Carrier Aggregationin LTE-A for High Throughput

[1] Mr. Arvindraj Desai, [2] Dr. M Bharathi, [3] Mr. Nandeesh G M
[1,2]Electronics and Communication department, RVCE, Bengaluru.
[3]Asmaitha Wireless Technologies (P) ltd

Abstract—Mobile networks have experienced a dramatic growth during the past few years. The current mobile networks support a variety of services, including web browsing, video streaming, file downloading etc. Long Term Evolution (LTE), marketed as 4G LTE, is a standard for wireless communication of high speed for mobile phones and data terminals. In conventional LTE system 20MHz bandwidth is allocated to a user which will result in a data rate up to 100Mbps. With certain features, LTE has evolved into LTE-Advanced and one of the key feature in LTE-Advanced is carrier aggregation i.e. scaling the bandwidth allocated to user equipment by using multicarrier technology to increase the data rate.This paper describes the simulation of carrier aggregation in the downlink physical layer to achieve higher data rate in LTE-Advanced. The technique is accomplished by using MATLAB/Simulink analysis tool. Five carriers of 20 MHZ is aggregated in this work to get a net bandwidth of 100MHZ and the corresponding data rate is 504Mbps.

Keywords-component; *Carrier Aggregation, LTE, LTE-A, OFDM, 4G.*

I. INTRODUCTION

Long Term Evolution (LTE) is the most advanced communication technology. Fourth Generation (4G) Communication is based on LTE technology. LTE tremendously increases the peak data rates that could be achieved by the present technologies. LTE supports channels of maximum bandwidth up to 20 MHZ only, and the data rate is 100 Mbps approximately. LTE-Advanced is the evolved version of LTE, with certain features added to it. One of the key difference between LTE and LTE-Advanced is that LTE-Advanced supports carrier aggregation, where scaling the channel bandwidth up to 100 MHZ is possible. Carrier aggregation in LTE-Advanced is a recent field of research. Instead of allocating a single channel to single user, multiple channels are aggregated and allocated to single user equipment. Due to this, the resulting net bandwidth allocated to particular user equipment will be much higher and will lead to high speed data. In conventional system, since single channel is allocated to user equipment, some part of the spectrum will remain unused and hence will be wasted. By using the carrier aggregation technique, the spectrum will be efficiently utilized and will not be left unused. Carrier aggregation provides efficiently utilizes the spectrum hence give high speed data. Most of the times, the mobile service provider has been licensed for a spectrum which is distributed and is not continuous. In such a case, the mobile service provider may use non continuous carrier aggregation for providing high data speeds to its customers. Another important aspect is that it is backward compatible. With each component carrier is compatible with LTE, carrier aggregation gives operators to migrate from Long Term Evolution to Long Term Evolution Advanced while continuing service to LTE users. Both LTE and LTE-Advanced users can operate within the same network [1].

II. SPECTRUM SCENARIOS

The Spectrum where the component carriers (CC) are in the same band, it is called intra band. If the component carriers are in different band, then it is called inter-band. Carrier aggregation is classified based on whether the carrier component (channels) are from the inter band or not and whether they are continuous or not in frequency domain. The different types of carrier aggregation are shown in the Fig 1. In this figure two component carriers are aggregated, whereas in practice up to 5 CCs can be aggregated [1].

