A Study and Survey of OFDM versus COFDM

Jyoti Kataria, Pawan Kumar, Tilak Raj

Abstract— Modern wireless communications system demands higher data rate environment and reliable transmission. OFDM which is suitable for high data rate transmission at reasonable complexity in wireless channels; combined with channel coding scheme for improving reliability of system called COFDM. Coding scheme can be chosen for any system which satisfies requirements of high data rate as well as good error capability and according to complexity, suitable delay and desired coding gain for system. The aim of this paper to making literature comparison of COFDM with OFDM and study shows that COFDM outperforms than OFDM with respect to reliable transmission, fading/noisy environment, BER performance, bandwidth efficiency.

Index Terms— COFDM,OFDM , Block Code & BER .

I. INTRODUCTION

Now-a-days wireless communication systems are facing problems mainly multi-path fading, frequency fading, Inter Symbol Interference (ISI), Inter Carrier Interference (ICI), lower bit rate capacity , requirement of larger transmit power for high bit rate, less spectral efficiency etc [1] [2]. OFDM is type of MCM technique which is suitable choice for full capacity wireless networks. OFDM is effective technique for high data rate wireless communication in multi-path channels and fading environment at reasonable complexity in wireless channels [2]. Because of its high speed data transmission and effectiveness in combating the frequency selective fading channel, it is adopted by many standards DAB, ADSL, WLAN, IEEE 802.11 a/g/n etc [12] [13].

Error control codes have become a vital part of modern digital wireless system; enabling reliable transmission to be achieved over noisy channels OFDM which is suitable for high data rate transmission is combined with FEC methods called Coded OFDM (COFDM) [1] which enables the OFDM system to enhance the system throughput [3].In Wireless communication systems main challenge is to provide high data rate environment and reliable transmission so channel coding scheme is essential for improving reliability of transmission. COFDM is more immune to impulse noise, random noise, multi-path distortion, fading and interference. [2] Main focus of this paper is to making literature review of OFDM versus COFDM with FEC scheme with respect to bit error rate performance, bandwidth efficiency, frequency diversity, multi-path environment. COFDM provides high spectral efficiency and reliable transmission by spacing channels close together. In this paper the OFDM is compared with COFDM which outperforms than OFDM with respect to the reliable transmission, fading environment, Bit Error Rate (BER), bandwidth efficiency, frequency diversity etc.

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II. LITERATURE REVIEW

Weinstein and Ebert et al (1971) made an important contribution to OFDM. Discrete Fourier transform (DFT) method was proposed to perform the base band modulation and demodulation . It's application is to minimize banks of subcarrier oscillators. They used guard band between symbols to combat ICI and ISI problem. Discrete Fourier transform is an most efficient signal processing algorithm . This system did not obtain perfect orthogonality between sub carriers over a dispersive channel [8].Wolfgang Eberle et al (1999) designed a flexible OFDM transceiver for a high-speed wireless LAN. The integration of a high speed OFDM base band transceiver on a single ASIC is an important step towards high-capacity WLAN at competitive prices . This transceiver provides a large degree of flexibility through programmable parameters with respect to both channel and user requirements. It provide a complete receiver synchronization . They presented an OFDM transceivers ASIC that integrates the complete physical layer for transmission and reception of QPSK modulated OFDM symbols including besides the basic OFDM functionality also the complete receiver synchronization and framing/deframing of packets on-chip .Ahmed Sghaier, Shawki Areibi et al (2008) proposed the pipelined implementation of OFDM system in which a pure VHDL design, integrated with some intellectual property (IP) blocks, is employed to implement an OFDM transmitter according to the IEEE 802.11a WLAN standard. The objective was to show FPGA's capability to accommodate such standards, and to emphasize on their programmability feature and Their main aim of work was to implement the digital baseband part of the physical layer of an OFDM transmitter that conforms to the 802.11a standard . The developed IP cores, available on-line could be easily extended to design other OFDM-based systems, for example fixed and mobile WiMAX. Their used methodology is based on the divide-and-conquer approach. First time pure VHDL design is employed to implement OFDM transmitter for the sake of standards of IEEE .

III. CODED OFDM

There are different methods to enhance the efficiency of OFDM, but this technique provides the better performance than other in fading environment. [9]. A robust data transmission can be achieved by combining OFDM with channel coding called COFDM [2] [4]. A promising candidate that provides a means to transmit data in a frequency selective channel is COFDM. This technique uses multiple orthogonal sub-carriers to convey the data and error correcting code which adds extra bits at transmitters to recover many or all the sub-carriers affected by deep fads [1].

The error correcting code usually adopted to improve OFDM system performance in adverse channel condition is FEC [11].

