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GUI Based Advanced Modulation Techniques Using Python

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***Abstract*—Modulation is a process of modifying a signal to transmit information over a communication channel. It is an essential part of modern communication systems, and it plays a crucial role in wireless, satellite, and optical communications. Modulation techniques can be broadly classified into two categories: analog modulation and digital modulation. In this strategy, we aim to explore different modulation techniques using the Python programming language. Python is a popular language for scientific computing and signal processing, and it provides a rich set of libraries for numerical analysis and data visualization. The main objective of this strategy is to simulate and analyze various Advanced modulation techniques using Python**

Keywords— Message Signal, Carrier Signal, Modulation, Demodulation, Tkinter, Mathplotlib, Scipy, root window, widget.

I. INTRODUCTION

Modulation is the process of varying the characteristics of Carrier signal in accordance with the characteristics of Message signal. [1-3] [5] Characteristics of the signal are Amplitude, Frequency and Phase. Message signal is a periodic waveform that contains the typical information to be transmitted. Whereas Carrier is also a periodic waveform with high Frequency. Modulation techniques are broadly classified into two types:

A) Analog Modulation Techniques and

B) Digital Modulation Techniques. [1-5]

This strategy proposes a Python GUI simulator to study Digital Modulation Techniques. Digital Modulaion Techniques are further classified: ASK- Amplitude Shift Keying, FSK- Frequency Shift Keying, and PSK- Phase Shift Keying.

For Amplitude Shift Keying, the amplitude of Carrier wave is shifted between two levels (i.e., binary 1 or 0) in accordance with binary input data. [1] [3] [4] [5] In ASK, both frequency and phase of the carrier remains constant while amplitude changes.

To understand this, let us consider a rectangular signal or one-sided square signal as a message signal that needs to be transmitted.

Therefore, the mathematical expression of the message signal would be:

sig= 1; t>0
0; t<=0 …. [1] [3] Eq1

The Carrier is a high frequency radio wave with amplitude Ac and frequency Fc, which is represented by:

$c(t)= Ac.\cos(2\mu f_c t)$ …. Eq2 [1] [3] [9]

Therefore, the equation for modulation of ASK signal is:

ASK_sig = sig*c(t) …. Eq3 [3] [9]

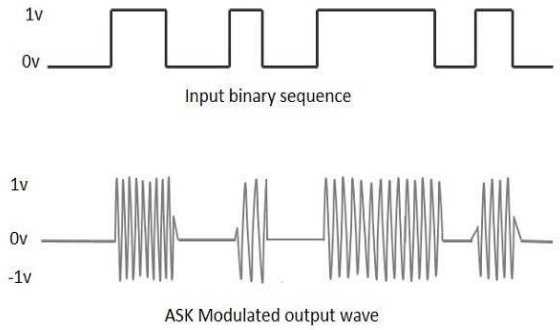

Fig 1 Input and Output waveforms

Similarly in Frequency Shift Keying, the frequency of the Carrier wave is shifted between two levels (i.e., binary 0 or 1) in accordance with the binary input data. [1] [3] [5] In FSK, both amplitude and phase of the carrier is constant.

FSK signal can be expressed mathematically as,

Fsk_sig = $\sin(2*\pi*f_l*t)$ [3] …. Eq4

Where, f_l = Fc + Fc*sig/2

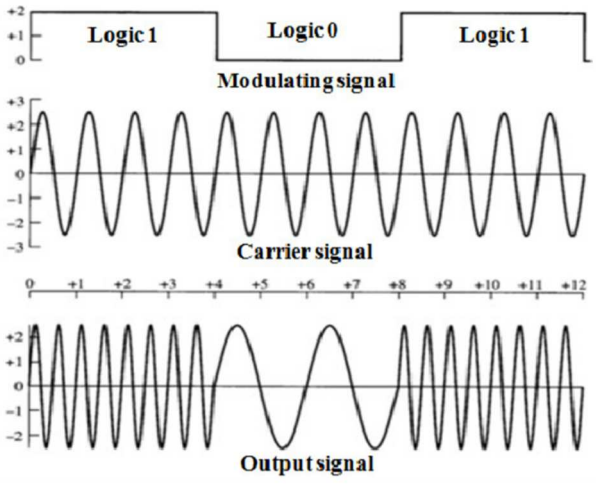

Fig2 Input and Output Waveforms of FSK

In PSK, the phase of carrier is shifted between two levels in accordance with the incoming digital data. [1] [3] [5] In PSK, the phase is varied while amplitude and frequency are remained constant.

