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Role of OFDM in 4G LTE networks: A Literature review

Deepali B. Ingle[1] andP. R. Gumble[2]
[1]*PG student,SGBAU, Amaravati (M.S.)*
[2]*Research guide Dept. of Electronics and Telecommucation, SGBAU,Amaravati (M.S.)*
Corresponding Author: Deepali B. Ingle

ABSTRACT-Orthogonal Frequency-Division Multiplexing (OFDM) effectively alleviates Intersymbol Interference (ISI) caused by the delay spread of wireless channels. Therefore, it has been used in many wireless systems and adopted by various standards. When the contemporary communications systems are considered, OFDM is a Multicarrier (MC) multiplexing scheme that maintains adaptive communications features by employing subcarriers in a flexible way.In this paper, we present a literature review on role of OFDM in 4th Generation (4G) Long Term Evolution (LTE) wireless networks. We address basic principle ofOFDM and the performance parameters of OFDM for LTE networks, such asInter Block Interference (IBI) and Peak-to-Average Power Ratio (PAPR) reduction. We also describe the applications of OFDM in current systems and standards.
Keywords—Orthogonal Frequency-Division Multiplexing (OFDM), 4th Generation (4G), Long Term Evolution (LTE), Inter Block Interference (IBI), Peak-to-Average Power Ratio (PAPR).

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I. INTRODUCTION

Wireless communications has become an emerging and fastly growing field in our modern life and creates enormous impact on nearly every feature of our daily life. A tremendous technological transformation during the previous two decades has provided a potential growth in the field of digital communication and lot of latest applications and technologies are coming up every day due to these valid reasons.

The concept of Multi-Carrier(MC) transmission was first explicitly proposed by Chang [1] in 1966.MC modulation, in particular Orthogonal Frequency Division Multiplexing (OFDM), has been successfully applied to a wide variety of digital communications applications over the past several years [4]. OFDM has capability of providing high-rate data transmission by splitting the serial data into many low-rate parallel data streams. It is also capable of offering a low-complexity high-performance solution for mitigating the ISI caused by a dispersive channel. Due to the above-mentioned merits, OFDM has been adopted in many broadband wireless standards, such as 802.11a/g Wi-Fi, 802.16 WiMAX, and LTE [11].

In this paper, we present a literature review on OFDM for 4G LTE networks. We start with basic principle of OFDM in section II and techniques to improve the system performance in Section III. Then, we address various applications in current systems and standards in Sections IV. Finally, we present our conclusion in Section V.

II. BASIC PRINCIPLE OF OFDM

Let $\{S_{n,k}\}_{k=0}^{N-1}$ with $E|S_{n,k}|^2 = \sigma_s^2$ be the complex symbols to be transmitted at the n^{th} OFDM block, then the OFDM modulated signal can be represented by

$$S_n(t) = \sum_{k=0}^{N-1} S_{n,k}\, e^{j2\pi k\Delta ft},\ \ 0 \le t \le T_s \text{ ---------(1)}$$

whereTs, Δf, and N are the symbol duration, the subchannel space, and the number of subchannels of OFDM signals, respectively. For the receiver to demodulate the OFDM signal, the symbol duration should be long enough such that $T_s\Delta f = 1$, which is also called the orthogonal condition since it makes $e^{-j2\pi k\Delta ft}$ orthogonal to each other for different k. With the orthogonal condition, the transmitted symbols $S_{n,k}$ can be detected at the receiver by

$$S_{n,k} = \frac{1}{T_s}\int_0^{T_s} S_n(t)\, e^{-j2\pi k\Delta ft}dt\,, \quad ----------(2)$$

if there is no channel distortion. The sampled version of the baseband OFDM signal S(t) in (1) can be expressed as

$$S_n\left(m\frac{T_s}{N}\right) = \sum_{k=0}^{N-1} S_{n,k}\, e^{j2\pi k\Delta fm\frac{T_s}{N}} = \sum_{k=0}^{N-1} S_{n,k}\, e^{j\frac{2\pi mk}{N}} -----(3)$$

which is actually the inverse discrete Fourier transform (IDFT) of the transmitted symbols $\{S_{n,k}\}_{k=0}^{N-1}$ and can efficiently be calculated by fast Fourier transform(FFT). It can easily be seen that demodulation at the receiver can be performed using DFT instead of the integral in (2).

