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ADJACENT CHANNEL INTERFERENCE COMPUTATION FOR COMPONENT CARRIER IN LTE-ADVANCED SYSTEMS

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ABSTRACT: The interference analysis for the user equipment (UE) in Long Term Evolution-Advanced (LTE-A) system with carrier aggregation (CA), in which the UE receiver is affected by the interference. Owing to the characteristics of Orthogonal frequency-division multiplexing (OFDM) signals, the slight frequency offset between a wanted signal and an interferer may result in quite different downlink throughput at UE, accordingly the interference level between component carriers (CCs) and Long Term Evolution (LTE) Adjacent Channel Interferer (ACI) was addressed related to the frequency spacing between them. In addition, the filters of receivers have significant influence on the capability of UEs in dealing with ACI. Base on the frequency response model of Chebyshev filters, the relationship between interference-resistance capability of LTE/LTE-A UE and the bandwidth of the receiver filter are studied. This paper discusses the interference between CCs and the adjacent channel interferer. By varying the spacing between central frequencies of interferer and its adjacent CC, the throughput on the adjacent CC is measured, and it is expressed as the relative throughput.

KEYWORDS: Carrier Aggregation, Long Term Evolution-Advanced, Orthogonal frequency-division multiplexing, Component Carriers, Adjacent channel interferer, Relative throughput, Central frequency.

1.INTRODUCTION:

The LTE format was first proposed by NTT DOCOMO of Japan and has been adopted as the international standard. The first commercial services were launched in Sweden and Norway in year 2009 December followed by the United States and Japan in 2010. More LTE networks were deployed globally during 2010 as a natural evolution of several 2G and 3G systems, including Global system for mobile communications (GSM) and Universal Mobile Telecommunications System (UMTS) (3GPP as well as 3GPP2). In order to support advanced services and applications 100Mbps for high and 1Gbps for low mobility scenarios must be realized.

In order to support wider bandwidth and achieve higher throughput, the carrier aggregation (CA) technique has been introduced in 3GPP Release 10 for long term evolution advanced (LTE-A) system, where the user

equipment (UE) may operate over up to 5 component carriers (CCs), and achieve a maximum bandwidth of 100MHz [1]. For the purpose of smooth evolution and maximal reuse of the LTE Release 8/9 design, the backward compatibility is maintained in each CC in LTE-A system with CA, and thus the complete set of LTE Release 8/9 downlink physical channels and signals are transmitted on each component carrier by the LTE Release 8/9 procedure [2]. It is significant to study the coexistence of LTE-A with LTE and legacy cellular systems. [3] and [4] provided analyses of interferences between CCs in CA system, both consider the impact of Doppler frequency shift and RF nonlinearities. Utilizing adjacent channel leakage ratio (ACLR) model, [5] gave a brief analysis of CA system

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interfering LTE system. The approach of adopting power control scheme to deal with coexistence issue for CA scenario is discussed in [6].

In [7], the issues of LTE-A system interfering 3G/B3G TDD systems was presented. All above literatures treated LTE-A system as the aggressors while legacy systems as the victims. However, the interference arising from other systems poses big challenges[8] of LTE-A system design, especially for UEs, which has not been considered in previous literatures.