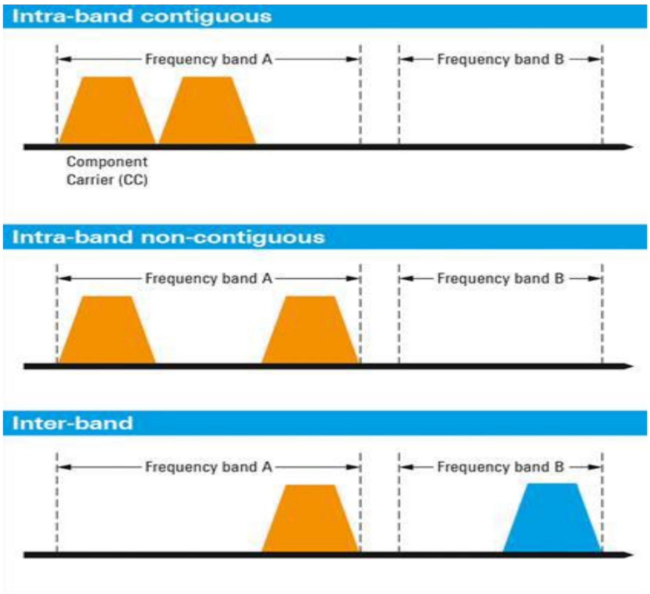


Fig.1 Spectrum Scenarios

Intra-band contiguous carrier aggregation: Both the component carriers are from the same frequency band andcontinuous to each other in frequency domain.Intra-band Non-contiguous carrier aggregation: Here both the carrier components are from the same band of frequency, but they are not adjacent or continuous in the frequency domain. Inter-band non-contiguous: In this case, the component carriers are from different bands of frequency and hence they will be always non continuous.

III. DEPLOYMENT SCENARIOS

The deployment scenarios are based on the three types of carrier aggregation, as shown in Fig.2. The two carrier frequencies considered are F1 and F2.

Scenario one: In scenario one, both the carrier components are in inter band and the responses of the antennas are almost same, have same coverage. Both overlap in all the areas of cell and hence carrier aggregation is possible in all the areas.

Scenario two: In scenario two, the coverage of component carrier F2 has smaller coverage than that of component carrier F1, as they are from widely separated bands. Hence carrier aggregation is possible in smaller area, where they overlap each other.

Scenario three: In scenario three, the response of one of the component carrier is purposely shifted, so as to improve the performance of users in the cell edge. Carrier aggregation is possible in cell edges also and hence users in the cell edge also experience high throughput [1].

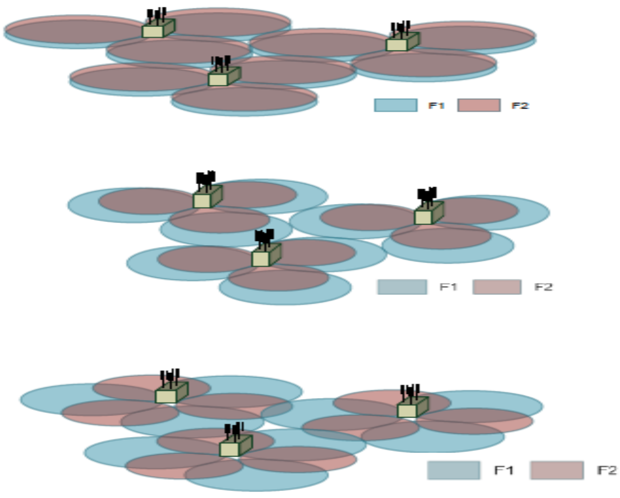


Fig.2 Deployment Scenarios

IV. IMPLEMENTATION OF CARRIER AGGREGATION

Fig.3 explains the carrier aggregation is implemented though the complex physical layer chain, which involves downlink shared channel implementation and physical mapping of it. The downlink channel implementing involves blocks namely CRC, Segmentation, Turbo coding and rate matching, physical mapping of the channel. Five downlink channels of 20MHz are aggregated.The component carriers are generated by the performing the DL-SCH processing and then it needs to be mapped in to actual physical channel. This mapping is done by PDSCH channel processing. The DL-SCH processing consists of five steps- CRC, Segmentation, Second CRC, Turbo coding, Rate Matching. The PDSCH processing consists of steps such as- Scrambling, Modulation mapping, Layer Mapping, Pre coding, Resource mapping, OFDM [2-9].

