

## Advanced Communication Test System

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### I. Introduction

Wireless telecommunication systems have increased at an enormous rate over the past few years. Various modulation techniques have been developed with the objective of improving the quality of service. The main goal of these techniques is to improve the bandwidth and power efficiency while keeping the bit error rate (BER) at acceptable levels.<sup>1,2,3</sup> The complexity of these systems along with the high frequency of transmission makes it difficult to develop undergraduate laboratories that can be used to teach the needed concepts. Some teaching systems exist but cannot be easily tied to existing commercial systems. Equipment to test and characterize these new commercial communication systems is complex and expensive.

To overcome some of these problems, student projects can be developed using a PC-based system for simulation and application. The PC-based system used in this example is LabVIEW, or Laboratory Virtual Instrument Engineering Workbench, a graphical programming language developed by National Instruments. It is used extensively for data acquisition, instrument control and analysis.<sup>4</sup> In this example, a communications system was developed through student projects and a coop experience. This system has the capability of simulating a receiver or transmitter using a number of different modern communication techniques. Although the system operates at a much lower frequency than modern communication systems, it can measure a number of parameters of the receiver or transmitter.

A number of modulation schemes are available in the system including phase shift keying (PSK), frequency shift keying (FSK), quadrature amplitude modulation (QAM) and a generic I and Q modulation scheme. A number of different variations of PSK and FSK are also included.

### II. Digital Modulation Wizard

The program allows for simulation of a wide variety of digital communication techniques. The user can configure all parameters used in the creation of a particular modulation scheme. The overall program works as a two-phase system. The first phase involves using a graphical configuration tool to

create a customized modulation scheme. The second phase involves the simulation of a communication link using this customized scheme. A saved configuration file serves as the bridge between the phases.

The graphical configuration tool is referred to as the Digital Modulation Wizard. This virtual instrument (VI) is the graphical user interface (GUI) to the entire toolkit. The user can execute this VI and graphically configure a modulation scheme and save that configuration in the required file format.

The configuration is done prior to running a simulation of this modulation type. The configuration file only has to be written once for multiple simulations of the same modulation type. When the user first executes the VI, Figure 1 pops up.

