Lab 7：Digital Carrier Wave Transmission

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Introduction:

1. Basic principles of Digital Carrier Wave Transmission

Basic principles:

- **I/Q signal representation:** In digital carrier wave transmission, the I/Q signal representation is a method of representing a modulated signal that includes both amplitude and phase information. The I/Q signal representation splits a modulated signal into two separate components: the in-phase (I) component and quadrature-phase (Q) component. The I component represents the amplitude of the signal, while the Q component represents the phase shift of the signal.
  The I and Q components are typically modulated by using a carrier signal with a known frequency. By combining the modulated I and Q components, the original signal can be reconstructed. This technique is widely used in applications such as digital communication systems, software-defined radio (SDR), and wireless communication systems.
- **Data Encapsulation:** Data encapsulation is a concept in computer networking and object-oriented programming, where data and its associated functions are packaged together as a single unit or object. This has many advantages, including data integrity, information hiding, and modular programming.
- **Symbol Mapping Table**: Symbol mapping table is a lookup table used in digital communication systems to map binary data symbols to corresponding signal waveforms. In a digital communication system, data is typically encoded into binary symbols, which are then mapped to a corresponding set of analog waveforms for transmission. The symbol mapping table provides the mapping between the binary symbols and their corresponding waveforms, which are then transmitted over the communication channel. The mapping table is typically designed based on the modulation scheme used in the system, such as amplitude-shift keying (ASK), phase-shift keying (PSK), or quadrature amplitude modulation (QAM). The symbol mapping table is an important component of the modulation process, as it determines the mapping between the digital information and the analog waveforms used for transmission.
- **PSK Modulator:** Phase-shift keying (PSK) is a digital modulation scheme used in digital communication systems to represent digital data by modulating the phase of the carrier signal. A PSK modulator is the device that modulates the phase of the carrier signal. To modulate a signal using PSK, a sequence of digital bits is mapped into a sequence of phase changes of the carrier signal. The phase change can have different values, depending on the value of the digital bit being transmitted. For example, a binary PSK (BPSK) modulation scheme has two possible phase changes, 0 and 180 degrees, representing the binary values 0 and 1, respectively. A more complex scheme like

quadrature PSK (QPSK) has four different phase changes, allowing it to transmit two bits of information at once. The PSK modulator applies the phase changes to the carrier signal as required, resulting in a modulated signal that contains the digital data being transmitted.

- **PSK Demodulator:** A PSK demodulator is a device or algorithm that extracts the digital information from a PSK-modulated carrier signal. It essentially reverses the process performed by the PSK modulator at the transmitter end. The demodulator analyzes the received signal and determines the phase of the carrier wave at specific points in time. It then uses this information to extract the digital information that was encoded in the phase shifts of the carrier wave. There are several different demodulation techniques that can be used for PSK, including coherent detection and differential detection. Each technique has its advantages and disadvantages and is chosen based on the requirements of the specific communication system.
- **Constellation Diagram:** A constellation diagram is a diagram used in digital communication, specifically in the field of digital modulation, to represent a signal waveform in a two-dimensional plane. It is basically a graph that plots the signal's in-phase component on the x-axis and the quadrature component on the y-axis. It is used to visualize and analyze the characteristics of a digital modulated signal, such as the phase and amplitude levels, as well as the levels of noise and distortion. By analyzing the constellation diagram, engineers can determine the signal's quality and the effectiveness of the modulation scheme. The constellation diagram is a critical tool in the modern communication system for designing and optimizing digital modulation schemes and for troubleshooting signal impairment.

2.LabVIEW Express Module:

- **UpSample module:**

  In LabVIEW, the UpSample module is used to insert zeros between samples of an input signal to increase the signal's sample rate. This is also known as an upsampling operation. When a signal is upsampled, new samples are generated by adding zeros to the original signal's sample stream. The UpSample module uses an interpolation filter to filter out the images that would be generated due to the upsampling process.

  The UpSample module takes an input signal along with an integer value which specifies the upsample factor. The module then inserts zeros between every original sample and applies an interpolation filter to the resulting signal. The output signal will have a higher sample rate and increased resolution.
- **Sinc Pattern Module:**

  In LabVIEW, the Sinc Pattern module is a function that generates a signal with a Sinc shape--that is, a waveform that is a sinusoidal function divided by the independent variable. The Sinc Pattern module is typically used for filtering and resampling operations.

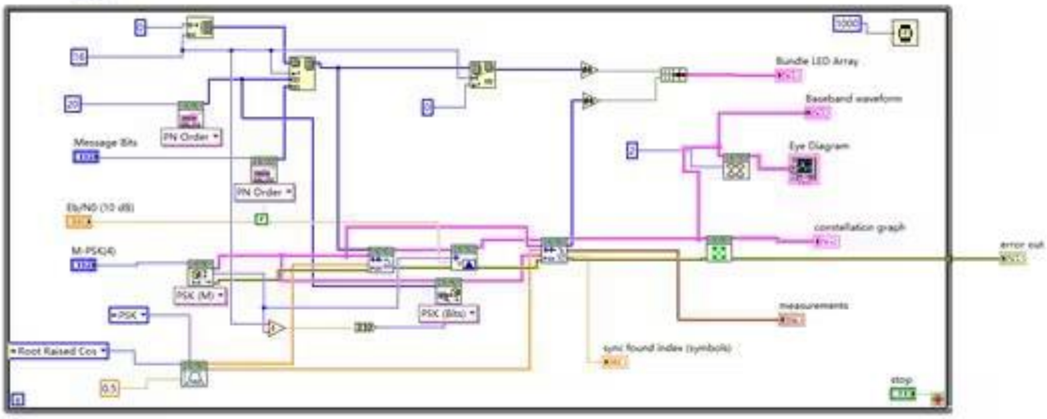
  The Sinc Pattern module takes as input parameters the desired length of the output signal, the sample rate of the input signal, and the cutoff frequency of the filter. Typically, the cutoff frequency is specified as a fraction of the Nyquist frequency - highest that can be represented by the sampled data.