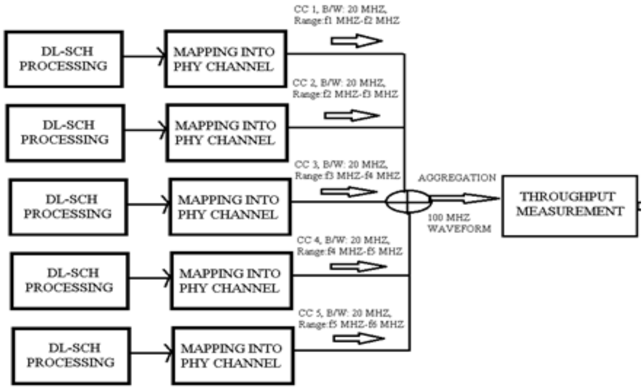


Fig.3 Implementation of Carrier Aggregation

Five component carriers, each of 20 MHZ bandwidth are generated. Each component carrier will be having different frequency band, so that they do not overlap and interfere with each other. For example, say component carrier 1 is in the range 2440-2460 MHZ, component carrier 2 in range of 2460-2480 MHZ, component carrier 3 in range of 2480-2500 MHZ, component carrier 4 in range of 2500-2520 MHZ, component carrier 5 in range of 2520-2540 MHZ. All these component carriers are aggregated and results in a net bandwidth of 100 MHZ. With such a large bandwidth, high speeds could be achieved. The resulting waveform is passed through the throughput measurement.

V. IMPLEMETATION OF DOWNLINK SHAREDCHANNEL:

The main function of PHY is the actual transmission and reception of data in forms of transport blocks. Each physical channel corresponds to a set of resource elements in the time-frequency grid that carry information from higher layers. PHY layer perform the actual transmission of data. Transport channel processing includes DL-SCH as shown in Fig. 4. DL-SCH as shown in the Fig. 7, includes five steps of CRC, segmentation, second CRC, turbo coding and rate matching. Physical layer processing includes PDSCH. PDSCH includes steps of scrambling, modulation mapping, layer mapping, precoding, resource mapping and OFDM respectively. The blocks are explained in detail respectively [10].

Table 1: Parameters of Physical Layer Chain

Channel Bandwidth (MHz)	1.25	2.5	5	10	15	20
Frame Duration (ms)	10					
Subframe Duration (ms)	1					
Sub-carrier Spacing (kHz)	15					
Sampling Frequency (MHz)	1.92	3.84	7.68	15.36	23.04	30.72
FFT Size	128	256	512	1024	1536	2048
Occupied Sub-carriers (inc. DC sub-carrier)	76	151	301	601	901	1201
Guard Sub-carriers	52	105	211	423	635	847
Number of Resource Blocks	6	12	25	50	75	100
Occupied Channel Bandwidth (MHz)	1.140	2.265	4.515	9.015	13.515	18.015
DL Bandwidth Efficiency	77.1%	90%	90%	90%	90%	90%
OFDM Symbols/Subframe	7/6 (short/long CP)					
CP Length (Short CP) (μs)	5.2 (first symbol) / 4.69 (six following symbols)					
CP Length (Long CP) (μs)	16.67					

A) DL-SCH (DOWN LINK SHARED CHANNEL):

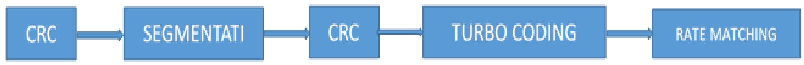


Fig.4 Down-Link Shared Channel

a. Crc

CRC stands for cyclic redundancy check (CRC) and if error in transport blocks occurs, CRC is used for error detection. The entire transport block is used to calculate the CRC parity bits. A cyclic generator polynomial divides transport block and generates 24 parity bits. These parity bits are then made appended at the end of transport block. The general polynomial is as follows.

G(x) = x^24 + x^23 + x^18 + x^17 + x^14 + x^11 + x^10 + x^7 + x^6 + x^5 + x^4 + x^3 + x + 1 -------- Eqn. 1

b. Segmentation

The input block size should be greater than 6144 bits, if it is greater than that, it is split in to smaller blocks. For those smaller blocks CRC is performed again and redundant parity bits are then appended to each resulting smaller blocks of the input block. Also, filler bits are added so the code block sizes are match a set of valid block sizes which is given input to turbo code. The block diagram of segmentation is as shown in Fig.5.

