A Brief Survey of Amplification Effects on MIMO-OFDM Systems

Vikrant Verma[1], Asst. Prof. Nehul Mathur[2]

[1]*Mtech Scholar,* [2]*Guide*

Department of Electronics and Communication Engineering, BIT, Bhopal

Abstract - In wireless communication system OFDMis widely used in multi-carrier modulation schemes. Modulation of all sub-carriers is orthogonal to each other in OFDM systemincrease the bandwidth efficiency of the system. The transmission frequency of OFDM channel changes over in the group of narrow band fading fading channel, one channel over each sub-channel.OFDM modulation and de-modulation is executed effectively by inverse discrete Fourier transform and discrete Fourier transform at the transmitter and receiver individually. For high speed wireless data transmission orthogonal frequency division multiplexing is a prominent strategy but the performance of OFDM framework is extremely sensitive to carrier frequency Offset (CFO), which cause inter-carrier interference (ICI). In this examination presents an extensive examination of multi-user MIMO-OFDM system nonlinear amplification effects.

Keywords- Wireless Communication, Inter-carrier Interference (ICI), OFDM, MIMO-OFDM, Nonlinear Amplification

I. INTRODUCTION

Radio transmission has allowed people to communicate without any physical connection for more than hundred years. When Marconi managed to demonstrate a technique for wireless telegraphy, more than a century ago, it was a major breakthrough and the start of a completely new industry. May be one could not call it a mobile wireless system, but there was no wire! Today, the progress in the semiconductor technology has made it possible, not to forgot affordable, for millions of people to communicate on the move all around the world.

The Mobile Communication Systems are often categorized as different generations depending on the services offered. The first generation comprises the analog frequency division multiple access (FDMA) systems such as the NMT and AMPS (Advanced Mobile Phone Services). The second generation consists of the first digital mobile communication systems such as the time division multiple access (TDMA) based GSM (Global System for Mobile Communication), D-AMPS (Digital AMPS), PDC and code division multiple access (CDMA) based systems such as IS-95. These systems mainly offer speech communication, but also data communication limited to rather low transmission rates. The third generation started operations on 1st October 2002 in Japan.

During the past few years, there has been an explosion in wireless technology. This growth has opened a new dimension to future wireless communications whose ultimate goal is to provide universal personal and multimedia communication without regard to mobility or location with high data rates. To achieve such an objective, the next generation personal communication networks will need to be support a wide range of services which will include high quality voice, data, facsimile, still pictures and streaming video. These future services are likely to include applications which require high transmission rates of several Mega bits per seconds (Mbps).

In the current and future mobile communications systems, data transmission at high bit rates is essential for many services such as video, high quality audio and mobile integrated service digital network. When the data is transmitted at high bit rates, over mobile radio channels, the channel impulse response can extend over many symbol periods, which leads to inter symbol interference (ISI). Orthogonal Frequency Division Multiplexing (OFDM) is one of the promising candidates to mitigate the ISI. In an OFDM signal the bandwidth is divided into many narrow subchannels which are transmitted in parallel. Each subchannel is typically chosen narrow enough to eliminate the effect of delay spread. By combining OFDM with Turbo Coding and antenna diversity, the link budget and dispersive-fading limitations of the cellular mobile radio environment can be overcomed and the effects of co-channel interference can be reduced.

In Figure 1.1: the modulator, the channel and the demodulator. The main question is how to design certain parts of the modulator and demodulator to achieve efficient and robust transmission through a mobile wireless channel. The wireless channel has some properties that make the design especially challenging: it introduces time varying echoes and phase shifts as well as a time varying attenuation of the amplitude (fade).

Orthogonal Frequency Division Multiplexing (OFDM) has proven to be a modulation technique well suited for high data rates on time dispersive channels. There are some specific requirements when designing wireless OFDM systems, for example, how to choose the bandwidth of the sub-channels used for transmission and how to achieve reliable synchronization. The latter is especially important in packet-based systems since synchronization has to be achieved within a few symbols.

