LTE Wireless Standard: Downlink

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***Abstract*—This project models the LTE Wireless Standard downlink receiver and transmitter system. Particularly, it attempts to implement OFDMA (Orthogonal Frequency Division Multiple Access), the basis of the LTE PHY layer.**

I. Introduction

Long Term Evolution (LTE) is a standard specified by 3GPP for fourth generation (4G) wireless communication. LTE was developed as a solution to the need for mobile internet connectivity. It provides high spectral efficiency, high peak data rates, and frequency flexibility. LTE is utilized globally by comericial network providers such as Verizon in the United States and Vodaphone in Europe.

Like, previous wireless standards, the specifications of the LTE system arise from the needs it meets. The 2G standards were developed to support mobile telephones and voice applications. The 3G standards introduced packet-based data and supported internet applications like email and web-browsing. The 4G LTE standard is designed to support IP packet-based networks and the sudden and urgent demand for band-width heavy applications like video streaming.

The higher data rates needed by the LTE system are achieved by Orthogonal Frequency Division Multiplexing (OFDM), Multi-Input and Multi-Output (MIMO), channel coding, scheduling, and link adaptation. OFDM allocates individual users in the time and the frequency domain and its signal generation in the transmitter is based on the Inverse Fast Fourier Transform (IFFT). This simulation focused on OFDM.

II. LTE Downlink Model

The LTE downlink (from tower to device) is fundamentally comprised of OFDMA. OFDMA is a robust modulation technique to combat multipath fading and interference. In OFDMA, the physical resources are represented on a time-frequency resource grid. Resource elements are grouped into resource blocks. Each resource block consists of 12 subcarriers with 15 kHz spacing in the frequency domain and 7 OFDM symbols in the time domain. The number of available RBs in the frequency domain varies depending on the channel bandwidth, and channel bandwidths may vary between 1.4 MHz and 20 MHz. This resource allocation was the main focus of the downlink simulation performed here. This simulation models a channel with 5 MHz of bandwidth. According to the standard, this uses 25 resource blocks. The number of subcarriers is 512, and the number of used subcarriers is 300.

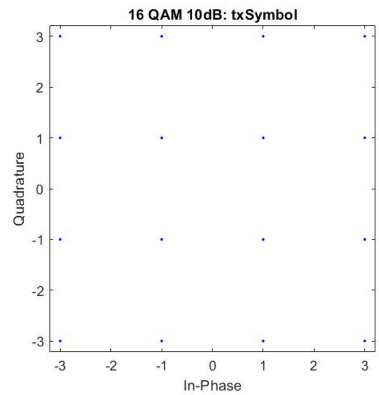

Fig. 1. This constellation plot shows the effect of 16QAM modulation on the input bits of the symbol.

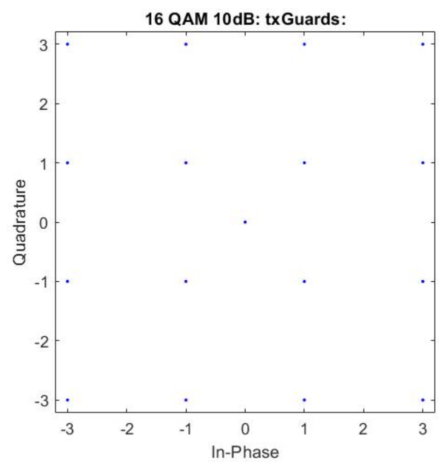

Fig. 2. This constellation plot shows the additions of the guards and 0 DC offset on the symbol.

A. Transmitter

A data block was created by generating enough random bits to fill a subframe. These bits were then modulated and shaped into a block (Fig 1). The columns represented symbols and the rows represented subcarriers. OFDM modulation was then implemented. In OFDM modulation, the data stream is modulated in parallel. Each symbol of the resource block was taken individually. Every first and eight symbol (the first symbol in each slot) in the array was selected to have a longer cyclic prefix (according to the standard). In a more complete simulation, pilot symbols would also be added to the location of these symbols as well as the fifth and twelfth symbols. The remaining symbols were assigned normal cyclic prefixes. The guard and DC offset were added to the symbol vector (Fig 2). The vector was passed through the FFT. Cyclic prefixes were added to the result by taking the last CP length number of bits from the end of the symbol and adding duplicates to the beginning. The purpose of the cyclic prefix is to reduce inter-symbol interference.

