CAREER EPISODE 3

INTRODUCTION

CE 3.1 During my Bachelor of Engineering (Telecommunications) from the [redacted] of Engineering and Technology, I worked on " Communication Trainer" as my final year project in the last Semester. I started this project in [redacted] and completed it in [redacted]. In this project, I designed a communication trainer for engineering students covering digital, analog, wireless and optical communication systems. I aimed to enhance their practical understanding through modular sections like modulation, oscillation, amplification, communication channels and fiber optics. I will explain my work on this project in this episode, along with the results I achieved.

BACKGROUND

CE 3.2 For my final year project, I chose to design and develop a communication trainer aimed at helping engineering students understand main concepts in digital, analog, wireless and optical communication systems. I aimed to create a detailed and practical tool that could improve the understanding of various communication concepts among undergraduate students. To achieve this, I divided the trainer into multiple sections; modulation, oscillation, amplification, communication channels and optical fiber. I implemented FSK and PWM modulator-demodulator circuits in the modulation section. In the oscillation section, I designed and tested various oscillator circuits like Hartley, phase shift, Colpitts and Wien bridge oscillators. I also worked on class C and Class D amplifiers to show different amplification techniques. To simulate real-world communication scenarios, I added channel models like AWGN, Rician and Rayleigh fading. For the fiber optics section, I added components like transmitter and receiver, ADC/ DAC, an optocoupler and a Phase Locked Loop (PLL). I used cooper wire for modulation, oscillation and amplification processes, while for transmitter receiver communication I transmitted light via optical fiber. I also added few important equipment like function generator to produce carrier signals of varying frequencies, oscilloscope to display circuit outputs and a power supply unit for both variable and fixed AC/ DC requirements.

CE 3.3 I conducted literature review to strengthen my theoretical knowledge and guide my practical work. I started by studying the research on hybrid FSK/ PSK modulation systems which helped me understand how combining modulation techniques can improve signal performance, range and resistance to interference. I also reviewed work on PWM and visited the communication systems laboratories at UET, Taxila, where I studied and observed circuits like ASK, BPSK and FSK modulators, improving my knowledge of how digital data is modulated using amplitude, phase and frequency variations. I also visited the communication lab at FUUAST university, where I explored the practical implementation of FSK, BPSK, PWM and PAM modulators, which reinforced my learning of various analog and digital modulation techniques. I also studied several books like Analog and Digital Communication System by B.P Lathi and Fundamental and Applications by Bernard Sklar to understand FSK and PWM modulation in depth. I also referred to optical fiber communication by Palais to learn about optical transmitters, receivers and fiber characteristics and I used Principles of Electronics by V.K Mehta to understand the working of oscillators and amplifiers, including how to calculate their operating frequencies using theoretical formulas. This review helped me design and implement various sections of my communication trainer.

CE 3.4 To start my project, I first planned the scope and objectives, identified the main components that needed to be developed like modulation circuits, oscillators, amplifiers and the optical communication section. I then formed a team by choosing fellow students who had relevant skills and a strong interest in communication systems. I took the lead role and assigned tasks to them based on their strengths and knowledge for balanced workload distribution and timely progress. I had regular team meetings to track development and overcome issues. I also had meetings with my project supervisor to gain technical guidance and approval at every stage. I compiled and edited a final thesis to show my design, implementation and research. Toward the end, I created a presentation that communicated my goals, methodology and results. I presented this in front of the faculty members by confidently explaining my work and answering their questions which helped me show my understanding and the academic value of the project.

PROJECT REPORTING HIERARCHY

Figure 1: Hierarchy

PERSONAL ENGINEERING ACTIVITIES

CE 3.5 I set out to design and develop a comprehensive yet cost-effective communication trainer as part of my final year project, that I designed specifically to support undergraduate students learning in analog, digital, wireless and optical communication systems. My motivation stemmed from my own experience during practical classes throughout my Bachelor's, where limited apparatus and small-sized modules often forced professors to divide students into groups, that wasted valuable learning time. I wanted to overcome these issues by creating a single, integrated platform that allows students to perform a wide range of communication experiments independently and efficiently. Using my knowledge, I added components like FSK and PWM modulator-demodulators, Class C and D amplifiers, various oscillators and channel for real-world simulation. I also added fiber topic communication using light transmission and included optical elements like transmitters, receivers, ADC, DAC, optocoupler and PLL circuits. To make my trainer self-sufficient, I added built-in tools like an oscilloscope which I developed using Arduino to visualize circuit outputs, function generator, power supply, LCD, microphone and speaker. I used Arduino to convert analog signals into digital form and interfaced the system with MATLAB Simulink to display real-time signal behavior graphically.

<table>
<tr><td colspan="3">MODULATION SECTION</td><td colspan="2">OSCILLATION SECTION</td><td colspan="2">AMPLIFEIRS SECTION</td><td colspan="2">OPTICAL FIBER SECTION</td></tr>
<tr><td colspan="3">PWM MODULATOR</td><td colspan="2">HARTLEY OSCILLATOR</td><td colspan="2">CLASSC AMPLIFIER</td><td colspan="2">OPTICALTRANSMITTER</td></tr>
<tr><td colspan="3">PWM DEMODULATOR</td><td colspan="2">COLPIT'S OSCILLATOR</td><td colspan="2">CLASS D AMPLIFIER</td><td colspan="2">OPTICAL RECEIVER</td></tr>
<tr><td colspan="3">FSK MODULATOR</td><td colspan="2">WEIN BRIDGE OSCILLATOR</td><td colspan="2">CHANNELS</td><td>PHASE LOCKED LOOP</td><td>LEDS</td></tr>
<tr><td colspan="3">FSK DEMODULATOR</td><td colspan="2">PHASE SHIFT OSCILLATOR</td><td colspan="2">• AWGN
• RAYLEIGH
• RICIAN</td><td>ANALOG AND DIGITAL LINK</td><td>OPTOCOUPLER</td></tr>
<tr><td rowspan="2">AUDIO SIGNAL</td><td rowspan="2">CARRIER SIGNAL</td><td colspan="2">MIC</td><td>SPEAKER</td><td colspan="2">POWER SUPPLY</td><td rowspan="2">ANALOG TO DIGITAL CONVERTER</td><td rowspan="2">DIGITAL TO ANALOG CONVERTER</td></tr>
<tr><td colspan="2">OSCILLOSCOPE</td><td>ENVELOPE DETECTOR</td><td>FUNCTION GENERATOR</td><td>LCD</td></tr>
</table>

