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Effect of Cyclic Prefix on OFDM Signal

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Abstract — To fulfill the 4G network systems requirement, higher reliability and high spectral efficiency are required. To achieve this Orthogonal Frequency Division Multiplexing (OFDM) is considered to be the best modulation technique for 4G - networks. OFDM can provide large data rates with sufficient robustness to radio channel impairments. OFDM is designed such a way that it sends data over hundreds of parallel streams which increases the amount of information that can be sent at a time. It can offer high quality performance in terms of bandwidth efficiency, robustness against multipath fading and cost effective implementation. A guard time, in the form of cyclic prefix (CP), is inserted between OFDM symbols to eliminate both the inter-symbol interference (ISI) and the inter-channel interference (ICI). In this paper we have studied the effect of cyclic prefix on data rate using OFDM modulation techniques. For this method to work efficiently the space between sub carriers should be maintained exactly at the specified position which satisfy the condition of orthogonality Zero padding (ZP) of multicarrier transmissions has recently been proposed as an appealing alternative to the traditional cyclic prefix (CP) orthogonal frequency-division multiplexing (OFDM) to ensure symbol recovery regardless of the channel zero locations.

Keywords — OFDM- Orthogonal Frequency Division Multiplexing, ISI- Inter-Symbol Interference, CP- Cyclic Prefix, BER- Bit Error Rate.

I. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) is a multi-carrier scheme used in modern broadband wire- less communication systems to transmit data over a number of orthogonal subcarriers. Whereas conventional transmission uses only a single carrier modulated with all the data to be sent, OFDM breaks the data to be sent into small chunks, allocates each sub-data stream to a sub- carrier and subsequently sends the data in parallel orthogonal sub-carriers. OFDMA (orthogonal frequency division multiple access) dynamically assigns subset of sub-carriers to individual users using either Time Division Multiple Access (TDMA i.e., separate time frame) or Frequency Division Multiple Access (FDMA—i.e., separate channels) technique. In an OFDM scheme a large number of sub channels or sub-carriers are used to transmit digital data. Each sub-channel is orthogonal to every other. They are closely spaced and narrow band. The separation of the sub-channels is as minimal as possible to obtain high spectral efficiency. OFDM is being used because of its capability to handle with multipath interference at the receiver. The basic principle of OFDM is to split a high-rate data stream into a number of lower rate streams that are transmitted simultaneously over a number of subcarriers. The relative amount of dispersion in time caused by multipath delay spread is decreased because the symbol duration increases for lower rate parallel subcarriers. The other problem to solve is the Inter Symbol Interference (ISI), which is eliminated almost completely by introducing a guard time in every OFDM symbol. This means that in the guard time, the OFDM symbol is cyclically extended to avoid Inter Carrier Interference (ICI). An OFDM signal is a sum of subcarriers that are individually modulated by using phase shift keying (PSK) or quadrature amplitude modulation (QAM) or any modulation scheme.

II. OFDM SYSTEM

The input symbols $\{Sk\,(i)\}\ N_i = 1$ denotes the transmit symbols for the k^{th} OFDM block. These symbols may come for instance from a M-QAM constellation. N denotes the number of OFDM sub-carriers (the number of constellation symbols to be transmitted in one OFDM block). After serial to parallel conversion of the input symbol stream, an N-pt IFFT is taken to get1 $\{X_k\,(i)\}\ N_i = 1$. After back parallel to serial conversion, a cyclic redundancy of length _ (the number of CP samples) is added as a prefix in such a way that $X_k(-i) = X_k(N - i)$ for i = 1, 2. . . _.

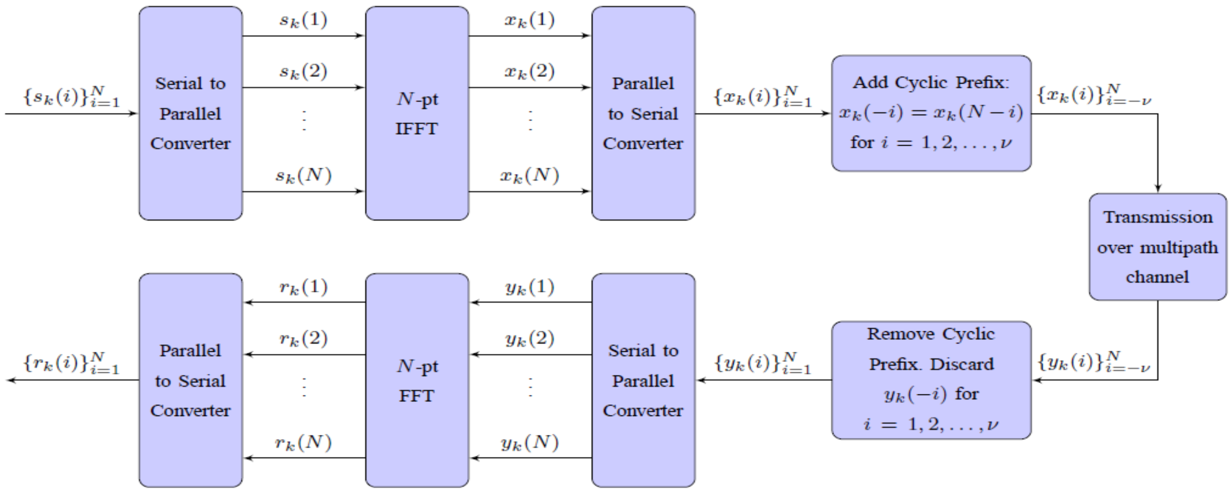

Fig.1 OFDM Transmitter - Receiver Structure.

