challenges to the design of the spreading waveform. In this paper, we investigate covert UWA communications from a non-coherent perspective. Two modulation schemes are addressed, namely, binary orthogonal modulation and binary differential phase-shift keying (DPSK). Both schemes are coupled with the DSSS technique and a RAKE receiver. The employed spreading waveforms not only account for the transceiver structure and frequency-selective nature of the UWA channel, but also serve to protect the privacy of the transmitted information. The effectiveness of the proposed methods is verified by numerical examples [2].

Tsimenidis et al, Two different synchronous downlink multiple-access schemes, interleave-division multiple access (IDMA) and code-division multiple access (CDMA), are considered for pragmatic underwater communications channels exhibiting extended multipath spread and time variability. Two single-element DFE-IDMA and DFE-CDMA receivers are proposed that utilize chip-level adaptive decision feedback equalization (DFE) and carrier phase tracking along with iterative interference cancellation (IC) and channel coding. The receiver equations describing the detection algorithms are derived and their performance is investigated and compared. To track and compensate for the channel effects, the DFE and carrier phase tracking units are jointly optimized based on the mean square error (MSE) criterion and adapted iteratively by exchanging soft information in terms of log-likelihood ratio (LLR) estimates with the turbo processing stage. The detection is implemented by using soft chip cancellation to remove multiple-access interference (MAI) effects between users. The performance of the proposed receiver structures is investigated and compared in short-range shallow-water acoustic channels using offline processing of signals acquired during sea trials in the North Sea. Results for synchronous multiuser scenarios, with two and four users at an effective rate of 439.5 b/s per user, demonstrate that the proposed DFE-based IDMA and CDMA receivers can provide bit error rate (BER) performances of approximately 10-5 at an average signal-to-interference-and-noise ratio (SINR) of 11 dB . The experimental results also demonstrate that these direct adaptive receivers have better performance and significantly mitigate the bit errors associated with the channel estimation (CE)-based IDMA and CDMA receivers with Rake reception while maintaining lower complexity. Furthermore, in some cases, the receivers with partial knowledge of the interleavers patterns or codes can still achieve performance comparable to those with full knowledge [3].

Xingzhong Xiong et al, Interleave-division multiple-access (IDMA) is one of the key multiple access techniques in the new wireless communication systems. In this paper, we investigate the basic principle of IDMA systems, analyze every model function, and build a simulation platform for IDMA systems. It is convenient to set the main parameters of the model of IDMA systems according to the simulation platform, and thus realize the performance simulation for IDMA systems flexibly. The simulation and test results show that the simulation platform satisfies the test of every function of IDMA systems. Moreover, the platform provides a flexible test method for IDMA systems, and can make use of those models in Simulink library already. This platform is convenient to extend the model function and study the performance of IDMA systems [4]

Xing-Peng Mao et al, In this paper, a novel scheme for achieving fast synchronization in interleave division multiple access (IDMA), called spreading-IDMA(S-IDMA), is investigated. By introducing an extra despreader after the interleaver, S-IDMA can exploit the advanced techniques from code division multiple access (CDMA) and derives signal to interference-plus-noise ratio (SINR) improvement before iteration detection process through correlation operation. Both theoretical analysis and simulation are carried out for evaluating the performance of S-IDMA in terms of signal to interference-plus-noise, bit error rate (BER) and complexity. It is indicated that S-IDMA can achieve fast synchronization with low computational complexity [5].

Utschick et al, This article presents comprehensive comparisons of interleave division multiple access (IDMA) and direct sequence code division multiple access (DS-CDMA) in terms of performance and complexity assuming iterative multiuser detection. IDMA can be seen as a special case of DS-CDMA with spreading gain of one using very low rate code and user-specific interleavers for user separation. We focus on three suboptimum linear detectors: minimum mean square error (MMSE), rake (or matched filter), and soft-rake detectors from practical concerns. We analytically prove that the three detectors are equivalent for asynchronous users of IDMA on frequency flat channels for complex modulation alphabets. Such equivalence has been shown only for binary phase shift keying (BPSK) in the literature. The equivalence guarantees the MMSE solution for IDMA without computationally expensive matrix inversions or matrix-vector multiplications. This is generally not the case for DS-CDMA since DS-CDMA is sensitive to user a synchronism. We also discuss complexity aspects when the MMSE detector is used where we focus on essential differences in complexity between IDMA and DS-CDMA, instead of discussing particular complexity reduction techniques. Computer simulations are performed in various scenarios and the performance is analyzed by bit error rate simulations as well as by extrinsic information transfer (EXIT) charts. The analysis reveals the advantages of IDMA over DS-CDMA in terms of performance and complexity under practical considerations, particularly in highly user loaded scenarios [6].

Feng Zhang et al, IDMA can be regarded as a special case of CDMA, where the spreading can be done by an arbitrary low rate channel code equal for all users and the separation can be done by user-specific interleavers. In this paper, we provide the anti-jamming performance analysis of partial band for IDMA systems. First, we investigate the basic principle of IDMA briefly. Then introduce the generation of the partial band jamming model and the cancellation of the partial band jamming in IDMA systems. The theoretical analysis and simulation results show that the iteration, spreading gain, the number of users, and the power of jamming will affect the performance of IDMA systems. Especially, the power of partial band jamming is the maximum impact factors for IDMA systems in the circumstances of partial band jamming [7]

Aliesawi et al, Two adaptive receivers for jointly detecting active users in an interleave division multiple access (IDMA) system are considered for highly dispersive underwater acoustic channels (UACs) using a continuous pilot approach. A direct adaptive interference cancellation (IC) IDMA receiver is proposed and compared with the standard Rake-IDMA receiver that performs adaptive semi-blind channel estimation developed by the authors. Both iterative decoding receivers incorporate a phase locked loop (PLL) and are optimized based on the minimum mean square error (MMSE) criterion. The theoretical basis of both receivers is presented along with experimental results obtained by processing data from actual underwater communication experiments. The transmission results of 3 active users at a data rate of 441.3 b/s per user within 4 kHz bandwidth demonstrate that the IC-IDMA receiver has better performance and significantly mitigates the bit errors associated with Rake-based IDMA receiver [8].

Xingzhong Xiong et al, Underwater acoustic channel is the most challenging channel in the world due to its time varying and frequency-selective characters and these characters make channel estimation a compulsory task for coherent orthogonal frequency division multiplexing (OFDM) underwater communication. Channel frequency response can be estimated by pilots that are already known to the receiver. Bit error rate (BER) performance can vary a lot according to different type of pilot pattern. Three kinds of pilot (Block, Comb and Scatter) are analyzed and each of them is proved to work well in some certain underwater environment. Underwater channel is demonstrated to be a comb filter. With channel estimation, stop band and pass band of the experiment channel are found and analyzed. Channel estimation error is more likely to occur in stop band than in pass band, especially when the channel coherence bandwidth is small. Inter channel interference (ICI) can cause large estimation error by increase its noise level. An improved transform domain filter can reduce the estimation SNR significantly [9].

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