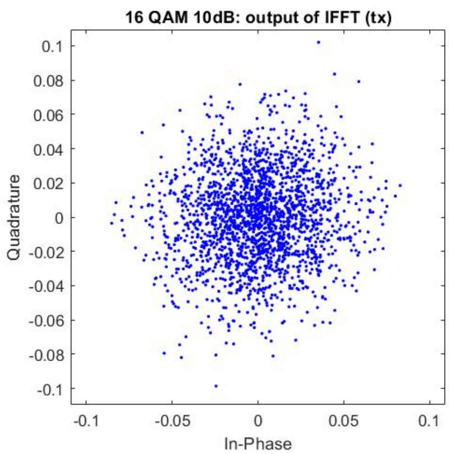

Fig. 3. The result of the IFFT on the symbol. Note that the

B. Channel

The symbols were sent through a channel that added AWGN noise following the addition of the cyclic prefix.

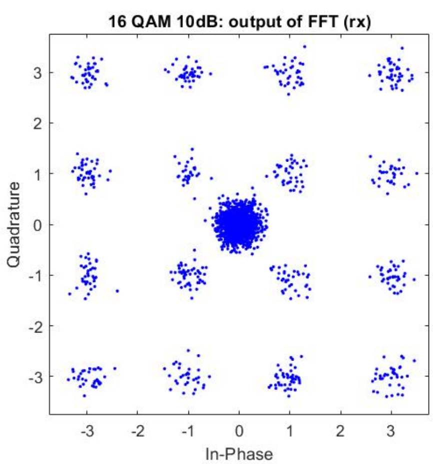

Fig. 4. The result of the FFT on the symbol. The figure shows noise and signal recovery.

C. Receiver

The receiver was modeled by undoing the OFDM operations performed by the transmitter. Every operation was tested step by step with no channel present to ensure the exact recovery of the original data stream. First, the cyclic prefix was removed from the symbol by creating a new vector without the CP bits. Next, the symbol was passed through the FFT. This converted the symbol back to the frequency domain. The constellation plot (Fig 4) shows that the modulation is evident again. Noise is also visible. The guard bands were then removed and the symbols were appended to a matrix to reform a data block. The demodulation loop then demodulated each symbol, created a block of recieved data, and compared the recieved data to the transmitted data to print a BER.

TABLE I
COMPUTED BER FROM INPUT PARAMETERS

Modulation/SNR	BER
16 QAM, 0db SNR	0.0381
16 QAM, 10db SNR	0
64 QAM, 0db SNR	0.0949
64 QAM, 10db SNR	5.3e-4

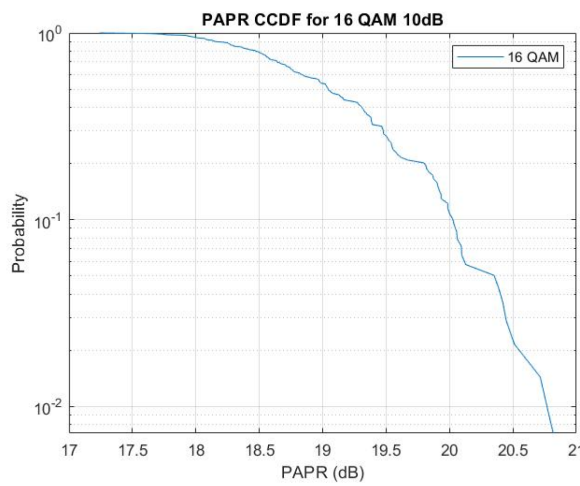

Fig. 5. The PAPR plot would illustrate reduction of error when pilot symbols are included. The main drawback of OFDM is high PAPR.

The simulation can be run for 16 and 64 QAM and 0 or 10 dB. Plots similar to those above created under the remaining combinations of parameters can be accessed on the GitHub repository *https://github.com/sophiejaro/ECE408*.

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