'Divide a wide frequency band' into multiple small/narrow frequencies. This is the meaning of 'Frequency Division'. Since all the data on each of these subcarriers are transmitted simultaneously, we can say this is a kind of 'Multiplexing'.

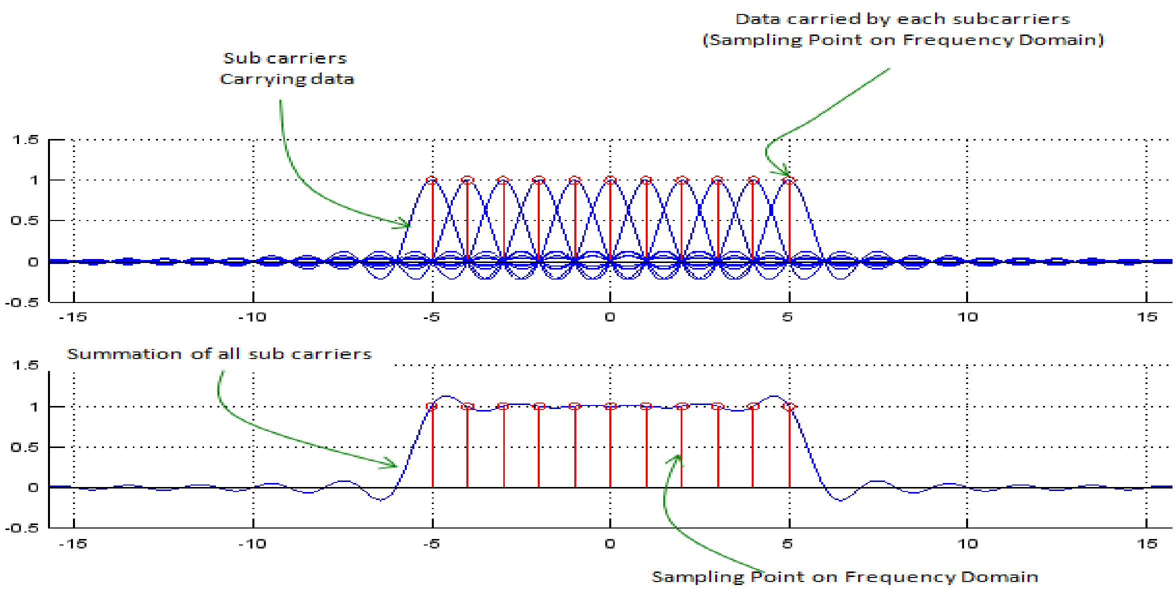

Fig. 2 OFDM Signal.

Now we may have a question at this point. How small we can make it for each subcarrier (subcarrier, divided frequency)? For example, if given 1 MHz bandwidth as a full band, how many subcarriers are supposed to split into? If split it into 1000 sub carriers with 1 KHz interval and carry one bit on each sub carrier, It can transmit 1000 bits simultaneously. If split it into 100 sub carriers with 10 KHz interval and carry one bit on each sub carrier, you can transmit 100 bits at a time. If we want to split it into 1000 sub carriers. We may say I want to split it into even more sub carriers. But unfortunately it would not be possible to split it with too small intervals between sub carriers. If you split it into too many sub carriers with too small space between sub carriers, there would be much high possibility of interference between adjacent sub carriers. However, if we separate each subcarrier too much and have small number of sub carriers, it would have much less interference between sub carriers but in that case the data rate would be decreased. As a kind of optimal solution, OFDM split the band into multiple sub carriers in such a way as shown below. In the following illustration, at each sampling point in frequency domain there is only one carrier which has non-zero value and all other sub carriers has zero value at the sampling point.