Figure 2: Block diagram

CE 3.6 I designed the block diagram to represent the flow and interaction among the components. I implemented PWM and FSK modulation and demodulation techniques using discrete components and ICs. For FSK modulation, I used the XR2206 waveform generator to convert square wave digital signals into 2 distinct frequencies based on logic levels. I calculated the frequencies using the values of resistors R1=1K, R5=10K and Capacitor C1=100n. To recover the FSK signal, I designed a demodulator using the LM565 PLL which included a VCO and a phase detector. I connected the components like resistors, capacitors and a μA741 comparator to adjust the loop filter and remove unwanted signals, converting frequency variations back to digital signals. I then implemented PWM and demodulation circuits to explore time-domain signal processing. For the PWM modulator, I used a μA741 op-amp as a comparator to modulate the width of output pulses based on the amplitude of the input sine wave compared to a sawtooth reference. I adjusted the pulse width using R2=10K, C2=0.1μ and a variable resistor RV1= 1M. On the receiver side, I used the MC1496 balanced modulator/ demodulator IC to demodulate the PWM signal by multiplying it with a carrier, followed by a low-pass filter to retrieve the original signal. I adjusted gain and filtering components like coupling capacitors, resistors and additional op-amps for signal integrity.

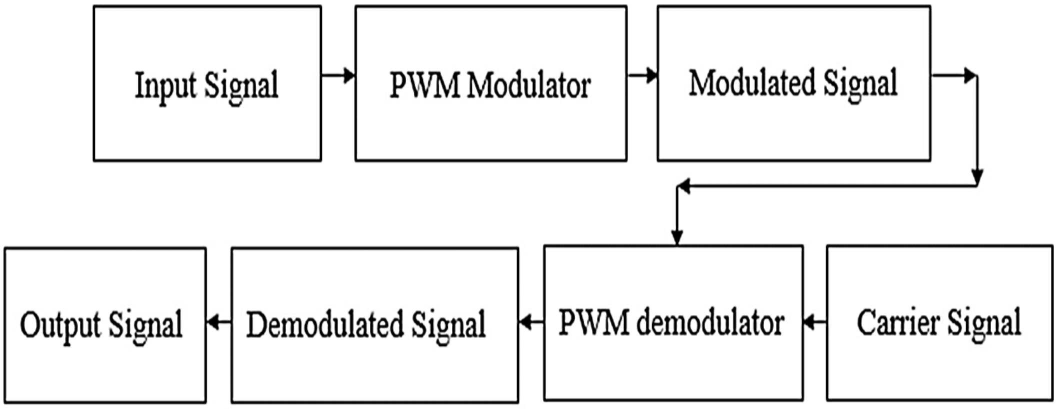

Figure 3: PWM block diagram

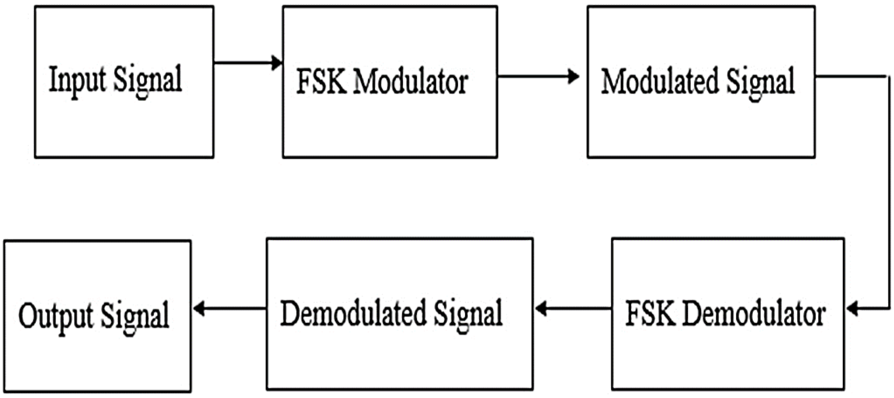

Figure 4: FSK Block diagram

CE 3.7 For oscillators, I started with the Colpitts oscillator, where I chose capacitors C1=1000p and C2=0.1μ, and inductor L1=27μ to form the LC tank circuit. I calculated these values for stable oscillation frequency. I checked thermal stability by properly biasing the resistors and applied emitter bypass capacitor and a biasing resistor for bypassing AC signals, improving the feedback loop for frequency consistency. I also designed a Hartley oscillator, which unlike the Colpitts used two inductors and 1 capacitor. I calculated the inductance using mutual inductance principles, and amplified the model for balanced inductors for smooth performance.

$$L = L1 + L2 + 2M$$

In the phase shift oscillator, I used BC107 transistor and created a 3-stage RC feedback network. This provided a 180° phase shift in addition to the 180° of the amplifiers, using total of 360° required for sustained oscillations. I then developed a Wein bridge oscillator using the 741 op-amp, including RC series parallel feedback networks. By adjusting the potentiometer, I adjusted the frequency of oscillator.

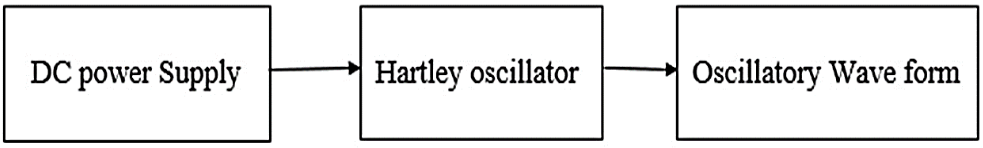

Figure 5: Hartley oscillator Block Diagram

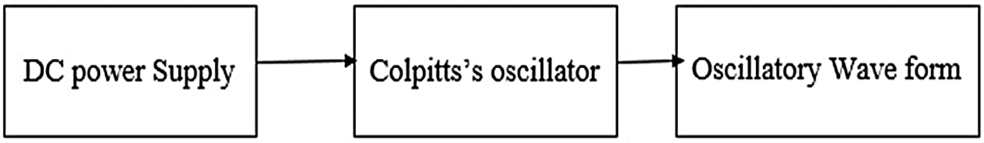

Figure 6:Colpitts's oscillator Block Diagram

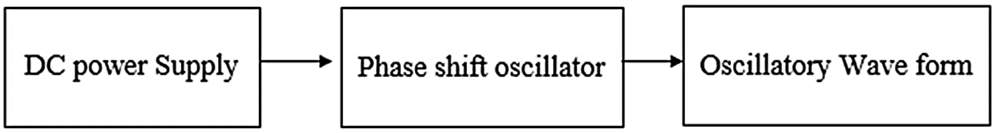

Figure 7: Phase shift oscillator Block diagram

Figure 8: Wien Bridge Oscillatorr Block Diagram

CE 3.8 For the amplification, I implemented a Class C amplifier with 2N3904 NPN transistor, improved to operate at 5MHz, ideal for narrowband RF amplification. I chose LC tank components based on resonant frequency calculations and applied coupling capacitors to allow AC while blocking DC components. To complement modern telecom needs, I also worked with Class D amplifier with BD5460 IC which I knew operates as a switching amplifier. This component, known for high efficiency of up to 95% and minimal power dissipation, was ideal for compact low-power telecom audio systems. I applied decoupling capacitors to control cut-off frequency and added switches for shutdown control, showing my understanding of power management in telecom equipment.

