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ICI Suppression in OFDM Systems for LTE

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Abstract— 4G technology bring great prospects for the future. To obtain the desired goal, a multiplexing technique known as the OFDM i.e. Orthogonal Frequency Division Multiplexing was being suggested. OFDM provides sufficient data rate as other methods but requires less bandwidth. The idea of OFDM was conceptualized in the 60's. Weinstein and Ebert showed that OFDM can be employed or implemented using Fast Fourier Transform (FFT). With arrival of VLSI and advancement in DSP techniques, OFDM was practically implemented. OFDM has three main problems namely Intersymbol Interference (ISI), PAPR known as Peak-to-average Power ratio and the intercarrier Interference (ICI). One of most severe problem among these is ICI. Efficient methods were proposed to eliminate the ISI and reduce PAPR. This paper explains the factors that causes ICI in the 4G LTE wireless system and possible solutions to this kind of interference. The ICI increases the system probability of bit error rate (BER) increases. The system BER can be reduced by reducing the factors which have significant affects to cause ICI.

Keywords— OFDM, Multicarrier Techniques, 4G, LTE, Digital Modulation

I. INTRODUCTION

The word LTE represent or is known as Long Term Evolution. LTE system is compatible with Global System for Mobile Communication (GSM) technology, which uses the 3G network (third generation). Advanced LTE (Advanced) is a more elaborate version of LTE and promises to provide extensive coverage and high download and upload rates. Created on the basis of Wideband Code Division Multiple Access (WCDMA) and GSM, the LTE aims to maintain compatibility with GSM and high speed packet access (HSPA), it is a mobile data transmission technology that operates in the 700MHz range that is currently destined for open television (Channel 52 to 69 of the UHF), this frequency has a range up to 4 times greater than the 2500MHz used today for this purpose, plus the difference this time is that this technology prioritizes data traffic instead of voice traffic as occurred in previous generations , This network is faster and more stable this is a network for data, remembering that when LTE was created there was no voice traveling over this network and with the adaptations that were made, one of the solutions found was to demote the connection to use the GSM / WCDMA network when using voice and another solution developed later allowing the phone to work normally on the 4G network was voice over LTE (VoLTE). The main differential of LTE is the data network. In laboratory tests, an experimental LTE network with 20 MHz of spectrum has reached approximately 300 Mbps downstream and 75 Mbps upstream. However, the actual browsing speed is at 100 Mbps download and 50 Mbps upload. The response time of the LTE is noticeably lower than what we know of the 3G networks: under normal conditions, the latency of the network reaches a maximum of 30 ms. LTE brings great prospects for the future. Some operators are considering the possibility of transmitting in LTE broadcasting, this will require a much more robust network architecture than today's networks, and we will follow the advances that LTE has provided in the not-too-distant future. LTE brings great prospects for the future. Some operators are considering the possibility of transmitting in LTE broadcasting, this will require a much more robust network architecture than today's networks, we will follow the advances that LTE has provided in the not-too-distant future.

The characteristics of each generation are always a unique part of the architecture of each. And the evolutionary process of these characteristics led the fourth generation to be 10 times better than its predecessor to 3G, providing high performance in the use of digital technology to support the various types of services such as: Mobile Digital TV HDTV, video conferencing, broadband internet access and etc. The main differential of LTE is the data network. In laboratory tests, an experimental LTE network with 20 MHz of spectrum has reached approximately 300 Mbps downstream and 75 Mbps upstream. However, the actual browsing speed is at 100 Mbps download and 50 Mbps upload. The response time of the LTE is noticeably lower than what we know of the 3G networks: under normal conditions, the latency of the network reaches a maximum of 30 ms.

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4G network was VoLTE. Tiago Andrade Mota in his tutorial "3G Networks and Evolution for 4G Networks" (2009) covers the following features of the 4G system technology:

- Evolution of the Third Generation Partnership Project (3GPP) for an efficient use of bands above 5 MHz.
- Usage of multiple input multiple output (MIMO) methods to Technology based on Code Division Multiple Access (CDMA). Another difference is the amount of users hanging on the network: 5 MHz of spectrum allows up to 200 simultaneous accesses - practically double the current networks.
- Use of Orthogonal Frequency Division Multiplexing (OFDMA) in the downlink and Multiple Access Frequency Division by single Carrier (SC-FDMA) in the uplink, to reduce the Average Peak Package (PARP) for being inefficient by the loss of high gain, thereby reducing the difficulty of the mobile device.
- Supports Packet Switching (PS) only. In other words, the voice to user is provided through voice over internet protocol (VoIP) or using technologies legacy.
- Scalable bandwidth is up to 20 MHz, with smaller bands covering 1.25 MHz, 2.5 MHz, 5 MHz, 10 MHz and 15 MHz. Also the 1.6 MHz band for specific cases.
- Maximum downlink data rate of up to 100 Mbits and uplink up to 50 Mbits / s with 20 MHz bandwidth