Figures 1,2 and 3 shows Input and output Waveforms of ASK, FSK and PSK respectively.

In PSK, the carrier without phase shift is represent binary '1' and carrier phase shifted by 180° is represent by binary '0'. PSK can be mathematically expressed by,

Psk_sig = sin (2*π*Fc*t + phase) [3]

Where, phase= $\pi + \pi$*sig/2 …. Eq4

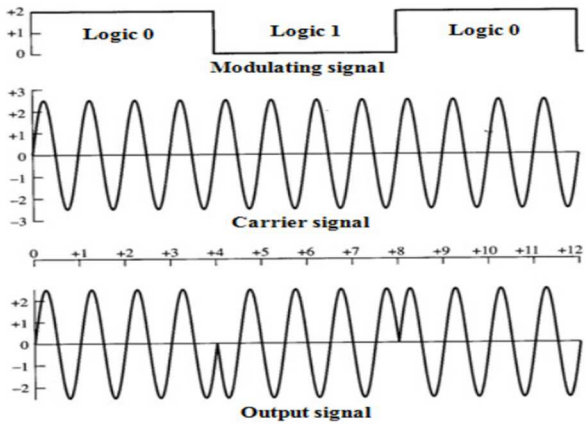

Fig 3 Input and Output Waveforms of PSK

II. RELATED WORKS

A. Digital Modulations Using Python

Mathuranathan Viswanathan [2] describes about the simulation of Digital Modulation Techniques using Python. Python is a free, open source, high-level general-purpose language that comes with a rich repertoire of robust standard libraries. As a free open-source language, python helps us to reduce the development costs significantly. The code written in python is easily readable by humans and is compatible with major platforms and operating systems. Python distributions are also available for Arduino microcontroller and Raspberry Pi, minicomputer. Python comes with a range of packages like SciPy and NumPy, that support complex numerical and scientific computing. Above all, python is supported by a very strong world-wide developer community that are instrumental in providing thousands of packages for free, which enable us to accomplish complex development tasks.

Python has maintained the top spot, since 2017, in the IEEE Spectrum's annual interactive ranking of the top programming languages.

B. Python GUI Programming with Tkinter

Alan D. Moore [4] describes the implementation of Graphical User Interface using Python Programming Language. Python offers multiple options for developing GUI (Graphical User Interface). Out of all the GUI methods, tkinter is the most commonly used method. It is a standard Python interface to the Tk GUI toolkit shipped with Python. Python with tkinter is the fastest and easiest way to create the GUI applications. Creating a GUI using tkinter is an easy task.

To create a tkinter app:

- Importing the module – tkinter
- Create the main window (container)
- Add any number of widgets to the main window
- Apply the event Trigger on the widgets.

Importing tkinter is same as importing any other module in the Python code.

Tkinter is often chosen for developing small to medium-sized desktop applications and tools, it has its limitations, particularly in terms of modern aesthetics and advanced features. For larger and more complex projects, developers may opt for other GUI libraries like PyQt, wxPython, which provide more advanced capabilities and a wider range of visual elements.

However, Tkinter's simplicity and integration with Python continue to make it a preferred choice for educational purposes and rapid prototyping. Additionally, Tkinter's ability to create lightweight and platform-independent applications remains a valuable asset in specific scenarios.

Tkinter is an invaluable tool for GUI programming in Python, offering a straightforward approach to creating user-friendly applications. Its cross-platform compatibility, event-driven model, and integration with Python make it an ideal choice for both beginners and experienced developers, enabling them to bring their software ideas to life with ease and efficiency. As the Python ecosystem continues to evolve, Tkinter will remain a fundamental component in the world of GUI programming, preserving its status as a reliable and approachable solution for building graphical interfaces.

C. A Python Based GUI For AM Modulation

Akhtar Nadaf implements Amplitude Modulation Scheme using Python's GUI interface. Created a window by importing the required libraries. Tkinter, numpy and matplot are the required libraries.

Tkinter is a standard GUI library for Python. Python & Tkinter is fast and easy way to create GUI applications. Tkinter is a useful tool for creating a wide variety of graphical user interfaces, including windows, dialog boxes, and custom widgets. It is particularly well-suited for building desktop applications and adding a GUI to command-line programs.

