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A Review of Channel Estimation Techniques in MIMO-OFDM LTE System

***Shivangi Jain*[1] *and Prof. Amrita Khera*[2]**

[1]*Resaerch Scholar, Department of Electronic and Communication Engineering, Trinity Institute of Technology & Research, Bhopal (Madhya Pradesh), INDIA*

[2]*Professor, Department of Electronic and Communication Engineering, Trinity Institute of Technology & Research, Bhopal (Madhya Pradesh), INDIA*

(Corresponding author: Shivangi Jain)

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ABSTRACT: Long Term Evolution (LTE) of the Universal Mobile Telecommunication System (UMTS) also known as the Evolved Packet System (EPS) is a transilient move in the field of mobile communications. Such a revolution is necessitated by the unceasing increase in demand for high speed connections on networks, low latency and delay, low error rates and resilience because modern users and network applications have become increasingly dependent on these requirements for efficient functionality and performance. Third Generation Partnership Project Long Term Evolution (3GPP LTE) promises high peak data rates for both uplink and downlink transmission, spectral efficiency, low delay and latency, and low bit error rates.

Keywords: Long Term Evolution, UMTS, Third Generation Partnership Project, MIMO, OFDM, channel estimation.

I. INTRODUCTION

LTE (Long Term Evolution) is a new high performance air interface for cellular mobile communication systems developed by the 3rd Generation Partnership Project (3GPP), collaboration between groups of telecommunications associations. LTE represents a major advance in cellular technology. It is the next step in a continuous move to wider bandwidths and higher data rates. LTE is expected to be the next major standard in mobile broadband technology that promises to enhance the delivery of mobile broadband services through a combination of very high transmission speed, more flexible and efficient use of spectrum, and reduced packet latency. The demand for high speed and widespread network access in mobile communications increases everyday as the number of users increases and applications are constantly developed with greater demand for network resources. As a result of this trend, mobile communications has experienced significant developments within the last two decades which is the result of tremendous research that have been carried out. The 3rd Generation Partnership Project Long Term Evolution (3GPP LTE) is the system that marks the evolutionary move from third generation of mobile communication i.e. Universal Mobile Telecommunication System (UMTS) to fourth generation mobile technology. The first work on LTE of the 3GPP UMTS specifications involving the completion of its feasibility studies. This release also included further improvements on High Speed Packet Access (HSPA). Specification of LTE and System Architecture Evolution (SAE) constitutes the main of the 3GPP UMTS specifications. As at the time of writing, work is currently in progress for the enhancement of LTE which is featured of the 3GPP UMTS specifications and named LTE-Advanced (LTE-A). A comprehensive summary of the evolutionary trend of the 3GPP UMTS is given in Under the 3G/UTRAN (Universal There are four principal media for transmission of high-speed data to and from customer premises [3] DSL: Digital Subscriber Loop. It mainly uses Discrete Multi-tone (DMT) technique that is widely applied to xDSL. Coaxial cable: originally installed for unidirectional (“downstream”) transmission of television, but increasingly being used for bi-directional data transmission. Optical fiber: it is originally used for very high-speed trunk transmission, but now being implemented in FTTH (Fiber to the Home), FTTE (Fiber To The Exchange) and FTTN (Fiber To The Neighborhood). Wireless: use of multicarrier modulation becomes an attractive solution in wireless, high data speed transmission system. The DMT technique is a version of MCM in the base band, and OFDM (orthogonal frequency division multiplexing) technique is a special case of MCM in the pass band. In the discussion below, if not specified, all MCM means multicarrier modulation in the pass band.

Multicarrier Modulation has been called by many names – orthogonally multiplexed Quadrature Amplitude Modulation, orthogonal FDM, and dynamically assigned multiple QAM [4]. It is greatly developed to practical application as signal processing techniques (mainly digital) have improved over the years. An MCM signal can be processed in a receiver without the enhancement of noise or interference and the long symbol time used in MCM produces a much greater immunity to impulse noise and fast fades [4]. The following sections will have a look backward to the history of MCM, the key techniques used in MCM, the current applications of MCM and finally look forward to the future of MCM. This paper will also investigate the components with related products used in the modulation process, and some wireless LAN standards. MCM was implemented in high frequency military modems in the '60s as well as in some telephone modems [8]. Orthogonal multiplexed QAM [3] it was used in FDM telephony group-band modems and its main

A. Channel Coding in LTE

The preferred channel coding for LTE is turbo coding. This selection in favour of turbo coding is based on few reasons UMTS release 6 HSPA also uses turbo code. For backward compatibility reasons, dual-mode LTE terminals will need to implement turbo code therefore some decoding hardware can be reused. To avoid increased implementation complexity as the terminals have to support two different coding schemes. There are some major channel coding schemes used in the LTE system Turbo coding: Chiefly used for large data packets which common occurrence in downlink and uplink data transmission, paging and broadcast multicast (MBMS)transmissions, in other words, for Uplink shared channel (UL-SCH), downlink shared channel (DL-SCH), Paging Channel (PCH) and Multicast Channel MCH [2, 10]. Rate 1/3 convolution coding mainly used for downlink control and uplink control as well as broadcast control channel.

