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Physical Layer Frame Structure in 4G LTE/LTE-A Downlink based on LTE System Toolbox

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Abstract: *LTE/LTE-A is the standard for next generation wireless communications which provides high data rates of 1 Gbps. LTE-A is an extension of LTE providing five times higher bandwidth compared to LTE. Release 10 LTE-A is backward compatible with Release 8 LTE making it a highly dissolvable system. Traditional system models in LTE used the 3GPP spatial channel model where the parameters have to be changed at the backend which is a slightly complex process. In this paper, a new approach for the modeling of LTE/LTE-A systems in the downlink is done where the physical signals and physical channels are generated and plotted onto the specified indices. This is much easier compared to the models used traditionally.*
Keywords: *3GPP, LTE, LTE-A, LTE system toolbox, Physical frame structure*

I. Introduction

The communication scenario in the world is growing at a large pace and the industry is gearing up for a thousand times more faster and reliable data rates. So, the standards of wireless communication are taking a transition to meet the demands of the rapidly growing customer base. The 3GPP (Third Generation Partnership Project) is an organisation of telecommunication associations for the development and improvement of GSM standard and was later extended for the development of newer standards of wireless communication.

Multiple Input Multiple Output (MIMO) is a default feature in LTE systems to boost the overall data rates. It offers superior data rates without requiring additional bandwidth and transmit power. The number of antennas at the transmitter or receiver will decide the number of data streams supported. Traditional cellular systems provide best performance under line-of-sight conditions but MIMO tries to provide best performance under rich scattering conditions. LTE systems make the promise of delivering large data rate to users which is substantially larger than what the current 3G systems are offering. This is a challenging proposition as wireless networks are subject to interference and multipath. So, MIMO techniques have emerged as a solution to provide high data rates by exploiting multipath characteristics of wireless channel. This is accomplished by using several antennas at the transmitter and receiver leveraging spatial dimensions. When the signals are properly combined at the receiver, data rate of each MIMO user will be improved [1]. The different configurations possible for MIMO are 2X2,4X4, 8X8. Higher configuration of MIMO antennas will lead to higher data rates.

OFDM (Orthogonal Frequency Division Multiplexing) is a multi-carrier modulation technique where the total bandwidth is split into a large number of smaller and narrow bandwidth units known as subcarriers which are orthogonal to each other. Orthogonality means that the maximum of one subcarrier is at the minimum of the next subcarrier thereby eliminating inter symbol interference (ISI). Frequency representation of one OFDM subcarrier is a sinc function. OFDM converts high speed data channel into a number of low speed channels so that processing becomes easier. OFDMA (Orthogonal Frequency Division Multiple Access) is an access scheme that uses OFDM principle to organize the distribution of scarce radio resources among several users enabling multi-user communication [2]. A set of carriers known as pilot carriers are used to track the residual phase error if present after correction of the frequency. The carriers of OFDM are having different frequencies and Discrete Fourier Transform (DFT) is applied to generate orthogonal subcarriers. The reason for choosing OFDMA in the downlink is the bandwidth flexibility it offers, since changing the number of subcarriers can increase or decrease the used frequency bandwidth.

SCFDMA (Single Carrier Frequency Domain Multiple Access) is used in the uplink transmission scheme of LTE. It is a very desirable technique for the uplink to have an efficient usage of power amplifier in the transceiver antenna. This provides a high battery life to the devices used by the customers. SCFDMA provides low peak to average power ratio (PAPR) which is an advantage over the OFDMA technique used in the downlink.

MIMO-OFDM is the dominant air interface for 4G and 5G broadband systems. It combines MIMO technology which multiplies capacity by transmitting different signals over multiple antennas and OFDM which divides a radio channel into a large number of closely spaced subchannels to provide more reliable communication at higher speeds. MIMO provides a high data rate along with OFDM eliminating the interference makes the MIMO-OFDM medium a highly reliable one [3].

II. Long Term Evolution (LTE)

The LTE (Long Term Evolution) became a standard for wireless communications under the 3GPP after the GSM and CDMA. These standards are structured as release versions by 3GPP board and the first LTE was released in 2008. First generation (1G), second generation (2G) and third generation (3G) of mobile communication works on GSM standard and 4G and higher generations work on LTE standard.