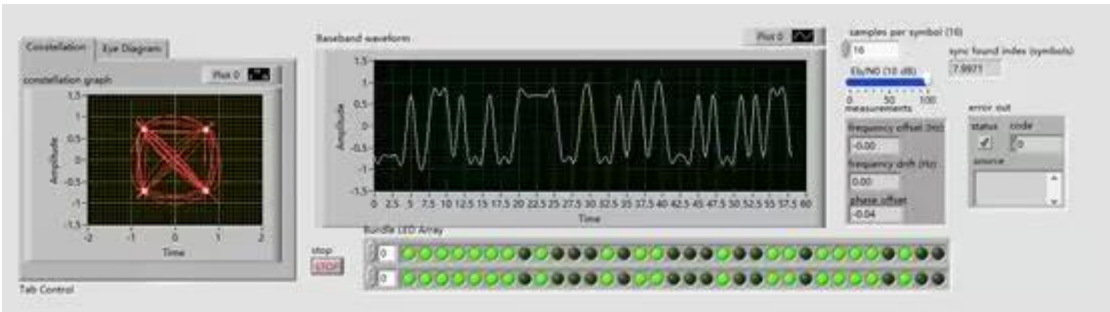
Once these parameters have been specified, the Sinc Pattern module generates a waveform with a Sinc shape, centered around the mid-point of the signal. This waveform acts as the filter kernel to be convolved with the original signal. The length of the filter kernel depends on the cutoff frequency chosen.

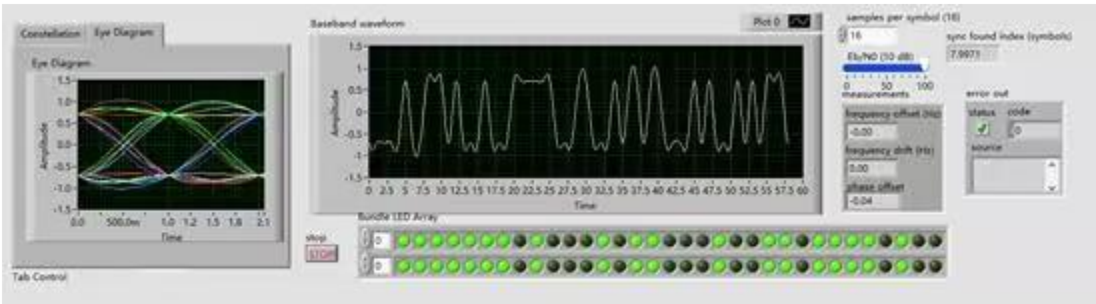
- **Arctangent Module:**
  In the LabVIEW Decimate module, the downsampling operation is accomplished by selecting every Nth sample in the input signal, where N is the decimation factor. The module features several options for resampling, such anti-aliasing filter design and filter order.
  The anti-aliasing filter design is the process of designing a filter that removes higher frequency components that might cause aliasing, which occurs when the signal frequency content exceeds the Nyquist frequency. The filter order determines the complexity of the filter and can help improve the signal quality.
- **Sinc Pattern Module:**
  Formula nodes in LabVIEW are a programming construct that allows you to write mathematical expressions in textual form. You can use them to perform calculations on input data, manipulate signals, or transform data into different representations.
  Using a formula node is straightforward. You drag a formula node from the functions palette and place it on the block diagram. Then you double click the node and insert your mathematical expression or formula. The inputs and outputs of the formula node are represented by terminals, which are connected to other nodes on the block diagram.
  Formula nodes can be used for complex mathematics and higher-level algorithms. LabVIEW provides a rich set of mathematical functions, including trigonometric, exponential, logarithmic, and statistical functions. You can use these functions in combination with your own standard arithmetic operators.

Lab results & Analysis:

1.Digital Carrier Transmission System Simulation 4-PSK (Bit Transmission)