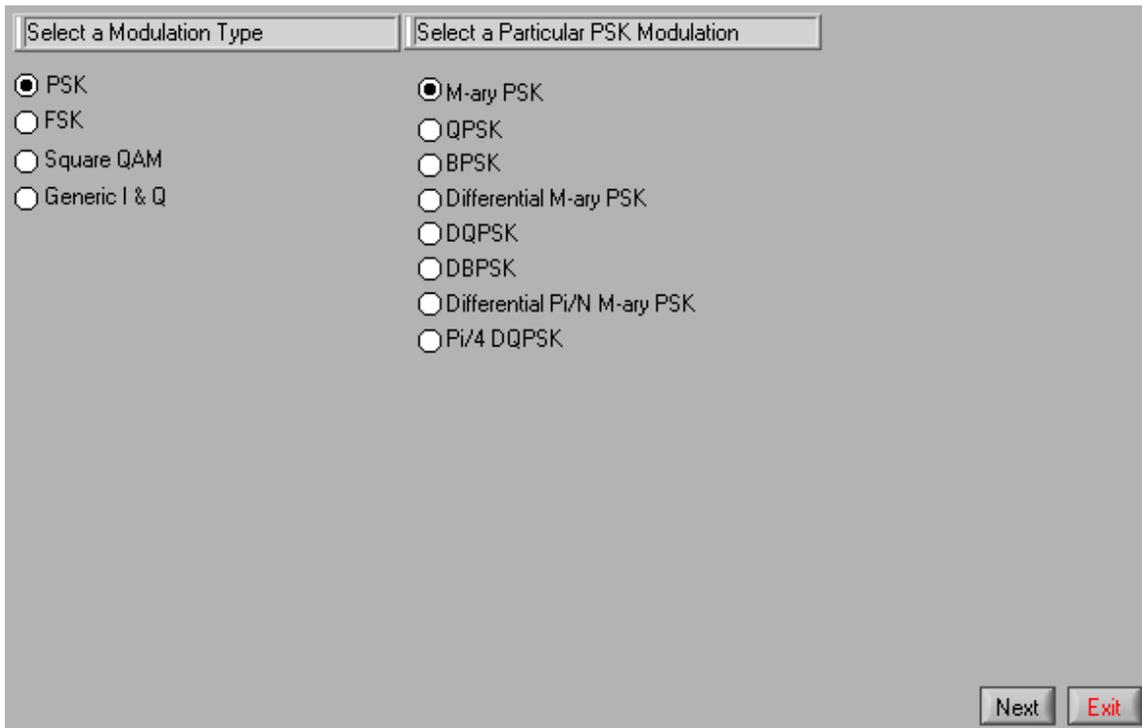


Figure 1. Modulation Selection Screen.

There are two columns of radio buttons that allow the user to select the general modulation type and the specific modulation type. In Figure 1, only the particular modulation schemes for PSK are shown. After both the general modulation scheme and the specific modulation scheme are selected, the user presses the Next button, at the bottom of the screen, to continue the configuration. The next screen that comes up allows the user to input the modulation cluster information that is pertinent to the selected general modulation type, as shown in Figure 2.

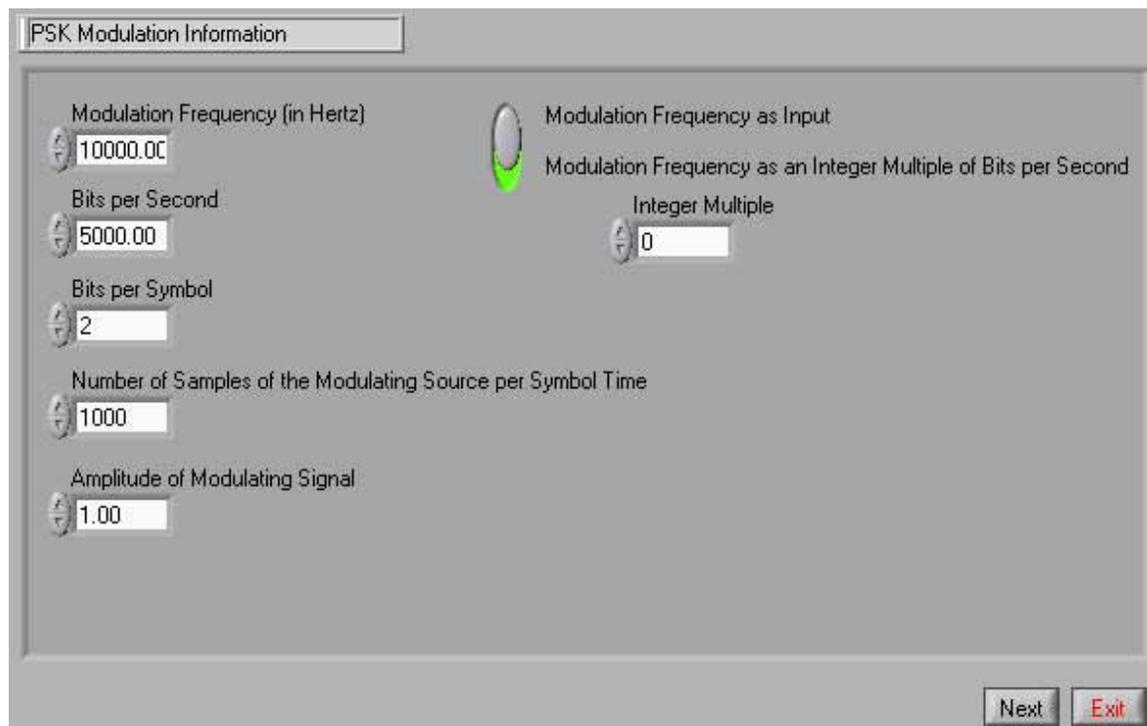


Figure 2. Modulation Information Screen

The Next button is grayed out until the user has provided a complete set of data. At that point, the Next button will turn active and the user can move on to the next screen. The screenshot in Figure 2 does have the appropriate information input, thus the Next button is enabled. After pressing the Next button the screen in Figure 3 appears.