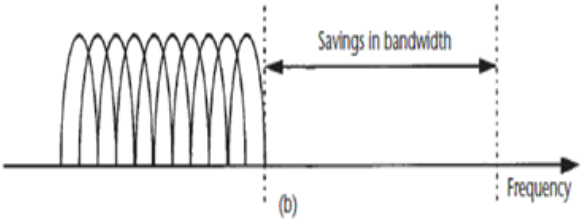

Fig. 1 COFDM Signal

By using the overlapping multi-carrier modulation technique, save almost 50% of bandwidth as shown in Fig.1. Transmission quality can be further improved by combining FEC and interleaving that overcomes the effect of burst errors and fading type errors [11]. OFDM is combined with channel coding by which error of weak sub-carrier is corrected by the information of strong sub-carriers is corrected by the information of strong sub-carriers; thereby the total error rate is decreased. If channel coding is not used system efficiency is limited to the power of weakest sub-carriers [12].

A. Properties of COFDM

- Frequency Diversity

The error correction is achieved by coding orthogonal sub-carriers or adding redundancy to information, which enhance the performance of OFDM system and improves the frequency diversity. [9]

- Fading environment

COFDM enhance its transmission quality by combining FEC and interleaving that provides a memory less channel breaking sequential fading correlation and increase the diversity and gives reliable transmission with reduced BER and high gain with high signal to noise ratio. [1].

IV. SIGNIFICANCE OF FEC

If you are Reliability is a very important requirement while transmitting data over network, data may be lost during transmission. The primary function of error control code is to enhance the reliability of message during transmission carrying symbol through communication channel. Error control code can also ease the design process of digital transmission system. [11]

There are three schemes to remove the error during transmission are [7]:-

1. Error Detection Code
2. Automatic Repeat Request (ARQ)
3. Error Correcting Code

An error detection code is used to detect the error which is present in data block, used with a protocol at data link or transport level. ARQ is used with error detection code in which error detection code used to detect the presence of an error and discards that block of information then retransmit of that block. Error correcting codes are designed in such a way that they are used not only to detect the presence of error but also correct errors, which avoid the need of retransmission process. [7].

Error detection and ARQ is not suitable for wireless transmission because of [7]:

- BER is high at wireless transmission medium because of this large number of retransmission is applicable.
- Highly inefficient techniques
- If retransmission is possible then propagation delay is very long compared to transmission time of single frame.
- Retransmission is not appropriate for satellite system, because of very limited capacity back channel or no back channel.
- Retransmission schemes is responsible to high delay, thereby increase the cost of system and loss.

Now-a-days in cellular networks (1G,2G,3G) 3G cellular schemes are most popular that have more risk about data corruption because of interference and transmission medium, so characteristics of cellular environments specific wireless events may affect the end user performance. In order to avoid these problems FEC has been proposed as an alternative technique for error correction over wireless networks. Performance of COFDM and uncoded OFDM is shown in Fig.2 [14]

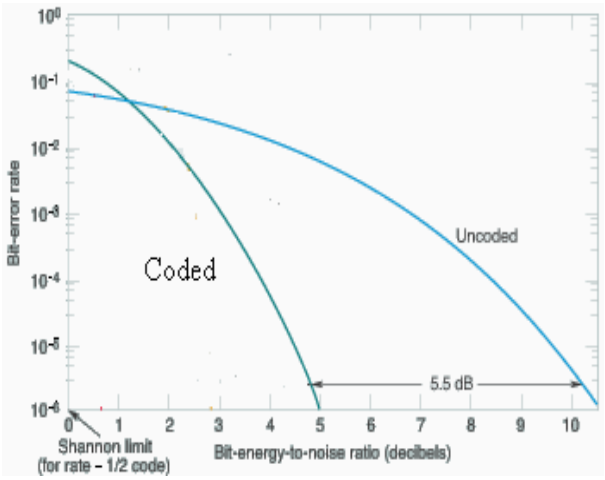

Fig. 2 Comparison between coded and uncoded OFDM [7]

Advantages of Combining FEC with OFDM [6] [11]

- Transmission power requirement of digital transmission scheme can be reduced by using error controlling schemes. For example applied in cellular mobile communication.
- Even the size of transmitter, receiver antenna can be reduced by use of error control code while increasing the performance.
- Access of more users to same radio frequency in multi-access communication system can be ensured by use of error controlling techniques. For example as in case of CDMA.
- Jamming margin in spread spectrum communication system can be effectively increased by using suitable error control technique.

V. FEC PROPERTIES AND TERMINOLOGY

FEC provides reliable delivery and requires additional redundant data to be appended to original data prior to transmission across the communication networks.[14] FEC is a suitable choice for wireless communication networks which is accomplished by adding redundancy to data message using prescribed rules and at receiving side FEC decoder decodes that information to realize the error and correct them.

[11] Two main clases of FEC: Linear block code which are hamming code, cyclic code, BCH code, Reed Solomon Code and the Convolution Code [7]. Functioning of FEC at transmitter side and receiver side is shown in Fig. 3 and Fig. 4 respectively.