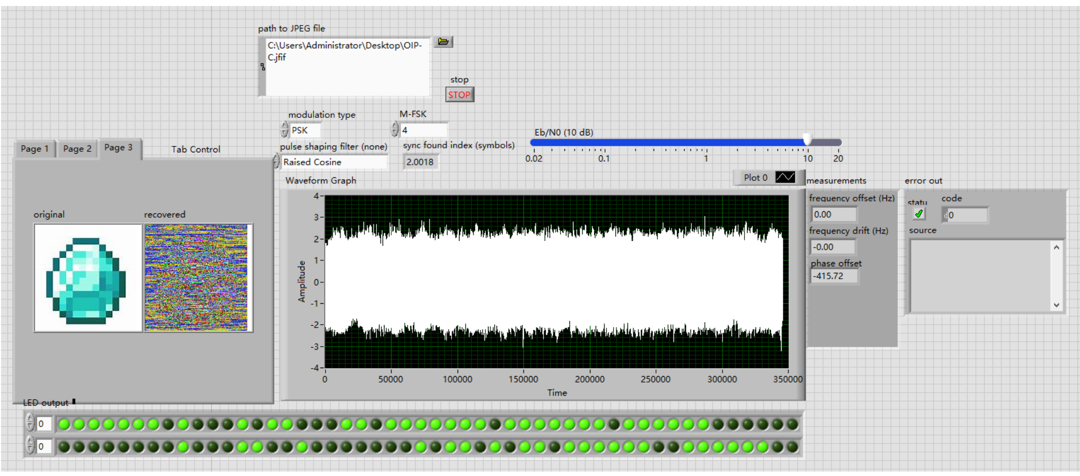




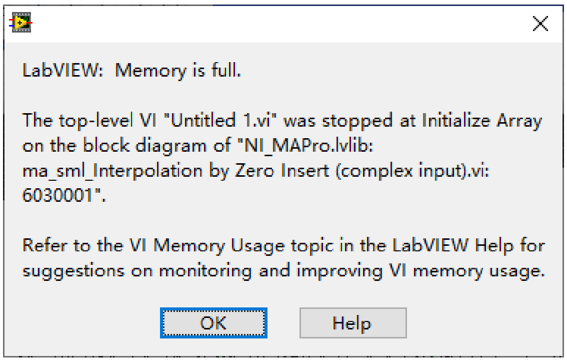


2. Digital Carrier Transmission System Simulation 4-PSK (Image Transmission)

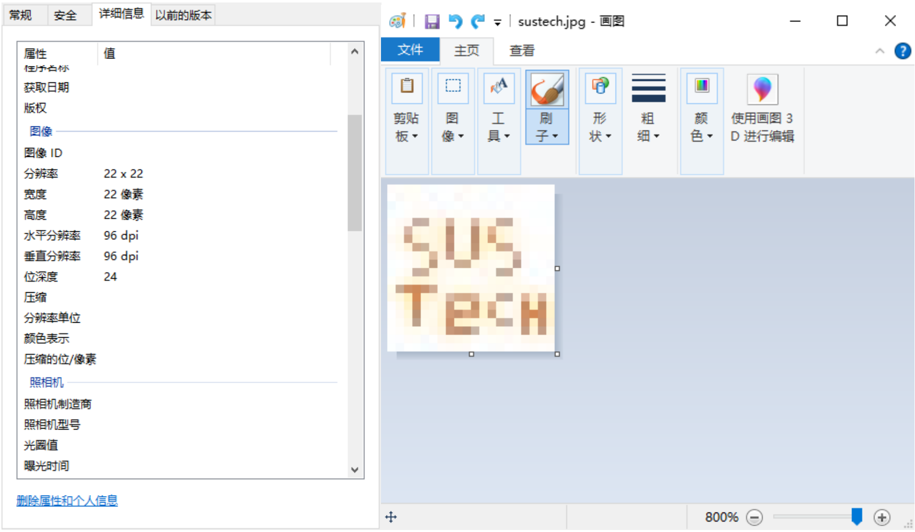
We choose a mincraft diamond as the image to transmmit, which is only 216Kb but still too large to transmmit.



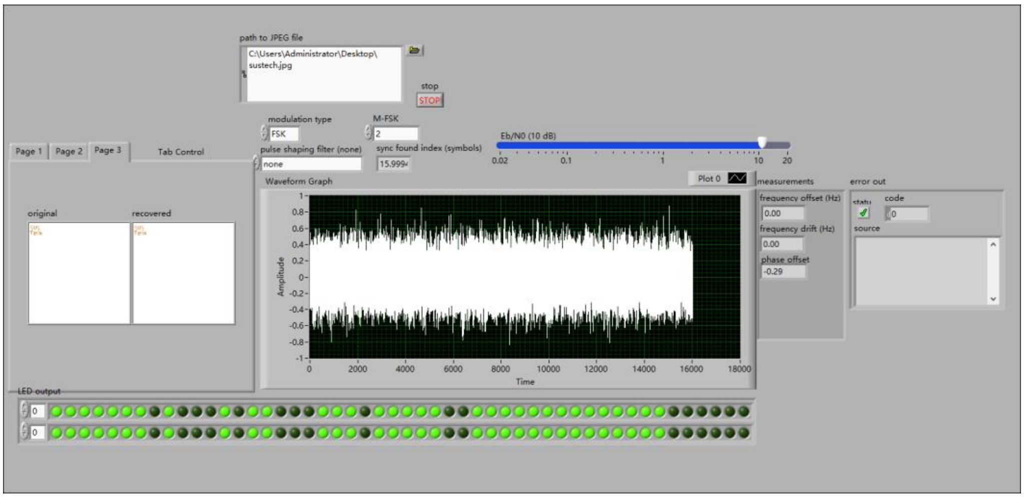
A error of "memory full" is reported by the the labview, seems like the labview program will cost a lot ram.

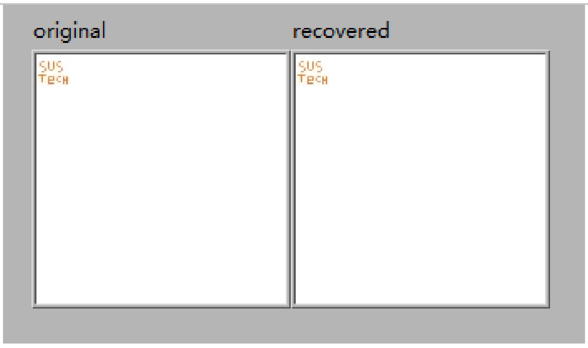


So, we paint a similar jpg file which is only 22*22px, just as the smille face jpg demo.



It works.