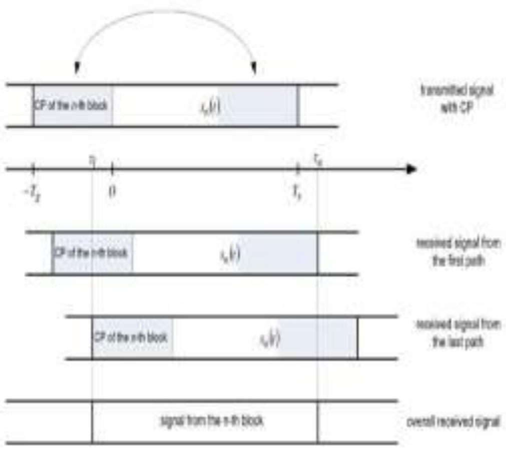

Fig.1. Function of the Cyclic Prefix [5]

A cyclic prefix (CP) or guard interval is critical for OFDM to avoid Inter Block Interference (IBI) caused by the delay spread of wireless channels. They are usually inserted between adjacent OFDM blocks. Fig. 1 shows the function of the CP. Without the CP, the length of the OFDM symbol is Ts. With the CP, the transmitted signal is extended to T = Tg + Ts and can be expressed as

$$\widetilde{S_n}(t) = \sum_{k=0}^{N-1} S_{n,k}\, e^{j2\pi k\Delta ft}\,, \quad -T_g \le t \le T_s \quad ------(4)$$

It is obvious that $\tilde{S}_n(t) = S_n(t+T_S)$for $-T_g \le t \le 0$which is why it is called the CP. The impulse response of a wireless channel can be expressed by

$$h(t) = \sum_i \gamma_i \delta(t-\tau_i) ------(5)$$

whereτ_i and γ_i are the delay and the complex amplitude of the i^{th} path, respectively. Then, the received signal can be expressed as

$$x_n(t) = \sum_i \gamma_i \tilde{S}_n(t-\tau_i) + n(t) -----(6)$$

where$n(t)$ represents the Additive White Gaussian Noise (AWGN) at the receiver. As demonstrated in Fig. 1, $x_n(t)$ consists of only the signal component from the n^{th} OFDM block when $\tau_l \le t \le \tau_u$, where $\tau_l = -Tg + \tau_M$, $\tau_u = Ts + \tau_m$, $\tau_m = \min_i\{\tau_i\}$, and $\tau_M = \max_i\{\tau_i\}$, otherwise, the received signal consists of signals from different OFDM 0blocks. If $\tau_l \le 0$ and $\tau_u \ge T_s$ then

$$x_{n,k} = \frac{1}{T_S}\int_0^{T_S} x_n(t)\, e^{-j2\pi f_k t}dt$$
$$= \frac{1}{T_S}\int_0^{T_S}\left\{\sum_i \gamma_i \tilde{S}_n(t-\tau_i) + n(t)\right\} e^{-j2\pi f_k t}dt \;= H_k S_{n,k} + n_k \quad ----(7)$$

for $0 \le k \le N-1$, and all n, where H_k denotes the frequency response of the wireless channel at the k^{th} subchannel and is defined as

$$H_k = \sum_i \gamma_i e^{-j2\pi k\Delta f\tau_i} ------(8)$$

andn_k is the impact of AWGN and is defined as

$$n_k = \frac{1}{T_S}\int_0^{T_S} n(t)\, e^{-j2\pi f_k t}dt ------- (9)$$

It can be proved that n_k are independent identically distributed complex circular Gaussian with zero mean and variance σ_n^2. With H_k, transmitted symbols can be estimated. For singlecarrier systems, the received signal is the convolution of the transmitted sequences or symbols and the impulse response of wireless channels in addition to AWGN, whereas the impact of the channel is only a multiplicative distortion at each subchannel for OFDM systems, which makes signal detection in OFDM systems very simple and is also one of the reasons why OFDM is very popular nowadays [5].

III. PARFORMANCE PARAMETERS OF OFDM

A. Interblock Interference:

As we have seen in Section II, the CP or guard interval effectively avoids IBI. If a guard interval is used instead of the CP, that is, transmitting no signal in the place of the CP in Fig. 1, the IBI and Intercarrier Interference (ICI) can be avoided by the following processing

$$\widetilde{x_n}(t) = \begin{cases} x_n(t+T_s) & \text{if } 0 \le t \le \tau_m \\ x_n(t) + x_n(t+T_s) & \text{if } \tau_m \le t \le \tau_M \\ x_n(t) & \text{if } \tau_M \le t \le T_s \end{cases} \quad --------(10)$$

if there is no CP or guard interval, or its length is not long enough, the delay spread of wireless channels will cause both IBI and ICI [5].