LTE follows a flat architecture which is completely different from the architecture of GSM which is having a two dimensional architecture. It is an all IP architecture where all the devices are having an IP address and it is called as Evolved Packet Core. LTE provides a bandwidth of 20 MHz which is capable of a downlink peak rate of 300 Mbps and an uplink peak rate of 75 Mbps. LTE follows an all IP based network architecture called as Evolved Packet Core (EPC).

In LTE systems, the base station is called as eNB (evolved node B) which directly communicates with the mobile station or UE (user equipment). Evolved node B is the hardware in the mobile phone network that communicates directly with the mobile. It is similar to Base Transceiver Station (BTS) in GSM which is controlled by the Radio Network Controller (RNC). There are three processes which occurs at the eNB: first is the transmission mode selection, second is precoding, and the third is resource allocation and scheduling. In this paper, resource allocation and scheduling is considered based on the mobility of users [4].

III. Long Term Evolution – Advanced (LTE-A)

LTE-A (Long Term Evolution-Advanced) is an extension of LTE which provides a bandwidth of 100 MHz which is capable of a downlink peak rate of 3.3 Gbps and an uplink peak rate of 500 Mbps. LTE-A uses a technique known as carrier aggregation for obtaining the 100 MHz bandwidth which in turn reflects in high data rates. It means that a number of different component carriers are combined at the device so as to increase the data rate and bandwidth. A maximum of five component carriers can be combined to get a bandwidth of 100 MHz. The bandwidth can be split and used like 1.4 MHz, 3.5 MHz, 10 MHz, 15 MHz and 20 MHz. It includes smoother handoff procedures, new transmission protocols and stuffing more bits per second into a single hertz of spectrum.

In LTE/LTE-A systems, the multiple access schemes are based on FDM (Frequency Domain Multiplexing). OFDMA is widely employed in downlink and it has very robust characteristics against frequency selective channels. The reason for using OFDMA in the downlink is the bandwidth flexibility it offers, since changing the number of subcarriers used can be increased or decreased. SCFDMA (Single Carrier Frequency Division Multiple Access) is a very desirable technique for the uplink transmission.

IV. Simulation Scenario

The simulation scenario under consideration is MATLAB R2014a. It is the penultimate version of MATLAB released in 2014. The main highlight of this version of the software is the addition of LTE system toolbox which consists of more than 200 functions. These functions are inbuilt in the software and it can be used for the design, simulation and verification of LTE wireless communication systems. There are several propagation models which can be configured, simulated, measured and analysed for end-to-end communication links.

TABLE 1 shows the configuration and parameters used for simulation. The simulation parameters in the table correspond to those parameters defined at the base station or eNB. These parameters are assigned with the values specified in the table. The number of downlink resource blocks of 6 corresponds to 1.4 MHz of system bandwidth in LTE system. The parameter name should be same as that in the table and each parameter should be prefixed with 'enb.'.

Table 1: Simulation configuration and parameters

Simulation Parameters	Value
CyclicPrefix	Normal
PHICHDuration	Normal
Ng	Sixth
NDLRB	6
System bandwidth	1.4 MHz
DuplexMode	FDD
NCellID	1
NSubframe	0
CFI	1

V. Physical Frame Structure of LTE

Scheduling is the process of allocating resource blocks to users. One resource block has duration of 7 OFDM symbols (0.5 ms) in the time domain and 12 subcarriers in the frequency domain. Two such resource blocks constitute a PRBP (Physical Resource Block Pair) which has duration of 14 OFDM symbols (1 ms) in the time domain. A number of such PRBP's constitute a PRBG (Physical Resource Block Group) and usually resources are allocated as PRBG's so as to reduce the system overheads. The first and foremost step in an LTE system is to create physical signals and physical channels for the transmission of control data and user data. Specified slots in the time and frequency domain are allocated by default by this toolbox [5].

5.1 Physical signals

There are two physical signals in LTE which are Primary Synchronisation Signal (PSS) and Secondary Synchronisation Signal (SSS). These are used by the user equipment (UE) to obtain the identity of the cell and frame timing. Fig. 2 shows the constellation of PSS which is identical to that of Zadoff Chu sequence. These physical signals and their indices are generated by the inbuilt functions and the physical signals are mapped to the indices [2].

