ISSN: 2278 – 1323
International Journal of Advanced Research in Computer Engineering & Technology
Volume 1, Issue 5, July 2012

OFDM: BER performance by Cyclic Prefix Length

Inderjeet Kaur **Dr.Y.K.Mathur**

Abstract— **Orthogonal Frequency Division Multiplexing (OFDM) is one of the recent year's equalization approaches used in order to reduce the inter-symbol interference introduced by the frequency selectivity of the radio channels. The circular extension of the data symbol, commonly referred to as cyclic prefix is one of the key elements in an OFDM transmission scheme. The influence of the cyclic prefix duration on the BER performance of an OFDM system with in-frame DBPSK modulation is evaluated by means of computer simulation in a multipath fading channel.**

Index Terms— **OFDM, BER, DBPSK modulation, Fast Fourier transform (FFT), QAM.**

I. Introduction

Mobile radio communication systems are increasingly required to offer a variety of services and qualities for mobile users. As the radio channel is far from transmission medium, exhibiting both frequency selectivity and time variant character [1]. In this context, one of the most challenging issues in a radio communication system is to overcome the inter-symbol interference introduced by the multipath propagation of the signal between the transmitter and the receiver's antennas.

The use of the adaptive equalization to the receiver could be the solution for avoiding this unwanted phenomenon, but this complex equalization technique proves oftentimes unsuited for being used in real-time applications, at data rates of tens of Mbps in an unfriendly dispersive radio channel environment because of its important computational complexity. OFDM is an optimal version of multicarrier modulation techniques, which mitigates the effect of the ISI phenomenon keeping a relatively reduced complexity of the equalization process. Indeed, intuitively one can assume that the frequency selectivity of the channel can be mitigated if, instead of transmitting a single high rate serial data stream, the transmission is performed simultaneously using several narrow-band subchannels (with a different carrier corresponding to each subchannel), on which the frequency response of the channel seems "flat".

Hence, for a given overall data rate, increasing the number of carriers reduces the data rate that each individual carrier must convey, therefore lengthening the duration of the symbol that modulates each individual

subcarrier [2]. Slow data rate (and long symbol duration) on each subchannel means that the effects of ISI are severely reduced. In addition, a cyclic prefix is inserted in front of each OFDM symbol. The circular extension is discarded on the receiver side, is obtained by copying a number of samples from the end of the OFDM symbol in front of it in order to prevent two consecutive frames to interfere each other as a result of the time dispersion caused by the multipath propagation. This way the receiver can independently process each frame, in order to estimate the transmitted information. Furthermore, the equalization process is facilitated by this operation of cyclic prefix insertion and extraction. In this paper, we had focused on the influence of the cyclic prefix duration on the BER performance of an OFDM system with in-frame DBPSK modulation. The performance evaluation in Rice fading conditions is done by means of computer simulation.

II. BLOCK-DIAGRAM OF OFDM TRANSMISSION SCHEME

In the figure 1, a classical OFDM transmission scheme using FFT (Fast Fourier Transform) is illustrated. The input data sequence is base-band modulated, using a digital modulation scheme. Various modulation schemes could generally be employed such as BPSK, QPSK (also with their differential form) and QAM with several different signal constellations. In our system, DBPSK method is chosen in order to encode the binary information. Data is encoded "in-frame" (the baseband signal modulation is performed on the serial data, which is inside a "DFT frame", or equivalently an OFDM symbol). The data symbols are parallelized in N different substreams. Each substream will modulate a separate carrier through the IFFT modulation block, which actually generates the OFDM symbol, performing the multicarrier modulation. A cyclic prefix is inserted in order to eliminate the inter-symbol and inter-block interference (IBI) [3]. The data are back-serial converted, forming an OFDM symbol that will modulate a high-frequency carrier before its transmission through the channel. The radio channel is generally referred to as a linear time-variant system. To the receiver, the inverse operations are performed in order to estimate the transmitted symbols.

III. CYCLIC PREFIX AND EQUALIZATION PROCESS

OFDM symbol transmits data in blocks in any type of a non-ideal transmission channel such as a multipath channel

Manuscript received Jul 2, 2012.
Inderjeet Kaur *is currently pursuing PhD degree program in Computer Science & Engineering in SinghaniaUniversity, Rajsthan, India, PH-9711317003. E-mail: inderjeetk@gmail.com*
Dr.Y K Mathur is professor and Dean in PDM college of Engineering, Bahadurgarh, India, PH-9711317003. E-mail: ykmathur55@gmail.com.

in mobile communication systems, or a classical dispersive channel as in wired transmissions will "spread" the OFDM symbol, causing the blocks of signal to interfere one another.

