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LTE-U Link Adaptation for Next Generation Wireless Networks

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ABSTRACT

The motive behind the paper is to employ link adaptation in Long Term Evolution LTE waveform to improve the Bit Error Rate BER performance and Spectral Efficiency in real time on Software Defined Radio SDR platform. There are evident rapid changes in the wireless channel which will introduce the fading of signals and, thereby affecting the communication system performances. Having single design link or static link design will not provide better performance all the time in rapidly changing wireless scenario, so there must be a dynamic link waveform generation to provide a promising performance even in the rapidly changing wireless channel. So, this paper aims at implementing an Adaptive Modulation Coding AMC and power allocation scheme based on channel condition for the LTE Link. Hence, this paper focused on LTE-U (Unlicensed) Link Adaptation concepts and its implementation in real time hardware. NI USRP-RIO 2943R Software Defined Radio SDR has been used to validate the method. Link Adaptation or AMC is used in wireless systems for matching of modulation, signal power, coding, and bit error rate to the conditions on the radio link. To find out the channel condition at the given time the performance of the link is analyzed on the receiver side in terms of BER. This information is fed back to the transmitter side. Based on which the transmitter will adopt the link by selecting appropriate modulation coding scheme and transmit power.

Keywords: Link Adaptation Algorithm, LTE, Real, SDR-USRP RIO 2943R, Unlicensed LTE-U.

1. INTRODUCTION

LTE is an emerging and promising technology for providing broadband internet access. LTE is already implemented in 4G standard and is considered for future standards. Starting from this premise, it is clear that the optimization of all LTE aspects is a topic worth of investigation researched. So, any work related to LTE is appreciable for future generation. This paper intent to study the performance based on link adaptation. At the present time, a complete system level simulator is not available for these communities. Day by day there is a rapid increase in number of subscribers leading to an increase in network size. Hence, to bridge this gap, herein, LTE-U must be used to frame LTE links which will give options to use unlicensed spectrum and finally, link adaptation shall be performed to provide a complete performance verification of LTE systems. Salient feature of LTE are reduction in the cost per bit, lower cost services, better user experience, the flexibility to use new and existing frequency bands, a simplified and lower cost network with open interfaces, and a reduced complexity with less power consumption. Therefore reduced latency for packets and spectral efficiency improvements are expected.

Link adaptation or adaptive modulation is a term used in wireless communication which decides the matching of the modulation, coding, signal parameters and protocol parameters to the conditions on the radio link [1]-[2].Choice of modulation type may be QPSK, 16-QAM, 64-QAM, 256-QAM to achieve a link adapted and the selection for the required modulation scheme depends on the noise level and the interference present in the channel. Out of these, QPSK bit rate is low but can tolerate higher levels of interference while the others have higher bit rates but are more prone to errors due to interference and

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noise, hence it requires stronger Forward Error Correction FEC coding, which has advantage of coding gain at the cost of lower information bits.

2. SYSTEM MODEL

Link adaptation makes the proper use of the channel capacity possible, matching the transmission parameters, power spectrum, and various modulation schemes and coding bit error rate in accordance to the channel condition. National Instrument LTE Framework tool is used for this purpose. In this work, the author investigates the capacity, channel gain, Block Error Rate by employment of various combinations of adaptive modulation schemes (QPSK/ QAM) and adaptive power control in an LTE link established using NI USRP-RIO 2943. Based on the feedback received from the receiver, the transmitter adapt the preferred modulation order depending upon the BER achieved i.e., whether it is higher or lower than the threshold and transmitter power for the target performance. The adaptive module is written with LabVIEW Communication Design Suite 1.0 software and put up on controller of SDR platform.