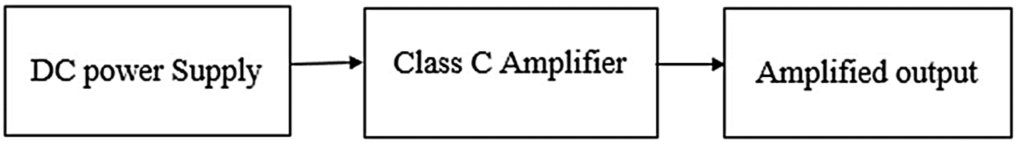

Figure 9: Class C Amplifier Block Diagram

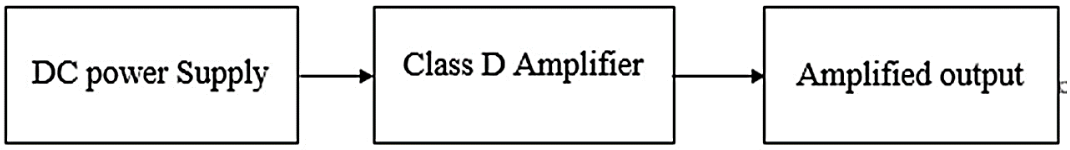

Figure 10: Class D amplifier block diagram

CE 3.9 I developed an optical communication system using a laser touch-based transmitter and receiver. I used a BC548 transistor with a µ741 op-amp to amplify audio from a microphone and modulate the laser using BD139. On the receiver side, I used phototransistor paired with an LM386 audio amplifier to recover the signal. I precisely aligned and avoided AC light interference, showing my practical knowledge of optical transmission. I also implemented a PLL and understood how the internal VCO and phase detector lock onto input signals. I isolated and transferred signals securely by using a 4N35 optocoupler. By switching an IR LED, I controlled the phototransistor, showing how light can safely carry signals across circuits. For signal conversion, I built a fast flash type ADC using 4 comparators, translating analog inputs into digital outputs. I also designed a DAC using an inverting op-amp and binary switches to convert digital signals back into analog.

CE 3.10 I moved on to the simulation using Proteus software. For the modulation section, I simulated the PWM modulator where I fed an input signal to the modulator circuit and the modulated output was then transmitted to the demodulator. By injecting the carrier signals at the demodulator input, I retrieved the original signal at the output, thereby validating the modulation-demodulation process. I performed similar tasks for FSK modulation and developed the FSK modulator and connected its output to an FSK demodulator, checking that the demodulated output matched the original signal. Coming to the oscillation section for each oscillator type, I provided a regulated 12V DC power supply and checked the generation of stable oscillations at the output. I analyzed the behavior of each circuit during simulation and checked if the output met the desired frequency and waveform requirements. These oscillators I knew were important to generate carrier signals used in modulation. In the amplification section, I applied DC power to each amplifier circuit and noticed the signal amplification behavior. Using Op-amps and switching techniques, I checked that both amplifiers delivered high efficiency with minimal distortion. I simulated the circuits and reviewed the amplified outputs checking that the signals were enhanced as expected.

CE 3.11 I simulated channel models using MATLAB Simulink, each of these models played an important role in testing and analyzing the performance of modulated signals under various noise conditions, allowing me to explore several aspects of signal transmission. For the AWGN channel, I worked with real-time audio input which I first sampled before passing it through the AWGN channel after modulation. I then demodulated the signal to retrieve the output. In the simulation, I included the AWGN channel's noise characteristics, checking that the system mimicked real-world communication conditions where random noise can corrupt the signal. I analyzed the performance of the modulation and demodulation processes, checking the ability of the system to recover the transmitted signal despite the noise interference. Moving on to the Rician channel, I repeated the process with real-time audio input, which I sampled and modulated before passing it through the Rician channel. This channel with its LoS path components and multipath fading introduced a more complex environment than AWGN. The signal was then demodulated to extract the output. In the simulation, I modeled the Rican fading and ensured that the system could still recover the transmitted signals. I applied the filtering and signal processing techniques to consider the distinct characteristics of the Rician channels that helped me check the system under these fading conditions.