2. PROPOSED SYSTEM MODEL:

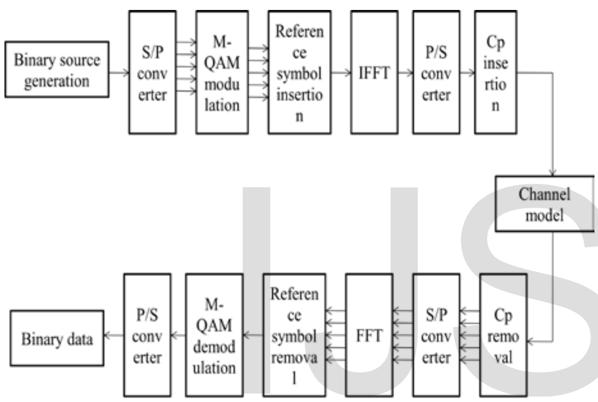

Figure 1 : Block diagram of LTE Transmitter and Receiver

2.1. Transmitter:

Blocks of digital data set have been paralleled and mapped into data blocks using M-QAM modulation technique. Every data block referred to a symbol of data is attached to an individual sub-carrier. The Inverse Fast Fourier Transform (IFFT) is used in order to generate the time version of transmitted signal. The time domain signals corresponding to all subcarriers are orthogonal to each other. However, the frequency spectrum overlaps. To remov/e ISI on the transmitted signal inserted cyclic prefix in front of every transmitted symbol in the block diagram.

2.2. Channel model:

In mobile communication when a transmitter and receiver transmit and receive data and signal it uses channel. A channel model is a set of rules or ways from which data or signal will smoothly sent or receive through the channel. A good channel model is essential for a high class of communication, That will save bandwidth, signal power that increases the system capability.

2.2.1. AWGN channel model:

The additive white Gaussian channel model is the one of the simplest channel model in wireless communication. It is simple because a white noise is only added with the wireless channel. The AWGN channel model does not consider any fading effect, Inter-symbol interference that is why it is very simple and straight forward. It is a simple mathematical model it only consider the thermal noise and shot noise.

2.3. Receiver:

Cyclic prefix is removed at the receiver end and the symbols are converted parallely. Using Fast Fourier Transform(FFT) frequency version of the received signal is generated. The reference symbols are removed and data blocks are de mapped using M-QAM demodulation technique. Parallel bits are converted into serial and binary data is provided to the user.

Downlink CA signals in LTE-A system can be regarded as LTE downlink signal

$$S(t) = \sum_{k=0}^{N-1} d_k e^{j2\pi(f_c+k\Delta f)t}, (k \in Z, 0 \le t < T_{sym}) \quad (1)$$

$$F(t) = \sum_{l=0}^{M-1} c_l e^{j2\pi(f_n+l\Delta f)t}, (l \in Z, 0 \le t < T_{sym}) \quad (2)$$

Where T_{sym} is the symbol period, d_k and c_l are the Kth and lth symbol, f_c and f_n are the central frequencies, Δf is the sub-carrier spacing, N denotes the number of sub-carriers in OFDM signal.

When the UE receives S(t) and F(t) at the same time, we focus on the interference

$$f(t) = e^{-2\pi(fc+i\Delta f)t, i=0,1....,N-1.} \quad (3)$$

and thus the demodulated signal is

$$R_i = \int_0^{T_{sym}} f(t)[S(t) + F(t)]dt = D_i + I_i, i = 0,1,., N-1. \quad (4)$$

The resultant consists of two parts. The first part D_i is the wanted symbol on each sub-carrier, and the second part I_i is the unwanted one from the interferer.

For the first part, only when k=I can the information on the ith sub-carrier be obtained:

$$D_i = T_{sym} d_i, k = i. \quad (5)$$

While for the unwanted part,

$$I_i = \sum_{l=0}^{M-1} c_l((e^{j2\pi\Delta f_n T_{sym}} - 1)/(j2\pi\Delta f_n)). \quad (6)$$

For CA downlink signals of LTE-A, the spacing between two adjacent CCs can be expressed as

$$\left[\frac{BW_{(1)} + BW_{(2)} - 0.1|BW_{(1)} - BW_{(2)}|}{0.6}\right] 0.3[MHZ] \quad (7)$$

Where and are the bandwidths $BW_{(1)}$, $BW_{(2)}$ of two adjacent CCs respectively. This implies that the spacing between center frequencies of contiguously aggregated CCs is an integral of 300 kHz, so as to be compatible with the 100 kHz frequency raster of Release 8/9 and preserve the Orthogonality of the subcarriers with 15 kHz spacing. Therefore, if S(t) and F(t) are two adjacent CCs in a CA impact on S(t) . The ith sub-carrier in S(t) can be described as

signal, there is no interference between them due to the orthogonality.