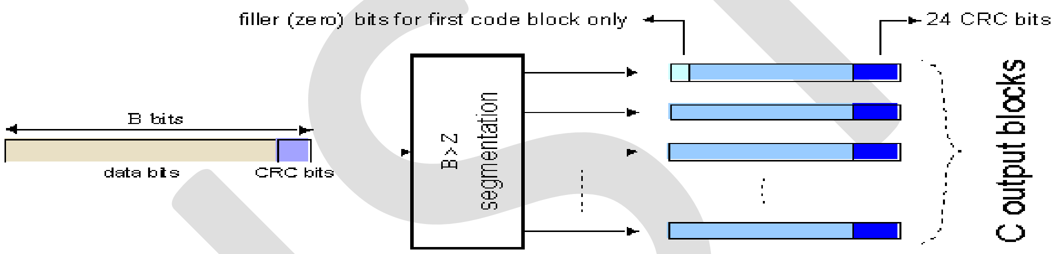


Fig.5, The block diagram of Segmentation.

c. Turbo coding

The constituent encoders shown in the Fig.6, used are convolutional encoders. The input Ck bits to the first constituent encoder is the input bit stream (Ck) to the turbo encoding block. Second constituent encoder input is from the output of the QPP interleaver, a permutated version (Ck') of the input sequence.

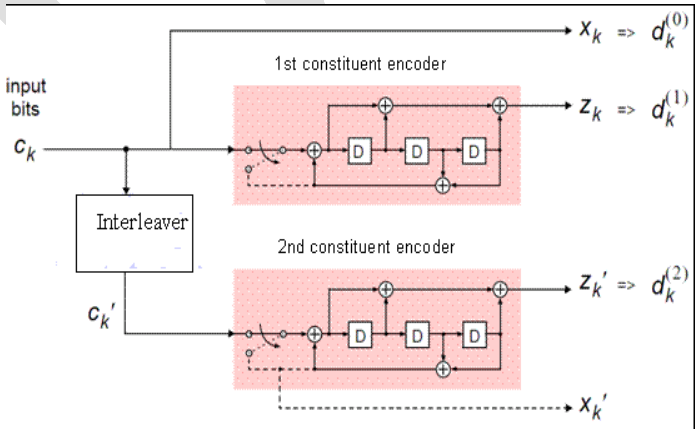


Fig.6, The block diagram for the turbo coding.

d. Rate matching and modulation

The output from the turbo coder is given to the rate matching block which creates an output bit stream with a code of a desired rate. The rate matching algorithm which is capable of producing of any arbitrary rate. The bit streams from the turbo encoder are interleaved which is followed by bit collection to create a circular buffer. Bits are selected and trimmed from the circular buffer which will lead to creating an output bit stream with the expected code rate.

B) PHYSICAL CHANNELS: ACTUAL TRANSMISSION

Each physical layer channel gives you a set of resource elements in the time-frequency grid which is also called as resource grid that carry information from higher layers to the physical layer. The basic existence that make a physical channel which are resource elements and resource blocks. A resource element is a single subcarrier over one OFDM symbol, and typically which could carry one (or two with spatial multiplexing) modulated symbol(s). A resource block is a set of collection of resource elements and in the frequency domain this represents the smallest portion of resources that could be allocated. The transport channels are need to be mapped in to the actual physical channels.

i. Physical Downlink shared channel

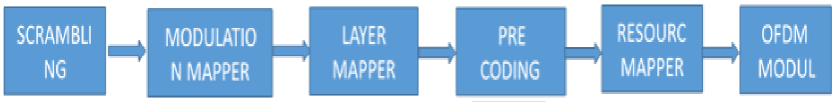


Fig.7 Physical Downlink shared channel

Physical downlink shared channel carries user data originating from the higher layer. It is connected to the DL-SCH. It undergoes various steps, which are scrambling, modulation mapper, layer mapper, precoding, resource mapping, and OFDM modulation [11]. The block diagram is as shown in Fig.8, Scrambling is responsible for producing a set of scrambled bits from the input bits according to the relation given by the equation $b^{\wedge}=b+c \bmod 2$ ….Eqn 2. Where $b^{\wedge}$ is the scrambled bits, b denotes the input bits and c denotes the scrambling sequence.Modulation mapper maps the bits of input to complex modulation symbols with the specified modulation scheme. There are three types of modulation schemes for the PDSCH. Those are QPSK (Quadrature phase shift keying), 16QAM (Quadrature Amplitude Modulation) and 64QAM (Quadrature Amplitude Modulation). Layer mapper splits the data sequence in to a number of layers according to the standard of 3GPP. Precoding is used for transmission in multi-antenna techniques in wireless communication technology. In the conventional system of single-stream beam forming, the same signal is radiated from each of the transmit antennas with appropriate phase and gain. So that the signal power is expected to be maximized at the output of receiver end. The resource-mapping block which is responsible for mapping the actual data symbols, reference signal symbols and synchronization symbols into a manifest resource element in the resource grid [12].