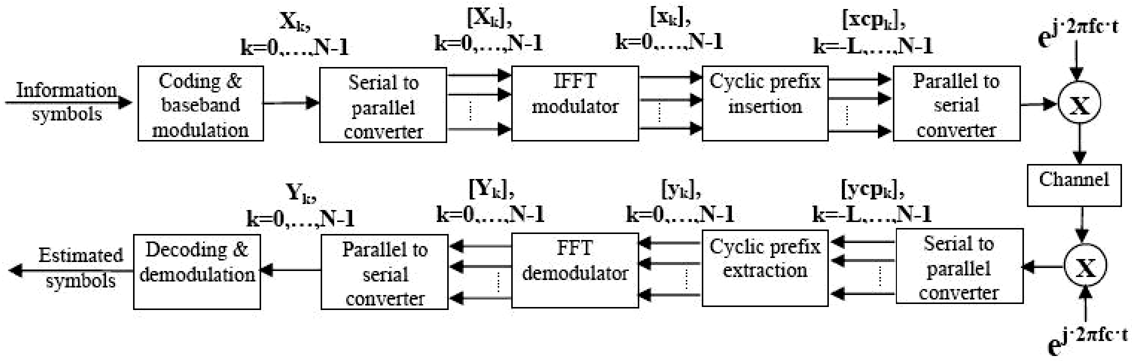

Figure 1: Block Diagram of OFDM Transmission system

This type of interference is called Inter-Block Interference. IBI could lead to inter-symbol interference, since two adjacent blocks will overlap, causing the distortion of the samples affected by overlapping. In order to combat this interference, cyclic prefix (CP) can be used at the beginning of each symbol. The interference caused by the time dispersion of the previous transmitted block is entirely absorbed by the prefix samples that are discarded to the receiver, if cyclic prefix spans more than the multipath channel impulse response. The last L samples of the OFDM symbol are copied in front of the data block to form cyclic prefix [4], as it can be seen in figure 2. Generally, the radio channel exhibits both time variant and frequency selective characteristics. Considering that the channel parameters remain constant during the transmission of an OFDM symbol, the way that the transmission medium distorts each particular frame is similar to the distortion caused by an electronic filter [1],[5]. The equivalent discrete response of the channel which is considered as a linear FIR filter of order L, on the basis of this assumption, the equation can be written as:

$$C(z) = \sum_{n=0}^{L} c[n].z^{-n} \qquad (1)$$

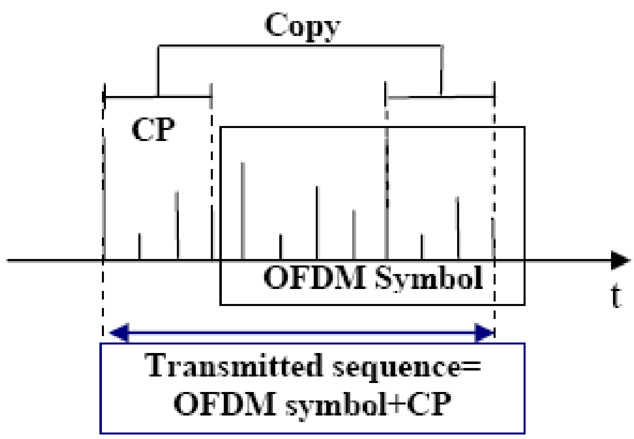

Figure 2: Cyclic Prefix insertion

The equivalent base-band signal at the channel output can be obtained by the operation of convolution, as follows:

$$ycp[n] = xcp[n] * c[n] \qquad (2)$$

Discarding the L CP samples from the received sequence, the remaining (useful) signal can be expressed as:

$$y[n] = x[n] \otimes c[n] \qquad (3)$$

where $\otimes$ denotes the circular convolutional operator [6]. It can be seen from equation 3 that the temporal support of the signal is preserved by the circular convolution. In our case, N transmitted signal samples convolved with L+1 channel impulse response samples will conduce to a received symbol of length N. These received samples of length N will be used in the demodulation process. Since the circular convolution will not "spread" the signal, the receiver can independently process each data block. The interference from the previous transmitted blocks is totally eliminated through this operation of CP insertion/extraction. Furthermore, since $x[n] = IDFT\{X[k]\}$ and taking into account the effect of the DFT demodulator, the received symbols Y[k] can be expressed as:

$$Y[k] = DFT\{IDFT\{X[K]\} \otimes c[n]\}, k = 0,1......N-1 \qquad (4)$$

Since the DFT of a circular convolution of two discrete time signals is equivalent to spectral multiplication equation 4 can be re-written as:

$$Y[k] = DFT\{IDFT\{X[k]\}\}.DFT\{c[n]\}$$
$$= X[k].C[k], k = 0,1,........N-1 \qquad (5)$$

where C[k] represents the sampled frequency response of the equivalent base-band discrete channel, corresponding to the frequencies $\Omega_k = k(2\pi / N)$. The crucial consequence of the relation above is that each modulation symbol X[k] could be recovered at the receiver by a simple point-wise division operation, also known as "one-tap frequency domain equalizer", as can be seen from the equation (6).