3. PERFORMANCE ANALYSIS:

Implementing the Chebyshev filter to minimize the interference, this was occurred due to carrier frequency offset.

3.1. Chebyshev filters:

Chebyshev filters are analog or digital filters having a steeper roll-off and more pass band ripple (type I) or stop band ripple (type II) than Butterworth filters. Chebyshev filters have the property that they minimize the error between the idealized and the actual filter characteristic over the range of the filter.

The frequency response function of the nth-order Chebyshev low-pass filter is

$$G_n(\omega) = \frac{1}{\sqrt{1 + \varepsilon^2 T_n^2\left(\frac{\omega}{\omega_0}\right)}} \quad (8)$$

Where ω is angular frequency,

ε is the ripple factor,

ω0 denotes the cutoff frequency,

$T_n^2\left(\frac{\omega}{\omega_0}\right)$ is a Chebyshev polynomial of the nth order.

Chebyshev polynomial of the nth order can be further formulated as:

$$T_n\left(\frac{\omega}{\omega_0}\right) = \begin{cases} \cos\left(n.\arccos\left(\frac{\omega}{\omega_0}\right)\right); 0 \le \omega \le \omega_0 \\ \cosh\left(n.\arccos\left(\frac{\omega}{\omega_0}\right)\right); \omega > \omega_0 \end{cases} \quad (9)$$

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4. SIMULATION RESULTS AND DISCUSSION

4.1. Simulation Parameters:

No .Of bits per symbol	=	52
No .of symbols	=	10000
Length of FFT	=	64
Type of modulation	=	PSK modulation
Cyclic prefix	=	16

Two carrier components are allocated continuously in a LTE-A downlink signal with CA. The frequency and power of both Component Carriers are configured according to 3GPP UE receiver testing specification [10], and the power of the interferer is 38dB higher than the CCs. By varying the spacing between central frequencies of interferer and its adjacent CC, the throughput on the adjacent CC is measured

Fig. 2 illustrates the relationship between the relative throughput and central frequency spacing. It can be seen that the relative throughput varies periodically with a cycle of 1 MHz, and it reaches the minimum level when the central frequency spacing equals to the odd multiple of 0.5 MHz, while comes to the maximum level when the spacing equals to the even multiple of 0.5 MHz

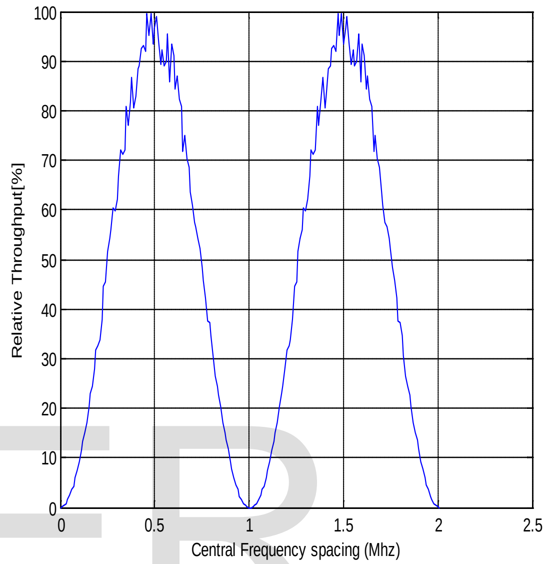

Figure.2 Relative throughput of the CC adjacent to interferer

The simulation results on filter performance are presented in Fig. 3 to Fig. 5, which are based on both LTE release 8 and LTE-A CA scenarios. First the simulation of LTE Release 8 UEs with bandwidths of 5 MHz and 10 MHz Fig.3 presents the relative throughput of the LTE UEs without filters. Two curves locate very closely to each other, which mean the signals with different bandwidths suffer the similar interference actually. But when a 4th-order Chebyshev band-pass filter is inserted in the UE, the curves scatter from each other, and the smaller bandwidth signal locates on the right side while the larger ones on the left, which indicates that the signal with smaller bandwidth get better protection from the filter.

