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Unsighted Medium Assessment for Multiuser OFDM-IDMA Arrangement

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Abstract: **Over the last decade, the data rate and spectral efficiency of wireless mobile communications have been significantly enhanced. OFDM technology has been used in the development of advanced systems such as 3GPP LTE and terrestrial digital TV broadcasting. In general, bits of information in mobile communication systems are conveyed through radio links to receivers. The radio channels in mobile radio systems are usually multipath fading channels, which cause inter-symbol interference (ISI) in the received signal. The ability to know the channel impulse response (CIR) and Channel State Information (CSI) helps to remove the ISI from the signal and make coherent detection of the transmitted signal at the receiver end of the system easy and simple. The information about CIR and CSI are primarily provided by channel estimation. It compares various efficient channel estimation algorithms. Channel estimation of OFDMIDMA scheme is important because the emphasis from previous studies assumed the implementation of MC-IDMA in a perfect scenario, where Channel State Information (CSI) is known. MC-IDMA technique incorporates three key features that will be common to the next generation communication systems; multiple access capability, resistance to multipath fading and high bandwidth efficiency. OFDM is almost completely immune to multipath fading effects and IDMA has a recently proposed multiuser capability scheme which employs random interleavers as the only method for user separation. MC-IDMA combines the features of OFDM and IDMA to produce a system that is Inter Symbol Interference (ISI) free and has higher data rate capabilities for multiple users simultaneously. We present the basic principles of OFDM-IDMA transmitter and receiver. Comparative studies between Multiple Access Scheme such as Frequency Division Multiple Access (FDMA), Time Division Multiple Access (TDMA), CDMA and IDMA are carried out.**

Keywords: **FFC, CDMA, IDMA, OFDM, CSI, AMPS, TACS, Wireless**

1. INTRODUCTION

1.1 Evolution of Wireless Communication Systems

There was an explosive growth and high demand for high quality voice, data and video services in the 20th century. The carrier of these services has largely been wireless links. Wireless communication services thus made a way through into our society in an unprecedented scale. In recent times, there has been an increase in the demand for data transmission and bandwidth efficiency in wireless transmission due to the phenomenal and exponential growth of wireless communication. The demand in communication calls for technologies that will make efficient use of the limited available electromagnetic resources and provide high quality of service (QoS) and broadband data access in the most rational way. In the past decade, new methods and products for wireless communication systems have resulted from gradual development of different technologies that evolved in the public, military and commercial sectors, sharing the available radio resources. A chronological evolution of wireless communication systems is summarised as follows:

1.1.1 First Generation (1G) Wireless Communication Systems

The last few decades have seen an increase in the amount of information transmitted over the air. Transmission of voice signals employing analog frequency division multiple access (FDMA) was used in first generation of wireless telecommunication technology. The standard used in this early system varies from one country to another. The United State of America used the Advanced Mobile Phone Service (AMPS), while United Kingdom and Scandinavia used the Total Access Communication System (TACS) and the Nordic Mobile Telephone (NMT) respectively, [1]. Each user in this generation was assigned a unique frequency band and the signals from different users were separated in the frequency domain using the multiple access scheme called FDMA. Though data security is extremely important in any wireless communication but in the first generation systems, there was compromise in data security because advanced encryption methods were not authorised. Only a simple technique could be utilised to intercept conversations.

1.1.2 Second Generation (2G) Wireless Communication Systems

In the second generation system, there was improvement in technologies that supported Integrated Circuits (IC). Digital technology was adopted and it was more economical and practical than its predecessor that utilised the analog technology. Code Division Multiple Access (CDMA) and Time Division Multiple Access (TDMA) are the multiple access digital technologies used in the second generation systems. The second generation system supported speech service and low data-rate, data services. It provided better data services, high spectral efficiency, more advanced roaming and

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3- times increase in user capacity. In 1991, the second generation standard was used in the production of the first digital cellular service and its commercial operation commenced in Europe [2]. Many of the cellular systems used at present time depend on 2G.

1.1.3 Third Generation (3G) Wireless Communication Systems

October 1st 2002, mark the inception of the operation of 3G communication system in Japan. The 2G complexity was augmented by the 3rd generation system. When compared to 1G, it achieved 10-fold increase in system capacity by using CDMA or TDMA which are more complex multiple access techniques. Improved quality images and video stream transmission, data services with expeditious internet access are the 3G standards supported services. The International Telecommunication Union (ITU) released an interdependent set of recommendations which were used to construe International Mobile Telecommunications-2000 (IMT-2000), that served as the global standard for 3G wireless communication. By linking many varied systems' based networks, IMT-2000 provided access for worldwide wireless communication. It combined current services and networks with the aim to achieve a unified generation network, as shown in fig 1.1.

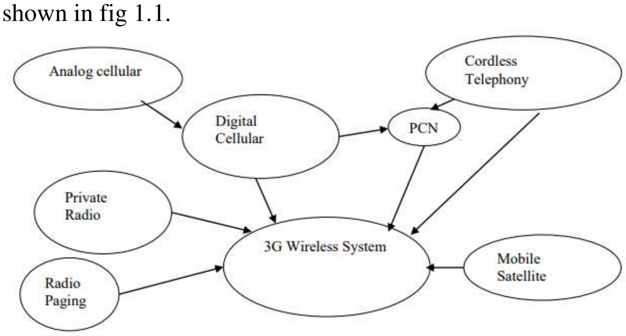

Figure 1.1: A unified third generation network.