$$\hat{X}[k] = Y[k].C^{-1}[k], k = 0,1,......., N-1 \qquad (6)$$

Thus, the CP theoretically eliminates both inter-block interference (IBI) and inter-carrier interference (ICI). IBI and ICI are eliminated because each block preserves its temporal support and each serial symbol received on the k^{th} carrier will depend only on the corresponding k^{th} carrier transmitted symbol, not being affected by the adjacent carriers respectively.

IV. SIMULATION RESULTS

Considering the effect of the cyclic prefix duration on the BER performance of an OFDM system using inter-frame DBPSK modulation has been simulated. Two multipath delayed components with respective delays τ_1 and τ_2 and one deterministic line-of-sight (LOS) path has been considered in a three-ray Rice fading channel. In these simulations τ_1 was taken as zero and τ_2 as normalized delay using relation $\tau_{2N}= \tau_2/L_{CP}$. Where, L_{CP} represents the cyclic prefix duration expressed as the number of serial samples. For the Rice fading channel $K=P_{LOS}/P_D$, which is the ratio between the signal power carried by the LOS path (P_{LOS}) and the total power of the two multipath components ($P_S=P_1+P_2$). Equal power for the two multipath components was considered during the simulations. A white Gaussian noise is added to the signal at the output of the Rice fading channel. The time interval between the moments in which the first and the last significant component of the multipath signal arrives to the receiver is referred to as maximum excess delay (T_M) and it is expressed in number of serial samples.

Another parameter of the simulation is the number of subcarriers N that equals the number of serial samples composing an OFDM symbol.
The time variant character of the radio channel is quantified by the maximum Doppler shift parameter, f_D. The value of this parameter is also expressed in a normalized manner, as f_D*T_S, T_S denoting the OFDM symbol duration. A robust differential modulation scheme such as DBPSK was chosen for encoding the binary information. No channel estimation techniques are employed and consequently no further equalization is done to the receiver.

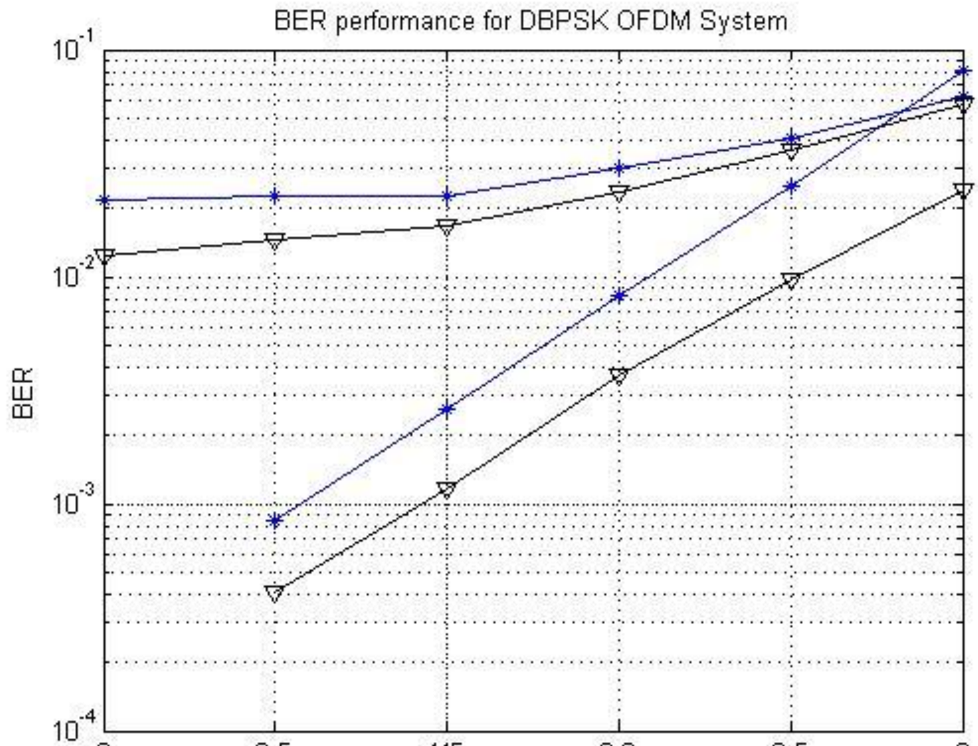

Figure 3: The influence of the cyclic prefix duration on BER performance for DBPSK-OFDM system, Rice fading channel, K=3dB, SNR=30dB, N=64, fD*TS=0.001