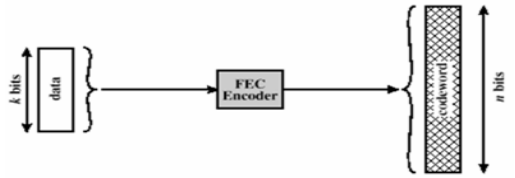

Fig. 3 Transmitter side [7]

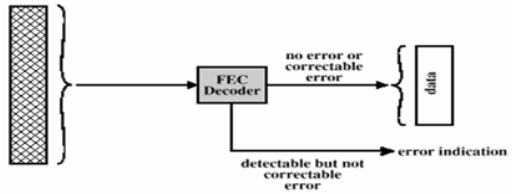

Fig. 4 Receiver side [7]

Block Code versus Convolution Code [7]

Block Code

- Operate on static block.
- No data dependency between block.
- Take k-input bit and produce n-output bits where k and n are large.
- Useful for computer networks.

Convolution Code

- Operate on data stream.
- Applicable where require better performance with low cost.
- Data passes through convolution code in a continuous stream.
- Most useful in wireless applications.

Properties of FEC [8] [11]

Application of an FEC code and a judicious choice of the code parameters are guided by several conflicting factors. Some of these factors are described in brief:

- **Nature of communication channel**

Effects of many physical communication channel manifest in random and isolated errors while some channels cause bursty errors. The modulation technique employed for transmission of information, sensitivity level of a receiver (in dBm), rate of information transmission are some other issues.

- **Available channel bandwidth**

As mentioned, use of an error-control scheme involves addition of controlled redundancy to original message. This redundancy in transmitted massage calls for larger bandwidth than what would be required for an encoded system. This undesirable fact is tolerable because of the obtainable gains or advantages of coded communication system over an encoded one for a specified overall system performance in terms of BER or cost.

- **Hardware complexity cost and delay**

Some FEC codes of larger block length asymptotically satisfy the requirements of high rate as well as good error correcting capability but the hardware complexity, volume, cost and decoding delay of such decoders may be enormous..

VI. CODED OFDM SYSTEM MODEL

The block diagram for COFDM is shown in fig. 5. In COFDM at transmitter side data is loaded into randomizer which will generate random number of sequence then it is coded via FEC encoder and interleaving is used which will enhance the performance of system [11], then the modulated signal is transmitted via IFFT . At receiving side signal is demodulated, de-mapped, de-interleaved and then decoded via FEC decoder to recover the transmitted information.

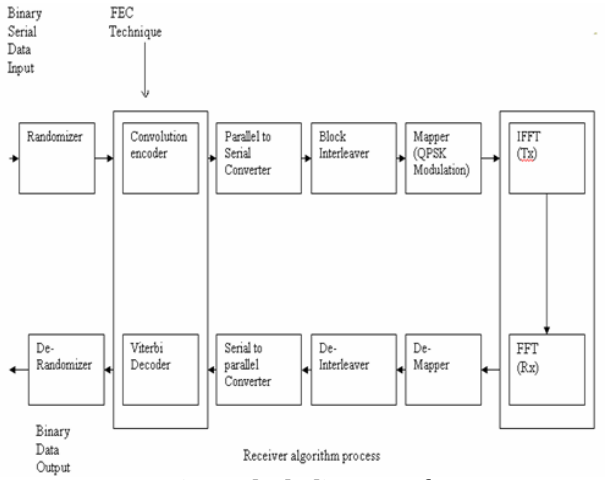

Fig. 5 Block diagram of COFDM

IEEE 802.16 OFDM system with FEC has examined in [6] for different coding rate with AWGN channel and simulated using MATLAB shows that convolution code is suitable as FEC channel coding. Performance of Wi-Max IEEE 802.16e OFDM has investigated with FEC codes using MATLAB [15] which shows the results with FEC and without FEC, performance is enhanced with FEC. To reduce is PAR in WLAN OFDM system MSR has proposed in [10] which is based on convolutional coding, improves only PAR but not BER which is important concern.

Performance results under different modulating technique with different coding rate have examined [12] using MATLAB provides convolutional coding is suitable with ½ rate. Performance of OFDM with several channel coding has examined [9] shows convolution coding is preferred due to less complexity. The effects of convolution coding on BER performance has examined [8] which shows FEC provides improvement in BER, bandwidth efficiency, companding with FEC coding provides the reduction in PAR.COFDM has examined over multi-path environment [4] which provides that performance of OFDM with coding and without coding and effect of coding.

VII. CONCLUSION

In this paper performance of COFDM with OFDM has examined and results shows that COFDM is more suitable choice which provides high spectral efficiency and reliable transmission and outperforms than OFDM with respect to BER, bandwidth efficiency and fading environment. Study also shows that FEC is best channel coding schemes in wireless communications to enhance the system throughput using with interleaving which fulfills the requirement of high data rate transmission and has good error capability with negligible delay, complexity.

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