Output SNR Analysis And Detection Criteria For Optimum DCT-Based Multicarrier System: Review

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Abstract - The demand for multimedia data services has grown drastically which drive us in the age of 4th generation wireless communication system. This requirement of multimedia data service where user are in large numbers and with bounded spectrum, modern digital wireless communication system adopted technologies which are bandwidth efficient and robust to multipath channel environment known as multicarrier communication system. The modern digital multicarrier wireless communication system provide high speed data rate at minimum cost for many users as well as with high reliability. The multi-carrier modulation (MCM) technique has been seen to be very effective for communication over channels with frequency selective fading. It is very difficult to handle frequency selective fading in conventional communication receivers as the design of the receiver becomes hugely complex. The Discrete cosine Transform (DCT) has been the dominant medium-access technique in the fixed and nomadic modern wireless communications.

Keywords- Multi carrier modulation (MCM), Discrete cosine transform (DCT), OFDM, Fourier transform (DFT), signal-to-noise ratio (SNR).

I. INTRODUCTION

In a basic communication system, the data are modulated onto a single carrier frequency. The available bandwidth is then totally occupied by each symbol. This kind of system can lead to inter-symbol-interference (ISI) in case of frequency selective channel. The basic idea of OFDM is to divide the available spectrum into several orthogonal subchannels so that each narrowband subchannel experiences almost flat fading. Orthogonal frequency division multiplexing (OFDM) is becoming the chosen modulation technique for wireless communications. OFDM can provide large data rates with sufficient robustness to radio channel impairments. Many research centers in the world have specialized teams working in the optimization of OFDM systems. In an OFDM scheme, a large number of orthogonal, overlapping, narrow band sub-carriers are transmitted in parallel. These carriers divide the available transmission bandwidth. The separation of the sub-carriers is such that there is a very compact spectral utilization. With OFDM, it is possible to have overlapping subchannels in the frequency domain, thus increasing the transmission rate. The attraction of OFDM is mainly because of its way of handling the multipath interference at the receiver. Multipath phenomenon generates two effects (a) Frequency selective fading and (b) Intersymbol interference (ISI).

The "flatness" perceived by a narrowband channel overcomes the frequency selective fading. On the other hand, modulating symbols at a very low rate makes the symbols much longer than channel impulse response and hence reduces the ISI. Use of suitable error correcting codes provides more robustness against frequency selective fading. The insertion of an extra guard interval between consecutive OFDM symbols can reduce the effects of ISI even more. The use of FFT technique to implement modulation and demodulation functions makes it computationally more efficient. OFDM systems have gained an increased interest during the last years. It is used in the European digital broadcast radio system, as well as in wired environment such as asymmetric digital subscriber lines (ADSL). This technique is used in digital subscriber lines (DSL) to provides high bit rate over a twisted-pair of wires.

In single carrier system, single carrier occupies the entire communication bandwidth but in multicarrier system the available communication bandwidth is divided by many sub-carriers. So that each sub-carrier has smaller bandwidth as compare to the bandwidth of the single carrier system. These tremendous features of multicarrier technique attract us to study Orthogonal Frequency Division Multiplexing (OFDM). OFDM forms basis for all 4G wireless communication systems due to its huge capacity in terms of number of subcarriers, high data rate in excess of 100 Mbps and ubiquitous coverage with high mobility. The introduction chapter consists of following parts: Overview, Historical Development of OFDM, principle of orthogonality, advantages and disadvantages of OFDM technique, and the applications of OFDM technique.

Different transform techniques such as Discrete Fourier transform (DFT) and its inverse (IDFT), discrete Hartley transform (DHT) and its inverse (IDHT), Discrete Cosine Transform and its inverse (IDCT) are used to perform the modulation and demodulation operations and compared the performance of the designed OFDM system. The complexity of an OFDM-based transceiver would also be reduced if the corresponding modulator/demodulator could be implemented using purely real transforms like discrete Hartley transform (DHT) and discrete cosine transform (DCT). Since the DHT and IDHT definitions are identical, can use the same hardware or program to implement the modulator and demodulator of the OFDM system.

A discrete cosine transform (DCT) is a Fourier-related transform similar to the discrete Fourier transform (DFT), but using only real numbers. The DCT is often used in signal and image processing, especially for lossy data compression, because it has a strong "energy compaction" property: most of the signal information tends to be concentrated in a few low-frequency components of the DCT. The Discrete cosine transform (DCT) is also a real valued transform, used to find where the power is concentrated in a signal.