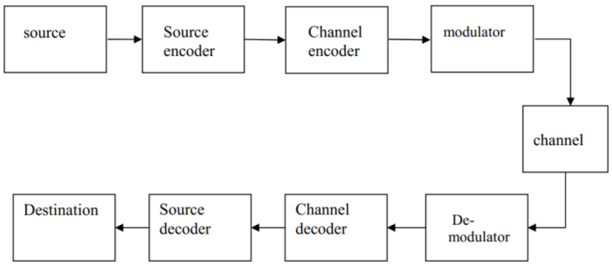

Figure: 1.1 Functional Block in a Communication System.

In order to achieve good performance the receiver has to know the impact of the channel. The problem is how to extract this information in an efficient way. Conventionally, known symbols are multiplexed into the data sequence in order to estimate the channel. From these symbols, all channel attenuations are estimated with an interpolation filter.

II. MIMO-OFDM

Since its inception, wireless communications technology has continued to evolve. Digital succeeded analog in wireless communications for reasons related to resource (e.g. bandwidth) economy, flexibility, cost, etc. For improved quality of service (QoS), such as throughput, data rate and bit-error ratio (BER), different channel coding and multiple access schemes have been investigated by researchers based on design merits.

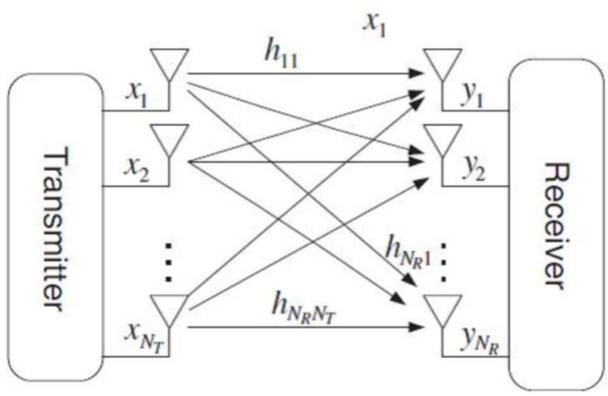

Fig.2.1 N_R X N_T MIMO System

Recently, an enhanced FDM technology, orthogonal frequency division multiplexing (OFDM) and multiple accesses (OFDMA), has dominated the market as the air-interface protocol for wideband systems, including those employing multi-antenna technology. The commonest examples include wireless fidelity (WiFi), world-wide interoperability for microwave access (WiMAX), digital audio/video broadcasting (DAB/DVB) and long-term evolution (LTE).

MIMO-OFDM is a combination of MIMO (multi input multi output) communication with OFDM. MIMO-OFDM converts a frequency selective MIMO channel into multiple paraller flat fading MIMO channels.

n MIMO frequency selective channel ISI occurs between current and previous transmitted vector, so MIMO-OFDM system one need to perform the IDFT or IFFT opreration at each transmitted antenna. MMSE (minimum mean squared error) or ZF (zero forcing) receiver are uesd for the receiving MIMO-OFDM symbols.

Spatial multiplexing yields a linear (in the minimum of the number of transmit and receive antennas) capacity increase, compared to systems with a single antenna at one or both sides of the link, at no additional power or bandwidth expenditure. The corresponding gain is available if the propagation channel exhibits rich scattering and can be realized by the simultaneous transmission of independent data streams in the same frequency band. The receiver exploits differences in the spatial signatures induced by the MIMO channel onto the multiplexed data streams to separate the different signals, thereby realizing a capacity gain.