B. Peak To Average Power Ratio:

The Peak to Average Power Ratio (PAPR) of transmitted signal $s(t)$on time interval τ. PAPR is defined by following relationship:

$$\mathrm{PAPR}\{s(t),\tau\} = \frac{\max[s(t)]^2}{E\{[s(t)]^2\}} ------(11)$$

where$\max[s(t)]^2$ is the peak signal power and $E\{[s(t)]^2\}$ is the average signal power.

Amplitude clipping is considered as the simplest technique which may be under taken for PAPR reduction in an OFDM system. A threshold value of the amplitude is set in this case to limit the peak envelope of the input signal. Signal having values higher than this pre-determined value are clipped and the rest are allowed to pass through un-disturbed. Amplitude clipping can cut-off the peak from thesignal and solve the high peak power problem. This clipping limits the peak of the input signal to a fixed value or otherwise passes the input signal through unperturbed with phase left unchanged. The clipped signal is:

$$B(x) = \begin{cases} x, & |x| \le A \\ Ae^{j\phi(x)}, & |x| > A \end{cases} -----(12)$$

where, B(x) is the amplitude value after clipping, x is the initial signal value and A is the threshold set by the user for clipping the signal.

The problem in this case is that due to amplitude clipping distortion is observed in the system which can be viewed as another source of noise. This distortion falls in both in – band and out of band. Filtering cannot be implemented to reduce the in band distortion and an error performance degradation is observed here. On the other hand spectral efficiency is hampered by out of band radiation. Out of band radiation can be reduced by filtering after clipping but this may result in some peak regrowth. A repeated filtering and clipping operation can be implemented to solve this problem. The desired amplitude level is only achieved after several iteration of this process.

The Cumulative Distribution Function (CDF) is one of the most regularly used parameters, which is used to measure the efficiency of any PAPR technique. Normally, the Complementary CDF (CCDF) is used instead of CDF, which helps us to measure the probability that the PAPR of a certain data block exceeds the given threshold.

By implementing the Central Limit Theorem for a multi – carrier signal with a large number of subcarriers, the real and imaginary part of the time – domain signals have a mean of zero and a variance of 0.5 and follow a Gaussian distribution. So Rayleigh distribution is followed for the amplitude of the multi – carrier signal, where as a central chi-square distribution with two degrees of freedom is followed for the power distribution of the system. The CDF of the amplitude of a signal sample is given by

$$F(Z) = 1 - \exp(Z) ----(13)$$

The CCDF of the PAPR of the data block is desired is our case to compare outputs of various reduction techniques. This is given by

$$P(\mathrm{PAPR} > Z) = 1 - P(\mathrm{PAPR} \le Z) = 1 - F(Z)^N = 1 - (1 - \exp(Z))^N ----(14)$$

This expression assumes that the N time domain signal samples are mutually independent and uncorrelated [6].