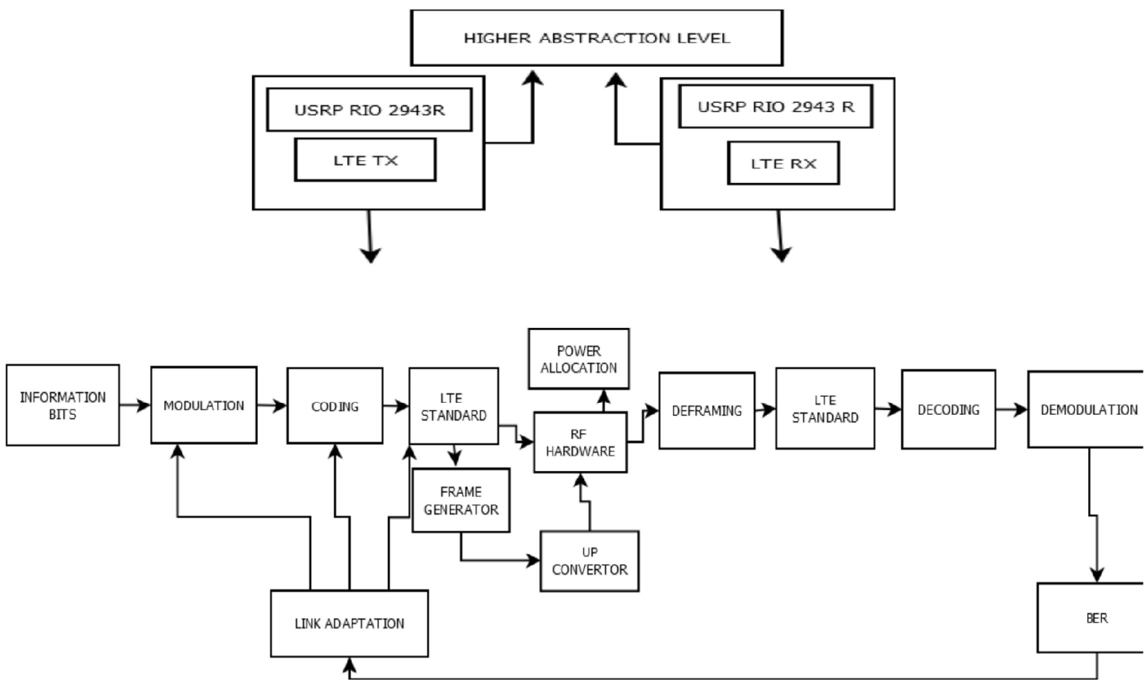

Figure 1: Link Adaptation in LTE Wireless Links

Fig.1 represents the basic working block for the link adaptation technique which will be introduced in the LTE application framework. In the figure, left side is the transmitter and the right is receiver side where the channel analysis is done and BER is calculated. After that, a feedback is sent to the transmitter where the further process takes place.

The methodologies mentioned below is be implemented in order for achieving the required adaptation in the wireless network:

1. ***Power Allocation Technique*****:** To adapt the transmission the signal power in the transmitter side right before the transmission based on channel condition.
2. ***Modulation schemes*****:** The major modulation schemes used for link adaptations are BPSK, QPSK, 16QAM, 64QAM, 256QAM. Out of these 256 QAM offers the highest data rate. But, BPSK is more reliable even though it offers lower data rate because in the constellation diagram the two points are situated quite apart i.e. only a higher noise level can make any changes to the waveform or introduce any error.

3. ***Selection of Coding Scheme***: In LTE both block codes, turbo codes and convolutional codes are used. Depending on the SNR (Signal-to-Noise Ratio), a combination of modulation coding scheme and code rate is selected to ensure that the BER (Bit Error Rate) is less than 10^{-3}.
4. ***BER Measure***: It can be calculated using the formula (No. of incorrect bits received)/ (total no. of bits transmitted).