III. LITERATURE REVIEW

P. Aggarwal, F. Jabin and V. A. Bohara,[1] In this examination, author evaluate the performance of carrier aggregated dual band (DB) multi- user (MU) multi-input-multi- output (MIMO) orthogonal frequency division multiplexing (OFDM) system in the presence of transmitter nonlinearity and frequency-selective fading channels. As a benchmark, the performance has been compared with a linear DB MU-MIMO-OFDM system which employs a conventional transmits preprocessing technique to mitigate the inter-user interference. A two-dimensional (2D) memory polynomial (MP) is considered to model the transmitter nonlinearity. Author show that transmitter nonlinearity leads to nonlinear interference in a DB MU-MIMO- OFDM system which can not be eliminated by the conventional transmit preprocessing techniques. As a consequence, there is an irreducible error floor which degrades the performance of the nonlinear DB MU-MIMO-OFDM systems. Author has also shown that the irreducible error floor is the function of number of aggregated bands as well as number of users present in the system. The impact of number of bands and users has been shown by comparing the symbol error rates of a nonlinear single band (SB) MU- MIMO-OFDM system vis-a-vis nonlinear DB MU-MIMO-OFDM system for a multi-path frequency selective Rayleigh fading channel.

A. Kiayani, V. Lehtinen, L. Anttila, T. Lahteensuo and M. Valkama, [2] In order to provide higher data rates and to improve radio spectrum utilization, 3GPP has introduced the concept of CA in its Release 10 and onward commonly known as LTE-Advanced. The CA technology, particularly when applied in a noncontiguous manner, poses serious design and implementation challenges for radio transceivers, mainly due to the allowed flexibility in the transmitted signal characteristics and the nonlinear RF components in the TX and RX chains. As a consequence, substantial nonlinear distortion may occur that not only degrades the transmitted signal quality but can also affect the concurrent operation of the coexisting receiver when operating in the FDD mode. In this article, the key technical design challenges in terms of linearity requirements for LTE-Advanced mobile terminals are reviewed, and the corresponding self-interference problem related to the potential desensitization of the device's own receiver is highlighted. Then technical solutions to mitigate the self-interference at the RX band due to a nonlinear PA in the transmitter chain are reviewed, with specific emphasis on digital self-interference cancellation methods. As demonstrated through simulation and actual RF measurement examples, the cancellation solutions can substantially mitigate the RX desensitization problem, thus relaxing the RF isolation requirements between the TX and RX chains. Such cancellation methods are one potential enabling technique toward the full exploitation of the fragmented RF spectrum and the CA technology in future LTE-Advanced and beyond mobile networks.

P. Aggarwal and V. Ashok Bohara, [3] this work analyzes the impact of nonlinear high power amplifiers (HPAs) on the multiband carrier aggregated (CA) long-term evolution-advanced (LTE-A) system. It is assumed that the LTE-A system consists of a multi-input-multi-output (MIMO) orthogonal frequency-division multiplexing (OFDM)-based downlink physical-layer architecture. It has been shown that the nonlinear distortion caused by HPAs can be represented in terms of a complex attenuation factor and additive zero means Gaussian “nonlinear" noise. The closed-form generalized expressions of complex attenuation factor and variance of additive Gaussian nonlinear noise are derived that are applicable to any number of aggregated bands with any nonlinearity order and memory depth. From these expressions, the overall performance of a multiband CA-MIMOOFDM system in terms of symbol error rate and error vector magnitude for M-ary quadrature amplitude modulation (M-QAM) has been evaluated. Author also investigates the combined effect of a number of aggregated bands, input-back off, and diversity gain on the performance of a CA-MIMO-OFDM system. It is observed that diversity gain can improve the performance of CA-MIMO-OFDM in low signal-to-noise ratio (SNR) region. However, in the high SNR region, there is no substantial effect of increasing diversity on the performance. A good agreement between the analytical and simulation results in the multipath Rayleigh fading channel validates the theoretical results obtained in this examination.