NumPy is a general-purpose array-processing package. It provides a high-performance multidimensional array object and tools for working with these arrays. It is the fundamental package for scientific computing with Python. It is open-source software.

Matplotlib is a plotting library for the Python programming language and its numerical mathematics extension NumPy. It provides an object-oriented API for embedding plots into applications using general-purpose GUI toolkits like Tkinter, wxPython, Qt, or GTK.

III. METHODS/SOFTWARE

As this paper developed with Python, latest version of Python i.e., 3.11 or 3.10, Matplotlib, and NumPy to installed. First install Visual Studio Code. Then install Tkinter, Matplotlib, and NumPy. Next, import these libraries in code and prepare the code for simulation.

Visual Studio Code creates an interactive computing environment irrespective of operation system. Create a new empty file with .py extension and rename it with Advance Modulation Techniques.

Python is used here instead of Matlab for simulating Modulation techniques ,even though the later is traditionally used for this purpose. Python has revolutionized scientific computing and data visualization with its libraries making it an valuable tool for simulating modulation techniques.

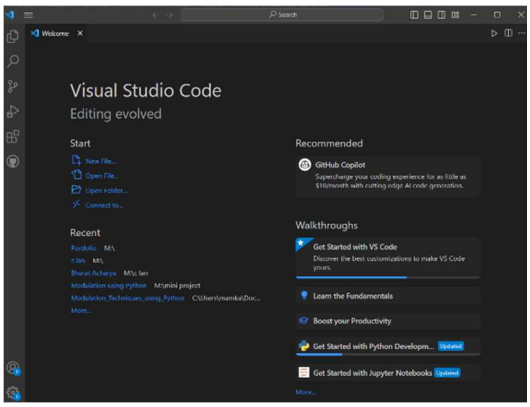

Fig 4 Visual Studio Code Interface

This paper uses functions from Tkinter, Matplotlib, scipy, numpy libraries. Start with import these libraries. Install these libraries before importing. Use pip install to install these libraries. Example: pip install matplot, to install matplot library.

First import various Python library packages in the code, for smooth operations of functions.

```
from tkinter import *
from matplotlib.figure import Figure
from matplotlib.backends.backend_tkagg import (FigureCanvasTkAgg, NavigationToolbar2Tk)
from tkinter import ttk
import numpy as np
import matplotlib.pyplot as plt
from math import pi
from scipy.fftpack import fft
from scipy import signal
```

Fig 5 Importing libraries

Fig 5, shows how to import Python packages required for this project.

Then, create a root window using Tk() function and add other components to the root window. We can also provide title to our root window. Follow the below steps shown in below snippet.

```
root = Tk()
root.title('Advance Modulation Techniques')
fig1 = Figure(figsize=(2,2) , dpi=100)


root.mainloop()
```

Fig 6 Creating Root Window

Fig 6, creating of window using tkinter library

Next, create interface between Figure and Tkinter Canvas and create the widgets, group them using frame function. For creation of interface use FigureCanvasTkAgg class. A window of size 600*100 is created by using command Tk()title is assigned as shown in Fig 6.

For user defined values of Amplitude and Frequency in generation of Carrier signal use entry widget from Tkinter package. However digital signal is generated automatically using the equation mentioned in the code.

III. RESULTS AND DISCUSSION

A. Implementation

The below fig 7 Explains about flow chat. Firstly, One-sided square wave is generated by clicking on plot button inside the widget. Then the user needs to enter the Amplitude and Frequency values in the entry widget for generation of carrier signal which is used for modulation process.

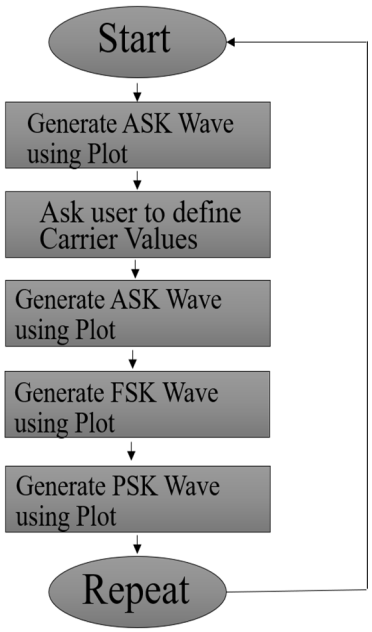

Fig 7 Flowchart

Using plot button in ASK, FSK, and PSK generator widgets ASK, FSK, and PSK waveforms are plotted. To clear the whole interface and to regenerate the waves use clear button.