1.1.4 Fourth Generation (4G) Wireless Communication Systems

Researchers and industries triggered by the evolution of new technologies and the ever increasing demand for high data rate services by users in the mobile systems, came up with an exhaustive illustration of the imminent fourth generation (4G) mobile communication system even before the deployment of 3G systems. The recommendation of ITU-R M.1645 "Framework and overall objectives of the future development of IMT-2000 and systems beyond IMT-2000" was approved by ITU in June 2003 [3]. 4Gs essential characteristics include:

- The support of data rates for high mobility up to 100 Mbps and low mobility up to 1 Gbps for mobile access and local access, respectively.
- The increase in system security and reliability because of its packet based architecture.
- The optimization of its spectrum and interoperability capabilities.
- The fast and high data rate, improved network capacity and it is absolute integration with wired line backbone networks.

Several challenges in communication system are yet to be overcome in spite of the 4G essential characteristic. These include the request for high transmission rate for data (up to 1Gbps), quality of service (QoS) management, a perfect global roaming, high user capacity, incorporation of 3G and next-generation components and there compatibility. High bit rate data transmission is required for high quality audio, video, and mobile integration in this current and future mobile communication system. Data transmission over a radio channel at very high bit rates can cause the Channel Impulse Response (CIR) to spread across several symbol periods, thus causing Inter Symbol Interference (ISI) in the system. ISI can be mitigated using a multicarrier system, Orthogonal Frequency Division Multiplexing (OFDM), which will be discussed later. The research on 4G communication systems specifically focused on spectral efficiency and system complexity. Thus different multiple access schemes were considered to achieve this goal. OFDMbased multiple access schemes and associated hybrid technologies have become popular and have been the focus of recent mobile communications research due to their inherent advantages which include efficient and reliable high data-rate transmission as well as low system complexity.

1.2 Fundamental of the Wireless Channel

The wireless communication channel has undesirable effects on transmitted signals that pass through it due to changes of its physical properties. The transmission through the radio channel propagation contains multipath reception. The complexities of the radio channel environment interact with the transmitted signal. These complexities arise from the physical properties of the channel. The distorted, delayed and phase shifted received signal is the result of the combination of the effect of scattered buildings and other structures, reflected, diffracted, and scattered copies of the signal transmitted that arrive at different times with differing attenuation level at the receiver. Figure 1.2 shows the effect of reflection and diffraction on the received signal. Reflection takes place if the signal hits an object with a relatively large surface compared to the wavelength of the signal. Diffraction takes place when the transmitted signal encounters an opaque body with a larger surface compared to the wavelength of the signal. It then leads to bending of a wave around an obstacle. Scattering happens if the transmitted signal strikes an object, and the size of the object compared to the signal wavelength are the same or the signal wavelength is smaller. A perfect understanding of the fundamental characteristics and challenges confronting radio channel systems helps in the design and implementation of cellular communication schemes. The parameters that characterize wireless channels are discussed below.

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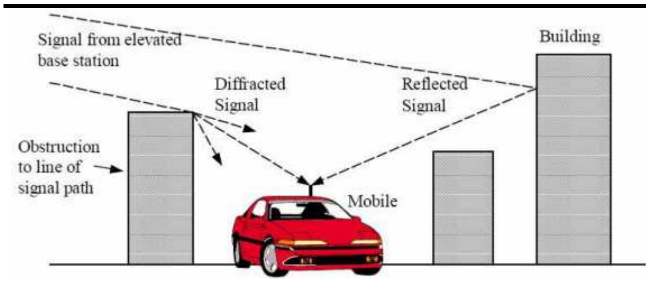

Figure 1.2: Effect of Reflection, Refraction and Diffraction on signal.

2. RESEARCH MOTIVATION AND OBJECTIVES

Wireless communication has been facing various inherent challenges based on the near unpredictable nature of the wireless environment. These challenges include multipath fading, co-channel interference and Doppler effect among others. Taking into account the plethora of applications and users, there is high demand for data transmission at high speeds. The ability to guarantee broadband mobile data access, at a very high speed, poses a big challenge to future wireless communication. There is also a constant need to ensure that the available spectrum is distributed fairly among the numerous users. The demand has inadvertently led to the evolution of various multiuser communication systems. In the first to third generation wireless communication systems, FDMA, TDMA, and CDMA were the most commonly used techniques for multi-user systems [10, 11]. However, the combination of OFDM with multiple access techniques formed a hybrid scheme called multicarrier-multiuser systems (MC-MU). MC-MU has brought a lot of gains to multi-user wireless communication systems in terms of spectral efficiency and high data transmission rates. Orthogonal Frequency Division Multiplexing-Time Division Multiple Access (OFDM-TDMA), Orthogonal Frequency Division Multiple Access (OFDMA), Orthogonal Frequency Division Multiplexing-Code Division Multiple Access (OFDM-CDMA), and the most recently introduced Orthogonal Frequency Division Multiplexing-Interleave Division Multiple Access (OFDM-IDMA) [12] are the multiuser techniques which are OFDM based.

Users in OFDM-TDMA wireless communication systems are distinguished by means of time slots. All the sub-carriers in the system are allocated to a specific user for usage at a particular OFDM symbol duration. At the transmitter, all symbols from all the users are combined to form an OFDMTDMA frame. OFDM-TDMA was adopted by the IEEE 802.16 standard as an option for transmission at the 2.11 GHz band [13]. Though, there are advantages of power saving, simplicity in resource allocation and ease of implementation associated with OFDM-TDMA system, the system exhibits relatively high latency, frequency-re-use factor greater than index factor of 3, and very poor flexibility [14]. Despite all that, there is also the problem of inherent performance degradation for delay constrained systems [14]. The multiple access scheme called OFDMA is based on OFDM transmission technique. The idea of OFDMA is initially proposed in [15] for the return channel in Community Antenna Television (CATV). In OFDMA all the available sub-carriers are divided into non-overlapping subsets and are arranged into different sub-channels which in turn are assigned to distinct users. Interference between users is avoided due to orthogonality among the sub-carriers, thus achieving higher system flexibility and efficiency in the allocation of system resources. Orthogonality is achieved if the condition that the frame length is smaller compared to the cyclic prefix length.