3. The effect of modulation order and Eb/No on the system

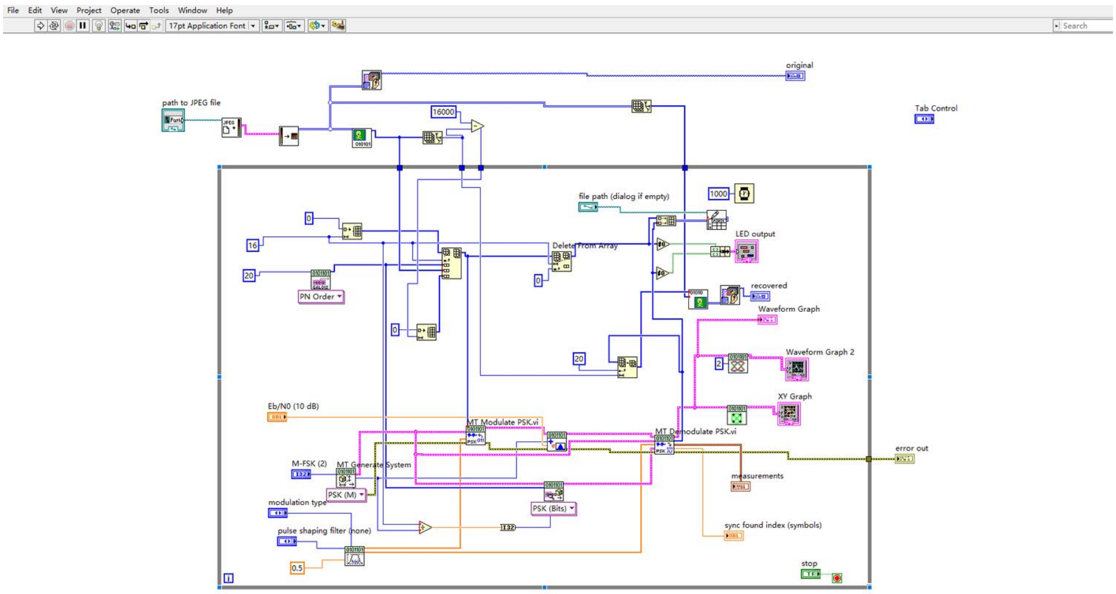
The BER can be calculated by the formula follow:

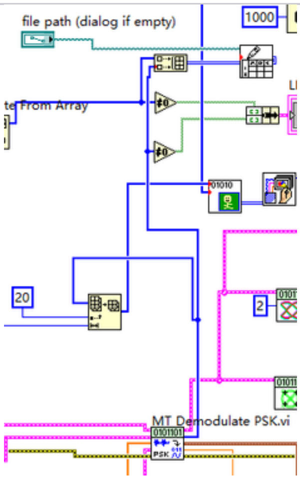
$$BER = \frac{errorBits}{sizeOfArray}$$

As Dr.wu mentioned, we just save all the bits and do the process using some other tool we are familiar with.

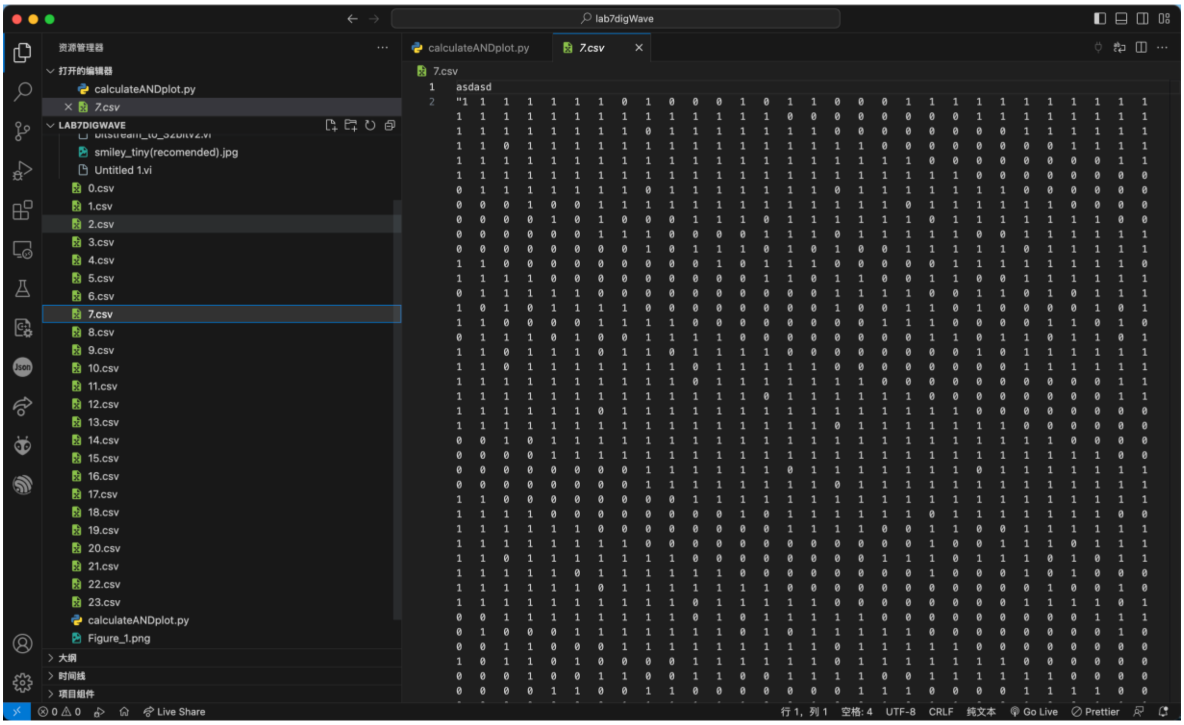
The function "write to spreadsheet file.vi" is used to save the origin and recovered bits.