II. MULTICARRIER MODULATION

The idea of using a better transform than Fourier's as the core of a multicarrier system has been recently introduced. However, very little interest has been given to the alternative methods. With the current demand for enhanced performance in wireless communication systems, it's high time looked forward to the possible advantages that wavelet-based modulation could have over OFDM systems.

Frequency division multiplexing (FDM) extends the concept of single carrier modulation by using multiple subcarriers within the same single channel. The total data rate to be sent in the channel is divided between the various subcarriers. The data do not have to be divided evenly nor do they have to originate from the same information source. Advantages include using separate modulation/demodulation customized to a particular type of data, or sending out banks of dissimilar data that can be best sent using multiple, and possibly different, modulation schemes. Orthogonal Frequency Division Multiplexing (OFDM), is now a popular technique for MCM (Multi-Carrier Modulation), is deployed in various standards of IEEE, especially in the wireless systems. It also looks promising for the 4G mobile technologies. OFDM converts a frequency selective fading channel into a collection of the flat fading sub-channels. The key ideas of OFDM were patented, on 1967-68. The wireless channels offers much more unpredictability and other challenges than their wire line (like twisted wire pairs or coaxial cables) counterparts, due to the presence of multipath, Doppler spread etc., This difficulty in the wireless channels is mainly due to the frequent change in the environment and other factors because of the mobility of the user, and presence of different environment conditions.

A. OFDM for Multicarrier Transmission

In a wireless communication system, the signal is carried by a large number of paths with different strengths and delays. Such multipath dispersion of the signal is commonly referred as "channel-induced inter symbol interference (ISI)." In fact, the multipath dispersion leads to an upper limitation of the transmission rate in order to avoid the frequency selectivity of the channel or the need of a complex adaptive equalization in the receiver. In order to mitigate the time- dispersive nature of the channel, single-carrier serial transmission at a high data rate is replaced with a number of slower parallel data streams. Each parallel stream will be then used to sequentially modulate a different subcarrier. By creating N parallel sub streams, will be able to decrease the bandwidth of the modulation symbol by the factor of N, or, in other words, the duration of a modulation symbol is increased by the same factor. The orthogonal subcarriers are separated by a frequency interval of $Af = 1/Ts$, where Ts is the OFDM symbol duration, as shown in Fig. 2.1.

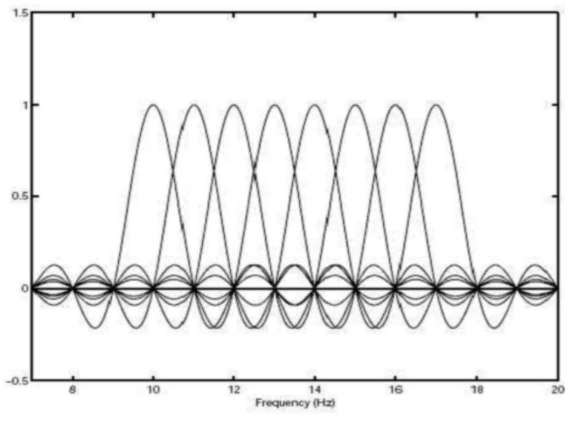

Figure 2.1 OFDM transmission spectrums.

If the FDM system above had been able to use a set of subcarriers that were orthogonal to each other, a higher level of spectral efficiency could have been achieved. The guard bands that were necessary to allow individual demodulation of subcarriers in an FDM system would no longer be necessary. The use of orthogonal subcarriers would allow the subcarriers' spectra to overlap, thus increasing the spectral efficiency. As long as orthogonality is maintained, it is still possible to recover the individual subcarriers' signals despite their overlapping spectrums. If the dot product of two deterministic signals is equal to zero, these signals are said to be orthogonal to each other. Orthogonality can also be viewed from the standpoint of stochastic processes. If two random processes are uncorrelated, then they are orthogonal. Given the random nature of signals in a communications system, this probabilistic view of orthogonality provides an intuitive understanding of the implications of orthogonality in OFDM. As the sinusoids of the DFT form an orthogonal basis set, and a signal in the vector space of the DFT can be represented as a linear combination of the orthogonal sinusoids. One view of the DFT is that the transform essentially correlates its input signal with each of the sinusoidal basis functions. If the input signal has some energy at a certain frequency, there will be a peak in the correlation of the input signal and the basis sinusoid that is at that corresponding frequency. This transform is used at the OFDM transmitter to map an input signal onto a set of orthogonal subcarriers, i.e., the orthogonal basis functions of the DFT. Similarly, the transform is used again at the OFDM receiver to process the received subcarriers. The signals from the subcarriers are then combined to form an estimate of the source signal from the transmitter. The orthogonal and uncorrelated nature of the subcarriers is exploited in OFDM with powerful results. Since the basic functions of the DFT are uncorrelated, the correlation performed in the DFT for a given subcarrier only sees energy for that corresponding subcarrier. The energy from other subcarriers does not contribute because it is uncorrelated. This separation of signal energy is the reason that the OFDM subcarriers' spectrums can overlap without causing interference. Figure 2.2 demonstrate typical multicarrier OFDMsystem.