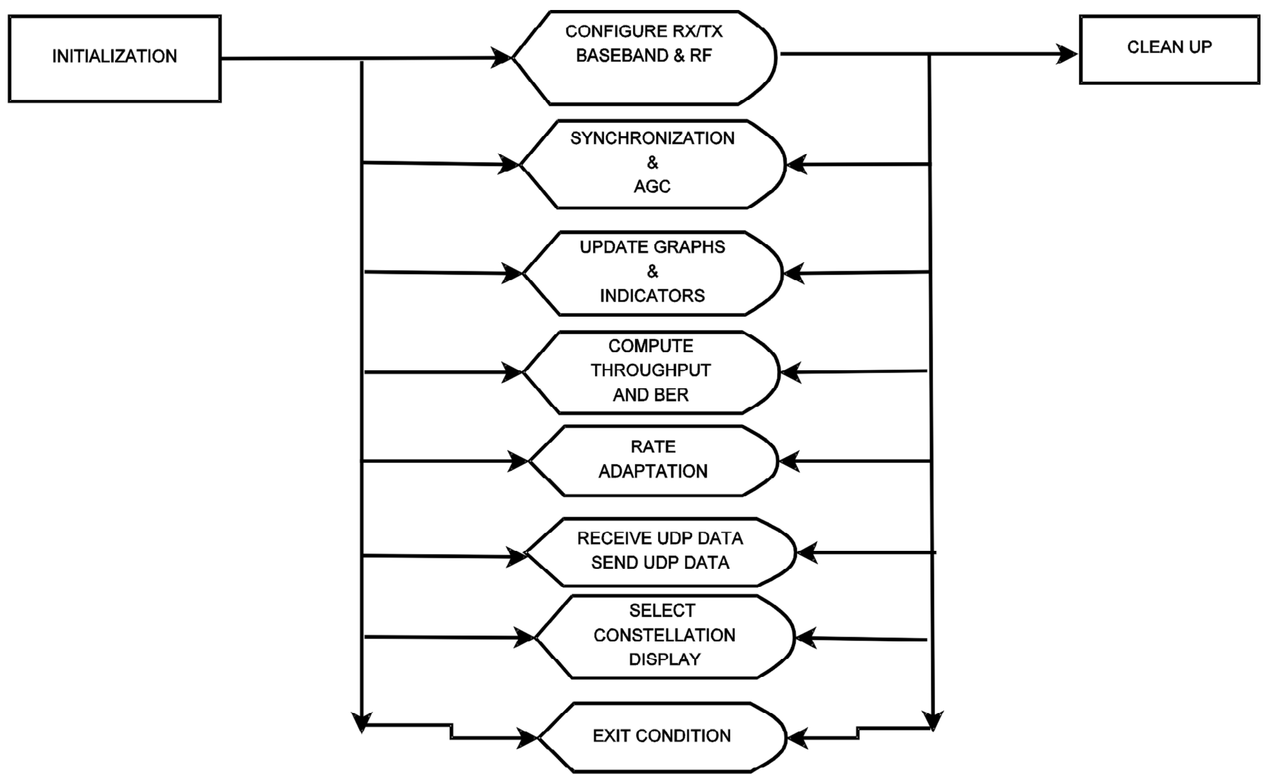

Figure 2: Flow Chart for the Link Adaptation

This flow chart in the fig. 2 represents the higher abstraction model of the entire LTE waveform generation process which takes place in the framework. The various processing chains as shown in the figures are for various functions which are executed on a single run.

2.1. The following section will presents the functions of processing block for achieving link adaptation.

2.1.1. Initialization

The code begins with the initialization block. It sets controls and indicators to default values. Then, it creates the session cluster by starting the necessary queues and loading the FPGA bit file to the RIO device that is configured. The processing loops in this framework use this session cluster while the code is running to exchange data or to access the FPGA resources. All loops are implemented using while loops which run parallely during the execution of the host VI.

2.1.2. Configure RX\TX and Baseband Data

This loop handles the configuration of the RF and the LTE processing chains. After enabling RX or TX switches, some specific parameters are passed to the LTE FPGA processing chain using the settings present on the front panel, e.g. the Modulation and Coding Scheme (MCS) and the Resource Block Allocation are configured upon enabling the downlink transmitter (DL TX).

2.1.3. Updated Graphs and Indicators

This loop reads and processes status information from the FPGA and updates the graphs and indicators on the front panel. This loop also updates the constellation diagram.

2.1.4. Rate Adaptation

The rate adaptation which is present in DI and eNodeB host sets the Modulation and Coding Scheme (MCS) depending on the achieved wideband SINR value. This value is either read directly from the FPGA or received from the UE as part of the uplink feedback.

2.1.5. Receive UDP Data/Send UDP Data

The processing loop handles incoming UDP data used as payload for DL TX in the DI and eNodeB host configuration. The data is provided by an external source and read from the port number specified on the front panel. In the UE and DL host variant, this processing loop also handles outgoing UDP data. This data stream containing the payload data which was received and decoded from the DL RX. After the data is transferred to the host using a target to host FIFO, the data is coded as UDP stream and sent to some other application.

2.2. Rate Control via AMC

There are two mechanisms available for rate adaptation in LTE,first of these which is Adaptive Modulation Coding, AMC, changes the modulation order among QPSK

BER for QPSKis given below[2]

$$P_{QPSK} = \text{erfc}(\sqrt{E_b/2N_o}) \tag{1}$$

For 16-QAM/64-QAM modulation the BER is

$$P_{QAM} = 3/2\text{erfc}(\sqrt{E_b/10N_o}) \tag{2}$$

Accordingly adjusts the rate of the channel code. The channel code rate is thus adjusted according to the channel parameters analysed at the eNB.In the DL, both the modulation order utilized for a given transmission are specified by the MCS index, which is transmitted along with the PDCCH. The MCS index consists 28 other different possibilities.