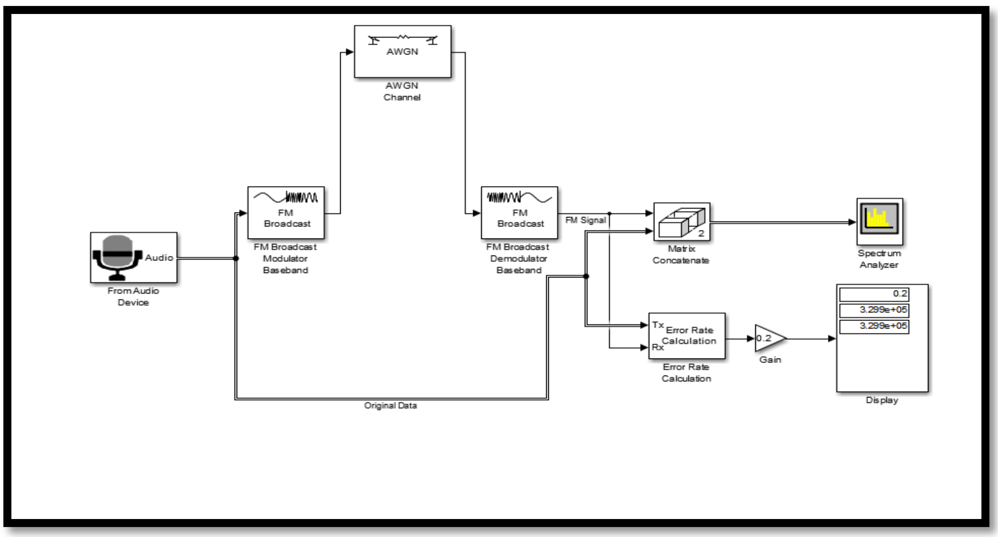

Figure 11: AWGN Simulation

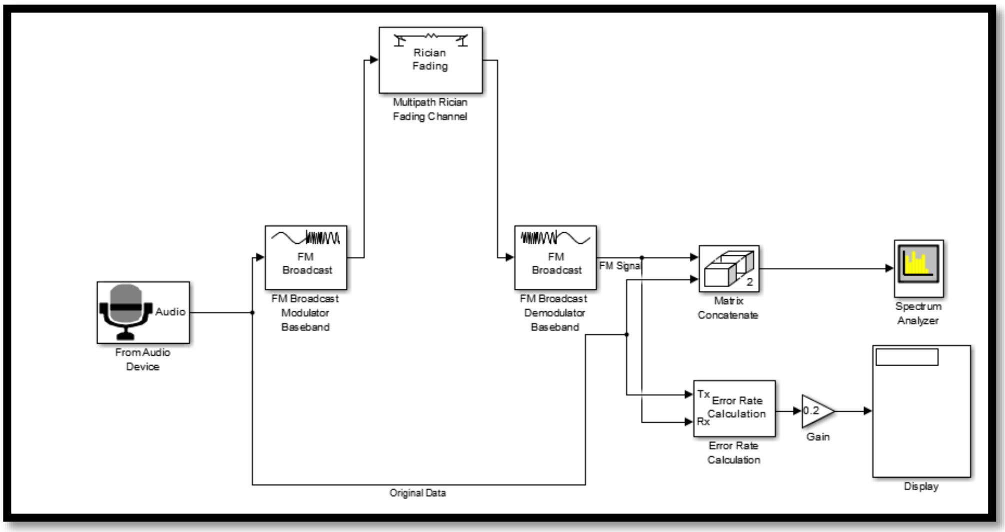

Figure 12: Rician Channel simulation

CE 3.12 Similarly, for Rayleigh channel, I worked with a real-time audio input, sampled and modulated the signals and passed them through the Rayleigh fading channel. I implemented the Rayleigh channel in the simulation and analyzed how the system responded to deep fades and optimized both the modulation and demodulation schemes for signal recovery. I then simulated the optical fiber section, where I converted the electrical-signals into optical for transmission through fiber and then again to the electrical-signals at the receiver. Through simulation, I analyzed key factors like attenuation and dispersion to minimize signal degradation over distance. I also developed a PLL system to show frequency synchronization, where I used a phase detector, low-pass filter and a VCO to match the output frequency with the input frequencies.

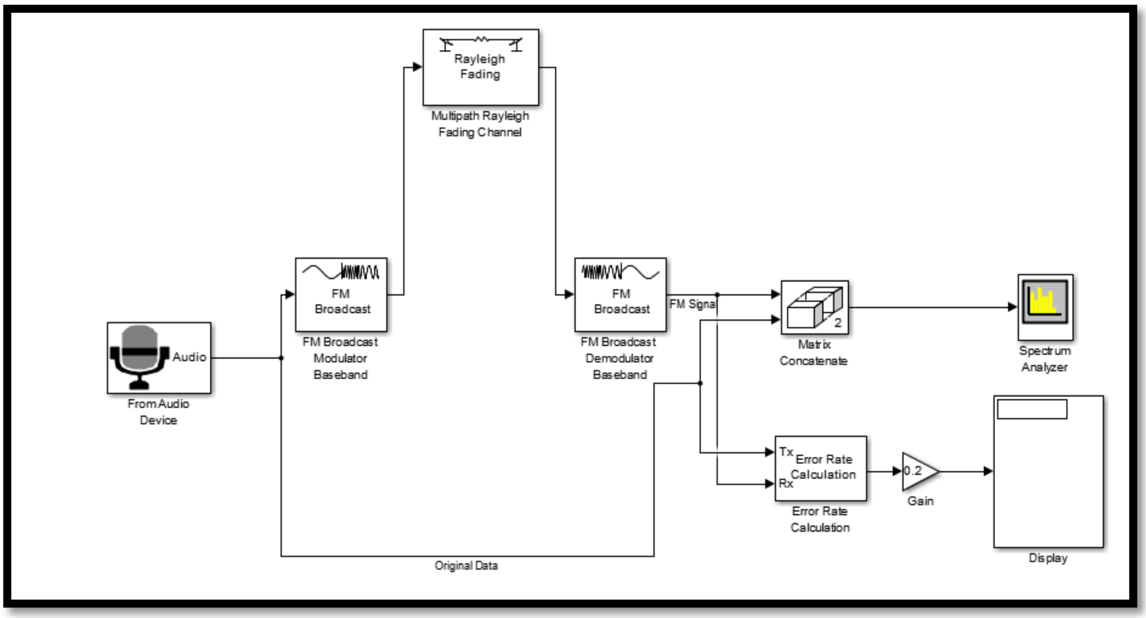

Figure 13: Rayleigh Channel Simulation

CE 3.13 I conducted several experiments to analyze the hardware circuits. In experiment 1, I connected the digital signal to the modulator and applied the required 9V DC power. Using an oscilloscope, I observed and recorded the FSK output waveform, which helped me assess the ability of my system to convert analog signals into digital ones efficiently. In experiment 2, I worked on the optical fiber transmitter and receiver system. I transmitted an audio signal through optical fiber cables and connected the transmitter and receiver circuits, applied the necessary voltages and used the oscilloscope to monitor and compare the output signals at both ends. It helped me understand the principles of optical communication and fiber optic signal transmission.