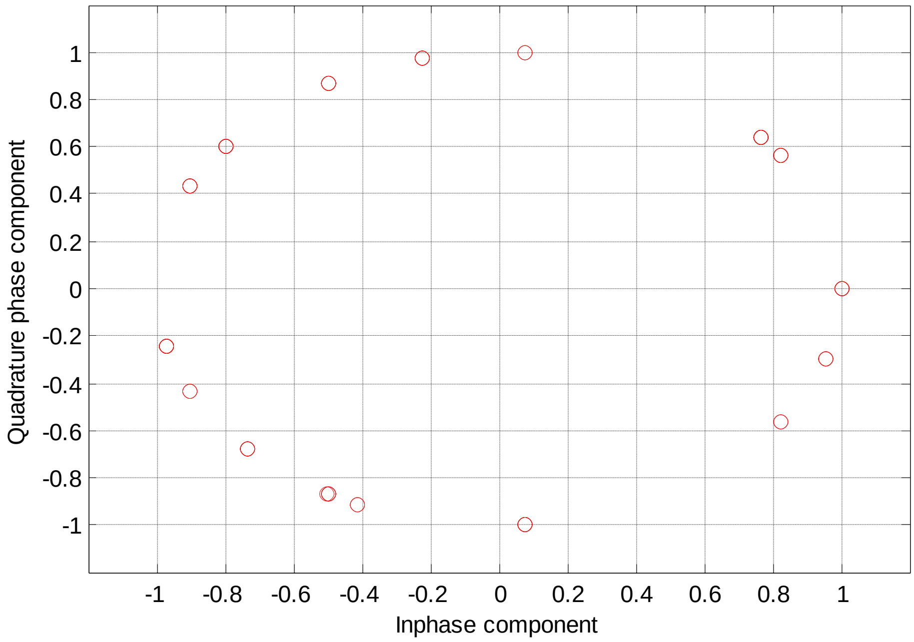

Fig. 1 Constellation diagram of Primary Synchronisation Signal

5.2 Physical channels

There are five physical channels in LTE which carry the different control data and user data. These channels and their indices are generated by the functions and the channel symbols are mapped to the indices [6]. The different physical channels are:

5.2.1 Physical Broadcast Channel (PBCH)

MIB is the first information to be broadcasted by eNB irrespective of the users present in the cell. This is a 24 bit value which describes the system bandwidth and is transmitted through PBCH channel. If MIB cannot be configured, the UE considers the cell as barred and no communication will be possible.

5.2.2 Physical HARQ Indicator Channel (PHICH)

LTE uses HARQ scheme for correction of errors in the received control and user data. The eNB will send a HARQ indicator to UE to indicate a positive or negative acknowledgement for the data. This HARQ indicator value is sent through PHICH channel. The data sent through this channel is either a 1 or 0 depending on whether the data is correctly received or not.

5.2.3 Physical Control Format Indicator Channel (PCFICH)

PCFICH is the control channel in LTE which is to be decoded by the UE to decode the other control channels and data channels. This channel transmits the information regarding the number of OFDM symbols used by the control data. It is represented in terms of Control Format Indicator (CFI) which can take values 1, 2 and 3. If CFI value is 1, there is only one OFDM symbol that carries the control data in each sub-frame.

5.2.4 Physical Downlink Control Channel (PDCCH)

The downlink scheduling and control information (DCI) is carried by the PDCCH to each of the UE in the cell. It gives the information about resource block carrying the data and the demodulation scheme that should be used to decode the data. The user data can be decoded only if the DCI is decoded.

5.2.5 Physical Downlink Shared Channel (PDSCH)

PDSCH is the channel which transmits all the user data. The majority of the OFDM symbols in the time domain carry the user data in each sub-frame. In Fig. 2, the OFDM symbol indices 2, 3, 4, 11, 12. 13 are allotted for user data and all the 72 subcarriers in those OFDM symbols carry the data to the UE.