OFDMA support unlimited spectrum sharing among users. Some properties of OFDMA are as follow [16]: A maximum of one user is allocated to each of the subcarriers and the selected length of cyclic prefix must be longer than the delay spread. It also utilises DFT and IDFT implementation to reduce computational cost and complexity. It achieved parallel transmission by using the IFFT to modulate each of the coded bits on a subcarrier. Likewise, the signal experience frequency selective fading with a better performance of BER in fading environments. In this scheme, sub-carrier spacing is quite small and it is therefore sensitive to frequency offset and phase offset which is highly pronounced at high mobile speed due to Doppler effect, the amplitude is large and when the signal goes through the amplifier non-linearity the BER increases. To mitigate this problem MC-CDMA is deployed. It is made up of OFDMCDMA. In MC-CDMA each user data symbol is spread over the different subcarriers and is multiplied by the spreading codes for onward transmission. As a result, multiple copies of the same data symbol are transmitted on different subcarriers. This implies signal spreading takes place in the frequency domain and the system attains frequency diversity. The individual merit of OFDM and CDMA contribute to the inherited advantages of MC-CDMA. However, the demand for power control in MC-CDMA is a disadvantage [14]. Although the rate loss is avoided in MC-CDMA systems, Multiple Access Interference (MAI) is the major challenge associated with this scheme. MAI can be overcome at the receiver by using Multi-User Detection (MUD). The use of MUD is a costly option because of its high computational complexity [14].

In order to circumvent the problem of high complexity in MUD associated with MC-CDMA systems, Ping et al [17] around 2002, introduced a multiple access scheme which is interleave-based and obtained a system with enhanced performance, receiver with less complexity and a system with high spectral efficiency. In 2006 Mahafeno proposed the hybrid MC-MU system called OFDM-IDMA that is MC-IDMA [12]. In this scheme, ISI and MAI over a multipath channel are dealt with by MCIDMA. It made use of iterative chip-by-chip MUD system which is applicable to as many users as possible. It means that MC-IDMA is not user limited. The scheme utilised all the inherent advantages associated with the widely used multiple access scheme which are OFDMA, CDMA, IDMA. It discards their disadvantages in the process. The receiver has a simple structure with less complex MUD incorporated, and the number of users do not affect the cost. MC-IDMA achieves optimal performance. It avoids matrix operations. Correlation of signal from different users is avoided by employing chip-level interleaving. MC-IDMA wireless communication system is a new multiusers technique. Extensive studies on this scheme bear witness to a system that is not susceptible to error -an almost perfect system. Perfect systems are still elusive though. The system must be affected by its environmental. The channel impulse response is not known at the receiver. It then makes detection of the message information difficult. There is thus a need for the channel to be estimated. In MC-IDMA, channel estimation deserves more attention as only a few studies have been conducted in this area. A soft based decision directed channel estimation was used by the authors in [18, 19] to implement the least mean square (LMS) algorithm for their proposed channel impulse response (CIR) estimation in the time-domain. However, the limiting factors associated with the use of LMS algorithm are excess mean square error (MSE), data and slow dependence convergence problems. Furthermore, channel estimation scheme based on pilot-assisted symbol was proposed in [20]. The authors employ concurrent transmission of both pilot and information symbols. Unfortunately, the use of pilot symbols is known for its wastage in the scarce communication bandwidth. Besides, the channel estimation employed by such scheme makes use of interpolation techniques at data points and the pilot symbols exclusively. The estimation of the channel at data point cannot be 100 percent perfect. An estimation scheme, employing the combination of linear algorithm-based CIR estimation and adaptive algorithms-based CIR prediction is proposed for MC-IDMA systems in [21]. In the proposed scheme, the channel estimator exchanges soft information with the MUD only. However, the complexity of the proposed scheme is high.

A robust channel estimation technique, better than what has been reported in [18-21], need to be investigated. From the literature few works exist that estimate the MC-IDMA system employing semi-blind channel estimator. The newly proposed MC-IDMA systems is estimated using the semiblind channel algorithm bearing in mind both optimum performance and energy efficiency of the multi-user systems is the motivation for this study, the aim and objectives of this thesis include :

- Development of algorithm for semi-blind channel estimation for OFDM-IDMA based multiuser systems.
- Development of simulation and generation of comprehensive results in terms of bit error rate (BER) and mean square error (MSE).
- Performance analysis for the developed semi-blind channel estimation schemes.

3. MULTILPE ACCES SCHEMES, OFDM AND IDMA OVERVIEW

Recently, a number of ways have been proposed to utilize and manage the available radio spectrum among the users of the wireless communication systems efficiently. Multiple simultaneous users in a system are supported with users utilizing any of the multiple access techniques which are related to the frequency band, the time band and the code band. The use of Orthogonal Frequency Division Multiplexing as a prominent technology in high rate data transmission is also a global convergence. The fourth-generation (or the professed 3.9 G) mobile systems, WiMax, WiBro, WiFi etc are all wireless local network systems that are OFDM based. Digital multi-carrier modulation is the scheme used by OFDM. It is used in data transmission at high data rates with frequency-selective channels. This chapter gives a broad view of the OFDM process. It introduces IDMA as a best multi-user system to be combined with the OFDM system (thus forming the MC-IDMA) in order to obtain energy efficient wireless communication systems. This chapter also introduces the study of different channel estimation techniques that exist. The estimation of the channel using the pilot symbols (Pilotassisted channel estimation method), estimation based on inherent information in received signal, and intrinsic information in the unknown data symbols, respectively. The last channel estimation techniques called decision directed channel estimation is also discussed. The importance of semiblind channel estimation schemes and the reason why it is better than other estimation schemes is highlighted here.