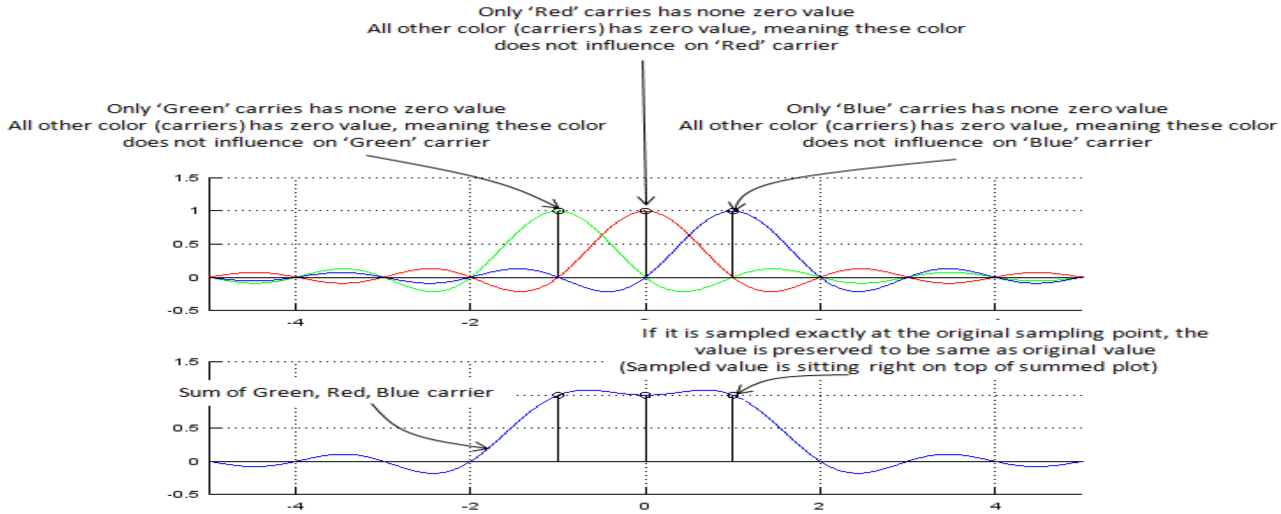

Fig. 3 OFDM Signal with multipal sub carrier.

III. CYCLIC PREFIX IN OFDM

BER (Bit Error Rate), Bit error rate is a key parameter that is used in assessing systems that transmit digital data from one location to another. BER is applicable to radio data links, Ethernet, as well as fiber optic data systems. When data is transmitted over a data link, there is a possibility of errors being introduced into the system. If this is so, the integrity of the system may be compromised. As a result, it is necessary to assess the performance of the system, and BER provides an ideal way in which this can be achieved. BER assesses the full end to end performance of a system including the transmitter, receiver and the medium between the two. BER is defined as the rate at which errors occur in a transmission system.

OFDM is very good method of utilizing the given frequency wisely, but there is a drawback to this method. For this method to work efficiently the space between sub carriers should be maintained exactly at the specified positions which satisfy the condition of orthogonality. What if the spaces between sub carriers are not maintained accurately and they are drifting around. One example for this case is shown below. It would not see much differences when each sub carriers are plotted separately (upper plot), but we would notice the differences when all of these sub carriers are summed together as shown on lower plot.

To add Cyclic Prefix to the time domain data we got from input data sequence. Cyclic prefix generation is very straight forward; it is direct copy of some portion of data from the end and putting the copy at the beginning of the data sequence. So by adding the cyclic prefix possibility of inter symbol interference get reduce and orthogonality of OFDM signal is maintain also bit error rate also get reduced.

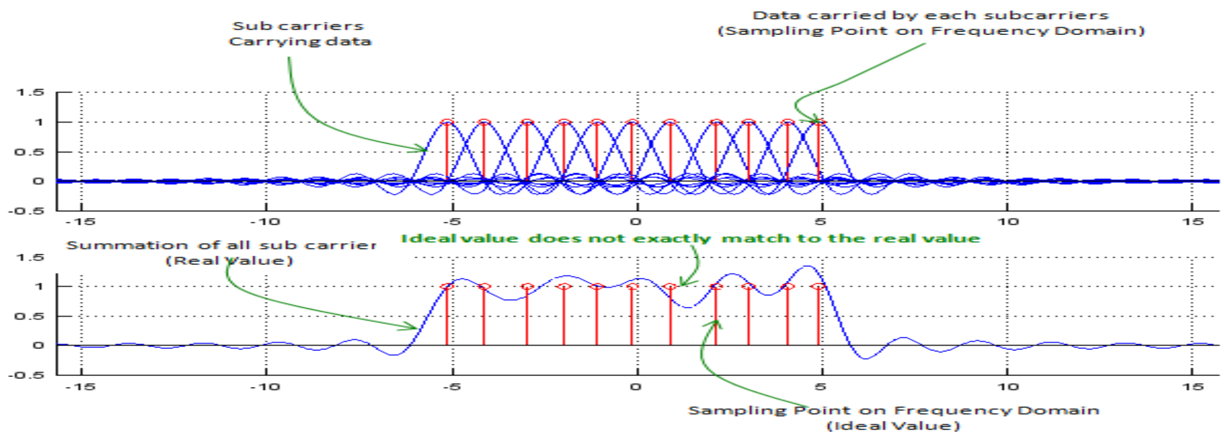

Fig.4 OFDM Signal showing ideal values does not exactly match to real value.

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IV. CONCLUSIONS

It is a block modulation scheme where a block of N information symbols is transmitted in parallel on N sub-carriers. A guard time, usually in the form of cyclic prefix (CP), is inserted between OFDM symbols to eliminate both the inter-symbol interference (ISI) and the inter channel interference (ICI). Transmission of cyclic prefix reduces the data rate. As cyclic prefix duration increases the data rate decreases, hence the cyclic prefix duration should not be much more than the duration of the maximum expected multipath channel.

V. ACKNOWLEDGMENT

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