The wave form generation is based on OFDM Equation for OFDMA is given below

$$X(k) = 1/N\, \Sigma_{i=0}^{N-1}\, x(i)\, e^{12\pi ki/N} \tag{3}$$

2.3. Channel State Information (CSI) Feedback

The CSI that can be reported by a UE in the LTE standard enables power control, channel dependent scheduling, and AMC. According to the LTE standard, the CSI feedback should analyse the channel condition and helps in the appropriate selection of the MCS which could be sustained and is required under the present channel conditions, while simultaneously maintaining a transport block error probability not exceeding 0.001 which is the threshold that we have kept. In order to analyse the channel conditions, a UE measures the channel using the DL reference signals.

2.4. Power Control

Power control is an important component in LTE link adaptation. Power control has been widely used to counteract interference in wireless networks [4]. In LTE, power control is performed in the DL via open loop procedure, and in the UL via closed loop procedure. Power control is important because, although different subcarriers in a given cell are orthogonal, the UE might suffers due to inter cell interference between a UE and neighborcells at the cell edge in the Downlink transmission, and the eNB also suffers from interferences due to the errors from the RF hardware impairmentsof UE.

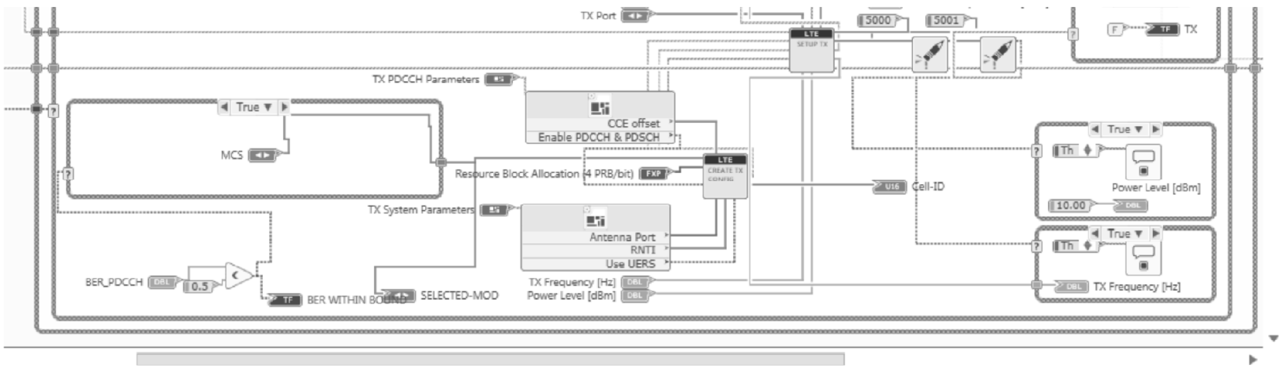

Figure 3: Modified LTE Application framework

3. HARDWARE AND SOFTWARE IMPLEMENTATION

3.1. USRP RIO 2943 Architecture

The NI USRP RIO software defined radio(SDR) platform assembles 2 full-duplex transmit and receive channels with 40 MHz/channel of real-time bandwidth and a large DSP oriented Kintex 7 FPGA. The analog RF front end interfaces with the Kintex 7 FPGA through ADCs and DACs clocked at 120MS/s.

Each RF channel includes a switch which allows us to use time division duplex (TDD) operation on a single antenna using the TX 1 RX1 port, or frequency division duplex (FDD) operation using two ports, TX1 and RX2 the USRP RIO 2943 model uses a frequency range of 2.4 GHz - 5 GHz. The Kintex 7 FPGA is a reconfigurable LabVIEW device that incorporates low latency applications.