3.1 Multiple Access Scheme (MAS)

In wireless services, a finite amount of spectrum is distributed and the ability to send information simultaneously by different users is desired. The limited spectrum can be shared effectively among as many users as possible. In general, a multiple-access scheme (MAS) is a scheme in communication where the limited available channel bandwidth is shared and allocated to various users resulting in efficient and high capacity usage of the limited spectrum. In wireless communications design, MAS ensures that the channels allocated to different users are well managed in spite of the limited spectrum. The sharing of the channel bandwidth among the various users is based on time, frequency, or codes, as the case may be. In the section below, the major multiple access scheme are discussed.

3.1.1 Frequency Division Multiple Access (FDMA)

The bandwidth is assigned to various users in the frequency domain and each user is allocated a finite portion of bandwidth for constant and permanent usage. The channel bandwidth is divided into a number of smaller non-overlapping channels separated by guard bands to prevent interference, (Fig. 2.1) Users are said to be frequency-orthogonal in FDMA. It stand to follow then that a particular user (ideally) cannot have impact on other user [23]. FDMA by nature is a narrowband MAS system which is usually executed in narrowband systems. However, since a finite portion of the bandwidth is permanently allocated to a specific user, the bandwidth becomes a wasted resource when the user is idle. As stated earlier, United State of America utilized Advance Mobile Phone Service (AMPS) as the first analog

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cellular system based on FDMA. According to [9], the mathematical expression for the number of simultaneous users that can share the limited channel bandwidth in FDMA scheme is given as

$$N = \frac{B_D - 2B_{Gd}}{C_B}$$

where, B_D is the total available bandwidth, B_{GD} the guard band to mitigate multipath delays and interference and C_B represent the channel bandwidth.

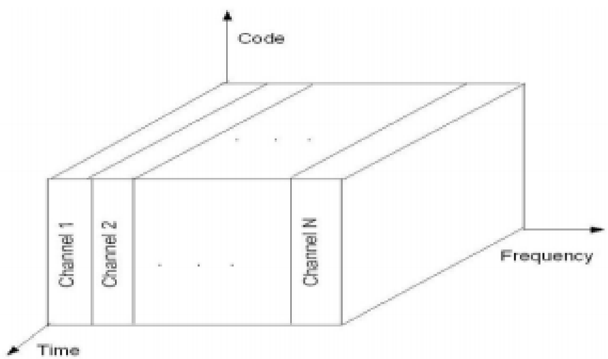

Figure 2.1: Specrum sharing with respect to frequency

3.1.2 Time Division Multiple Access (TDMA)

In this scheme, the whole bandwidth of the channel is available to all the users but only for a limited period of time. This means that TDMA is constrained in the time domain [4]. Since continuous transmission is not required in digital systems, TDMA transmission occurs in bursts. The same carrier frequency is useed by all the users but non overlapping time slots are available where the user can either transmit or receive radio signals. In TDMA, users are time-orthogonal, since transmission by different users is disjoint in time, fig. 2.2, [24]. In most cases, the accessible bandwidth is split into a small number of channels in contrast to FDMA and the users are assigned different time slots at which they can have the whole channel bandwidth for their transmission processes. In this modulation technique, the available bandwidth affect the number of time slots per frame. In the upper link of TDMA, the users transmit through different channels and have different delays. Synchronization of the transmitter in the up-link, to maintain orthogonality of the received signal, is important. Therefore, introduction of guard bands between TDMA channels to compensate for multipath and synchronization error is required. Two guard bands are used, each of the guard bands are positioned at the two different ends of the frequency assigned. TDMA is used in the GSM system. Mathematical expression for the total number of simultaneous users that can share the limited channel bandwidth in TDMA scheme is given by [9]

$$N = \frac{n(B_D - 2B_{Gd})}{C_B}$$

where, the maximum number of users allowed per radio channel is n, while B_D, B_{GD}, and C_B are the total available bandwidth, the guard band and the channel bandwidth respectively.

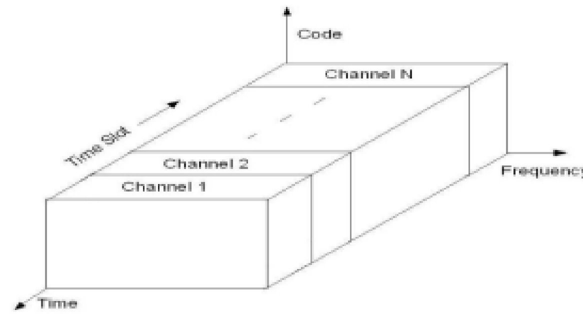

Figure 2.2: Specrum sharing with respect to time.

3.2 Fundamental Operations of OFDM

Orthogonal frequency division multiplexing is a modulation technique which is suited for high-datarate transmission in a delay dispersive environment. In OFDM, the whole channel is split into numerous narrow band sub-channels, also referred to as subcarriers. This splits the high data-rate stream into many low data-rate parallel streams that are transmitted over parallel narrow band multiplexed sub-channels that are mutually orthogonal. There is thus, no interference between subcarriers. It then becomes easier to separate signals carried by each sub carrier because of the absence of interference. OFDM is not just a modulation technique; it can also be referred to as a multiplexing technique. The OFDM technique allows for spectrum overlapping, thus ensuring the efficient use of the available bandwidth.