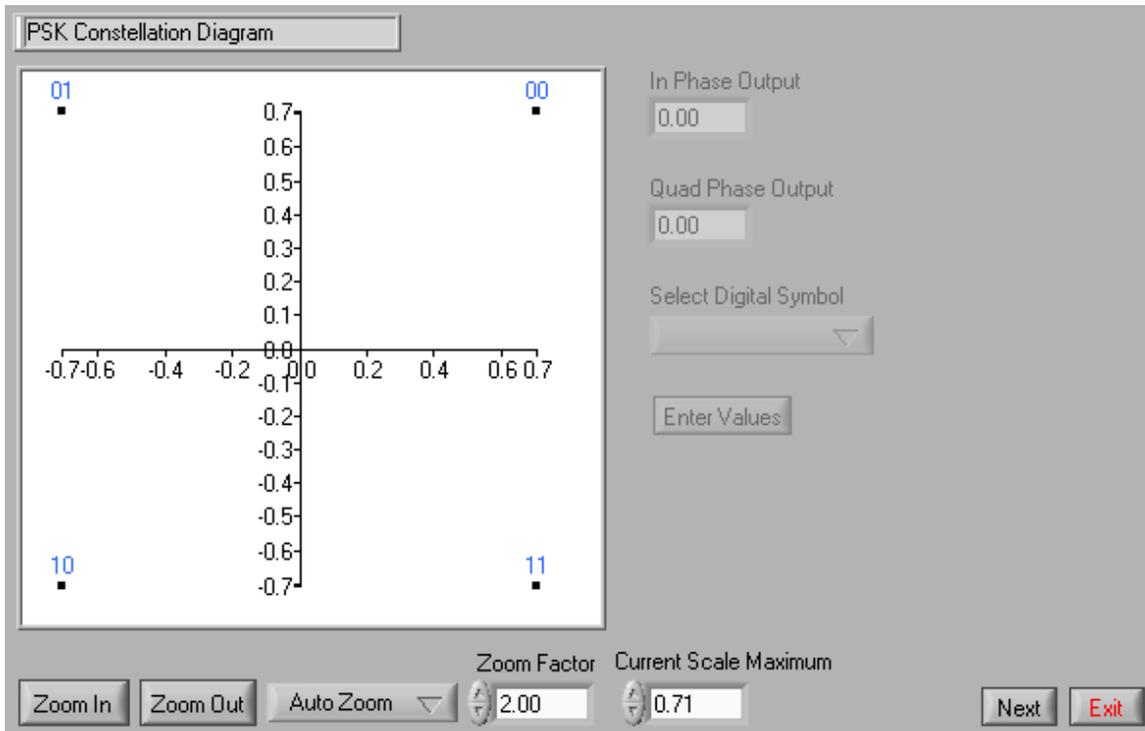


Figure 3. Constellation Diagram Screen

This screen displays the constellation diagram for the selected modulation type. The symbols that are associated with different in-phase and quadrature phase points are determined initially using default values. For Phase Shift Keying (PSK), the binary values increase from least to highest value as the angle increases, as is shown in Figure 3.

### III. System Simulation

After creating the modulation configuration, the user must make a system in LabVIEW that will execute the desired modulation and demodulation. The diagram in Figure 4 shows a VI that uses every VI in the toolkit to make a complete simulation, from the input waveform (Input Bits) to the output waveform (Output Bits). A constellation diagram measurement is also included.