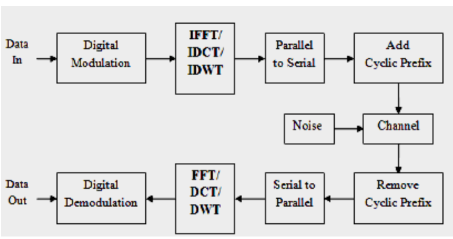

Figure 2.2 Typical OFDM system using DCT.

III. RELATED WORK

Chang He, L. Zhang, J. Mao, Aijun Cao, P. Xiao and M. A. Imran,[1] The discrete cosine transform (DCT) based multicarrier system is regarded as one of the complementary multicarrier transmission techniques for 5th Generation (5G) applications in near future. By employing cosine basis as orthogonal functions for multiplexing each real-valued symbol with symbol period of T, it is able to reduce the minimum orthogonal frequency spacing to 1/(2T) Hz, which is only half of that compared to discrete Fourier transform (DFT) based multicarrier systems. Critical to the optimal DCT-based system design that achieves interference-free single-tap equalization, not only both prefix and suffix are needed as symmetric extension of information block, but also a so-called front-end pre-filter is necessarily introduced at the receiver side. Since the pre-filtering process is essentially a time reversed convolution for continuous inputs, the output signal-to-noise ratio (SNR) for each subcarrier after filtering is enhanced. In this research work, the impact of pre-filtering on the system performance is analyzed in terms of ergodic output SNR per subcarrier. This is followed by reformulated detection criterion where such filtering process is taken into consideration. Numerical results show that under modified detection criteria, the proposed detection algorithms improve the overall bit error rate (BER) performance effectively.

L. Zhang, P. Xiao and A. Quddus,[2] Recently proposed universal filtered multicarrier (UFMC) system is not an orthogonal system in multipath channel environments and might cause significant performance loss. In this research work, the authors propose a cyclic prefix (CP) based UFMC system and first analyze the conditions for interference-free one-tap equalization in the absence of transceiver imperfections. Then the corresponding signal model and output signal-to-noise ratio expression are derived. In the presence of carrier frequency offset, timing offset, and insufficient CP length, the authors establish an analytical system model as a summation of desired signal, intersymbol interference, intercarrier interference, and noise. New channel equalization algorithms are proposed based on the derived analytical signal model. Numerical results show that the derived model matches the simulation results precisely, and the proposed equalization algorithms improve the UFMC system performance in terms of bit error rate.

L. Wen, R. Razavi, M. A. Imran and P. Xiao,[3] Low density signature orthogonal frequency division multiplexing (LDS-OFDM) and low density parity-check (LDPC) codes are multiple access and forward error correction (FEC) techniques, respectively. Both of them can be expressed by a bipartite graph. In this research work, construct a joint sparse graph combining the single graphs of LDS-OFDM and LDPC codes, namely joint sparse graph for OFDM (JSG-OFDM). Based on the graph model, a low complexity approach for joint multiuser detection and FEC decoding (JMUDD) is presented. The iterative structure of JSG-OFDM receiver is illustrated and its extrinsic information transfer (EXIT) chart is researched. Furthermore, design guidelines for the joint sparse graph are derived through the EXIT chart analysis. By offline optimization of the joint sparse graph, numerical results show that the JSG-OFDM brings about 1.5-1.8 dB performance improvement at bit error rate (BER) of 10-5 over similar well-known systems such as group-orthogonal multi-carrier code division multiple accesses (GO-MC-CDMA), LDS-OFDM, and turbo structured LDS-OFDM.