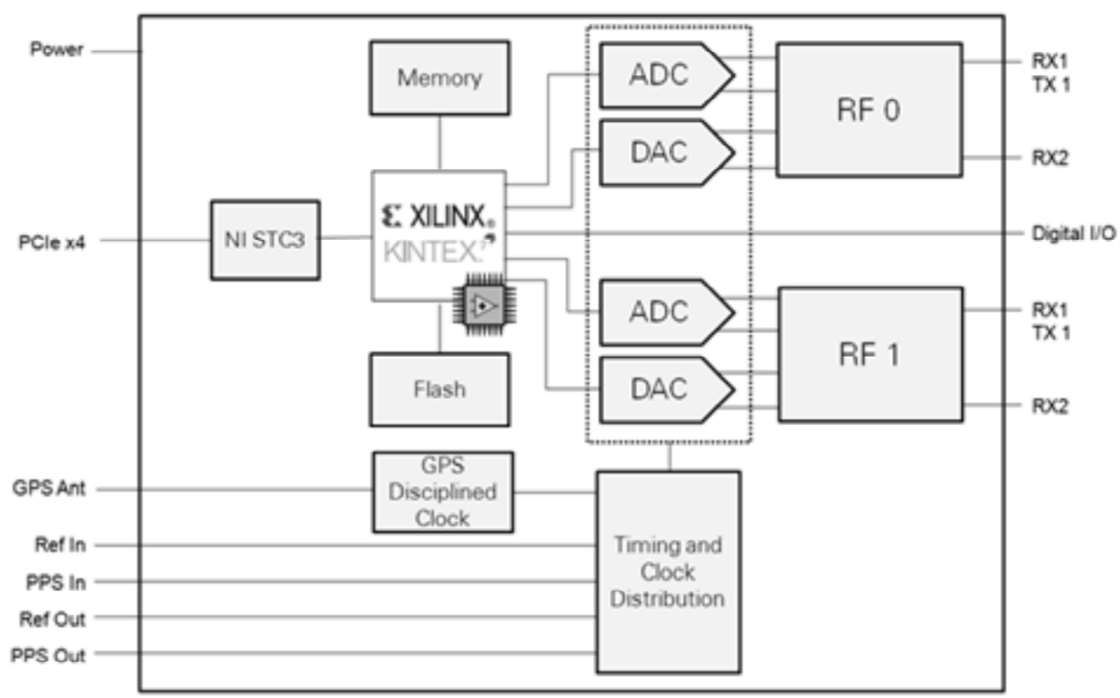

Figure 4: NI USRP RIO 2943R Architecture [6]

Fig. 3 shows the architecture for the NI USRP RIO 2943R and its various units

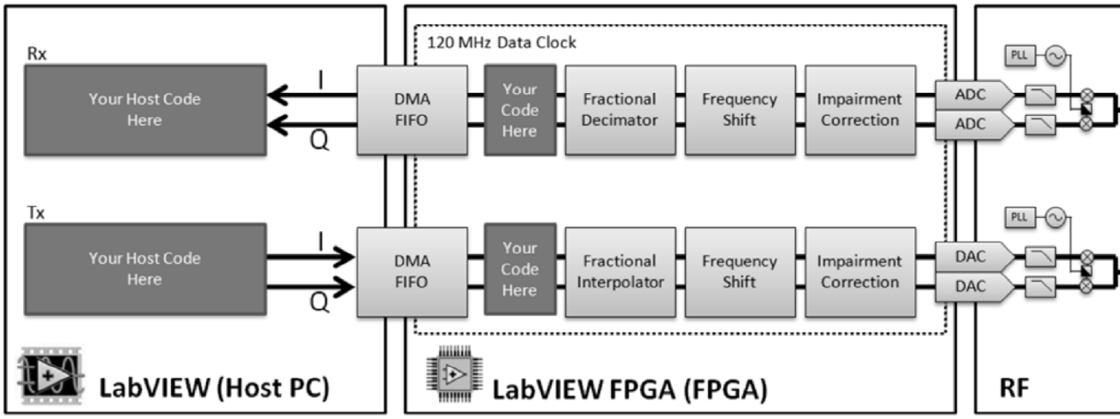

Figure 5: Typical Streaming Application using NI-USRP RIO driver (Host and FPGA)[6]

Table 1
Configurations Used for the NI USRP-2943R

Parameters	*ENB node*	*UE*
Transmitter Frequency	2.4 GHz	2.4 GHz
Resource Block Allocation(In Decimal)	8388607	8388607
Port	TX1/RF0, RECEIVE PORT=50000	RX2/RF1, TRANSMIT PORT=60000
Power Level (dBm)	10	10

3.2. LabVIEW Communication System Design CSD Suite 1.0

The entire application framework of LTE which is reconfigurable and can be modified using LabVIEW Communication System Design Suite 1.0. The higher abstraction model of the LTE Application Framework is available which is designed using LabVIEW CSD and the processing chain and block can be modified to achieve link adaptation to get a desirable LTE Link.