Due to the time, only QPSK data was saved and the step of Eb/No is only 1dB, which could be more small and accurate.

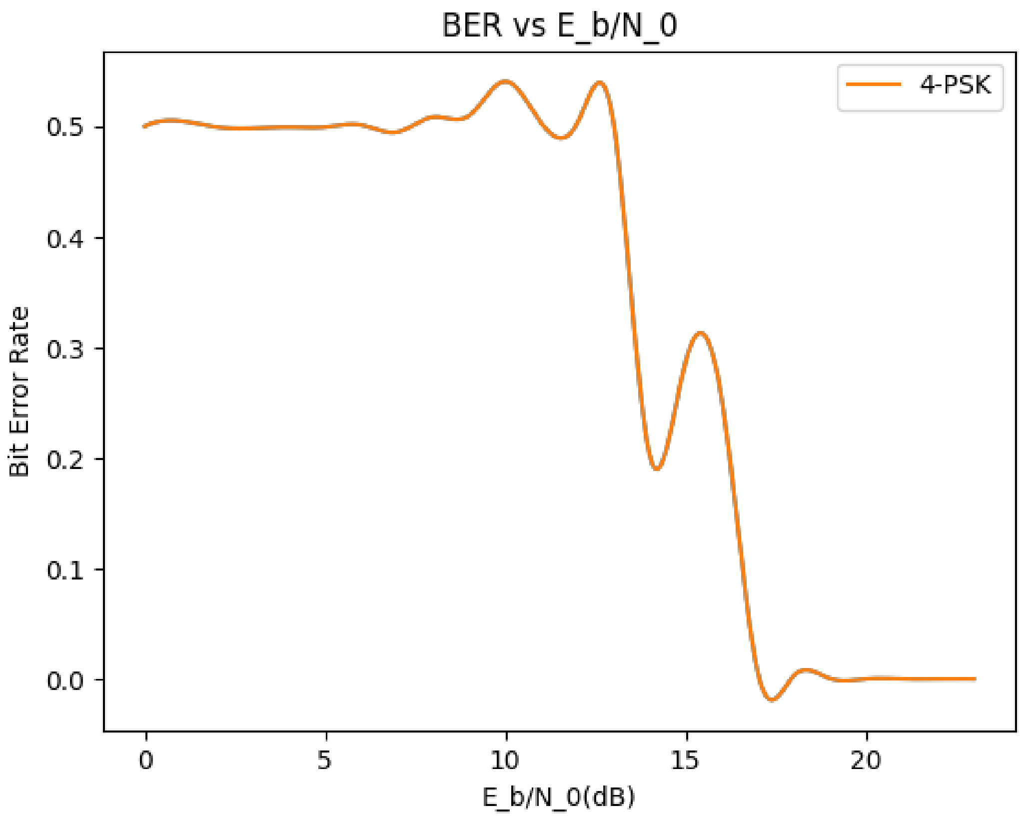




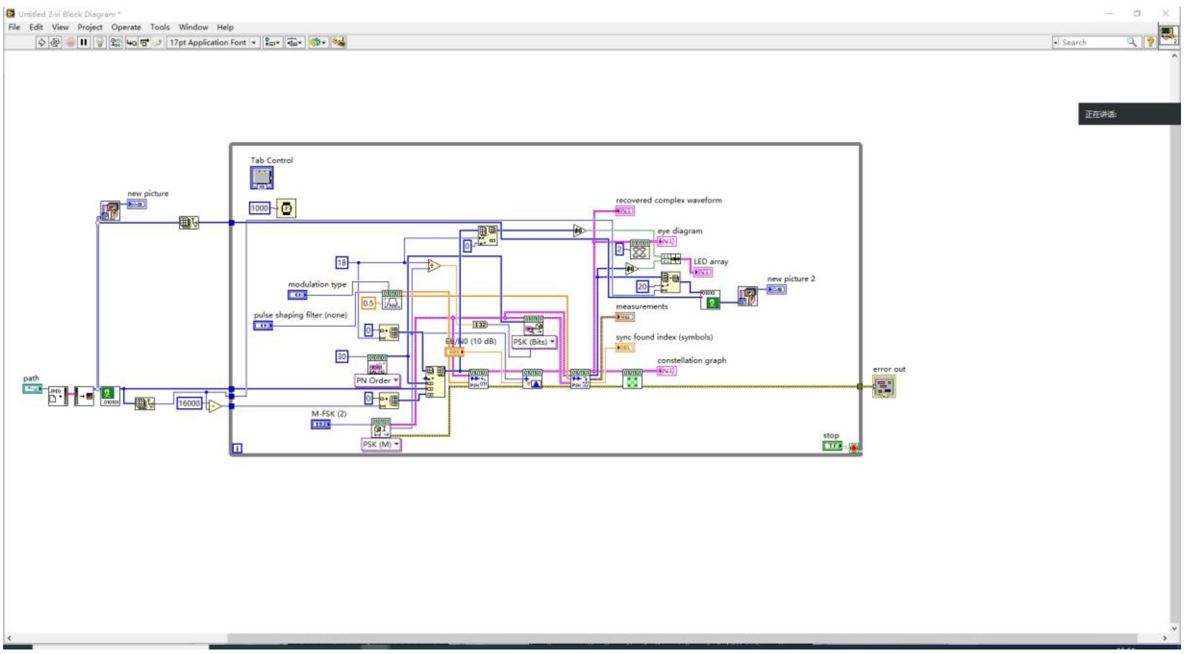
The data saved is 24 .csv file whose first row is origin bits and second row is recoverd bits.