P. Aggarwal and V. A. Bohara, [4] this investigation analyzes the impact of nonlinear distortion caused by high power amplifier (HPA) on a dual band carrier aggregated multi input multi output (MIMO) orthogonal frequency division multiplexing (OFDM) systems. A two dimensional (2D) general memory polynomial (GMP) has been used to characterize the behavioural model of HPA. The inband and cross modulation distortion, caused by nonlinear HPA on the carrier aggregated MIMO-OFDM system can be modelled in terms of complex phase shift and Gaussian nonlinear noise that distorted the received data symbol. The mathematical expressions for the complex phase shift and variance of Gaussian nonlinear noise have been formulated. Furthermore, this analysis is also augmented to evaluate the overall performance of aggregated MIMO-OFDM system in terms of probability of symbol error for Mary quadrature amplitude modulation (M-QAM) in presence of multi-path Rayleigh fading channel. Simulation results demonstrate the validity of analytically derived expressions.

Y. Hong, T. Wu and L. Chen, [5] In this examination, author reported an adaptive indoor multiple input and multiple output (MIMO) orthogonal frequency division multiplexing (OFDM) visible light communication (VLC) system using a receiver module with angular diversity. In order to improve the capacity of indoor MIMO-OFDM VLC systems, tilted receivers are utilized to increase channel diversity, thus reducing channel correlation. With the help of singular value decomposition-based technique, which decomposes the MIMO VLC channels into independent parallel sub-channels, adaptive resource allocation, namely, bit and power loading, is used for these sub-channels to further improve the proposed system's capacity. Based on a 4 × 4 indoor MIMO-OFDM VLC system, author investigates bit error rate (BER) performance of the proposed adaptive system with different polar angles in two typical indoor scenarios. Numerical simulation results show that with 50-MHz modulation bandwidth, average BER can be improved from 4.97 × 10-3to 1.66 × 10-5and from 1.90 × 10-3to 1.59 × 10-6for the two scenarios, respectively.

I. Iofedov and D. Wulich,[6] The influence of nonlinear power amplifiers (PAs) on the performance of multiple-input multiple-output (MIMO) orthogonal frequency-division multiplexing (OFDM) systems is investigated. A "full" MIMO scheme with transmitters (TX) precoding and receivers (RX) decoding is considered. It is shown, under assumption of high order OFDM and frequency selective channel, that the ratio between the useful signal and the nonlinear distortions is proportional to the number of TX antennas, i.e., the influence of the nonlinear distortions decreases as the number of TX antennas increases. The distortion reduction factor (DRF) is proposed as a performance metric for MIMO-OFDM systems with nonlinear PAs. A general formula for signal to distortion and noise ratio is obtained for the nonlinear PA with memory, described by the Wiener-Hammerstein (WH) model. Special cases of MIMO, such as maximum ratio transmission (MRT) and maximum ratio combining (MRC), are considered. A full agreement between the theoretical and simulation results is obtained. The main contribution of this examination is in a statement that TX processing reduces the effect of nonlinear distortions. This is obtained by novel approach for analysis of the MIMO-OFDM systems with nonlinear PAs with memory.

P. Singhal, P. Aggarwal and V. A. Bohara, [7] this examination presents the theoretical characterization of nonlinear distortion effects on a concurrent multi-band orthogonal frequency division multiplexed (OFDM) signal when passed through a nonlinear high power amplifier (HPA). The behavioural model of HPA considered for theoretical analysis is a 2-D memory polynomial model (MPM), which is a truncated form of the Volterra series. Author show that the inband and cross modulation distortion introduced due to nonlinear amplification of aggregated OFDM signals can be modelled as a complex attenuation factor and Gaussian nonlinear noise that distorted the received data symbol. Generalised expressions for the complex attenuation factor and Gaussian nonlinear noise in Rayleigh multi-path fading channel have been derived. From the derived expressions, received signal to noise ratio and probability of symbol error for each subcarrier is evaluated and illustrated for N band carrier aggregated OFDM system. Simulation results demonstrate the validity of analytically derived expressions.