Transmit resource grid when plotted shows which all physical signals and channels are transmitted in which all frames in the time and frequency domain. Fig. 2 shows the transmit resource grid in the downlink for a single sub-frame (1 ms). The X-axis shows the OFDM symbol index in the time domain and Y-axis shows the number of subcarriers in the frequency domain. PSS and SSS are transmitted in the 6^{th} OFDM symbol of every 0^{th} sub-frame and 5^{th} sub-frame. PBCH is transmitted in 0^{th} sub-frame of every radio frame. PCFICH is transmitted in the 0^{th} OFDM symbol of every radio frame and the number of OFDM symbols used by it depends on the CFI value which ranges from 1 to 3. Here, CFI value is taken as 1, so only one OFDM symbol carries PCFICH. PHICH and PDCCH are transmitted in the 0^{th} OFDM symbol of every radio frame. PDSCH is transmitted in OFDM symbol indices 2, 3, 4, 11, 12, 13 in every sub-frame.

Fig. 2 clearly shows which OFDM symbols are carrying what type of data. The number of resource blocks can take values of 6, 15, 25, 50 and 100. As the number of resource blocks increases, the number of subcarriers increases. For 100 resource blocks, there will be 1200 subcarriers in the frequency domain which corresponds to a system bandwidth of 100 MHz. So, for a duration of 14 OFDM symbols (1 ms), there will be 16800 resource elements.

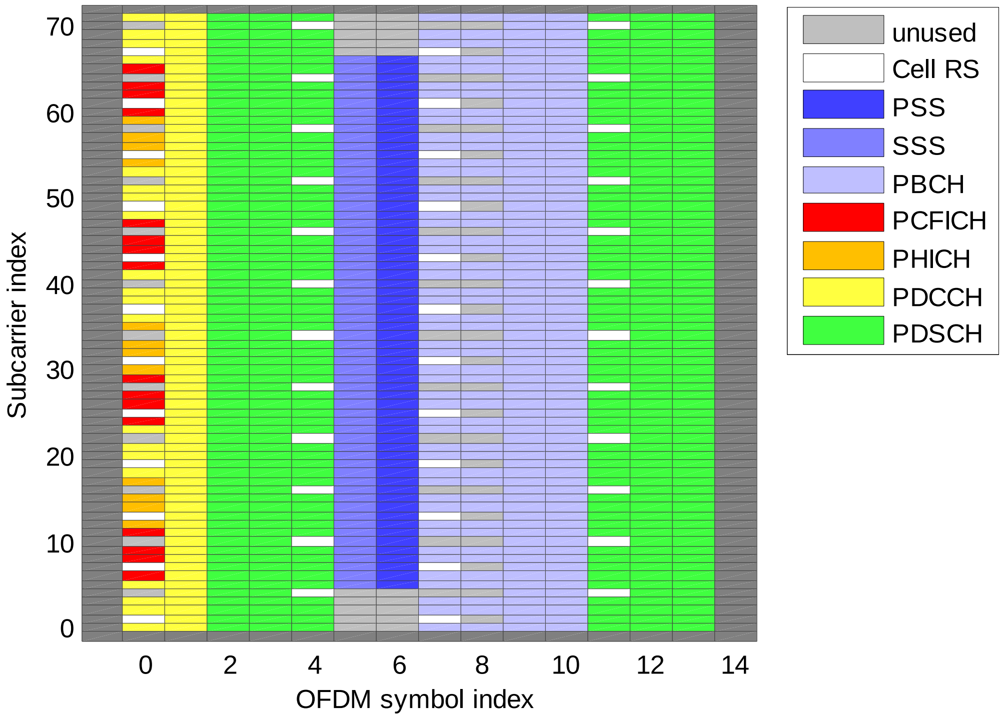

Fig. 2 Downlink transmit resource grid for a sub-frame (1 ms)

Fig. 3 shows the transmit resource grid for a single radio frame (10 ms). Here, 10 consecutive resource grids, each of 1 ms constitute a resource gird for a radio frame (10 ms). This can be obtained by changing the simulation parameter NSubframe to 9. The figure shows the information that is transmitted by the eNB in one single radio frame or 10 ms. Like this, there will be several resource grids transmitted in say 10 seconds or 1 minute or 1 hour as long as the communication is progressing between the UE and eNB in each cell.