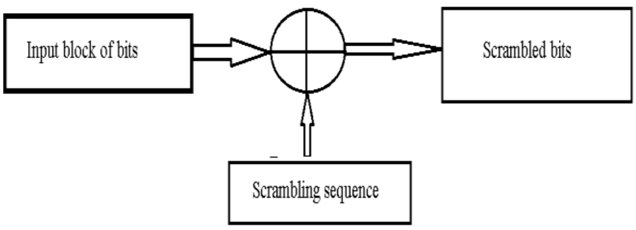


Fig.8, The block diagram for scrambling.

ii. MAPPING OF RS, PSS, SSS.

RS Mapping:

To allow retrieving the symbols which were sent from transmit end and to get back at the user equipment, reference symbols which are also called pilot symbols are inserted in the OFDM time-frequency grid or the resource grid to allow for channel estimation. Downlink reference or pilot symbols are put into the first and fifth OFDM symbol of every slot with a frequency domain spacing of six sub-carriers for a 3GPP's LTE system with a single antenna in normal Cyclic Prefix mode. To allow the user end to exactly estimate the coefficients of channel, nothing is transmitted on the other antenna at the same time-frequency location of reference signals. The location of reference symbols within the resource block is as shown in Fig.9.

Senchonization Sequences:

A User end is wishing to access the LTE system which follows a cell search procedure and which includes a series of synchronization levels by which the UE calculates time and frequency variable that are necessary for demodulating

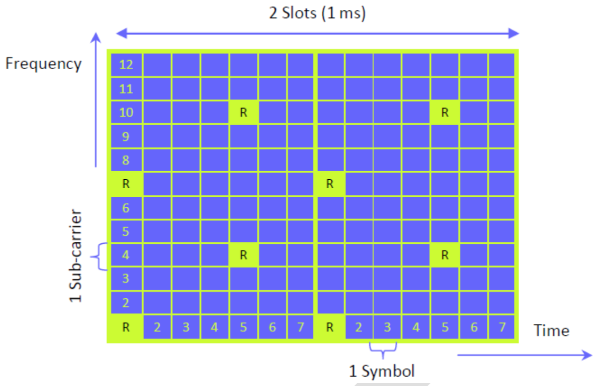


Fig.9, Location of reference symbols within resource block.

Downlink signals, for transmitting with correct timing and to obtain some critical system variables. According to LTE standard specification, three types of synchronization sequences are there. Symbol timing acquisition from which the start of correct symbol is calculated. Carrier frequency synchronization which reduces the impact of frequency errors determined from DS (Doppler shift) and errors from electronics components. And sampling clock synchronization. According to the 3GPP's standard specifications only two types of cell search are there and first one is for initial synchronization and second one is for detecting neighbour cells in preparation for transfer of handover. In cases of these two, the User Equipment is using two signals to broadcast for each cell. One is Primary Synchronization Sequence (PSS) which is generated by Zadoff-Chu sequence and Secondary Synchronization Sequence (SSS) which is generated by BPSK sequence. The recognition of these signals allows the UE to complete time and frequency synchronization with the help of synchronization signals and to obtain useful system parameters such as cell identity, cyclic prefix length, and access mode which are namely FDD or TDD. The PSS is pumped into the grid in the last OFDM symbol of the first and 11th slot of each radio frame which allows the UE to obtain and the slot boundary timing which does not depend on the type of cyclic prefix length. The PSS signal is common with any given cell in each sub frame in which it is going to be transmitted. The SSS is located in the sixth column of the resource grid, which is presented in the first and eleventh symbol of the resource grid of radio frame and it is located centre around DC. The User Equipment may be able to calculate the length Cyclic Prefix by looking at the absolute position of the SSS. The User Equipment will also be able to decide the position of the radio frame boundary of 10ms as the SSS signal exchanges in a particular manner between two transmissions. In the frequency domain, the PSS and SSS takes space, the central six resource blocks, and does not care which type of the system channel bandwidth it is, which allows the User Equipment to synchronize to the network without early knowledge of the allocated specified bandwidth. The PSS or SSS only uses 62 subcarriers in a slot in total, and 31 sub carriers centred around DC which leaves 5 sub-carriers at each ends of the 6 central resource blocks unused [13-14]. The location of both PSS and SSS symbols within the resource block sub frame is as shown in Fig.10.