Table 1: Summary of Literature Survey

SR. NO.	TITLE	AUTHOR	YEAR	APPROACH
1	Nonlinear Amplification Effects on Dual Band Multi-User MIMO-OFDM Systems	P. Aggarwal, F. Jabin and V. A. Bohara,	2018	Evaluate the performance of carrier aggregated dual band (DB) multi- user (MU) multi-input-multi- output (MIMO) orthogonal frequency division multiplexing (OFDM) system
2	Linearity Challenges of LTE-Advanced Mobile Transmitters: Requirements and Potential Solutions	A. Kiayani, V. Lehtinen, L. Anttila, T. Lahteensuo and M. Valkama	2017	In order to provide higher data rates and to improve radio spectrum utilization, 3GPP has introduced the concept of CA in its Release 10 and onward commonly known as LTE
3	On the Multiband Carrier Aggregated Nonlinear LTE-A System	P. Aggarwal and V. Ashok Bohara,	2017	Analyzes the impact of nonlinear high power amplifiers (HPAs) on the multiband carrier aggregated (CA) long-term evolution-advanced (LTE-A) system.
4	Characterization of HPA using two dimensional general memory polynomial for dual band carrier aggregated mimo-OFDM systems,	P. Aggarwal and V. A. Bohara,	2016	This examination analyzes the impact of nonlinear distortion caused by high power amplifier (HPA) on a dual band carrier aggregated multi input multi output (MIMO) orthogonal frequency division multiplexing (OFDM) systems
5	On the Performance of Adaptive MIMO-OFDM Indoor Visible Light Communications	Y. Hong, T. Wu and L. Chen,	2016	Reported an adaptive indoor multiple input and multiple output (MIMO) orthogonal frequency division multiplexing (OFDM) visible light communication (VLC) system using a receiver module with angular diversity
6	MIMO–OFDM With Nonlinear Power	I. Iofedov and D. Wulich	2015	A "full" MIMO scheme with transmitters (TX) precoding and receivers (RX) decoding is

	Amplifiers			considered
7	Nonlinear distortion analysis of multi-band carrier aggregated OFDM signals,	P. Singhal, P. Aggarwal and V. A. Bohara	2015	Nonlinear distortion effects on a concurrent multi-band orthogonal frequency division multiplexed (OFDM) signal when passed through a nonlinear high power amplifier (HPA).

IV. PROBLEM IDENTIFICATION

There is requirement of high data rate transmission in new generation of wireless communication systems so as to satisfy the requirements for multimedia communication. Bandwidth-intensive multimedia applications have supported the advancement of wireless innovation, e.g., mobile TV service through Digital Video Broadcasting (DVB) and wireless remotely coordinating. The new technology needs to solve to empower to enable ubiquitous broadband wireless communications is the integration of wireless LAN (WLAN) and Bluetooth is a big challenge with advanced wireless technology, for example, 3.5G High-Speed Downlink Packet Access (HSDPA), DVB, WiFi, WiMAX, and sensor networks.

The most of the new communication systems uses multi-carrier strategies for transmission and reception of signals, such as Orthogonal Frequency Division Multiplexing (OFDM). Multicarrier schemes are powerful technique for combating multipath fading and empower high data rate transmissions over mobile wireless channels. In order to parallel transmission OFDM system conveys the message data on orthogonal sub-carriers which empowers it to combating the distortion brought about by the frequency-selective channel or equally, the inter-symbol-interference in the multi-path fading channel. In any case, the advantage of the OFDM can be valuable just when the orthogonality is kept up. In the event that the orthogonality isn't adequately justified using any and all means, its execution might be degraded due to inter-symbol interference (ISI) and inter-channel interference (ICI).

V. CONCLUSION

This work reported an extensive survey of literature onnonlinear amplification effects on dual band multi-user MIMO-OFDM systems.In order to exploit fully the benefits provided by OFDM, advanced signal processing techniques are required to cope with several practical issues, e.g., accurate channel estimation, compensation of power amplifier nonlinearities, I/Q mismatch, phase noise, and synchronization. At the same time, implementation complexity should remain low and the PA power efficiency needs to be maximized. The influence of nonlinear amplification in multi-antenna OFDM systems is studied when employing broadband PAs.

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