Fig 8 GUI interface for Advance Modulation Techniques.

Fig 8, is our generated window. Signal generating frames consists of plot button which is used to plot the generated signals.

To save the generated results use save button form navigation tool bar below. Toolbar also helps to perform other actions with the generated results.

Fig 9 Output waveform 1

Fig 9, shows output waveforms of ASK, FSK, PSK modulations techniques for the input sequence 0001000111.

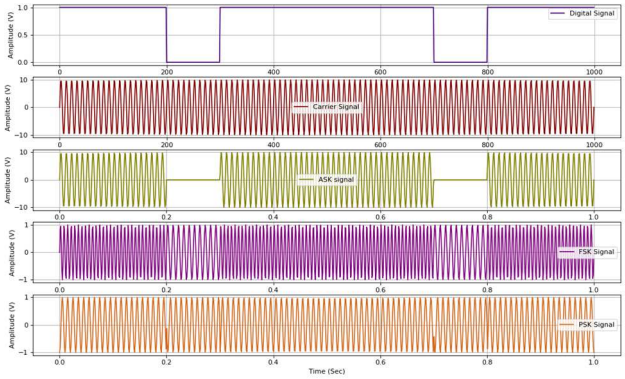

Fig 10 Output waveform 2

Fig 10, shows output waveforms of ASK, FSK, PSK modulations techniques for the input sequence 1101111011.

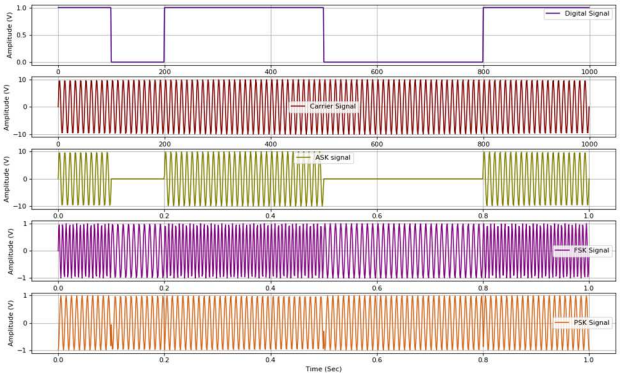

Fig 11 Output waveform 3

Fig 11, shows output waveforms of ASK, FSK, PSK modulations techniques for the input sequence 1011100011.

Difference between ASK, FSK, and PSK is clearly observed from the above results. In ASK, carrier is transmitted only when the input signal is high i.e., binary 1.

In FSK when the input sequence is high a high carrier is transmitted and when the input sequence is low frequency carrier is transmitted. It overcomes the major drawback of ASK i.e., ASK modulation is very susceptible to noise interface.

In PSK, there is phase shift in the PSK output whenever the input sequence changes from 1 to 0 and vise-versa. Compared to ASK, PSK is less susceptible to noise and compared to FSK, PSK requires less bandwidth.

IV. CONCLUSION

In this paper, we embarked on a comprehensive exploration of modulation techniques using Python, with a primary focus on understanding, implementing, and analyzing various modulation schemes. The main objectives of the paper were to gain insights into the fundamentals of modulation, develop practical coding skills in Python, and assess the performance of different modulation techniques. We can now confidently draw conclusions based on our findings as Fundamental Understanding, Python Proficiency, Performance Evaluation, and Future Exploration.

In summary, the paper on modulation techniques using Python has been a rewarding journey. We have achieved a deeper understanding of modulation, enhanced our programming skills, and contributed valuable insights into the performance of different modulation schemes. This paper has equipped us with the knowledge and tools to excel in the field of communication engineering and paves the way for future research and innovation.

V. FUTURE SCOPE

Process of Modulation, a fundamental aspect of modern communication systems, enabling the transmission of information over various communication channels. These techniques have evolved significantly over the years, and their future holds great promise and potential. The future of modulation techniques is tightly intertwined with emerging technologies, and several key areas promise to shape its development mainly, Terahertz Communication, Quantum Communication, 5G and beyond.

The future of digital modulation techniques is exciting and promising, with the potential to revolutionize communication in various ways. From quantum communication to 5G technology and beyond, these advancements will continue to shape our interconnected world, providing faster, more secure, and energy-efficient communication solutions. As we move forward, addressing challenges and embracing opportunities in this field will be crucial to realizing the full potential of digital modulation techniques in the years to come.

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