ICI IN FFT OFDM

OFDM has three main problems intersymbol interference (ISI), PAPR and ICI. In OFDM, the effect due to multipath fading which effects the successive symbols in getting overlapped is known as intersymbol interference (ISI). Inter Symbol Interference is being removed in by presenting a special or say distinctive guard intervals or spacing in-between symbols at the side of transmitter. Also guard intervals can be called or treated as sense special because that they don't comprise the zero paddings. This method is being named as the cyclic postfix or the cyclic prefix dependent on location of the attached portion of the symbol. Sometimes, the peak signals power gets much greater than average signal power and need very linear amplifiers with large dynamic range. This problem is known as Peak-to-Average Power ratio (PAPR) problem. The methods or approaches to resolve this problem comprise of 'coding' to evade the peaks or clipping the peaks. The third key problem in the OFDM is it so called sensitivity or compassion to the frequency-offset, errors in between receiver and transmitter, which effects is the loss or damage of the orthogonality in between the sub-carriers. This problem is known as Intercarrier interference (ICI). ICI is the worst problem of all in OFDM Technology as the information received in the data is completely damaged. In this chapter, graphical interpretation of ICI, modeling of ICI, factors involved in causing ICI and the previously proposed solutions are discussed.

III. ORTHOGONALITY OF OFDM

Frequency offset occurs between the transmitter and receiver, the carriers are shifted in frequency domain. When the data from a carrier is extracted at the receiver at particular frequency, it doesn't only contain the data at the desired frequency but also data from its neighbor carrier which is the result of ICI. This fact can be seen from the Figure 1.

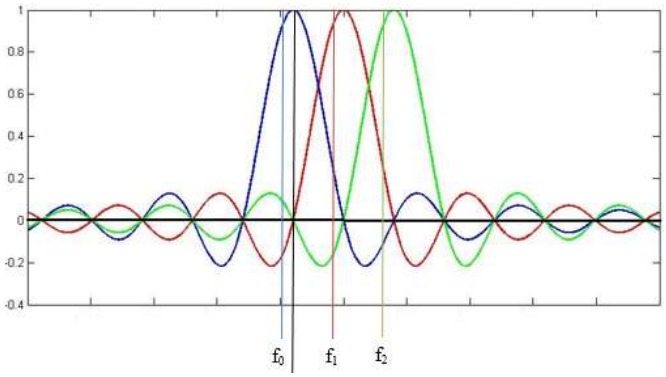

Figure 1. Orthogonal Carriers with frequency offset

IV. FACTORING CAUSING ICI

The factor causing the frequency offset or equivalently ICI may be Doppler shift and is because the relative motion of the transmitter or receiver, or also due to the differences of the so said frequencies between local oscillators at the receiver and transmitter.

Doppler Effect

It can be defined as the apparent shift in the received signal frequency due to the relative motion of transmitter, receiver or both. It occurs for narrow band communication. For example, the quality of phone conversation in a moving vehicle can be affected by Doppler shift.

Synchronization Error

Perfect frequency synchronization cannot be achieved between our practical world transmitter and receivers. It is because our practical oscillators are being typically unstable due to which it induces frequency's offset. Also the Small frequency offset may be negligible in other applications but OFDM is too sensitive even for very small frequency offsets

Multipath Fading

The role of multipath fading in frequency offset is not more prominent than the other two described above. Multipath fading means that more than one copy of the desired signal reaches the receiver. It causes ISI and also shifts the phases making the ICI worse. The multipath fading doesn't induce ICI itself but make the ICI worse. ISI is largely reduced by introducing Cyclic Prefix so the ICI needs to be concerned.

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V. SOLUTION FOR ICI

Frequency Domain Equilization

The method is implied for the ICI generated by fading distortion in the channel. As the fading distortion which is considered as the source of ICI is not truly one the main source of ICI, so this method cannot be used to address the ICI entirely.

Domain Windowing

OFDM signal has widely spread power spectrum. If the OFDM signal is passed through a band limited channel then there might be a chance that certain portion of the spectrum cut off which will certainly lead to ICI. By time windowing the signal the spectrum of the signal may be more concentrated. This method can only reduce the ICI induced by band limited channel which is also not the main source of ICI. So this method cannot be used to address the ICI entirely.