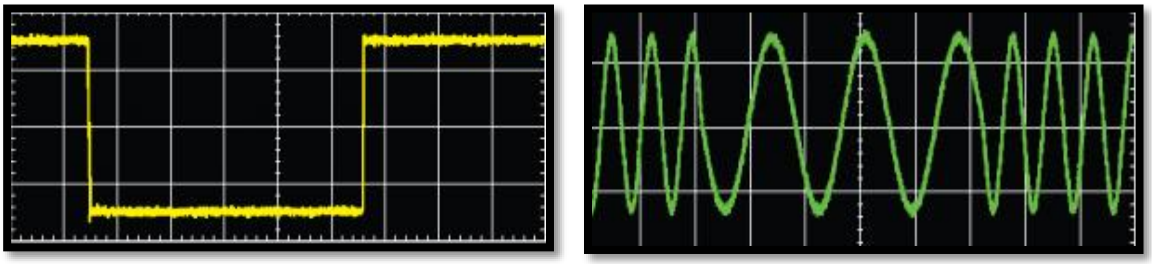

Figure 14: input signal: FSK Output Waveform

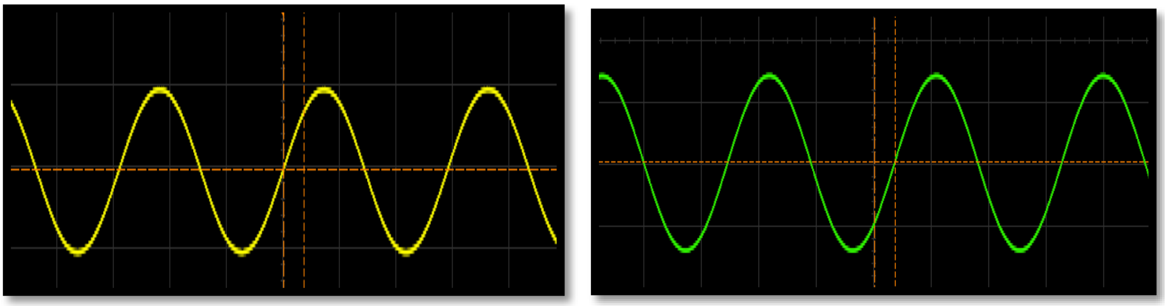

Figure 15: Transmitter and Receiver Output

CE 3.14 In the next experiment, I used oscillators to test signal behaviors in different conditions. In terms of signal channel performance, I analyzed the effects of AWGN, Rician and Rayleigh fading channels to evaluate their impact on signal recovery. These outcomes from the experiments helped me improve my understanding of Telecom systems, particularly in areas of signal modulation, noise handling and transmission methods. I also examined optical fiber communication by implementing a photo transmitter and receiver system and PLL for frequency synchronization. By using these components, I showed a solid grasp of telecom fundamentals. My ability to choose and implement these telecom components showed my proficiency in the field, as well as my capability to design and analyze complex communication systems for various applications.

