# Wi-Fi Implementation Using LabVIEW: Midterm Report

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## Introduction

One of the predominant schemes for wireless communication, Wi-Fi enables the majority of all internet traffic.As internet use increases, the need for Wi-Fi systems to provide higher throughput rates has persisted since its inception, leading to its implementation of Orthogonal Frequency Division Multiplexing (OFDM), first seen in the 802.11a standard. To gain a better understanding of this technology, the student proposes developing the modulation and demodulation techniques that are part of the Wi-Fi physical layer.

## Topic Background

Modern physical-layer Wi-Fi implementations incorporate a number of modulation and coding techniques to maximize throughput and robustness. Figure 1.1 illustrates the overall architecture.

A screenshot of a cell phone

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Figure 1.1: General Physical-Layer Architecture for Wi-Fi Systems

At its core, OFDM is a specialized technique of grouping up to multiple subcarriers (52, for this project’s scope) into a single channel. Each subcarrier sends individual data streams on a specified carrier frequency, in such a way that they are both tightly-packed and non-interfering.While most of the subcarriers present are data-bearing, there are four pilot subcarriers which provide a fixed, repeated signal for estimation processes. The layout of these subcarriers can be seen in figure 1.2.

It should be noted that the orthogonality of these subcarriers can be affected by changes in the physical space of transmission, whether that be the medium of the channel or movement of the devices; in both cases, the interference caused by this loss of orthogonality is known as *fading*, and is addressed via Forward-Error Correction coding and estimations of phase and frequency offsets of each subcarrier.

The transmission of bits of data by each subcarrier leverages the broad modulation scheme of Quadrature-Amplitude Modulation (QAM). In order to utilize this modulation technique, the transmitter and receiver must be synchronized, expecting a character to be transmitted at a fixed interval of time based on the period of the lowest-frequency subcarrier – the *symbol rate* of the channel. Synchronization is accomplished using a guard-time prefix, extending the first symbol prior to transmission.

A close up of a logo

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Figure 1.2: Subcarrier Layout of 52-subcarrier Wi-Fi system

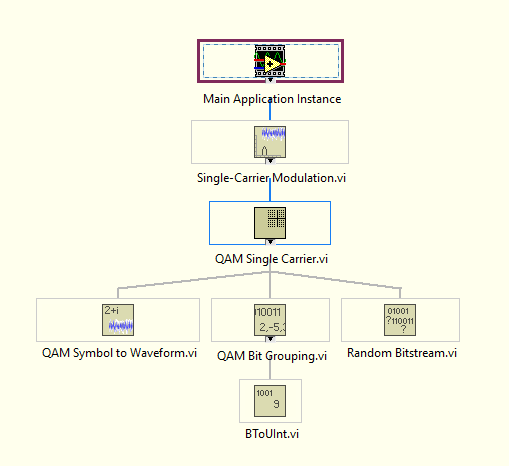
Given this synchronization, in-phase and quadrature (90-degree lagging) components of the subcarrier are used to determine bit values. Atransmitter may increase the complexity and bitrate of its subcarriers by using a larger range of component values.A graphical representation (1.3) of the supported modulation techniques is provided to better illustrate this.

A screenshot of a cell phone

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## Midterm Status

At the time of publication, the implementation includes a *Top VI* which allows for signal simulated noise and channel fading between the transmitter and receiver; *Top VI* implements the high-level QAM modulator (), OFDM transmitter (), OFDM receiver (), QAM demodulator (), and various helper functions, with VI hierarchy illustrated in figure X.X. At a cursory view, *Top VI* allows the user to specify QAM parameters (such as samples per symbol and complexity), while also providing basic analysis tools such as a frequency-domain waveform chart and constellation graph of the receiver; validation indicators are provided as well, referencing the number of correctly-received subcarriers and correctly-decoded bits. Finally, *Top VI* provides a control for selecting which QAM de/modulator is used: the Labview-provided de/modulation tools in the *RF Communications Toolbox*, or the custom-written de/modulation tools. It should be noted that Labview does not provide an OFDM implementation, which therefore must use the custom Vis.