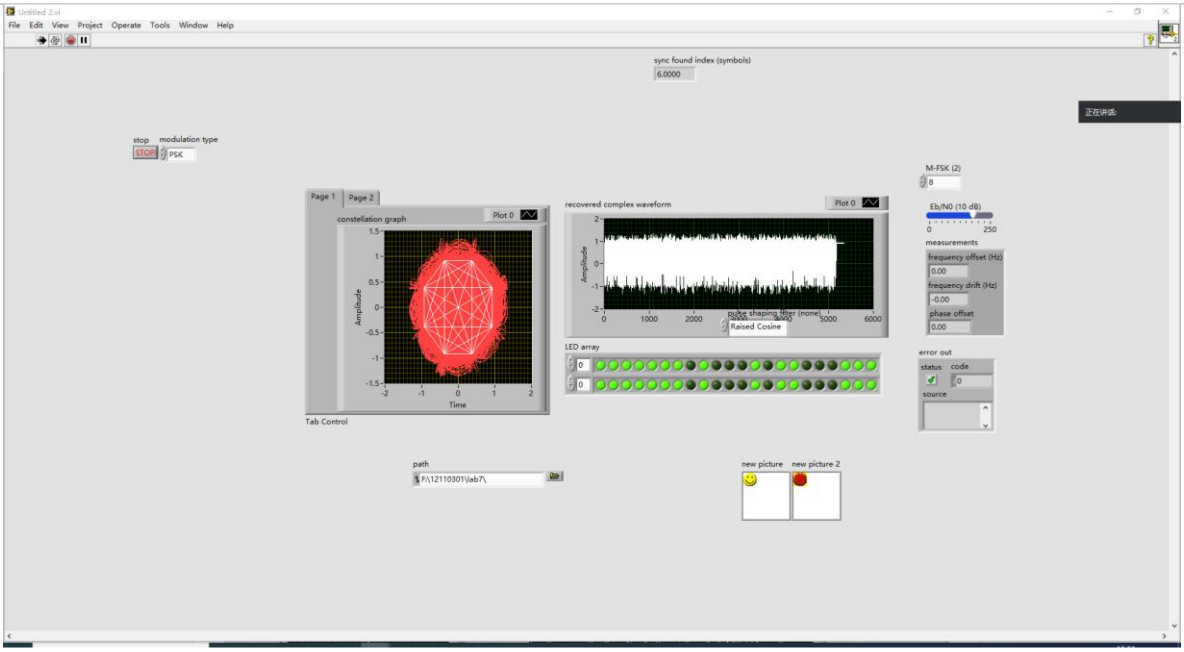


To calculate the BER, we use a python script to do the digital signal processing, which we attach on the end of the report. The script basicly compare every bit and record the difference, which is the errorBits. And some python package like pandas, matplotlib, numpy, scipy was used to deal the number and plot. The final plot is as below.



4.Digital Carrier transmission system simulation 8-PSK





The program block diagram and experimental results are shown in the figure, as shown in the diagram of program block diagram and experimental results, we can find that there are some color differences between the transmission results of 8 PSK and those of 4 PSK, as well as certain differences in constellation diagram.

5.Advantages and Disadvantages of Digital carrier transmission system and Its Value

Advantages:

- **Robustness:** Digital carrier wave systems are more robust against noise and interference compared to analog systems. They can employ error correction techniques and signal processing algorithms to mitigate noise and improve the overall reliability of the transmitted data.

- **Efficient use of bandwidth:** Digital modulation schemes can transmit more information per unit of bandwidth compared to analog modulation schemes. This allows for higher data rates and improved spectral efficiency, enabling more efficient use of the available communication channel.

- **Compatibility with digital systems:** Digital carrier wave systems are compatible with digital processing and storage systems, making it easier to integrate them into existing digital infrastructure. They can seamlessly interface with digital devices such as computers, smartphones, and digital signal processing equipment.

- **Better signal quality:** Digital modulation techniques can provide improved signal quality and lower signal degradation compared to analog systems. They are less prone to distortion and can maintain signal integrity over longer distances.

Disadvantages:

- **Increased complexity:** Digital carrier wave systems are generally more complex to implement compared to analog systems. They require additional encoding, decoding, and signal processing techniques, which can add complexity and cost to the overall system.

- **Higher bandwidth requirements:** Although digital systems can achieve higher data rates, they often require a wider bandwidth compared to analog systems. This can be a limitation in scenarios where available bandwidth is limited or expensive.

- **Sensitivity to synchronization:** Digital modulation schemes rely on accurate timing and synchronization between the transmitter and receiver. Any synchronization errors can lead to significant degradation in the received signal, resulting in data errors.

- **Power consumption:** Digital systems typically require more power for signal processing and conversion between digital and analog domains. This can be a concern in battery-powered or energy-constrained devices.

Value:

Digital carrier wave systems hold significant social value due to their impact on communication, connectivity, and information exchange. For example:

- **Enhanced Connectivity**: Digital carrier wave systems have revolutionized communication by enabling widespread connectivity. They have bridged geographical barriers, allowing people around the world to connect and communicate seamlessly. This connectivity fosters social interactions, facilitates collaboration, and promotes the exchange of ideas, knowledge, and cultural understanding.

- **Access to Information**: Digital carrier wave systems facilitate access to vast amounts of information. Through digital communication channels, individuals can access educational resources, news, entertainment, and various services. This access to information promotes learning, empowers individuals, and enhances opportunities for personal and professional growth.

- **Economic Empowerment**: Digital carrier wave systems play a crucial role in economic empowerment. They enable e-commerce, online banking, remote work, and digital entrepreneurship, creating new opportunities for businesses and individuals. Access to digital communication platforms expands markets, facilitates trade, and drives economic growth, particularly in sectors such as technology, digital services, and e-commerce.