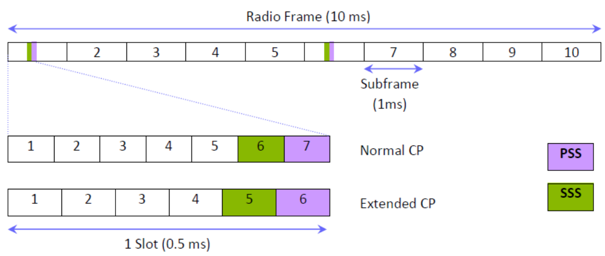
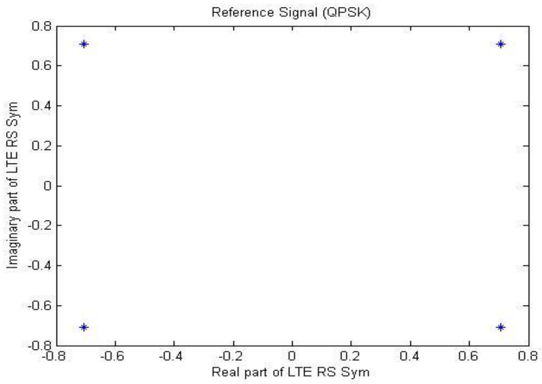


Fig.10, Location of PSS and SSS within resource block.

VI. SIMULATION RESULTS:

Fig.11, Fig.12, Fig.13 shows the synchronization and reference signal to build the LTE frame structure that is achieved with the help of transmitted bits. Fig.11 corresponds to reference signal, Fig.12 corresponds to primary synchronization signal (PSS) and Fig.13 corresponds to secondary synchronization signal (SSS). The reference signal clearly shows in the figure that it follows the QPSK sequence, similarly the PSS and SSS shows, following Zaddoff-Chu and BPSK respectively. Aggregation is carrier out for 5 component carriers (CC) of 20MHz, which is called symmetric aggregation, Refer Fig.13. The simulation for carrier aggregation is carried out for one CC of 20MHz and one CC for 10MHz, which is called asymmetric carrier aggregation, Refer.14. The simulation results shows the data rates for 20MHz is 100Mbps and aggregating of 5 component carriers shows 504Mbps.



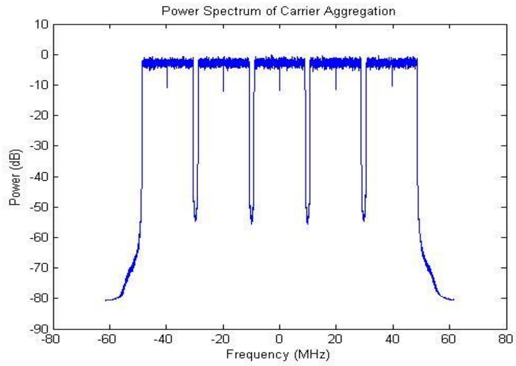
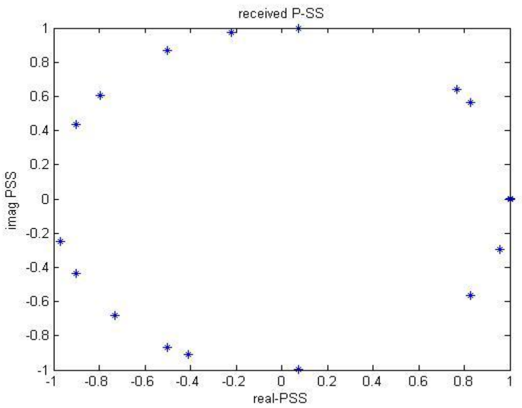