The frequency and power of both CCs are configured according to 3GPP UE receiver testing specification [10], and the power of the interferer is 38dB higher than the CCs. By varying the spacing between central frequencies of interferer and its adjacent CC, the throughput on the adjacent CC is measured

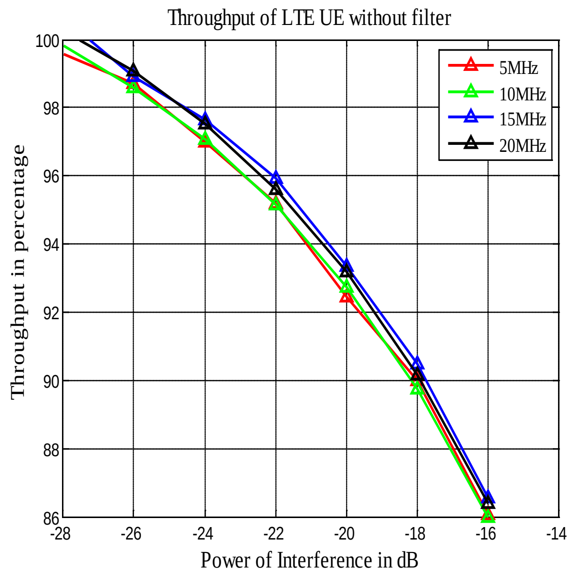

Figure.3. 5MHz, 10MHz, 15MHz, 20MHz Relative throughput of LTE UE without filter

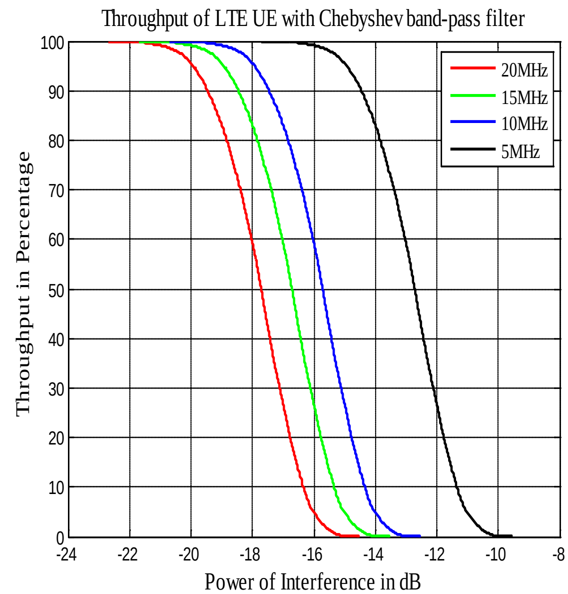

Figure.4. 5MHz, 10MHz, 15MHz, 20MHz Relative throughput of LTE UE with Chebyshev band-pass filter.

4.2. INFERENCE

Table.1 Comparing Relative throughput of LTE without filter

Frequency	**Power of Interference(dB)**	**Relative Throughput [%]**
5MHz	16	86.19
10MHz	16	86.11
15MHz	16	86.68
20MHz	16	86.38

Four curves (with bandwidths of 5 MHz, 10 MHz, 15 MHz, and 20 MHz) locate very closely to each other, which means the signals with different bandwidths suffer the similar interference actually.

The curves scatter from each other, and the smaller bandwidth signal locates on the right side while the larger ones on the left. Which indicates that the signal with smaller bandwidth get better protection from the filter.

5. CONCLUSION:

The analysis shows that the adjacent interference level varies with the frequency spacing between two signals periodically, and reaches at the highest level when the spacing is the odd multiple of half subcarrier spacing. Besides, the interference-resistance capability of the UE is highly related to the bandwidth of the receive filter, fixing other parameters of the filter, we derive that the increase of the bandwidth of the filter will reduce its ability to eliminate the adjacent interference signals. Meanwhile, theoretical analysis is sufficiently verified .by simulation results.

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