4. RESULTS AND DISCUSSIONS

The required BER with a target threshold of 10^(-3) is achieved by the AMC and power control introduced in modified LTE Framework for link adaptation using LabVIEW Communication System Design Suite. Below are the relevant graphs and outputs showing the power spectrum of Transmitter and Receiver and the output BER graph. For a moderate power level of 10dBm, when BER is below 0.5, selected modulation scheme is QPSK and when above 0.5, QAM is selected.

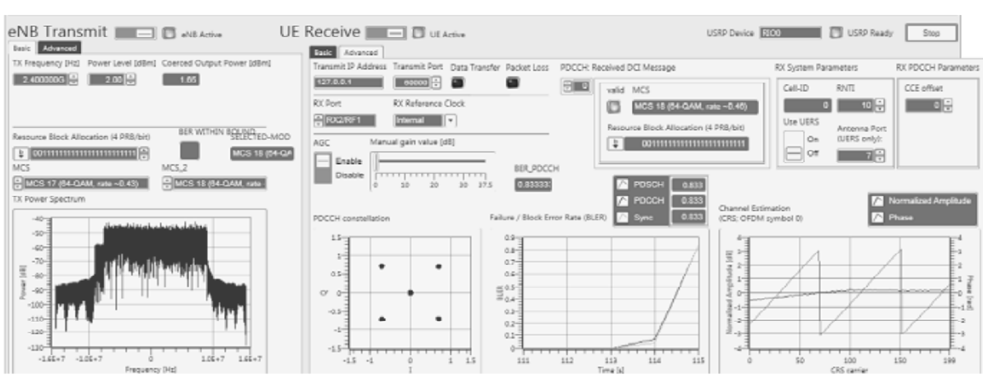

Figure 6: Front Panel QPSK Constellation Diagram

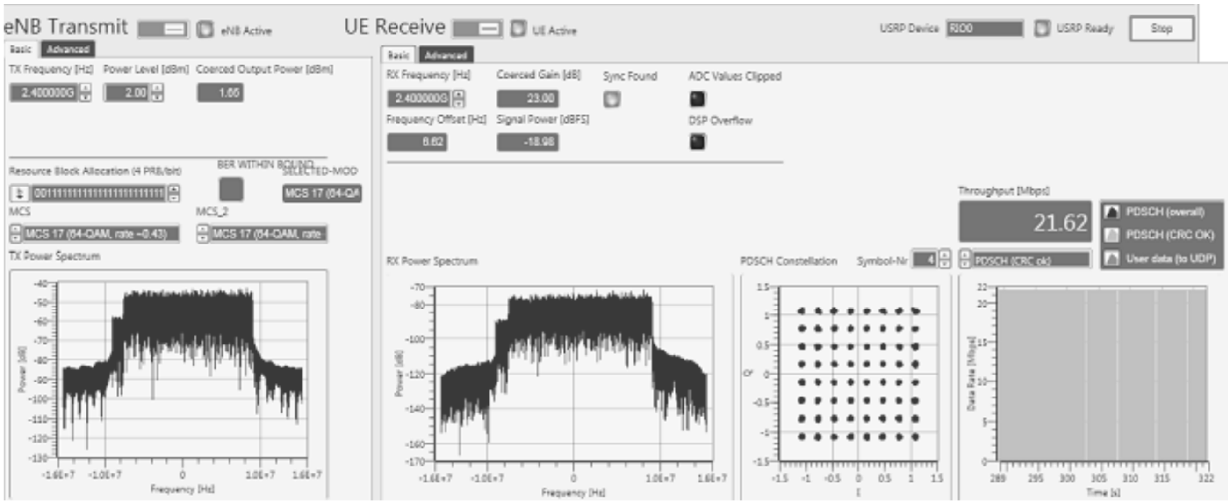

Figure 7: Front Panel (advanced) QAM Constellation Diagram

Fig.6 and Fig.7 shows the constellation diagram of the QAM and QPSK modulation techniques on the front panel of LTE application Framework which is modified to achieve link adaptation.