Figure 1.4: Current VI Hierarchy

Supporting the core transmitter/receiver pair is *Symbol to DataLen*, determining the number of bits need to provide 48 data-bearing subcarriers during the QAM modulation. Though the number of bits per QAM symbol should only vary by QAM complexity in accordance with table X.X, some control was altered due to *MT Modulate* requiring a minimum of 4 symbols (2 bits) in it’s symbol map. As a result, the dual-case structure in figure X.X was implemented to scale the number of bits per symbol.

|  |  |  |
| --- | --- | --- |
| QAM System | QAM Symbol Range | Bits required per symbol |
| BPSK | [-1+j0, 1+j0] | 1 (homebrew), 2 (MT Modulate) |
| QPSK | [-1-j1, 1+j1] | 2 |
| 16-QAM | [-2-j2, 2+j2] | 4 |
| 64-QAM | [-4-j4, 4+j4] | 6 |
| 256-QAM | [-8-j8, 8+j8] | 8 |

this utilizes several subVIs to craft the individual QAM weights and waveform from a randomly-generated bitstream. The *QAM Single Carrier* VI then combines all portions of this waveform generation, and allows for a direct comparison between the student’s generated system and the LabView modulation VIs part of their RF Communications toolbox.

The current project status is roughly a week behind the anticipated goal, where a complete OFDM transmission system would have been prepared for presentation. Much of this was due to a level of initial uncertainty on how to approach the project. Because of this delay in development time, both the deliverables and timeline have been adjusted.

Going forward, the student plans to finalize the transmission modulation; develop receiver demodulations for QAM and OFDM; and implement a simple transmission guard-time. Time-permitting, the student may implement some signal deterioration and recovery aspects; however, the student no longer plans to implement convolutional codes.

## Adjusted Deliverables

The student:

* Will provide capabilities for all subcarrier QAM modulation schemes in figure 1.3.
  + These will be selectable, based on a front-panel input.
  + This will be visible via a front-panel constellation diagram.
* Will effectively implement OFDM on a 52-subcarrier system.
  + This will be illustrated with an FFT and potentially a time-domain sink.
* Will provide a guard time for the beginning of each transmission.
* Will provide a hierarchical design that develops QAM, OFDM, and other potential system components in respective chains of subVIs.
* May implement simulations, estimations, and recovery techniques for channel fading.
  + These will be visible through additional constellation and FFT sink diagrams.
  + A subVI or hierarchy of subVIs will be developed for each above aspect.

While the student may use the RF Communications Toolbox to provide appropriate graphs/indicators, all features within this project should be implemented using Labview’s base components. This is because of the project focus on understanding the operation of the critical elements within the Wifi PHY.

### Deliverable Timeline

|  |  |  |
| --- | --- | --- |
| **Week of** | **Initial Goal** | **Modified Goal** |
| February 3rd | Develop QAM (tx) | Begin QAM Development (tx) |
| February 17th | Develop 52-subcarrier OFDM (tx) | Finalize QAM Development (tx) |
| February 24th | Refactor tx components | Begin OFDM Development (tx) |
| **March 3rd** | **Midterm Presentation** | **Midterm Presentation** |
| March 9th | Develop QAM (rx) | Finalize OFDM (tx) |
| March 16th | Develop OFDM (rx) | Develop OFDM (rx) |
| March 23rd | Guard Time | Develop QAM (rx) |
| April 6th | Recovery Techniques (Frame Detection, Frequency & Phase Offset Correction) | Guard Time Insertion/Removal, Development Catch-Up |
| **April 13th** | **Final Presentation** | **Final Presentation** |
| **April 20th** | **Final Report** | **Final Report** |

## License and availability

The student intends to develop and publish this project to his Github page under a General Public License. This is intended as a way of providing academic and professional reference, as well as to receive feedback.

# References

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