X. Ouyang and J. Zhao,[4] Channel cannot be compensated by single-tap equalizers in fast orthogonal frequency-division multiplexing (OFDM) easily unless the channel impulse response (CIR) is symmetric. In this letter, Propose a low-complexity fast OFDM scheme, which enables efficient single-tap equalization for generic linear channels without the symmetric limitation. Simulations under both wireless multipath fading and multimode fiber channels are provided to verify the feasibility. Compared with other schemes, the proposed technique is simpler and avoids net data rate loss. It is shown that this scheme exhibits better performance than the frequency-domain-equalization-based fast OFDM scheme under the wireless frequency-selective fading channel.

J. Zhao and A. Ellis,[5] Experimentally demonstrate transmission of 20-Gb/s four-amplitude-shifted-keying optical fast orthogonal frequency-division-multiplexing (F-OFDM) over various fiber lengths up to 840 km, and show that symmetric extension, instead of cyclic extension, based guard interval (GI) is required to enable chromatic dispersion (CD) compensation using one-tap equalizers after channel demultiplexing. Characterize the CD tolerance under different GI lengths and investigate the impact of fiber nonlinearity on the system performance.

C. Y. Hung and W. H. Chung,[6] The maximum likelihood (ML) detection for multiple-input multiple-output (MIMO) system achieves the optimal performances at the cost of high computational complexities, while the linear detectors attain low complexities with degraded performances. In this research work, propose two low-complexity detection schemes based on the minimum-mean-square-error (MMSE) detection for MIMO systems. Using on the MMSE-detected data as the starting point, the first scheme searches the constellation subspace using the ML criterion. To further reduce the complexity, the second scheme selects the constellation subspace for search using the reformulated ML criterion. Simulation results show the substantial performance improvements compared to the MMSE detection, with only slightly increased complexities.

Table 3.1 Summary of literature review.

Sr. No.	Title	Authors	Year	Approach
1	Output SNR analysis and detection criteria for optimum DCT-based multicarrier system,	Chang He, L. Zhang, J. Mao, Aijun Cao, P. Xiao and M. A. Imran,	2016	The impact of pre-filtering on the system performance is analyzed in terms of ergodic output SNR per subcarrier
2	Cyclic Prefix-Based Universal Filtered Multicarrier System and Performance Analysis,	L. Zhang, P. Xiao and A. Quddus,	2016	the authors propose a cyclic prefix (CP) based UFMC system and first analyze the conditions for interference-free one-tap equalization in the absence of transceiver imperfections
3	Design of Joint Sparse Graph for OFDM System	L. Wen, R. Razavi, M. A. Imran and P. Xiao,	2015	constructed a joint sparse graph combining the single graphs of LDS-OFDM and LDPC codes, namely joint sparse graph for OFDM (JSG-OFDM)
4	Single-Tap Equalization for Fast OFDM Signals Under Generic Linear Channels	X. Ouyang and J. Zhao,	2014	a low-complexity fast OFDM scheme, which enables efficient single-tap equalization for generic linear channels without the symmetric limitation
5	Transmission of 4-ASK Optical Fast OFDM With Chromatic Dispersion Compensation,	J. Zhao and A. Ellis,	2012	Characterize the CD tolerance under different GI lengths and investigate the impact of fiber nonlinearity on the system performance.
6	An improved MMSE-based MIMO detection using low-complexity constellation search,	C. Y. Hung and W. H. Chung,	2010	Two low-complexity detection schemes based on the minimum-mean-square-error (MMSE) detection for MIMO systems

IV. PROBLEM STATEMENT

The necessity of high data rate draws the great attention in multi-carrier system. It should be capable to operate smoothly in environment of high carrier frequency, high data transmission rate and mobility. The studied has shown that OFDM fulfil the multicarrier system necessities. OFDM is a multi-carrier modulation (MCM) technique in which complex data symbols (i.e, BPSK, QPSK, QAM, and MPSK etc.) are transmitted in parallel after modulating them over orthogonal sub-carrier. In single carrier (SC) system, one complex data is transmitted using one carrier and in this parallel transmission, N complex data is transmitted over N sub-carrier. Here the effective data rate of the system is same as of SC system. The parallel transmission increases the time period of symbol and the comparative amount of separation in time caused by multipath delay decreases.

V. CONCLUSION

In the present work various literature are studies and reviewed of multi-carrier system, occupied bandwidth on the channel is minimized as possible. This minimization is possible by reducing the frequency space between carriers. The narrow space among the carriers is obtained when they are orthogonal to each other. One of the promising multicarrier communication systems, OFDM, has been adopted by many wireless communication standards due to its several advantageous features in multipath environments. The system performance of a digital communication network can be enhanced by incorporating modulation and coding techniques.

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