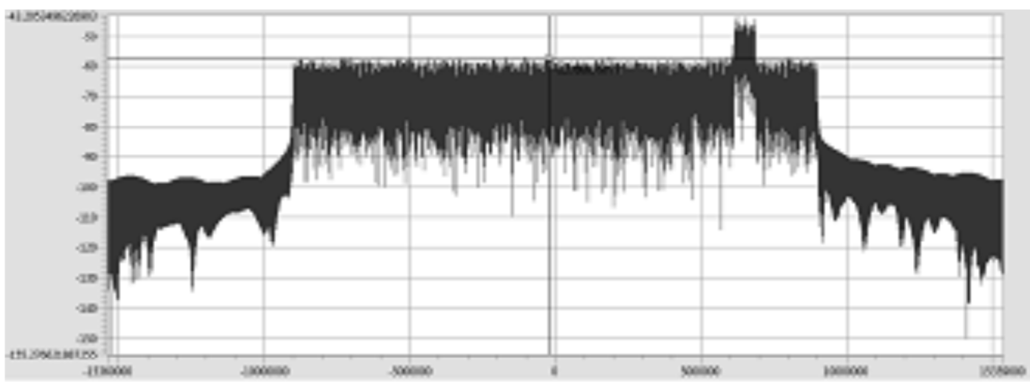

Figure 8: TX Power Spectrum

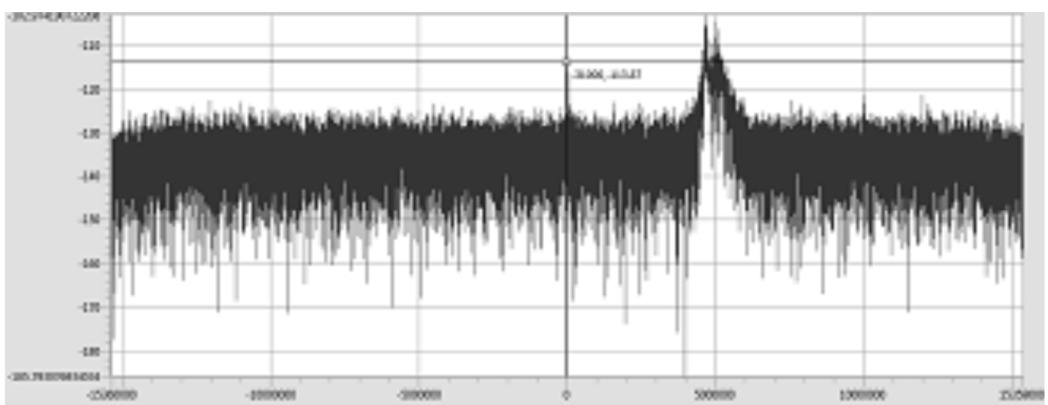

Figure 9: RX Power Spectrum

Fig.8 and Fig.9 shows the power spectrum obtained for the transmitter and receiver respectively.

Fig. 10 shows the graph for average BER Vs. TX power for QPSK and QAM modulation schemes respectively. It is understood from the graphs that as the power level increases, BER diminishes for both the cases.