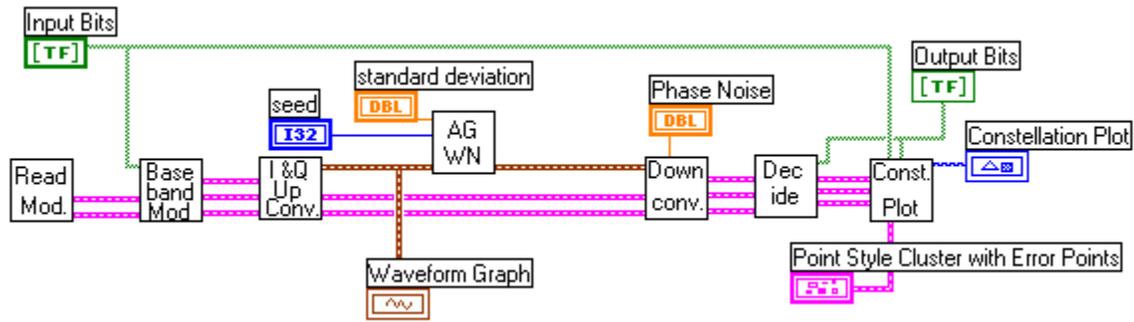


Figure 4. Simulation System Diagram

The Read Modulation VI, Read Mod in Figure 4, takes in a configuration file, generated by the user, and outputs the information in the appropriate format to the next block. The baseband modulator or encoder, Baseband Mod, takes as required inputs the binary data stream, Input Bits, and the modulation definitions from the first block. The Baseband Mod VI takes the input Boolean array and splits it into symbols. The number of bits in each of these symbols is determined by the modulation definition. The resulting output is a data cluster with in-phase and quadrature phase data for each inputted symbol or, for FSK schemes, the output is the frequency, phase, and amplitude data for each inputted symbol. The number of data points output by this VI corresponds directly to the number of points used in the RF waveform generated by the next VI. The baseband modulation can be thought of as the digital modulation phase of a modern communication system.

The inputs to the RF Up-converter VI are the data created by the baseband modulator and the user defined modulation technique. For PSK, QAM, and Generic I & Q techniques the data has in-phase and quadrature phase information that relates to all of the symbols included in the input bit array. The up-converter takes these data points and produces the radio frequency output waveform. In the analog case, the up-converter would be called the RF modulator.

The software loop that creates the RF output is executed for each incoming in-phase and quadrature phase data point resulting in one RF data point. The final result is an array that corresponds to the desired radio frequency signal for the inputted binary bit stream and modulation scheme. FSK schemes use the same loop structure. The loop takes in one data point that has the frequency, phase, and amplitude of the desired RF output wave. The result is an array that contains the FSK waveform for the inputted binary bit stream using the desired modulation scheme.

The Additive Gaussian White Noise (AGWN) VI is a very simplistic simulation of a channel with additive Gaussian white noise. The VI takes in the RF signal and adds white noise that corresponds to a Gaussian PDF with a standard deviation given by the user.

The RF Down-converter VI takes the RF signal and converts it back into baseband in-phase and quadrature phase data that corresponds to individual symbols, or into the frequency data for individual symbols transmitted using a FSK modulation scheme. The down-converter works coherently for phase modulation based schemes, which means that the down-converter has to know the modulation frequency, the carrier phase, and the symbol frequency. For FSK based schemes, the RF Down-converter works as an interpolating frequency estimator.

The Binary Decision VI uses the data from the down-converter, the modulation definitions and the modulation vectors. For phase modulation based schemes, the received in-phase and quadrature phase data is matched against the in-phase and quadrature phase data of the defined modulation vectors. The VI takes the in-phase and quadrature phase data and calculates a distance between a single point in the data stream and all of the in-phase and quadrature phase data points of the modulation vectors. The smallest distance is determined to be the point that was transmitted. Thus, the symbol that corresponds to the smallest error for the in-phase and quadrature phase data modulation vectors is selected as the demodulated symbol, and this symbol is concatenated on the output binary array. For FSK modulation schemes this VI looks through the given frequencies that are associated with the different symbols, and selects the smallest difference between the received frequency value, and given frequency values for the particular scheme. The smallest difference is determined to be the transmitted symbol, and that symbol is concatenated on the output binary array.