IV. APPLICATIONS OF OFDM

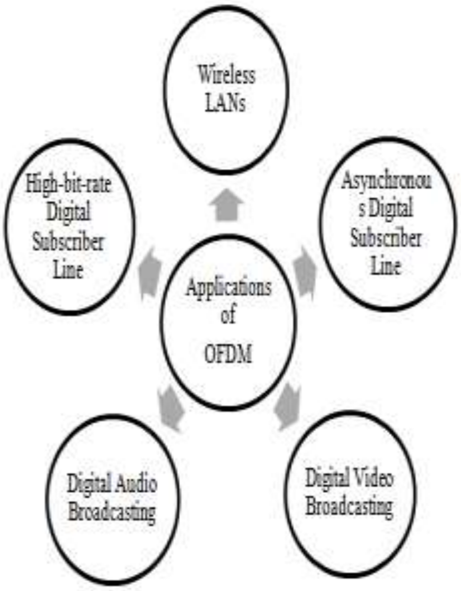

Fig.2. Applications of OFDM

Fig. 2 shows the applications of OFDM.It has been adopted as the new European Digital Audio Broadcasting (DAB) standard as well as for the terrestrial Digital Video Broadcasting(DVB) system. For fixed-wire applications, OFDM is employed in the Asynchronous Digital Subscriber Line (ADSL) and High-bit-rate Digital Subscriber Line (HDSL) systems [13]. In addition, OFDM has been considered or approved by many IEEE standard working groups, such as IEEE 802.11a/g/n, IEEE 802.15.3a, and IEEE 802.16d/e [5]. It has also been suggested for power line communications systems due to its resilience to time dispersive channels and narrow band interferers. More recently, OFDM applications were studied within the European 4thFramework Advanced CommunicationsTechnologiesand Services (ACTS) programmes. The MEDIAN project investigated a 155 Mbps Wireless Asynchronous Transfer Mode (WATM) network, while the Magic WAND group developed a Wireless Local Area Network (LAN).

V. CONCLUSION

In this paper, we have briefly described OFDM for wireless communications. We start with the basic principle of OFDM and techniques to deal with impairments in wireless systems, including IBI and PAPR reduction. The flexibility of OFDM provides opportunities to use advanced techniques, such as adaptive loading, transmit diversity, and receiver diversity, to improve transmission efficiency. OFDM for 4G LTE networks has intensively been an active research area over the last few years. Although OFDM has been chosen as the physical layer standard for a diversity of important systems, the theory, algorithms, and implementation techniques remain subjects of current interest. This is clear from the high volume of papers appearing in technical journals and conferences.

Research continues to offer availability of huge spectrum, to the emerging spectrum hungry application promising ultra-high data rates, extremely low latency, and cost and energy consumption in wireless networks at the same time providing good Quality of Service(QoS) to the user.

REFERENCES

[1]. R. W. Chang,"Synthesisof Band Limited Orthogonal Signals for Multichannel Data Transmission," Bell Syst. Tech. J., vol. 45, pp. 1775-1796, Dec. 1966.
[2]. L. J. Cimini, "Using Orthogonal Frequency Division Multiplexing," IEEE Trans. on Communications, Vol.-33, No. 7, pp. 665-675, July-1985
[3]. H. E. Principle, O. F. Transmitting, and D. By, "Multicarrier Modulation for Data Transmission : An Idea Whose Time Has Come," IEEE Communications Magazine, pp-5-14, May 1990.
[4]. T. J. Willink, P. H. Wittke, and S. Member, "Optimization and Performance Evaluation of Multicarrier Transmission," vol. 43, no. 2, pp. 426–440, 1997.
[5]. T. Hwang, C. Yang, S. Member, G. Wu, S. Li, and G. Y. Li, "OFDM and Its Wireless Applications : A Survey," vol. 58, no. 4, pp. 1673–1694, 2009.
[6]. S. Bhad, P. Gulhane, and A. S. Hiwale, "PAPR Reduction scheme For OFDM," Procedia Technol., vol. 4, pp. 109–113, 2012.
[7]. M. Barnela, "Digital Modulation Schemes Employed in Wireless Communication : A Literature review," vol. 2, no. 2, pp. 15–21, 2014.
[8]. P. Xu, J. Wang, S. Member, J. Wang, and F. Qi, "Multicell Multiuser MIMO OFDM Systems," vol. 64, no. 2, pp. 610–620, 2015.
[9]. A. Gorcin, H. Arslan, and S. Member, "An OFDM Signal Identification Method for Wireless Communications Systems," vol. 64, no. 12, pp. 5688–5700, 2015.
[10]. H. Kim, S. Member, H. Lee, S. Member, M. Ahn, S. Member, H. Kong, and I. Lee, "Joint Subcarrier and Power Allocation Methods in Full Duplex Wireless Powered Communication Networks for OFDM Systems," vol. 15, no. 7, pp. 4745–4753, 2016.
[11]. T. Mao, S. Member, Z. Wang, S. Member, Q. Wang, S. Chen, and L. Hanzo, "Dual-Mode Index Modulation Aided OFDM," pp. 1–11, 2016.
[12]. K. Ulovec, "Recognition of OFDM Modulation Method," Radioengineering, Vol. 17, No. 1 pp. 50–55,, April 2008.
[13]. Ahmad R. S. Bahai and Burton R. Saltzberg,"Multi-Carrier Digital Communications.Theory and Applications of OFDM", Kluwer Academic Publishers 2002.

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