3.2.1 Serial and Parallel Data Transmission

In a common serial data transmission system, the spectrum of each data symbol being transmitted occupies the whole available bandwidth and the symbol transmission is continuous. In this serial system, when fading occurs, several adjacent symbols may be totally destroyed because of the bursty nature of the Rayleigh channel. The system is more susceptible to delay spread impairments if the symbol interval is decreased. A multiplexed data system is also referred to as a parallel system which proffers an alternative solution to the problems confronted with serial transmission. In a parallel system, continuous streams of data are transmitted concurrently, so that large numbers of data elements are transmitted at any point in time. This system is designed such that the individual data element spectrum can only use a small fraction of the total bandwidth that is available. 2.3.3 FDM Scheme Versus OFDM Scheme Frequency-division multiplexing (FDM) is a scheme in which the total available bandwidths are divided into smaller non overlapping frequency bands. In a conventional FDM system, filters and demodulators are used at the receiver to recover information in each carrier. There is introduction of guard bands among all the various carriers. The use of guard bands results in inadequate use of the spectrum that is scarce and expensive. In

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a regular FDM system, a single fade or interference can lead to failure of the whole link. However, in a multicarrier system, only a small fraction or 0.01% of the subcarrier will be affected and hence can be corrected with error correction coding. Although, a conventional parallel data transmission can occur in FDM, there is inefficient use of bandwidth. Fig. 2.4 shows a conventional FDM and OFDM system. Fig 2.4 (A) represents the FDM system; the channels are spaced apart to prevent Inter-carrier-interference (ICI), and the signal message can be recovered with conventional filters and demodulators. It can be seen from Fig. 2.4 (B) that 50% out of the total bandwidth is conserved by the multicarrier modulation OFDM overlapping technique.

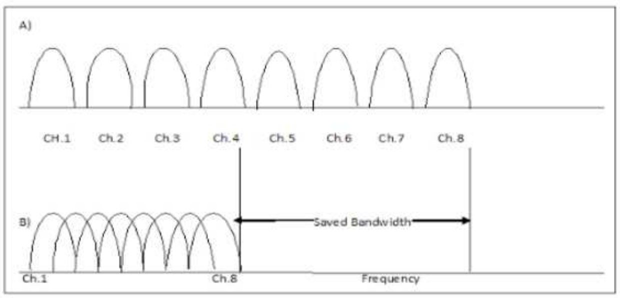

Figure 2.4: (A) and (B) conventional FDM and OFDM.

The word OFDM begins with letter "O", which stand for orthogonal. Orthogonality differentiates the commonly used FDM from OFDM. OFDM inherited all the advantages of FDM. Orthogonality is maintained between subcarriers by carefully choosing the frequency range between the subcarriers. It can be proven mathematically that when the dot product of two signals is zero, the two signals are said to be orthogonal. In fact, the subcarriers are spaced apart by distance of 1/T, where the duration of an OFDM system is represented by T. Figure 2.5 shows the frequency spectrum of subcarrier in an OFDM transmission. From the diagram, it can be seen that the spectrum of subcarriers significantly overlaps across each other, unlike in the conventional FDM operation. For a large number of subcarriers associated with parallel transmission, a large number of oscillators or arrays of sinusoidal generators and the coherent demodulator are needed. This makes the parallel systems costly. Implementing OFDM is therefore complex and costly. However, in 1971, [31] an effective way to reduce the OFDM implementation complexity was proposed by Weinstein and Ebert, who employed Discrete Fourier Transform (DFT) for effective baseband modulation and demodulation. DFT uses basis functions which are sinusoidal and cosinusoidal and are harmonically related functions. Thus, sinusoidal generators or oscillators are eliminated, thus, reducing complexity significantly. The work in [31] focuses on how to introduce sufficient processing, thus eliminating the bank of subcarrier oscillators. Inter-symbol-interference (ISI) and inter-carrier-interference (ICI) are mitigated using a raised-cosine windowing.

3.2.2 OFDM system block diagram

Briefly, the original data to be transmitted is split into streams of N parallel symbols, each of which has a lower data rate. The modulated data is assigned to subcarriers based on subcarrier assignment information obtained from subcarrier level sensing. Each subcarrier is modulated in phase and amplitude by the N parallel data streams which has a lower data rate. Figure 2.6 illustrates the OFDM transmission process that occurs at both the transmitter and receiver. In more detail, the principle of operation of OFDM systems is as follows: On the transmitter side, the binary serial data input is first channel coded. Application of channel coding on the input data ensures that the BER (bit error rate) is kept to the lowest value thereby improving the system performance. It is also used to lower the peak-to–average power ratio (PARP) as proposed in. The encoded data is interleaved; this is assigning adjacent data bits to nonadjacent bits to reduce the burst symbol error. The bits are then mapped into symbols depending on the type of modulation used; QPSK, 16/64 QAM or BPSK. The data symbols are used to modulate each sub-carrier in phase and amplitude, the number of symbols used depends on the type of modulation process.

The serial modulated data streams are changed to parallel and fed into the Inverse Fast Fourier Transformation (IFFT) which transforms the data stream from frequency domain to time domain. The original serial data is the effective Fourier Transform of multitone data signal and an inverse Fourier generator bank of coherent demodulators [31]. It can be seen that OFDM scheme is a complete digital modem built to perform Fast Fourier Transformation (FFT) and IFFT (the implementation of Discrete Fourier Transform (DFT) and Inverse Discrete Fourier Transform (IDFT)). It eliminates subcarriers (SC) oscillators and coherent demodulators used in FDM, thereby reducing the cost of the OFDM processor. When the signal is in the time domain, the DFT is used to compute its samples in the frequency domain. T is used to represent the sampling period, and N represent the number of points to be sampled as related to the frequency domain. The DFT basic frequency can be given as . An integer multiple of the basic frequency is the component of each frequency for each subcarrier. According to Nyquist sampling theorem, time domain signal sampling can generate a maximum frequency that is represented by . The center of the DFT point is where the carrier frequency is located. The operation carried out by IDFT is the opposite of DFT operation. The signal defined in frequency domain is converted to the time domain.