B. Wireless Channel Characteristics

Development of high-speed wireless LANs (WLANs) has changed the philosophy for potential bandwidth demanding multimedia applications. They no longer need to rely on an access to the high-speed wired networks but can he easily accessed in locations where every user having a compatible wireless modem can use the network. An example of such a scenario can be a lecture theatre [17] where not only the teaching material is distributed to student's notebook PCs via wireless network but also their class test solutions are submitted via the same way. A popular type of the high-speed W LANs currently being deployed is one complying with IEEE 802.11a

C. Channel Estimation

Demonstrated Medium Access Control (MAC) layer performance of different channel estimation techniques in UTRAN LTE Downlink. This paper uses an accurate LTE MAC layer simulator to perform a complete downlink LTE performance study. Results compare different channel estimation techniques showing significant difference among them, most of all regarding the robustness of the estimator against errors. Finally, LTE system performance assessment is presented employing a realistic channel estimator.

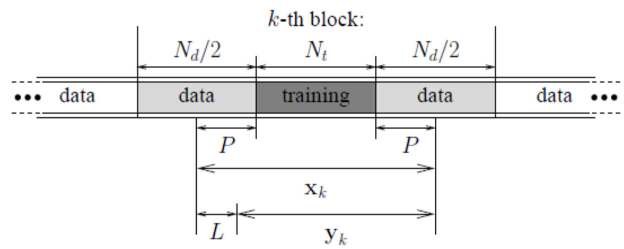

Fig. 1. Partitioning of the transmitted symbol vectors into blocks, each consisting of N_t training and N_d data symbol vectors.

The channel estimation algorithms based on least square (LS) and linear minimum mean square error (LMMSE) criteria, together with channel interpolation based on piecewise linear interpolation and DFT based interpolation are studied. By in terms of Mean Square Error (MSE) and uncoded BER, this paper concludes that the channel frequency responses of pilot tones are estimated by using LS estimator, and the channel frequency responses of data tones are interpolated by DFT based interpolation method is appropriate for the downlink of 3GPP LTE systems

D. 3G or The Third-Generation (WCDMA in UMTS, CDMA2000 and TD-SCDMA)

In EDGE, high-volume movement of data was possible, but still the packet transfer on the air- interface behaves like a circuit's switch call. Thus part of this packet connection efficiency is lost in the circuit switch environment. Moreover, the standards for developing the networks were different for different parts of the world. Hence, it was decided to have a network which provides services independent of the technology platform and whose network design standards are same globally. Thus, 3G was born [4]. The International Telecommunication Union (ITU) defined the demands for 3G mobile networks with the IMT-2000 standard.

An organization called 3rd Generation Partnership Project (3GPP) has continued that work by defining a mobile system that fulfills the IMT-2000 standard. In Europe it was called UMTS (Universal Terrestrial Mobile System), which is TSI- driven. IMT2000 is the ITU-T name for the third generation system, while cdma2000 is the name of the American 3G variant. WCDMA is the air- interface technology for the UMTS. The main components includes BS (Base Station) or nod B, RNC (Radio Network Controller), apart from WMSC (Wideband CDMA Mobile Switching Centre) and SGSN/GGSN. 3G networks enable network operators to offer users a wider range of more advanced services while achieving greater network capacity through improved spectral efficiency. Services include wide-area wireless voice telephony, video calls, and broadband wireless data, all in a mobile environment. Additional features also include HSPA (High Speed Packet Access) data transmission capabilities able to deliver speeds up to 14.4 Mbps on the downlink and 5.8 Mbps on the uplink. The first commercial 3G network was launched by NTT DoCoMo in Japan branded FOMA, based on W-CDMA technology on October 1, 2001 [2]. The second network to go commercially live was by SK Telecom in South Korea on the 1xEV-DO (Evolution-Data Optimized) technology.

E. Multicarrier Technique

OFDM is considered a multicarrier technique as it converts the serial data bits to transmitted symbols $X\ k$ that are either M-PSK or M-QAM mapped then dividing them into blocks of length N that are used as input to an Inverse Fast Fourier Transform (IFFT) stage to modulate them onto N-orthogonal subcarriers, constructing a time-domain samples $x\ n$, given by $x\ n\ =1N\ X\ k\ ej2\pi nkNN-1k=0\ ,n,k=0:N-1$ …(1)

Where, k is a subcarrier index used at the transmitter side and each frequency $2\pi kN$ represents a subcarrier which is orthogonal to the other subcarriers.

F. Orthogonality Concept

Two signals are orthogonal if their inner product is zero as, $cos\ 2\pi knN\ *cos\ 2\pi kmN\ =0,n\neq m$ …(2).