- **Social Inclusion:** Digital connectivity through carrier wave systems helps address social disparities by providing access to communication and information for marginalized communities. It enables individuals in remote areas, underserved populations, and developing regions to overcome barriers of distance and infrastructure, allowing them to participate in the global digital ecosystem, access essential services, and connect with the broader world.

- **Collaboration and Innovation:** Digital carrier wave systems foster collaboration and innovation by facilitating real-time communication, data sharing, and collaboration across geographical boundaries. They enable remote collaboration, virtual meetings, and online platforms for knowledge sharing, which drive advancements in fields such as research, education, healthcare, and business.

- **Crisis Response and Resilience**: Digital communication systems have proven invaluable during times of crisis and emergencies. They enable swift dissemination of information, coordination of relief efforts, and communication between affected communities and emergency responders. Digital carrier wave systems contribute to disaster preparedness, response, and recovery, enhancing societal resilience.

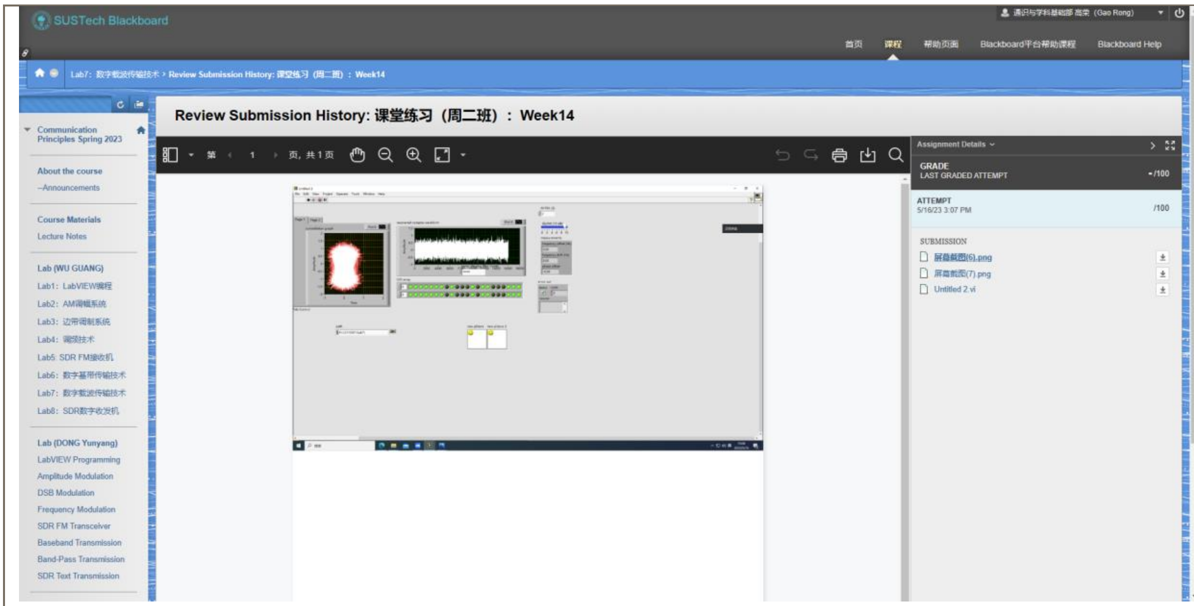
Overall, digital carrier wave systems have transformative social value by connecting people, enabling access to information, promoting economic opportunities, fostering inclusion, facilitating collaboration, and enhancing crisis response capabilities. They are essential in shaping a more connected, informed, and equitable society.

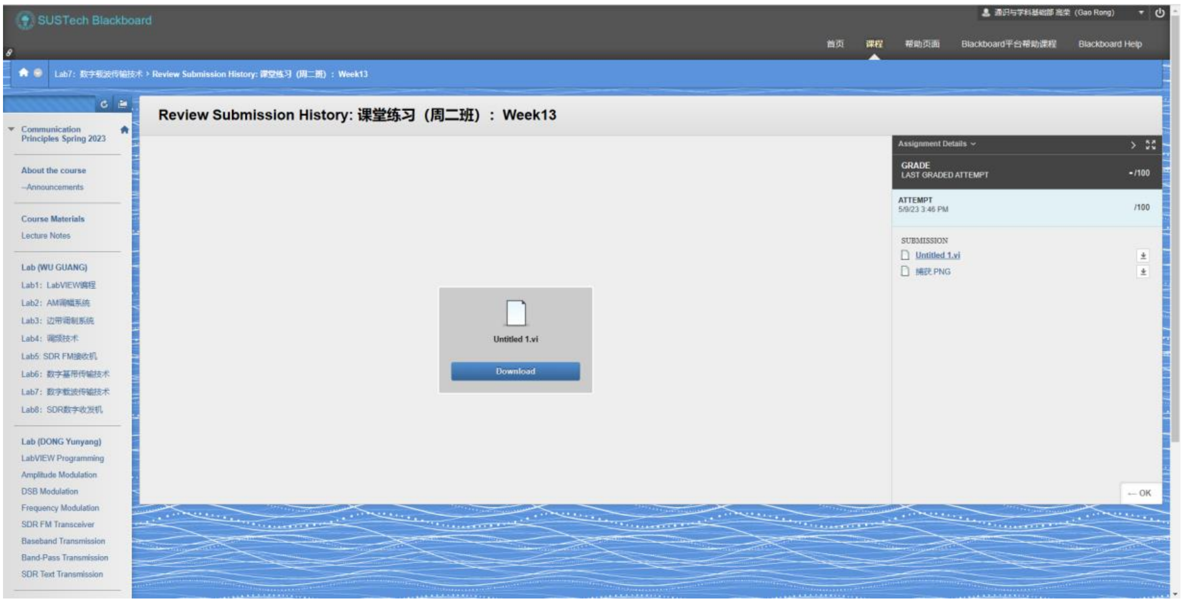
Experience:

In this lab, we need do some digital signal processing. We chosed python rather than matlab, the overall experience is somehow good and somehow not good. Because python have a larger community, you can always find someone meet the same problem on the internet, which is nice for debuging. However, python need to install some extenal package manually, while matlab originly support all the function we need like read .csv file and plot the graph.