The IDFT time signal has a time duration which is equivalent to NT. In essence, both are a reversible pair. DFT and IDFT can be used at transmitter and receiver side respectively. The parallel output of IFFT is converted to serial because the input of IFFT is made up of N samples (the symbols for the different subcarriers), therefore the output of IFFT also consist of N values. These N values need to be transmitted one after the other as temporal samples [39]. The output time-domain OFDM symbol is extended by a cyclic prefix (CP). Cyclic prefix (CP) is a special type of guard; it is a duplicate of the

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last part of the entire OFDM symbol which is pre-fixed to the transmitted symbol. The CP length TG is such that it is selected to be longer in length than the delay spread experienced by radio channel, , i.e., . Thus, the essential component of the signal received is perceived as the OFDM transmitted symbol convolved with the channel impulse response. The neighbouring OFDM symbols partially overlap due to dispersion. The cyclic prefix function is to preserve orthogonality among the subcarriers resulting in zero ICI. This only occurs when the CP length is maintained and is more than the delay spread. Also, within the FFT interval, an integer number of cycles must be produced by the delayed copy of the OFDM symbol. This is established by the cyclical extended portion of the OFDM symbols. An integer number of cycles are produced by individual sub-carrier when an OFDM symbol with no CP attached and is equivalent to the size of the IFFT employed to produce the signal.

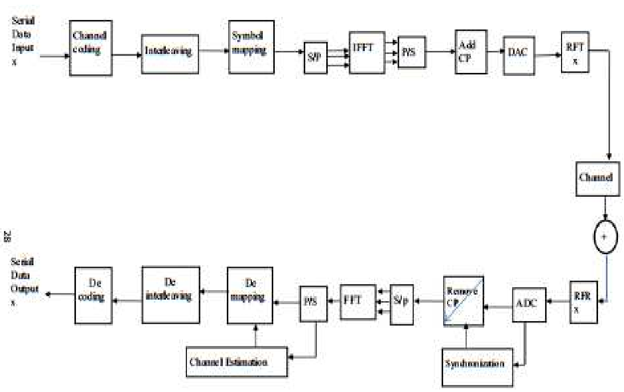

Figure 2.6: Block diagram of a baseband OFDM transceiver

The end-to-end placement of transmitted symbols copies lead to uninterrupted signal transmission with no disruption at ends. Addition of CP makes the system to have a longer symbol time because the end of the symbol is copied and appended to it in front. Figure 2.7 shows an OFDM system with the insertion of a cyclic prefix. The symbol period in the samples is represented by TS, which is the aggregate symbol period TS= TG + TFFT, where CP length in samples is given as TG and the estimated size of IFFT is used by TFFT to produce an OFDM signals. CP of not more than 10 per cent of the symbol's duration is employed thus leading to signal to noise ratio loss of 0.5 to 1 dB. The analogue OFDM symbol can be obtained using the digital-to-analog converter (DAC) before the signal is amplified and converted to the desired centre frequency before transmission in the frequency selective fading channel. Power consumption, complexity and cost, must be considered before using DAC.

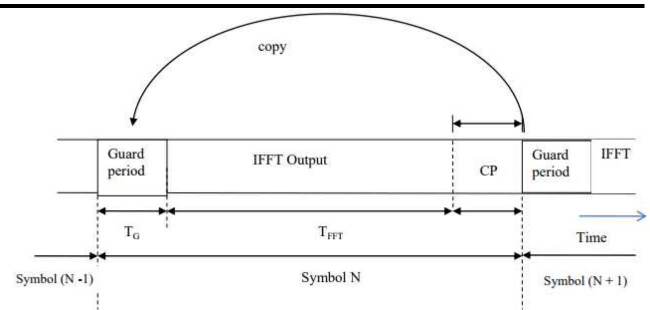

Figure 2.7: Cyclic prefix fitting.

The other part of the OFDM transceiver is the receiver end of the system where the transmitted symbols are passed through the analog to digital converter, removal of CP and at this point synchronization process takes pace such as symbol, carrier, frequency and sampling frequency synchronization. Serial to parallel conversion occurs to allow the FFT operation process which converts the time domain signal to the frequency domain representation. Channel estimation is also done either in the time domain or frequency domain and the information is used to detect or rececover the transmited data.

3.2.3 Advantages of OFDM systems [44]

- The spectral overlapping among sub-channels serve as a means to cancel equalization,combating impulsive noise, and making complete use of the available bandwidth [31].
- It is robust against frequency selective fading channel because the data is split into N parallel symbols. Each in the transmitted symbol has a bandwidth narrower than the bandwidth of sub-channel; hence OFDM experiences only flat fading.
- Narrowband interference has little effect on few subcarriers in OFDM because of OFDM is resistant to it.
- It uses cyclic prefix to eliminate ISI and ICI.
- Very large scale integration (VLSI) technologies have facilitated adaptation of OFDM by overcoming problems of high-speed cached-memory architecture [41]
- Impulsive parasitic noise and co-channel interference are avoided
- The use of steep band pass filter is removed due to spectral overlap among subcarriers. Orthogonality will ensure the separation of subcarriers at the receiver.
- There is an immunity embedded in OFDM which effectively deals with delay spread, a channel parameter that need attention in wireless communication.
- Multi-taps equalizer/detector is not used in OFDM receiver, thus reducing complexity.
- OFDM systems are cost effective and computationally efficient implementing modulation and demodulation with FFT techniques.
- It is less sensitive to sample timing offset compared to the single carrier system. A single carrier system is more sensitive to sample timing offset than OFDM

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3.2.4 Applications of OFDM

A Simple list of application include [38, 39]

- Digital Audio Broadcasting (DAB) is a standard in the European market and OFDM is used for the basis of this standard.
- Asymmetric Digital Subscriber Line (ADSL), High-speed Digital Subscriber Line (HDSL), and Digital Video Broadcasting (DVB) are all global standard that exploit OFDM for their basis.
- OFDM technology is used in the current wireless point-to-point and point-to-multipoint configurations that is Wireless Local Area Networks. IEEE 802.11a was published as a supplement to
- IEEE 802.11 standard and the use of OFDM in the 5GHz band was outlined.

