A Review: OFDM with Diversity Techniques in Wireless Communications

V. Sudha Rani
Assoc professor, ECE Department, Sreenidhi institute of science and Technology, Ghatkesar, Hyderabad, Andhrapradesh, India.

B.L Malleswari
Professor, ECE Department, GNITS, Hyderabad, Andhrapradesh, India.

ABSTRACT
This paper provides a review on OFDM with different diversity techniques in Wireless Communication Systems. A comparative study of OFDM, OFDM-CDMA, OFDM MC CDMA, STBC OFDM CDMA, CI-OFDM (Carrier Interferometry Orthogonal Frequency Division Multiplexing), MIMO-OFDM, MIMO SFBC CI-OFDM (Multiple Input Multiple Output Space Frequency Blocking Code Carrier Interferometry Orthogonal Frequency Division Multiplexing) system is provided. Comparative study is based on various parameters like PAPR, Bit Error Rate, spectral efficiency and channel estimation.

Keywords
Multiple input multiple output channels, OFDM, Broadband wireless access network, channel estimation, preamble, space-time block coding, PAPR, BER.

1. INTRODUCTION
Orthogonal Frequency Division Multiplexing is commonly used for high data rate Wireless Communications, due to its inherent error susceptibility in a multipath environment it has been chosen for several broad band wireless local area networks. OFDM has the property of high-speed transmission and robustness to multipath interference. Code Division Multiple Access is a Spread Spectrum technique that uses neither frequency channels nor time slots. All users in a CDMA system use the same frequency band simultaneously. In CDMA, the narrow band message is multiplied by large bandwidth signal, which is pseudo random noise code. The transmitted signal is recovered by correlating the received signal with the pseudo random code. All users in a CDMA system use the same frequency band simultaneously.

In the early 1990's researchers combined some of the characteristics of CDMA and spread spectrum with OFDM in order to create a more robust modulation scheme that could survive frequency selective fading and thus OFDM-CDMA was born. OFDM-CDMA system with various diversity schemes is considered for broad band wireless network. In 1993 frequency spreading system such as MC-CDMA, time spreading technique such as DS-MC-CDMA and MT-CDMA was proposed. MIMO-OFDM (multiple-input multiple-output) MIMO channels focuses on enhanced channel estimation and signal detection.CI-OFDM(carrier interferometry orthogonal frequency division multiplexing) system spreads each information across all N sub carriers using orthogonal CI spreading codes. As an application of MIMO architecture a preamble structure for the space time block coded (STBC) OFDM-CDMA systems with more than two transmit antennas is designed to be orthogonal in time domain.

Alamouti's OFDM (Orthogonal Frequency Division Multiplexing) system transmits information data by many sub-carriers, where sub-carriers are orthogonal to each other and sub-channels are overlapped so that the spectrum efficiency may be enhanced. OFDM can be easily implemented by the IFFT (Inverse Fast Fourier Transform) and FFT (Fast Fourier Transform) process in diversity technique STBC (Space Time Block Coding) is very efficient when delay spread is big or channel's time variation is very small during the coded continuous OFDM symbols and OFDM sub carriers is small. When Doppler spread is big or channel's time variation is large and channel is non frequency selective, the inter sub carrier's channel frequency is nearly constant in the OFDM systems with many sub carriers, the SFBC (Space -Frequency Block Coding) method is more efficient for high quality transmission.

The paper is organized as Section I is an introduction of the OFDM-CDMA and its diversity schemes. Comparison of OFDM with OFDM-CDMA.is discussed in section-II.OFDM CDMA with STBC OFDM-CDMA is compared in section – III. Comparative features of OFDM-CDMA with time frequency spreading OFDM-CDMA are highlighted in section-IV. Comparative features of OFDM with MIMO OFDM& MIMO SFBC CI OFDM are stated in section-V. Summary is provided in section –VI. [1]-[7].

2. COMPARISON OF OFDM WITH OFDM-CDMA.
Orthogonal Frequency-Division Multiplexing (OFDM) is commonly used for high-data-rate wire - less communications due to its inherent error resistance in a multipath environment and has been chosen for several broadband wireless local area network (WLAN) standards such as IEEE 802.11a, European HIPERLAN/2 and Japanese MMAC. OFDM can be easily implemented by the IFFT (inverse fast Fourier transform) and FFT (fast Fourier Transform) process in digital domain, and has the property of high-speed broad-band transmission and robustness to multipath interference.