Pulse shaping

In OFDM, each carrier consists of a main lobe followed by number of side lobes. If there occur some power of side lobe at the peak of other carrier, it is called ICI power and it induces ICI. To make the signal's power of its side lobes zero at peak of other signals or carriers, Pulse shaping is used. Some of the pulse shaping functions are rectangular pulse, raised cosine, root raised cosine etc.

Maximum liklihood Estimation

According to this method the so said frequency offset is 1st statistically predicted using the technique of maximum likelihood procedure or algorithm and after that it is cancelled at side of receiver. This method comprises the replication or repetition of the so said OFDM symbol afore the transmission and the comparison of different phases of the each of subcarriers in-between the consecutive symbols.

ICI Self Cancellation

This scheme was introduced by Zhao and Häggman for ICI mitigation. Note that the Last two techniques described are comparatively good than the other three former techniques for ICI reduction.

MODELLING ICI

The data is send by the transmitter to the channel. The channel adds noise to the data. The receiver receives the data from the noisy channel.
The received signal is given by

$$x(x) = s(n)e^{\frac{j2\pi n\varepsilon}{N}} + w(n) \quad (1)$$

Where 'ε' is the normalized frequency's offset that is being given by ΔfNTs. Δf is the alteration between received and transmitted signal frequency and Ts as subcarrier symbol's period. N is IFFT length. w(n) is so said AWGN produced in channel. Value of ε is commonly taken to be 0.2 or 0.4 and we have taken its value of 0.4.

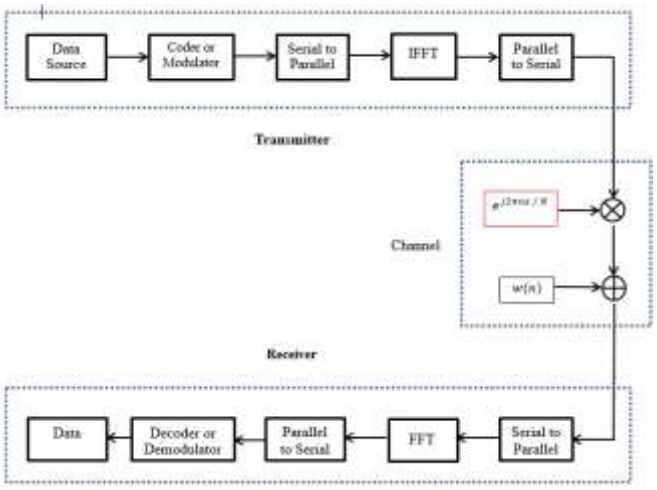

Figure 2. ICI model

RESCULTS OF FFT-OFDM

We have simulated the Fast Fourier Transform (FFT-OFDM) system in Matlab. Then ICI is added in the same FFT-OFDM and the results are compared with the system as shown in below figure 3. with the parameters and specifications shown in the table 1.

Parameter	Specifications
Modulation	BPSK
Data bits	512
No. of Carriers	64
Carrier Offsets	.4
Channel	Gaussian

Table 1. Parameters and specifications of OFDM systems used in figure 3.

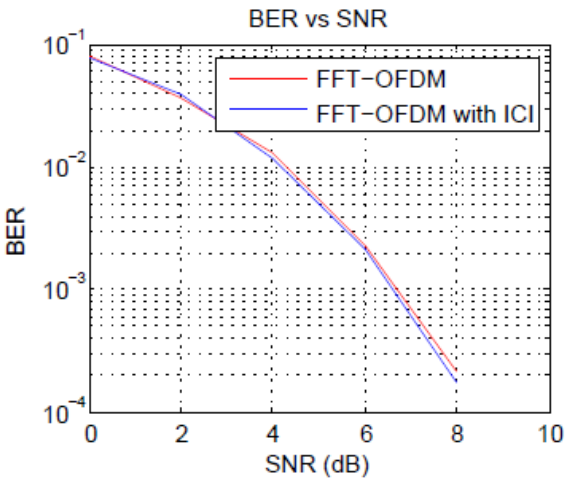

Figure 3. Comparison of FFT-OFDM system and FFT-OFDM with ICI

CONCLUSION

This paper explains the factors that causes ICI in the 4G LTE wireless system and possible solutions to this kind of interference. The ICI increases the system probability of bit error rate increases. The system BER can be reduced by

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