3.3 Interleave-Division Multiple Access (IDMA)

system In order to circumvent the problem of high complexity in MUD associated with CDMA systems, an interleaved-based multiple access scheme was recently studied by Ping et al [17] around 2002, proposed and investigated as a multiuser scheme in 2003. It was an extension and special type of well recognized multiple access communication technique CDMA. It has low complexity at the receiver, capable of asynchronous transmission [56], robust against multipath, offers diversity against fading, has high spectral efficiency and improved performance compared to CDMA. A spreading code that is unique is assigned to each user for encoding the information-bearing signal in CDMA systems. The correlation property of the spreading sequences is used to decode the desired signal at the receiver. As the number of users in the system increases, the performance of CDMA degrades rapidly due to multiple access interference (MAI). In order to accommodate more users in the system, there is need for complex techniques to cancel interference which are difficult to implement. IDMA is a promising system that inherits most of CDMA associated advantages such as: mitigation of interference from other cell users in particular and diversity against fading. The various difficulties embedded with CDMA systems are overcome by IDMA. More users are accommodated and its receiver's structure is simple because a very simple and effective chip-by-chip (CBC) and turbo-like iterative MUD strategy is used. The MUD is more relevant and produces efficient detection when the number of users in the system is large. The IDMA chip-by-chip detection is facilitated with interleaver processing to ensure that the codes are spread out and adjacent chips are uncorrelated, thereby preventing strong signals from other users and ensure it does not interfere with the decoding process of a specific user. CBC has a very low computational cost, and independent on the users number unlike in the CDMA, OFDM-CDMA and OFDMA schemes, it treats both MAI and ISI effectively and the required quality of service is not compromised. The various user-signals are separated at the receiver using the unique interleaver assigned to each. Thus it is named Interleave-Division Multiple Access (IDMA). IDMA scheme dedicates its entire bandwidth to coding using a low rate code for forward error correction (FEC), thus combining coding and spreading operation. According to [10], when the entire bandwidth is dedicated to coding, a multiple access channel (MAC) with perfect capacity is obtainable, hence IDMA has a larger coding gain.

3.3.1 The Transmitter Structure

The component of the conventional IDMA structure constitute the transmitter and receiver (transceiver) part as shown in Fig 2.9. Taking into consideration the transmitter part, with U th number of users transmitting data simultaneously, the concurrent input information bit from diverse users denoted by useru is first encoded by low rate forward error correction (FEC) code, thus generating a coded sequence where N is the subcarrier length.

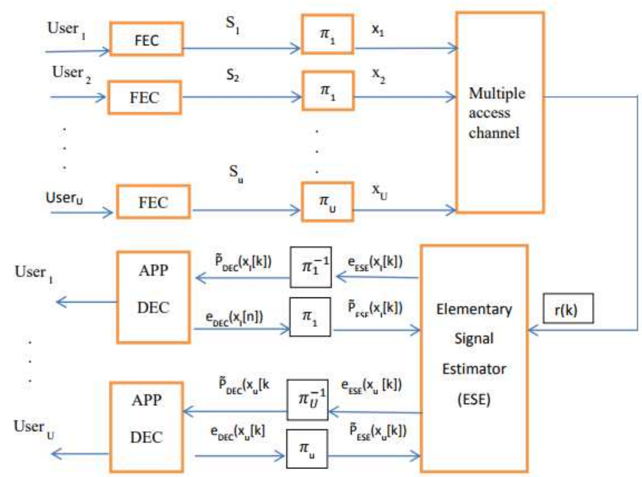

Figure 2.9: IDMA transmitter and receiver structure.

3.3.2 The Receiver Structure

According to, the receiver structure of IDMA is unique and sub-optimal in nature because it avoids the multiple access and FEC code constraint. The IDMA part of the receiver structure comprises of the Elementary Signal Estimator (ESE) and a posteriori probability decoders (DECs).

Multipath channel and a coarse soft-in-soft-out chip by chip (CBC) estimation detection is carried out for the initial eradication of interference among simultaneous users in the system. According to, the computational cost required for CBC is small and complexity involved is low. At the receiver, the estimated probabilities values of the transmitted chips x(k) are the outputs of the ESE. They are arranged separately with respect to simultaneous users, and later sent to the APP DECs. The ESE-APP DECs operation is iterative and it process its extrinsic information in a turbo-like manner. The output from ESE is fed to the APP DECs which perform APP decoding to remove FEC code constraint. The refined probabilities of the transmitted chips are fed back into ESE. The output of the ESE is improved.

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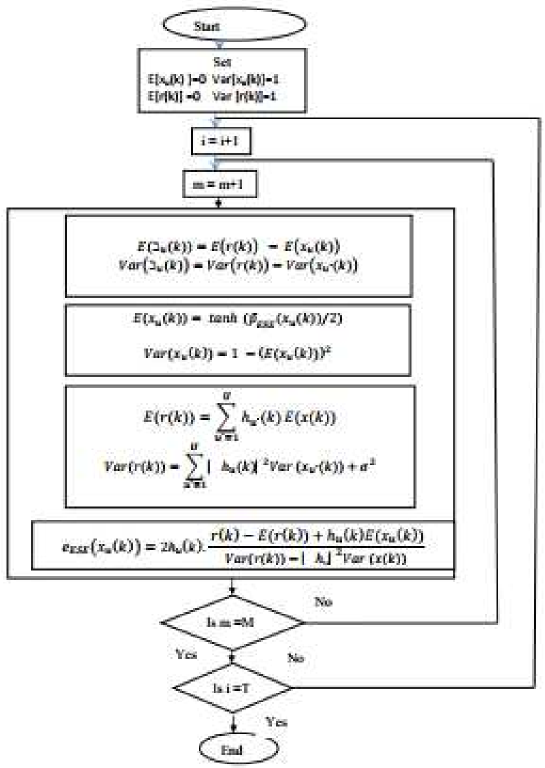

Figure 2.10: Chip-by-chip detection flow chart for IDMA system

3.4 Multiple access techniques comparison

The table below shows the performance comparison between IDMA system and other multiple access schemes. This indicates the potential of IDMA scheme for practical use according to.