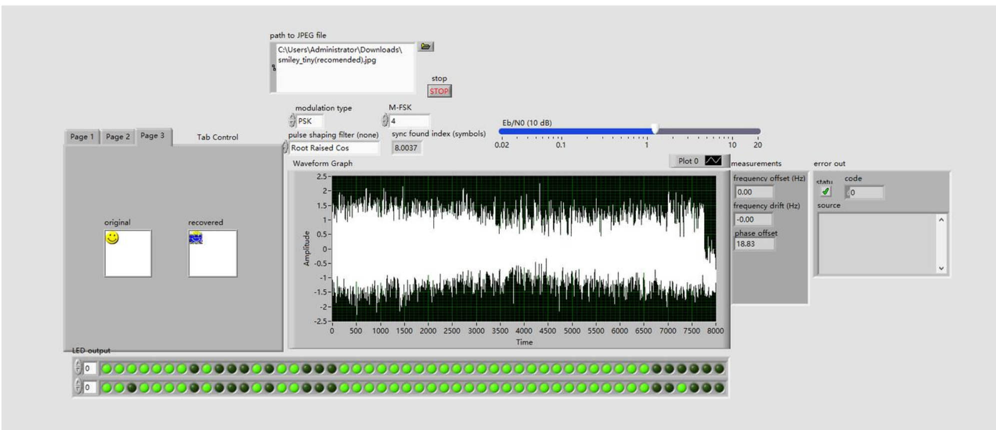
Submit shot:

12110301 高荣：





12210623 曹正阳：



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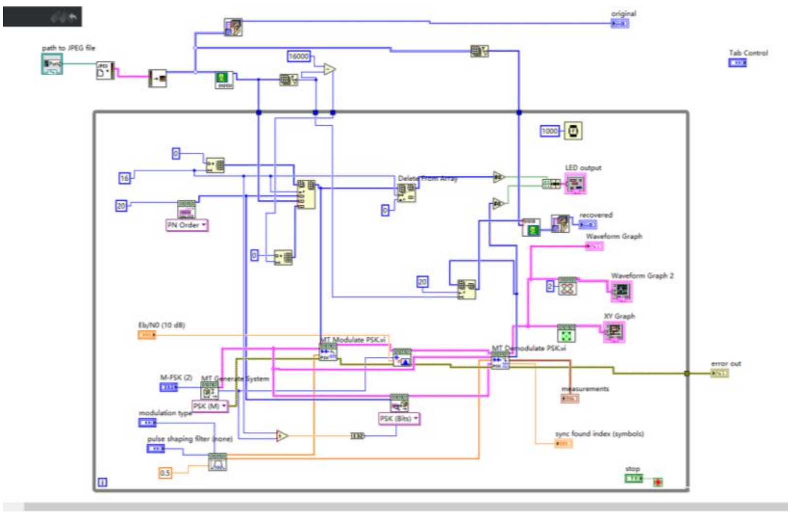
<tr><td colspan="2">
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```python
# BER calculate script
import os
import pandas as pd
import matplotlib.pyplot as plt
import numpy as np
from scipy.interpolate import make_interp_spline


def str_to_array(string):
    array = []
    # removing the first and last empty strings from the list
    string = string.split('\t')[1:-1]
    array = np.array([int(bit) for bit in string])
    return array


def calBER(a, b):
    if len(a) != len(b):
        raise ValueError("Arrays of unequal length")
    errorbits = sum(bit1 != bit2 for bit1, bit2 in zip(a, b))
    ber = errorbits / len(a)
    return ber


# list of file names
files = []

for i in range(24):
    file_name = str(i) + '.csv'
    files.append(file_name)


# initial ber
BERS = []
```

```
# loop over files
for i, file in enumerate(files):

    # read csv file into dataframe
    df = pd.read_csv(file)

    # initialize variables
    errorbits = 0
    size = len(df.columns)

    # turn the bits string into bits array
    # stupic asshole labview forget about the head row, i gotta
manually add a head for every single file, fxxk!
    origin = str_to_array(df.iloc[0, 0])
    recover = str_to_array(df.iloc[1, 0])

    # compare origin and recover columns to calculate bit errors
    BER = calBER(origin, recover)
    BERS.append(BER)
    print(BERS)



# plot BER vs file index
# Create an x-axis array to match the length of BERS
x = np.arange(24)

# Smooth the curve
x_new = np.linspace(x.min(), x.max(), 300)
spline = make_interp_spline(x, BERS, k=3)
BERS_smooth = spline(x_new)

# Plot the graph
plt.plot(x_new, BERS_smooth)
# set plot parameters
plt.xlabel('E_b/N_0(dB)')
plt.ylabel('Bit Error Rate')
plt.title('BER vs E_b/N_0')
plt.plot(x_new, BERS_smooth, label="4-PSK")
plt.legend()
plt.show()
# SUSTech EE Course Hero@github.com
```