OFDM is popular technique for the data transmission over multipath fading channels, the multipath components of this type of channels results frequency selective fading. This type of fading can cancel out or severely degrade signal strength of many of the OFDM tones producing irreducible error rate. The main limitation of OFDM-based transmission systems is the high peak-to-average power ratio (PAPR) of the transmitted signals .The high PAPR of OFDM makes the signal more sensitive to the nonlinearities of the HPA and result in signal distortion when the peak power exceeds the dynamic range of the amplifier. To transmit the high PAPR signal without distortion requires more expensive power amplifier. Besides, the non-linear distortions due to clipping and amplification effects in the transmitted signal will lead to both in-band and out-of band emissions. In band emission provokes BER (bit error rate) degradation whereas the out band emission results in spectral spreading .Here sub-channels are overlapped so that the spectrum efficiency may be enhanced.

OFDM-CDMA combined with SS (spread spectrum) characteristics were used to separate multiple asynchronous users operating in the same cellular channel communicating with a base station and to create more robust scheme (SS frequency domain can be viewed as frequency diversity).Additional benefit of this new system is that by applying multiuser detection (MUD) techniques in the demodulation process, the capacity of the system could be increased. In this data bits (or data symbols which are groups of bits) can be treated as virtual" users "and spread across the frequency domain."This spreading "can effectively reduce the degradation caused by frequency selective fading. On all the data bits allowing for better performance on multipath fading channels .In addition this approach yields a synchronous system and there are no near/far problems since the vertical users are all sent of the same power level.

OFDM-CDMA improves BER .BER is reduced in OFDM-CDMA but this advantage decreases as the signal-to noise ratio value increases. OFDM-CDMA wave form is less sensitive to errors in the channel estimation process than OFDM since the same channel estimates were used in the demodulation of both waveforms. High PAPR (peak to average power ratio)is a special drawback of multi-carrier transmission in OFDM-CDMA.OFDM-CDMA is severely affected by the channel estimation scheme and a more accurate channel estimation scheme is required for OFDM-CDMA. [1].

3. COMPARISON OF OFDM-CDMA WITH STBC OFDM-CDMA.

The current tendency toward broadband communications implies a big effort on research in improved and flexible multiple-access methods to cope with the increasing number of subscribers. A multicarrier (MC) modulation in combination with a well-known spread-spectrum technique offers promising multiple access schemes for fourth-generation (4G) broadband radio applications, known as MC code-division multiple accesses (MC-CDMA) and OFDM-CDMA. The performance of these OFDM-based systems can be improved by applying several diversity techniques. The main limitation of OFDM-based transmission systems is the high peak-to-average power ratio (PAPR) of the transmitted signals and large peaks will occasionally reach the amplifier saturation region and results in signal distortion, which causes bit-error-rate (BER) degradation. Partial transmit sequence (PTS) scheme is an efficient approach and a distortion less scheme for PAPR reduction by optimally combining signal sub blocks. In the selective-mapping (SLM) approach, some statistically independent sequences are generated from the same information and that sequence with the lowest PAPR is transmitted. Both techniques introduce additional complexity, but provide improved PAPR statistics with little cost in transmission efficiency.(OFDM)-Code division multiple access(CDMA) system employing various diversity schemes is considered as possible candidate for broad band wireless access network applications. STBC OFDM-CDMA is a very appealing technique for achieving high bit-rate transmission and provides significant capacity gain in wireless channels. STBC OFDM-CDMA offers an efficient exploitation of the available diversity and PAPR reduction[7].

4. COMPARISON OF OFDM-CDMA WITH TIME FREQUENCY SPREADING OFDM-CDMA.

OFDM-CDMA is an effective way to combat with frequency selective fading and narrow band interference. But the obvious weak point in the OFDM-CDMA is the high PAPR of the synthetically time domain signal which is directly proportional to the number of sub carriers .Therefore non-linearity pops up because of high signal peaks, which causes spectrum spreading, in-band distortion, out-band radiation and so high-level degradation of the system. With high SNR's BER is high in OFDM-CDMA. There are mainly three kinds of OFDM-CDMA systems they are MC-CDMA, DS-MC-CDMA and MT-CDMA .They are belonging to either Frequency spreading systems such as MC-CDMA or Time spreading system such as DS-MC-CDMA and MT-CDMA.