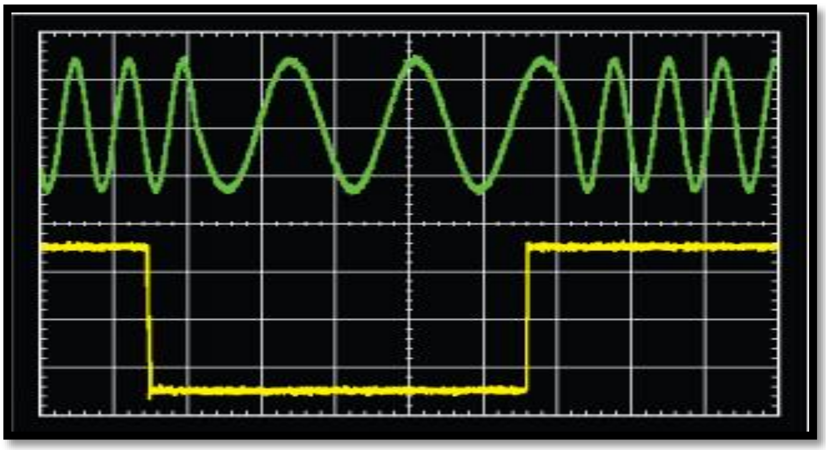

Figure 16: FSK modulator Output

Figure 17: FSK Demodulator output

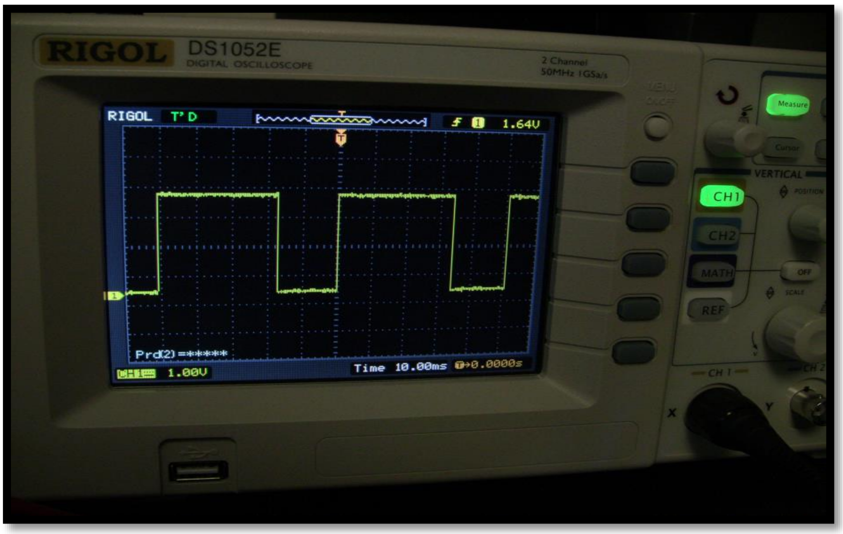

Figure 18: PWM Modulator output

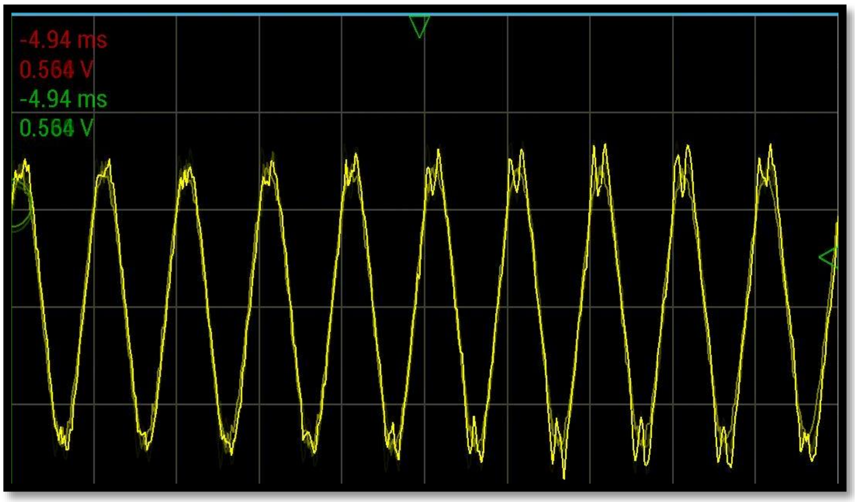

Figure 19: PWM Demodulator Output

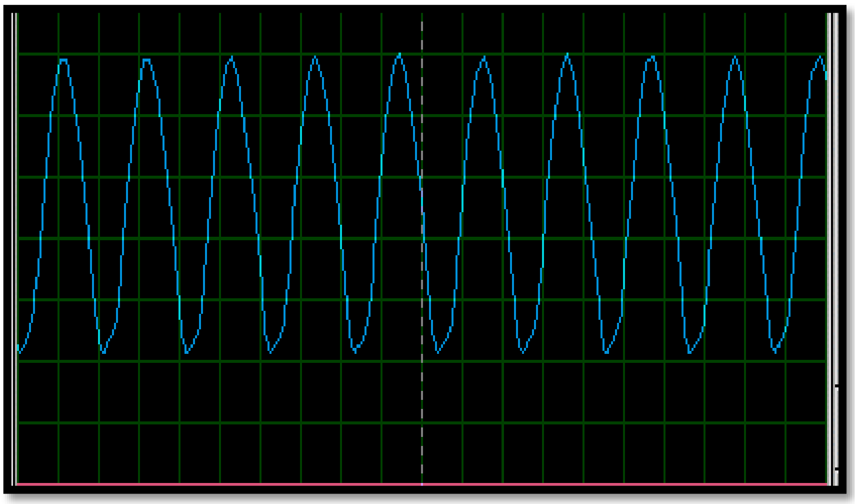

Figure 20: Colpitts Oscillator output

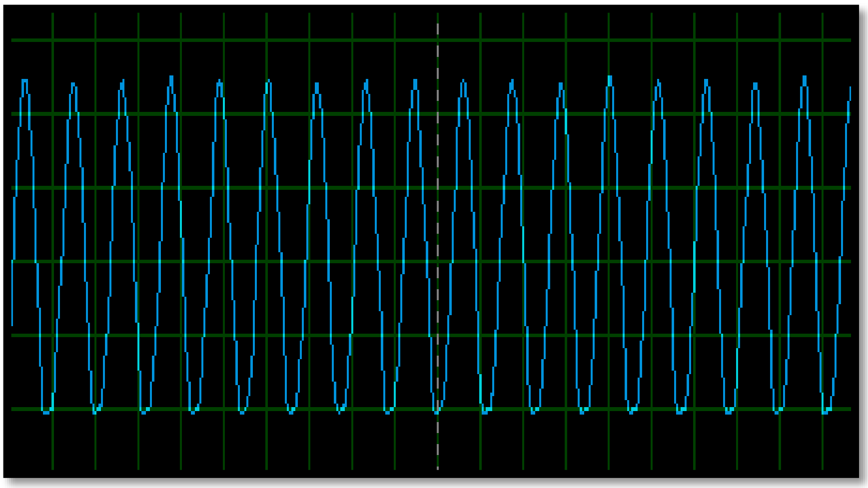

Figure 21: Hartley output

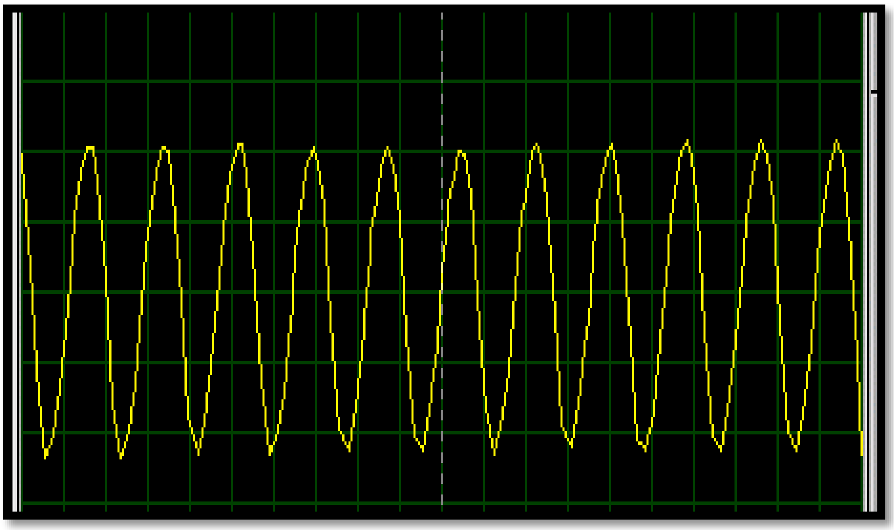

Figure 22: Phase-shift output

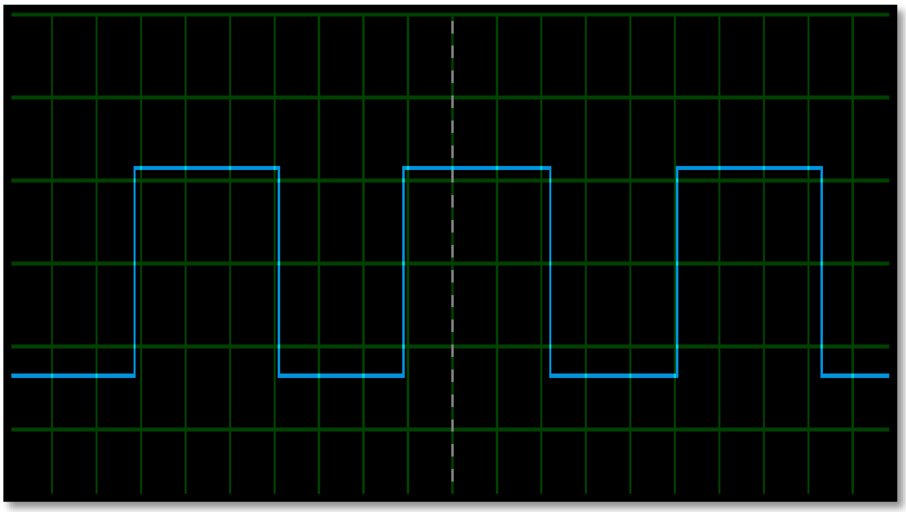

Figure 23: Wien-bridge output

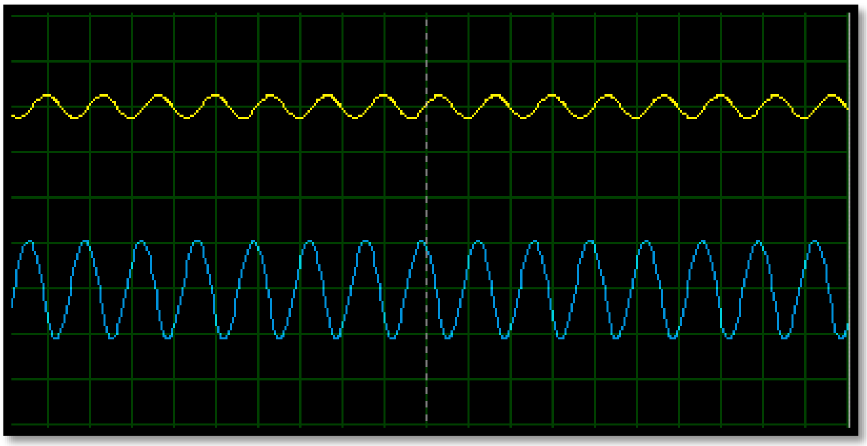

Figure 24: Class C Amplifier output

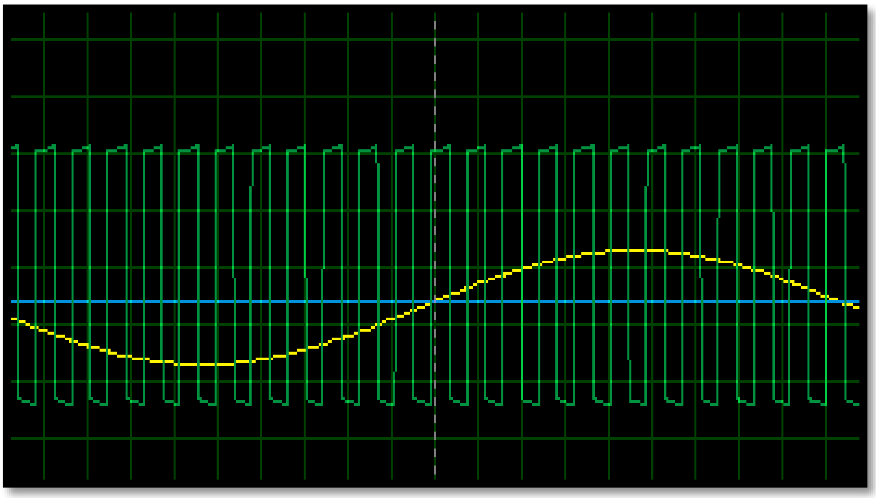

Figure 25: Class D amplifier Output