The Constellation Plot VI is specifically for visualization and measurement of the PSK, QAM, and Generic I & Q systems. This plot can display the decision boundaries, corresponding symbols, and various measurements. The style allows the user to look at error symbols as a consistent color, and display the binary symbol indicators as a color gradient according to the number of errors that the particular symbol space accrued, as shown in Figure 5. On top of this functionality the VI also displays the bit error rate, the symbol error rate, the number of bits received, the number of erroneous bits, the number of symbols received, and the number of erroneous symbols in the box to the right of the constellation diagram. Standard time and frequency displays are also available in LabVIEW.

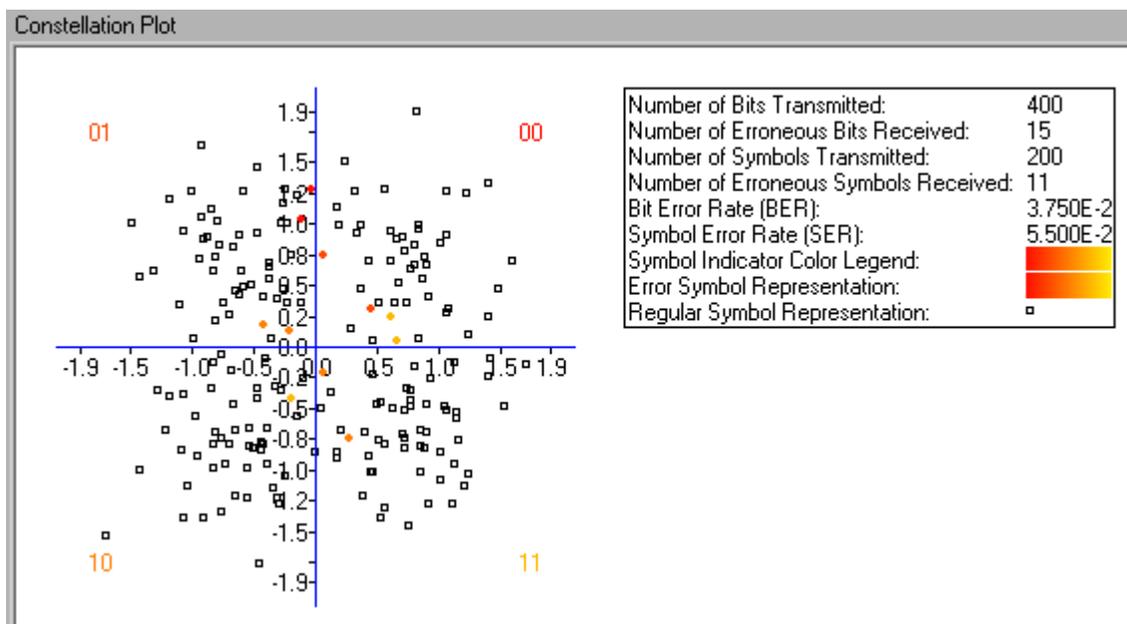


Figure 5. Constellation Plot With Gradient Colored Errors

#### IV. Conclusions

The LabVIEW simulation program can provide simulations of all of digital transmission types listed. In addition, this program is the building block for an actual transmitter and receiver. Two new interface boards produced by National Instruments, the 5411 Arbitrary Waveform Generator<sup>5</sup> and the 5911 Digitizer<sup>6</sup> card, can be used to transmit and receive electrical signals over a standard channel. With additional up conversion and down conversion systems many high frequency communication systems can be emulated.

#### Bibliography

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Heath Keene recently received his BS EE degree and is currently pursuing a Master of Science degree in Electrical Engineering at Texas Tech University. Most of this work comes from his efforts in his senior project lab and during a coop with National Instruments, Inc. in Austin, Texas.

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