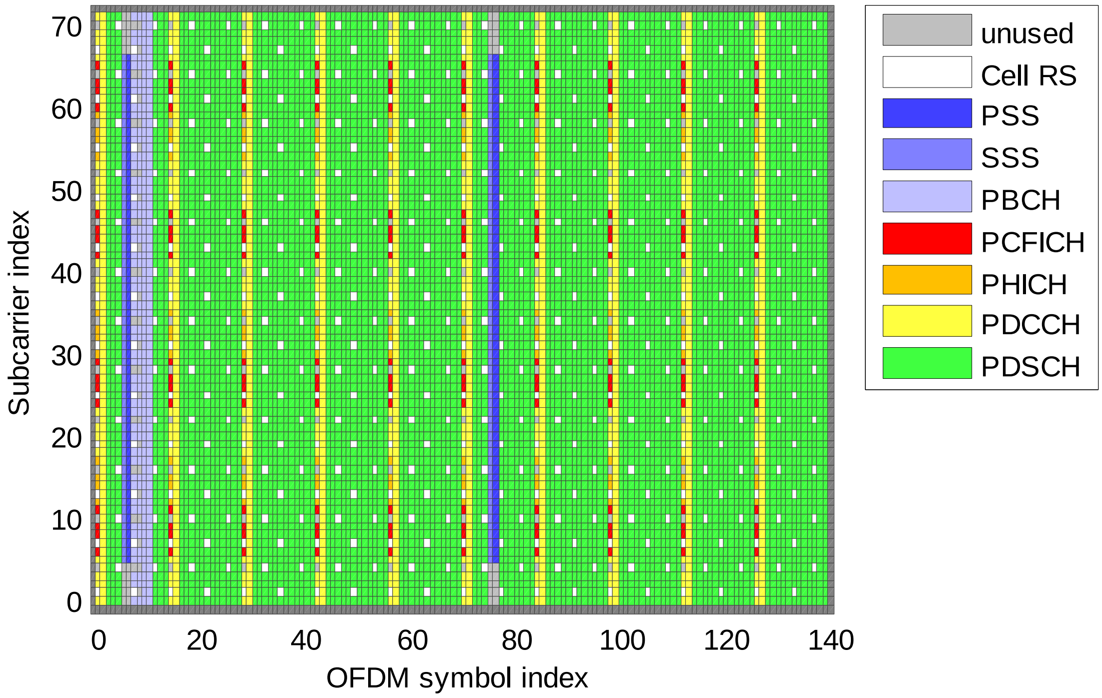

Fig. 3 Downlink transmit resource grid for a radio frame (10 ms)

VI. Conclusion

The physical frame structure of LTE is highly complex but at the same time it is highly flexible which makes it very much useful for modeling an LTE downlink system according to our requirements. As the number of resource blocks increases, the downlink transmit resource grid varies correspondingly. The physical frame structure of LTE is a combination of time domain OFDM symbols and frequency domain subcarrier indices. Traditionally, the system models were made using the 3GPP spatial channel model for LTE and a number of parameters have to be varied at the backend. But now, with the introduction of LTE system toolbox [7], the parameters can be varied at the front end which makes the system modeling of LTE wireless communication systems much easier than before.

References

[1]. J. P. Niu, D. W. Lee, T. Su, Geoffrey Y. Li, and Yusun Fu, "Joint Transmission Mode Selection and Scheduling in LTE Downlink MIMO Systems", IEEE Wireless Communications Letters, Vol. 3, pp. 173-176, April 2014.

[2]. J. P. Niu, D. W. Lee, T. Su, Geoffrey Y. Li, and X. F. Ren, "User classification and scheduling in LTE downlink systems with heterogeneous user mobilities", IEEE Transactions on Wireless Communications, Vol. 12, pp. 6205-6213, December 2013.

[3]. J. P. Niu, D. W. Lee, T. Su, Geoffrey Y. Li, and X. F. Ren, "Scheduling exploiting frequency and multi-user diversity in LTE Downlink Systems", IEEE Transactions on Wireless Communications, Vol. 4, pp. 1843–1849, April 2013.

[4]. J. C. Ikuno, M. Wrulich, and M. Rupp, "System level simulation of LTE networks", IEEE 71st Vehicular Technology Conference (Spring), Vol. 71, pp. 1-5. May 2010.

[5]. LTE System Toolbox, The Mathworks, Inc., January 2015.

[6]. LTE System Toolbox Introduction, The MathWorks, Inc., April 2014.

[7]. Houmann Zarrinkoub, "Modelling a 4G-LTE System in MATLAB", The MathWorks, Inc., November 2012.