Time-frequency spreading can achieve better BER with WH code compared to frequency spreading OFDM-CDMA. The time frequency system still kept the anti-noise ability of the spreading system and orthogonality between different users achieved by WH spreading code. In one word; time-frequency spreading system does well in PAPR performance.[3].

5. COMPARISON OF OFDM WITH MIMO-OFDM.

High data-rate in OFDM, the entire channel is divided into many narrow parallel sub channels, thereby increasing the symbol duration and reducing or eliminating the ISI caused by the multi path. Space–time coding is characterized by high code efficiency and good performance; hence, it is a promising technique to improve the efficiency and performance of Orthogonal Frequency Division Multiplexing (OFDM) systems. For wideband transmission space–time processing must be used to mitigate inter symbol interference. But with OFDM single input single-output (SISO) system with flat Rayleigh fading or narrowband channels the complexity of the space–time processing increases with the bandwidth, and the performance substantially degrades when estimated channel parameters are used.

Multiple transmit and receive antennas can be used with OFDM to further improve system performance. More bandwidth is required for higher data-rate transmission. However, due to spectral limitations, it is often impractical or sometimes very expensive to increase bandwidth. In this case, using multiple transmit and receive antennas for spectrally efficient transmission is an alternative solution. Multiple transmit antennas can be used either to obtain transmit diversity, or to form multiple-input multiple-output (MIMO) channels.

In MIMO-OFDM focus is enhanced channel estimation and signal detection .In MIMO-OFDM system to achieve transmit diversity gain and detect the transmitted signal, a space time processor must extract the required signals for space time decoders. Both space time processor and space time decoding require channel state information .Average power profile depends on the delay profiles of wireless channels .For signal detection including spatial pre whitenining and successive information cancellation Minimum Euclidian Distance (MED) decoding technique is used.

MIMO system can improve the channel system capacity by a factor of the minimum number of transmit and receive antennas. With more receive antennas, MIMO-OFDM results increased signal to noise ratio. It increases the system

capacity. Word error rates (WER) are less. Therefore MIMO-OFDM is the promising technique for highly spectral efficient broad band transmission & it can be effectively used in high-data-rate wire-less systems.[4].

The CI-OFDM (Carrier Interferometry Orthogonal frequency Division Multiplexing) is used widely along with space frequency block coding method which is more efficient for high quality transmission.. In the CI-OFDM technique, each information symbol is sent simultaneously over all carriers and the each carrier for the symbol is assigned a corresponding orthogonal CI spreading code. This CI/OFDM system not only can reduce PAPR problem significantly but also achieve frequency diversity gains without any loss in throughput .MIMO SFBC CI-OFDM reduces PAPR significantly compared with conventional MIMO SFBC – OFDM systems .With MIMO SFBC CI-OFDM spectrum efficiency can be increased and high quality transmission is possible.[6].

6. SUMMARY

In OFDM Wireless Communications, high data rates and data transmission on multipath channels are possible. OFDM signal has High PAPR. Multi path signal channels causes frequency selective fading which severely degrades the signal strength and produces irreducible error rate.

OFDM-CDMA is advantageous over OFDM on multipath/fading of channels .In the channel estimation process it is less sensitive to errors.BER is less at low SNR'S but it increases with high SNR'S. In the channel estimation process it is less sensitive to errors .But better channel estimation schemes are to be studied.

Compared with OFDM-CDMA, STBC OFDM-CDMA provides high bit rate transmission and significant capacity and gain. PAPR and BER are improved.

In Time frequency spreading OFDM-CDMA, PAPR performance is greatly improved. This system provides better BER.

MIMO-OFDM is highly spectrum efficient with reduced inter symbol interference and enhanced channel estimation .Increase in SNR and reduction in BER is possible with more receiving antennas.

MIMO SFBC CI-OFDM provides reduction in PAPR and reduction in BER .It increases the spectrum efficiency.

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