In frequency domain, this means that, the spectrum of each subcarrier has a null at the centre of the spectrum of other subcarriers. This is achieved in the OFDM system by the help of the IFFT stage as shown in equation. To prevent the transmitted OFDM symbol from Inter Symbol [16] Interference (ISI), a guard interval with length Ng is then added before transmission. This guard interval may contain a copy of last Ng samples of the IFFT output $x\ n$, where the transmitted OFDM symbol $s\ n$ is then takes the form,

$s\ n = x\ n+N\ if\ -Ng\leq n<0x\ n\ if\ 0\leq n\leq N-1$ …(3)

The guard interval in this case is named Cyclic Prefix (CP). CP preserves the orthogonality of the OFDM signal, permitting simple equalization process at the receiver side.

G. Multipath Propagation

In case of multipath channels, channel state information (CSI) is required at the receiver side to equalize for its effect. In this case, the transmission of known pilot symbols $XP\ k$ may be added to the transmitted signal at the transmitter side for the purpose of multipath channel estimation. After converting from parallel to serial, the signal is up-converted on a Radio Frequency (RF) carrier signal fc and then transmitted through a multipath channel exposed to fading and Additive White Gaussian Noise (AWGN) effects. In multipath channels, the signal is received from v-paths. The operation can be modeled as linear convolution operation [8] as the multipath channel can be modeled as a finite impulse response filter. This linear convolution operation is simply a multiplication in frequency domain by the help of Discrete Time Fourier Transform (DTFT). But the continuity of the signal in frequency makes the computations of the multiplication operation to be impossible on digital computers [8]. Hence, DTFT cannot be used to perform linear convolution operation and discrete signals are required to be used instead of continuous signals. Therefore, FFT which has the property of circular convolution is used instead to obtain such a linear filtering operation. So, if the output of the linear convolution operation was equivalent to the circular convolution operation, the equalization process at receiver side can then be simply obtained using one tap frequency domain equalizer. If the orthogonality concept is maintained, this operation can be achieved in the OFDM system

H. OFDM Receiver

The received signal is first down converted from the fc using a local oscillator then converted from serial to parallel before removing the CP part and then converted to the frequency domain using a FFT stage. The frequency domain received pilots $YP\ l$ are extracted to estimate the multipath channel's coefficients $H\ l$. In this paper, the DFT-based Least Square (LS) channel estimation [9] is used, where,

$H\ DFT-LS\ l = YP\ l/XP\ k$ …(4)

These channel estimated coefficients $H\ DFT-LS\ l$ are then used by a frequency domain equalizer to equalize for the channel's effects and get the equalized frequency domain data symbols $X\ l$ which is then de-mapped to obtain the received data serial bits.

I. Intercarrier Interference Problem

In the presence of mobility, a Doppler frequency is generated depending on the velocity vel and the fc used, where a maximum Doppler frequency fD is presented as,

$$fD=\pm vel*fcc \quad \ldots(5)$$

Where c is the velocity of light in the air. Taking the instability of the local oscillators used to generate the RF carrier frequency into considerations $fosc$ that is ±10PPM (Parts Per Million) of the carrier frequency [10], a total CFO Δf is generated, where, $\Delta f = fosc+fD$. This total CFO, Δf causes the receiver to sample away from the centers of the subcarriers as shown in Figure destroying the orthogonality and resulting in ICI between the subcarriers. This leads to system performance degradation.

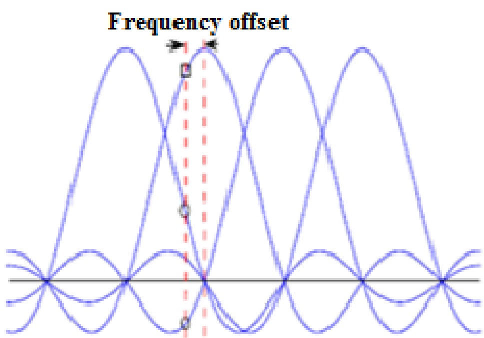

Fig. 2. ICI due to CFO in the OFDM spectrum.

II. CONCLUSION

The last few years have witnessed a phenomenal growth in the wireless industry. The ever increasing demands of users have triggered researchers and industries to come up with a comprehensive manifestation of the up-coming fifth generation (5G) mobile communication system. As the history of mobile communications shows, attempts have been made to reduce a number of technologies to a single global standard. The first generation (1G) has fulfilled the basic mobile voice, while the second generation (2G) has introduced capacity and coverage. This is followed by the third generation (3G), which has quest for data at higher speeds to the fourth generation (4G). Fifth Generation (5G) will bring higher data transfer speeds (reaching up to few gigabits per sec) and other high quality services. Estimator is a measure of its performance. In this paper a maximum likelihood derivation of the RP technique is presented. The CRLB derivation is also presented in this paper showing the parameters affecting its performance of the RP technique as an ICI reduction technique in multicarrier systems.

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