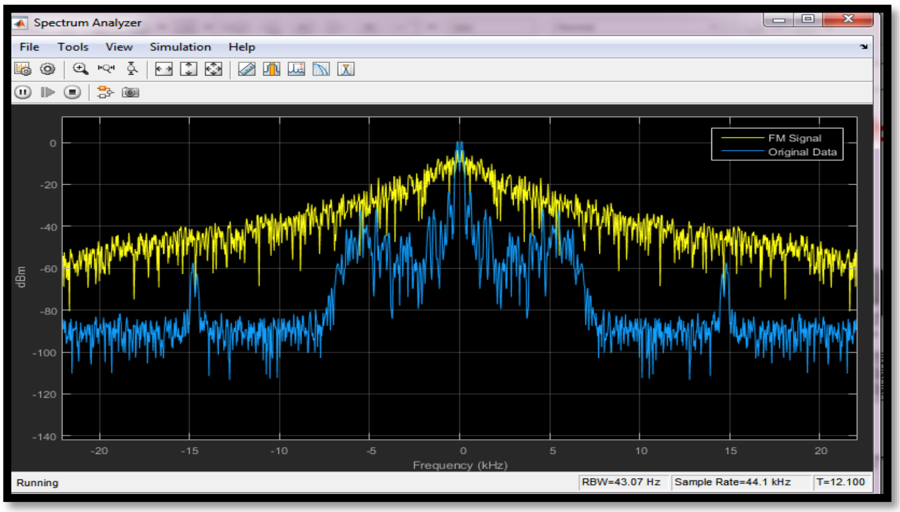

Figure 26: AWGN Output

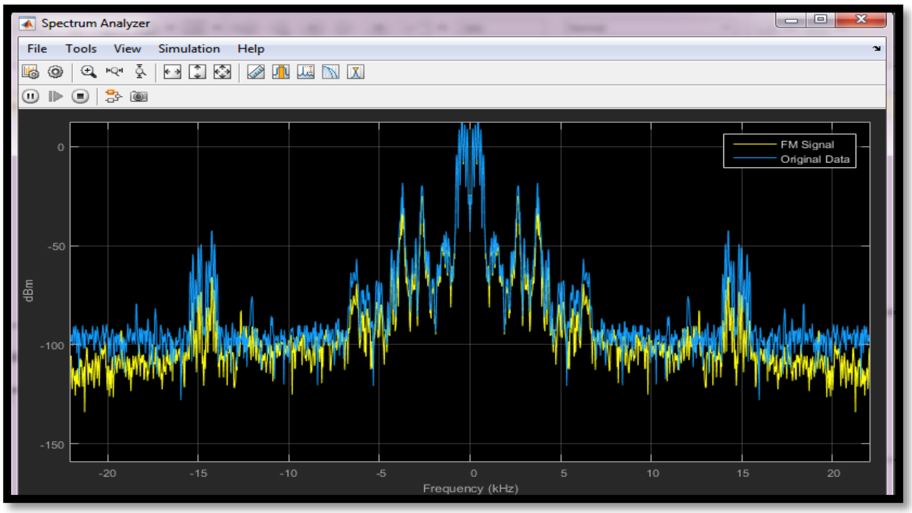

Figure 27: Rician output

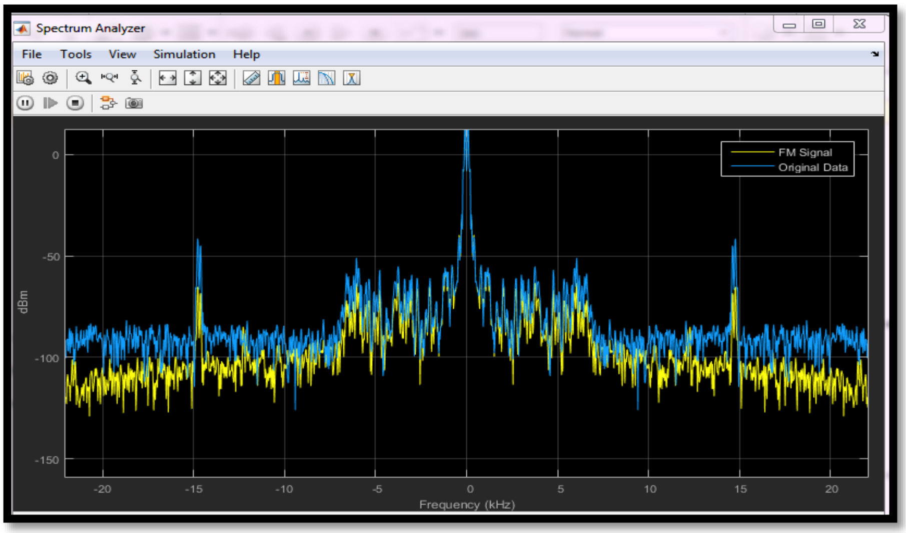

Figure 28: Rayleigh output

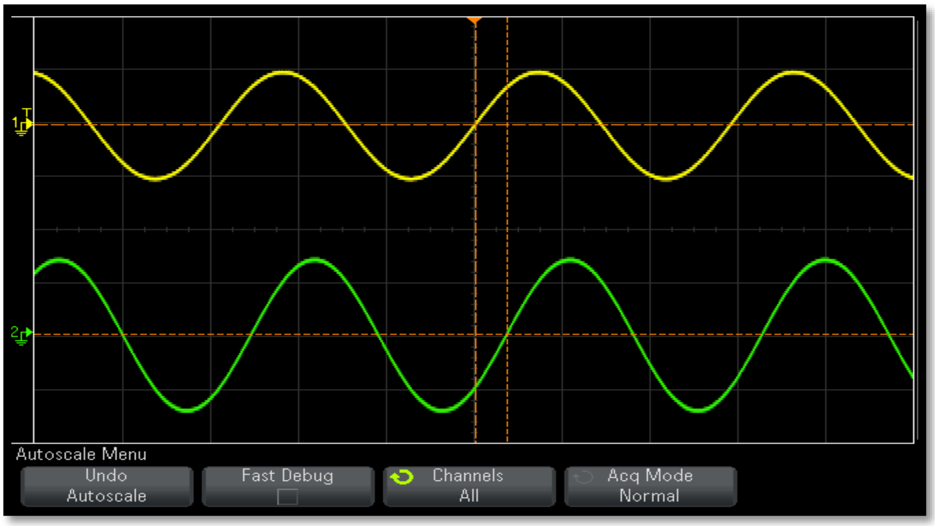

Figure 29: Transmitter and receiver output

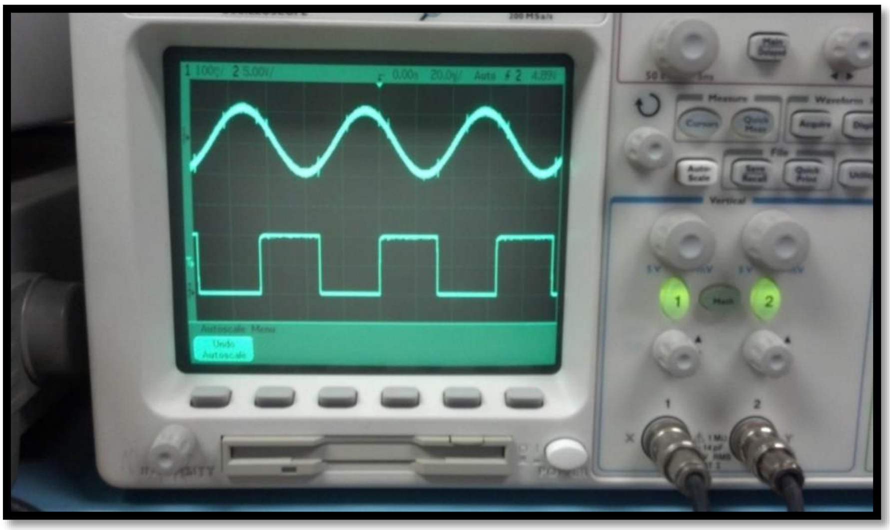

Figure 30: PLL Output

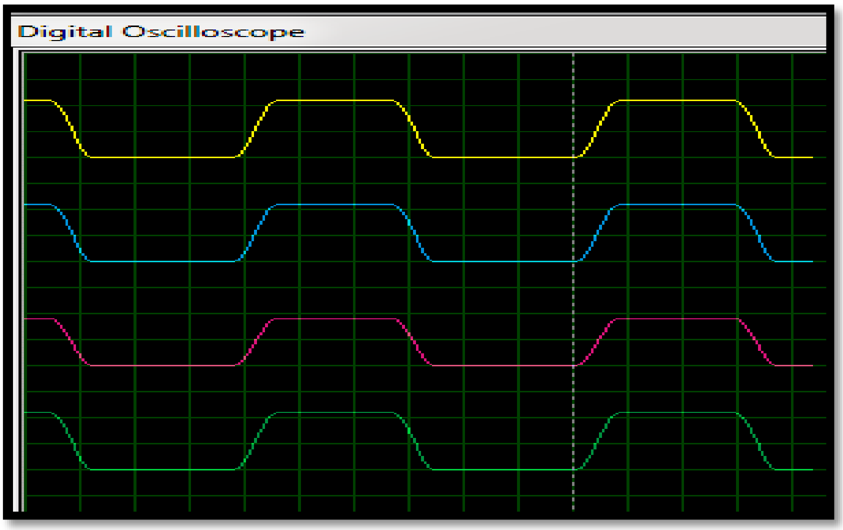

Figure 31: ADC output

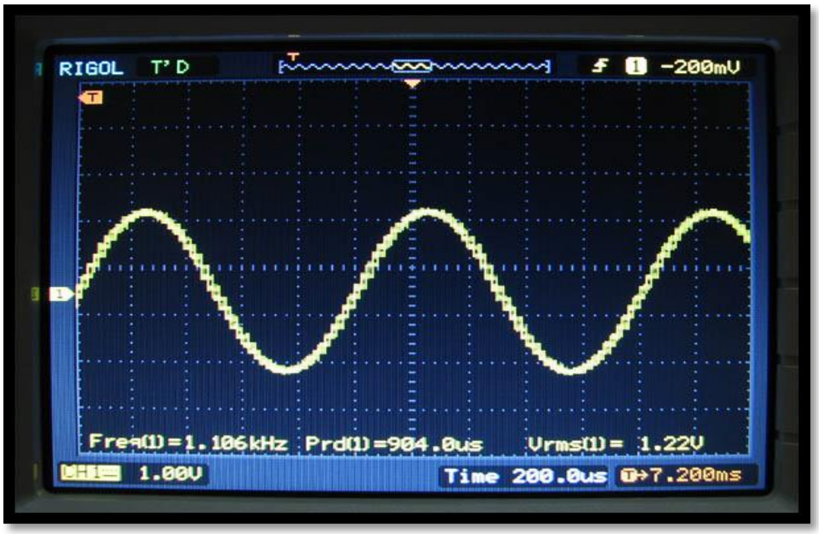

Figure 32: DAC Output

SUMMARY

CE 3.15 For my final year project, I designed, implemented and tested various communication systems and components. I started by developing FSK and PWM modulators and demodulators and then implemented optical fiber transmission using audio signals checking successful data transfer between the transmitter and receiver. I designed and analyzed various oscillators to study waveform generation. I also evaluated class C and D amplifiers for signal amplification. I further designed a PLL system for frequency synchronization. I conducted experiments using real hardware setups and recorded waveforms for analysis. Throughout this project, I used MATLAB Simulink and Proteus for simulations, which helped me model, check and improve each part of the trainer, showing my understanding of telecom principles and practical implementation. Throughout this project, I accurately presented results, avoided data manipulation, properly referenced sources and maintained academic integrity.