V. CONCLUSIONS

The performance of an OFDM system is influenced by the cyclic prefix duration, even by taking the unknown explicit form of the channel impulse response that cannot be used in the equalization process. The transmission is sensitive to the parameter obtained as the multipath delay of the channel normalized by the cyclic prefix duration. The improved BER performance is obtained in all cases by an increase in the OFDM symbol length.

REFERENCES:

[1] Jianwei Huang, Vijay G. Subramanian, Rajeev Agrawal, and Randall Berry, "Joint Scheduling and Resource Allocation in Uplink OFDM Systems for Broadband Wireless Access Networks " , IEEE Journal 2009.B. Sklar, Rayleigh Fading Channels in Mobile Digital Communication Systems- Part I: Characterization, IEEE Commun. Mag., July 2007
[2] Dusan Matic,OFDM as a possible modulation technique for multimedia applications in the range of mm waves, 10-30-38/ TUD-TVS, available on-line: www.ubicom.tudelft.nl/MMC/Docs/introOFDM.pdf
[3] Werner Henkel, Georg Tauböck, Per Ölding, The cyclic prefix of OFDM/DMT – an analysis, 2002 International Zürich Seminar on Broadband Communications, February 19-21 Zürich, Switzerland
[4] Lu, J. , Tjhung, T.T., Adachi, F.**,** BER performance of OFDM system in frequency-selective
[5] Rician fading with diversity reception, available online: http://www.cwc.nus.edu.sg/~cwcpub/zfiles/ict97_2.pdf.
[6] B. Sklar, Rayleigh Fading Channels in Mobile Digital Communication Systems- Part II: Mitigation, IEEE Commun. Mag., July 1997;
[7] Chini, A., Analysis and Simulation of Multicarrier Modulation in Frequency Selective Fading Channels ,Ph. D. Thesis, 1994.

Inderjeet Kaur

Pursuing Ph.D. under the supervision of Prof, (DR.) Yogesh K. Mathur. She received her M.Tech in Information Technology from GGS Indraprastha University, Delhi and B.Tech in Computer Engineering from Kurukshetra University, Kurukshetra. She is presently pursuing her PhD from Department of Computer Science & Engineering, Singhania University, Rajsthan, India. She has published 8 research papers in International/National Journals/Conferences. Her research areas include Wireless Communications, computer networks and Security Applications.

Dr.Yogesh Kr. Mathur

Ph.D. (Theoretical Physics) - Moscow University, Moscow, Russia (1982), M.Sc. Physics and Mathematics – Moscow University, Moscow, Russia (1978). Post Doctoral Positions held: Joint Institute for Nuclear Investigation, DUBNA, Russia (April 1982-Feb.1983), Department of Physics, University of Rochester, USA(Feb.1983-Dec.1983) and Department of Physics, University of Bielefeld, Germany (Dec.1983-Dec.1984). Academic Positions Held: CSIR Pool Officer, Department od Physics and Astrophysics, University of Delhi (as a member of Quark Physics Team headed by Prof. A.N.Mitra (FNA)) (Jan.1985-Jan. 1986), CSIR Research Scientist , Department of Physics and Astrophysics, University of Delhi.(Jan.1986-Aug.1988), Lecturer (Astt. Professor), Department of Physics and Astrophysics, University of Delhi (August 1988- May 1994), Reader (Associate Professor), Department of Physics and Astrophysics, University of Delhi(December1994-May 2005), Professor, Department of Applied Sciences and Humanities, ITM, Gurgaon Delhi(July 2005 –January 2011), Head ASH and School of Physics (April, 2010 to January 2011) and Professor, Department of Applied Sciences, PDM college of Engineering, Bahadurgarh (January 2011 till date).
Teaching Experience : Post Graduate: 21years, at the Department of Physics and Astrophysics, University of Delhi
Undergraduate : 7.5 years (5 years and 6 months at ITM, Gurgaon and 2 years at PDM college of Engineering, Bahadurgarh) Haryana, India.