Fig.11, Reference signal constellation plot. **Fig.12, Primary sync signal Constellation plot.**



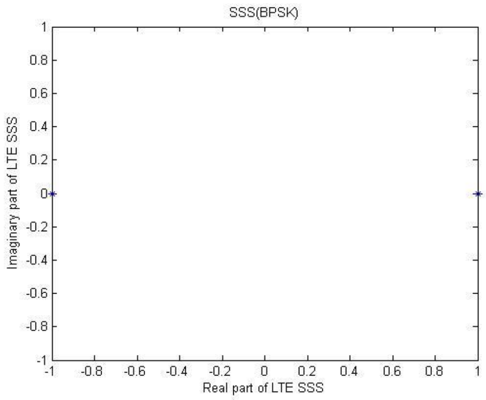


Fig.13, Secondary Sync Signal constellation plot.Fig.13, Symmetric carrier aggregation of 5 CC

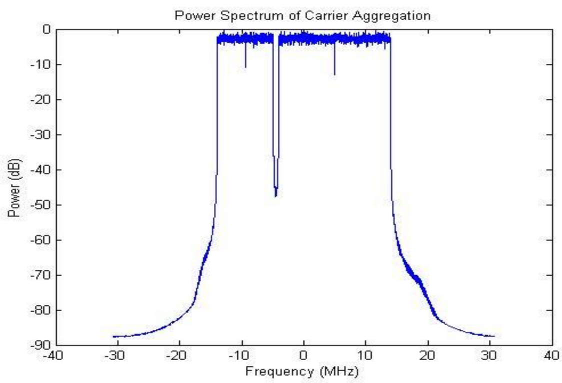


Fig.14, Asymmetric carrier aggregation of 2 CC

VII. Conclusion:

In this paper, LTE –Advanced is an evolving standard to meet the need for higher data rate, better coverage and the lower power consumption. In this project an attempt is made to increase the downlink data rate using Carrier Aggregation. It is economically feasible technique. The complex downlink physical layer for LTE is implemented and complex physical mapping of reference signal, primary synchronization signal and secondary synchronization signal is carried out. Five component carriers of 20MHZ bandwidth is aggregated to get a net bandwidth of 100 MHZ. The net data rate for this aggregated bandwidth is 504 Mbps. In this paper, presented the brief survey of the 3GPP's standard downlink physical layer implantation which includes the downlink shared channel and physical mapping of it. PHY layer perform the actual transmission of data. Transport channel processing includes DL-SCH. DL-SCH includes five steps of CRC, segmentation, second CRC, turbo coding and rate matching. Physical layer processing includes PDSCH. PDSCH includes steps of scrambling, modulation mapping, layer mapping, precoding, resource mapping and OFDM. In future, for the higher throughput we can adopt MIMO technique for the physical layer chain.

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Appendix: Abbrevations

CPE: Customer Premise Equipment
3G: Third Generation Communication Technology
4G: Forth Generation Communication Technology
RAN: Radio Access Network
LTE: Long Term Evolution

LTE-A: Long Term Evolution-Advanced
UE: User Equipment
IMT: International Mobile Telecommunications
PCELL: Primary Cell
SCELL: Secondary Cell
eNB: E node B or Base Station
CC: Component Carrier
SINR: Signal to interference and noise ratio
GSM: Global System for Mobile
DL-SCH: Downlink Shared Channel
CRC: Cyclic Redundancy Check
PDSCH: Physical Downlink Shared Channel
MATLAB: Matrix Laboratory
UMTS: Universal Mobile Telecommunication System
HSPA: High Speed Packet Access
3GPP: 3rd Generation Partnership Project
OFDM: Orthogonal Frequency Division Multiplexing
PAPR: Peak-to-Average Power Ratio
PTS: Partial Transmit Sequence
IFFT: Inverse Fast Fourier Transform
QAM: Quadrature Amplitude Modulation
FDMA: Frequency Division Multiple Access
QPSK: Quadrature Phase Shift Keying
RS: Reference Signal
PSS: Primary Sync Signal
SSS: Secondary Sync signal