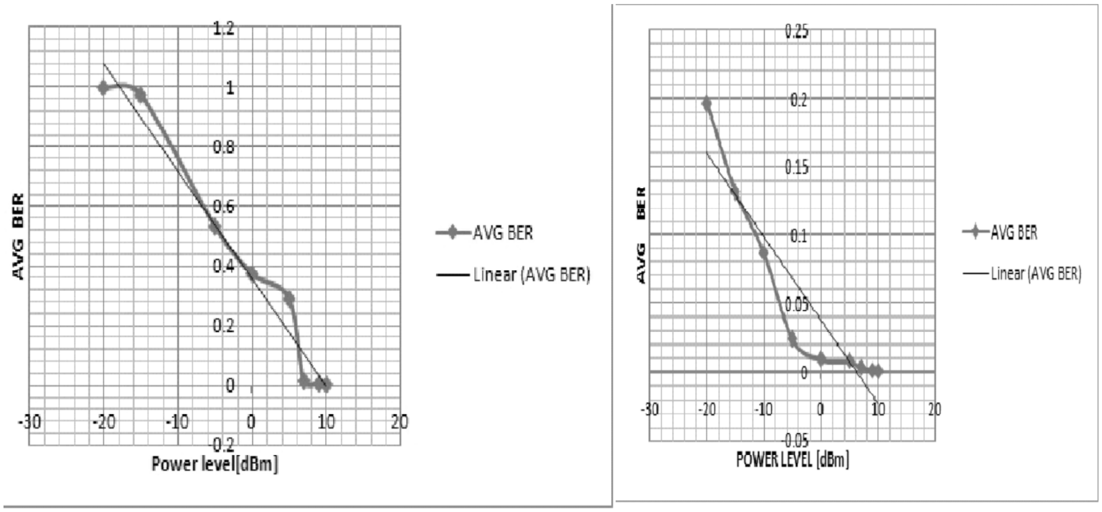

Figure 10: BER vs. TX power for QPSK& QAM modulation

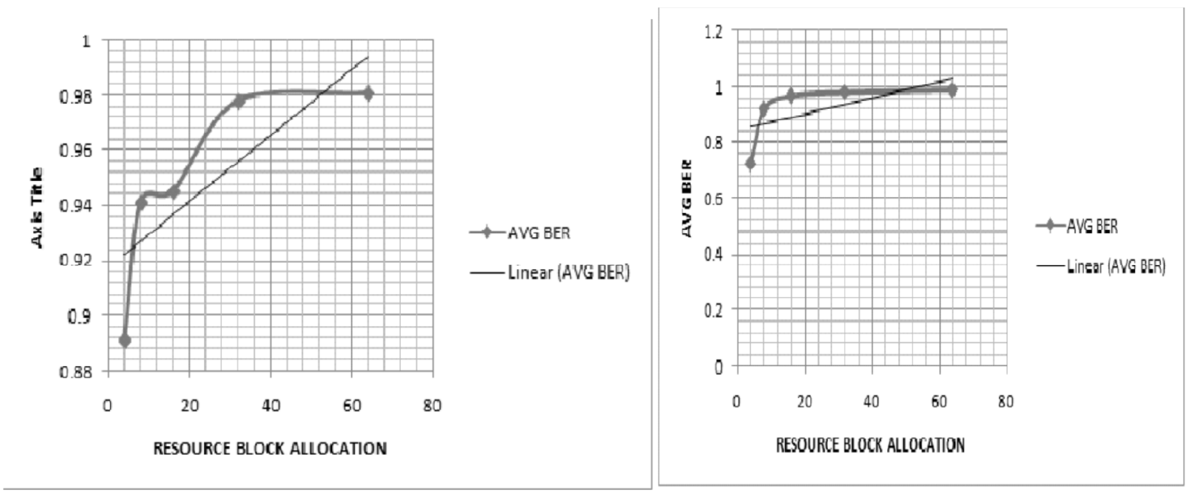

Figure 11: Avg. BER vs.RB Allocation(-10dBm)& (10 dBm) fixed power level

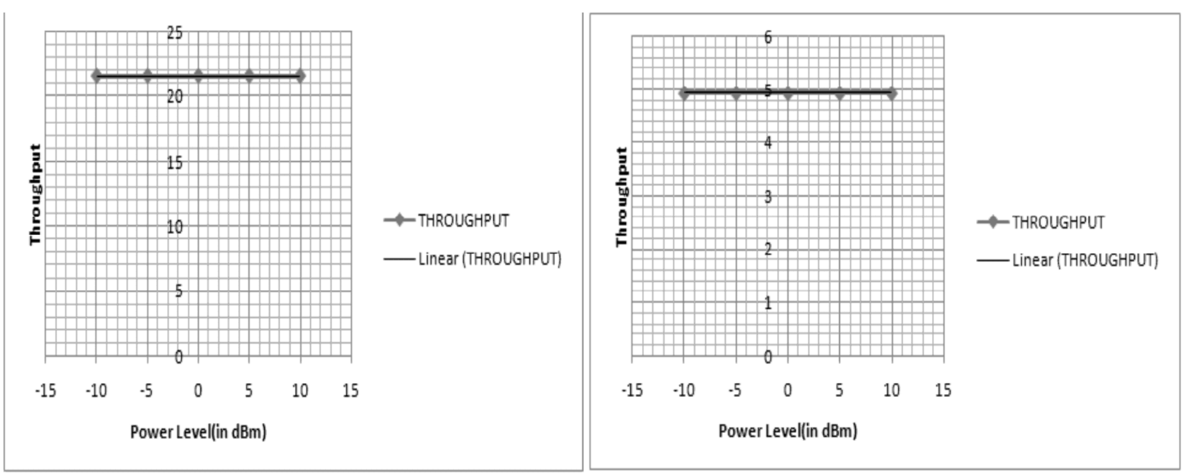

Figure 12: Throughput vs. Power Level for the QPSK& QAM Modulation scheme

Fig.12 shows the graphs for Avg. BER vs. RB allocation for the LTE link respectively.

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