Table 2-1: Comparison of different multiple access scheme.

	TDMA	FDMA	OFDMA	CDMA	IDMA
Multi-user separation by	Time slot	Frequency	Orthogonal frequency	Signature sequence	Interleaver
Methods to combat ISI	Equalization	Cyclic prefix [63]	Cyclic prefix	Rake receive	CBCdetection
High single-user rate can be achieved with		High order modulation		Difficult	Superposition coding rate
Elimination of Intra-cell interference		Not required			Iterative Multi-User-Detection
inter-cell interference		Sensitive		Mitigated	
Synchronization required		Needed		Not required	

Comparative analysis among the various multi users is shown in Table 2.1. The table shows the differences in operation of the MAS. The use of reduced spreading factor or adopting multicode CDMA lead to high data rates achievement in CDMA systems. In contrast, FEC code allotment with high coding rate lead to high data rate transmission in IDMA system. CDMA and IDMA system both utilise MUD to mitigate interference. However, CDMA is limited by the number of users and the high cost, while IDMA is not. In a similar manner, IDMA uses the CBC detection algorithm to combat intra-cell interference. The advantage is that the complexity associated with CBC does not depend on the number of users. It achieves multi-user gain in the case of each user with a rate constraint. It supports asynchronous transmission; therefore no complicated synchronization is required on the transmitted data while frame synchronization is required to maintain orthogonality in schemes like TDMA, FDMA, and OFDMA.

4. OFDM-IDMA CHANNEL MODEL AND ESTIMATION

4.1 Channel Modelling

The transfer characteristic of the physical medium which are derived from the observed characteristic of the received signal and the sum of the multipath components impinging at the receiver can be represented mathematically and is referred to as the channel model. Figure 3.1 represent the physical representation of the channel.

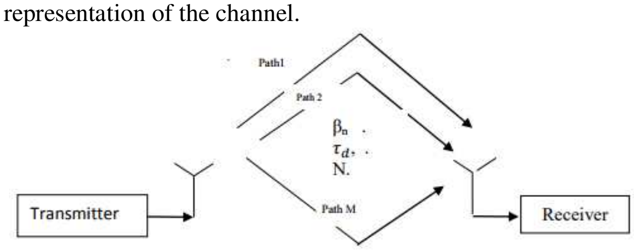

Figure 3.1: Multipath fading channel.

4.2 Comparison of the Estimation Methods

In this section, we present the comparison of the simulation results for the 3 different estimation algorithm proposed for OFDM-IDMA systems. The Mean Square Error (MSE) of each algorithm was investigated to determine the best performance algorithm. The computer simulations show the performances of the MMVE, the modified MMSE algorithm using the finite length impulse response and the SMVE using the structured correlation. The MMSE algorithm is referred to as Minimum Mean Value Estimator (MMVE), the modified algorithm is referred to as Modified Minimum Mean Value Estimator (MMMVE) and the last which makes use of structured correlation is referred to as Simplified Mean Value Estimator (SMVE). This section present the performance of the OFDMIDMA system model in terms of its MSE versus SNR performances for different number of users. The system model remains as OFDM-IDMA model employing QPSK modulation technique and in a Rayleigh fading multipath channel for 16 paths and operates at carrier frequency 2 GHz. The MCIDMA system model used 32 input data bits, spreading code of length 8 for different users. The number of sub-carriers is 64, and for the convenience, all the users in the simulations are assumed to have equal number of sub-carriers. The simulation results presented (BER and MSE) are documented for a Rayleigh channel with normalised frequencies of fDn = 0.0045, fDn = 0.1085 and the corresponding mobile speeds of 5km/h and 120km/h, respectively.

5. CONCLUSION

In mobile communication systems, there is a big increase in the demand for spectrum usage. An efficient usage of the scarce spectrum is obtained using Multicarrier IDMA systems. This thesis is devoted to the investigations of channel estimation in an OFDM-IDMA scheme on an uplink multipath fading channel environment. In this thesis a multicarrier multiple access communication technique namely, MC-IDMA is developed. The advantages exhibited by this system (MC-IDMA) are inherited from other multiple access techniques with additional benefits. Interleavers are the only means of users separation at the receiver and the entire bandwidth expansion is devoted to forward error correcting codes. The system used is a combination of OFDM and IDMA. The system used is designed in a way that the CP length of the OFDM component used is longer compared to the length of the delay spread. Thus Intersymbol Interference (ISI) is removed and its iterative IDMA with its CBC detection algorithm overcomes multiple access interference (MAI) efficiently in the system. Comprehensive work is carried out on MC-IDMA system. The system is assumed to be perfectly synchronised. However, due to the frequency selective and time-varying nature of the radio channel, channel estimation be done. An efficient channel estimation algorithm is proposed. The channel estimation using a linear minimum mean square error (MMSE) based algorithm is used for the estimation of the system. The performance and complexity of this algorithm on MC-IDMA is investigated in a Rayleigh fading multipath channel. The bit error rate is evaluated to predict the performance of channel estimation of MC-IDMA system using the MMSE algorithm. The performance is also evaluated in terms of the number of users in the system. Simulation results in terms of BER and MSE show that the MMSE based algorithm performs better irrespective of the number of users in the system compared to LMS estimation.

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