Lab 6： Digital Passband Transmission

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Introduction

1.Theoretical knowledge

I/Q signal indication

I/Q signals (In-phase and Quadrature) are a representation method used to describe modulated signals, commonly used in wireless communications and signal processing. I stands for "In-phase" and Q stands for "Quadrature."

I/Q signals are represented using complex numbers, where the real part represents the in-phase component of the signal and the imaginary part represents the orthogonal component of the signal. The I/Q signal can be thought of as a vector in an orthogonal coordinate system, where the I component follows the real axis and the Q component follows the imaginary axis.

The I/Q signal is typically multiplied by the sine and cosine functions (or quadrature carriers) to modulate and demodulate the signal. In modulation, the original signal is frequency converted and phase modulated, and multiplied by the sine and cosine functions to obtain an I/Q signal. In demodulation, the received I/Q signal is multiplied by the local sine and cosine functions, and the original signal is restored by filtering and sampling.

$$\mathrm{I} \cdot cos(2\pi f_c t) - \mathrm{Q} \cdot sin(2\pi f_c t)$$

Packet encapsulation

Packet encapsulation refers to the packaging of raw data into packets (also known as frames or messages) in a specific format in network communication for transmission and reception in a network.Through packet encapsulation, network communication can realize reliable data transmission, error detection and correction, routing and other functions, so that data can be effectively transmitted and exchanged between network nodes.

Symbol mapping table

A symbol mapping table is a graphical representation that defines the relationship between symbols and their corresponding signal points in a digital communication system.

In digital communications, symbols are used to represent discrete levels of information. These symbols can be represented by different signal points in the signal space, and symbol mapping tables can visualize this relationship.

A symbol map usually consists of a two-dimensional flat grid or a set of points. Each point in the grid represents a unique set of symbol combinations. The horizontal and vertical axes of the grid usually represent the in-phase (I) and orthogonal (Q) components of the symbol, respectively. The I and Q components can represent the amplitude or phase of the signal

QPSK	
bits	**Symbols**
00	1+1j
01	-1+1j
11	-1-1j
10	1-1j

PSK

A phase shift keying (PSK) modulator is a modulator commonly used in digital communication systems to convert digital data into a phase-modulated signal. The PSK modulator maps each discrete digital symbol to a different phase state, enabling the transmission of data

Determine the phase state: The PSK modulator determines the phase state corresponding to each digital sign based on the PSK modulation scheme used. For example, for 2PSK (also known as BPSK), two phase states, usually 0 degrees and 180 degrees, are used, representing two different number signs.

Map symbol to phase: Splits the input digital data stream into discrete symbols, each corresponding to a specific numeric value. Depending on the PSK modulation scheme employed, each symbol is mapped to the corresponding phase state. For example, for BPSK, the binary number "0" maps to a 0-degree phase state, while the binary number "1" maps to a 180-degree phase state.

Phase modulation: Depending on the phase state of the map, the PSK modulator modulates the continuous carrier signal to the corresponding phase. Sine waves are often used as carrier signals, expressing different number signs by changing phase. In BPSK, if the current symbol is a 0-degree phase state, then the phase does not change; If the current symbol is a 180-degree phase state, then the phase is reversed.

Filtering and transmitting: To meet bandwidth requirements and suppress noise, PSK modulators typically filter and adjust the modulated signal. The modulated signal is then sent to the receiver via the channel.

Noise channel

Noise channel is a common type of channel in digital communication systems, which will introduce random noise disturbances to interfere and damage the signal.

In the noise channel, the transmitted signal is subjected to additional noise interference during transmission. This interference can be electromagnetic interference from the external environment, internal noise of the device, attenuation of the signal, multipath effects, etc. Noise channels can cause distortion, loss, and errors in the signal.

Error detection and correction coding: By introducing error detection and correction coding, the reliability of data transmission can be improved. These encoding schemes detect and correct errors during transmission, thereby reducing bit error rates.

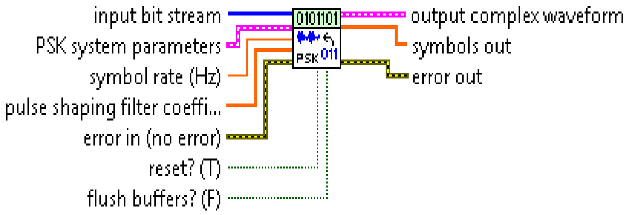
Adaptive modulation: Select the appropriate modulation scheme based on the quality of the channel and the noise level. Adaptive modulation can dynamically select modulation parameters based on channel conditions to improve the efficiency and reliability of

transmission.
Channel equalization: Through channel equalization technology, the received signal can be compensated, counteracting the distortion and interference caused by the channel, thereby improving the quality of the signal.
Forward error correction: By introducing forward error correction technology, the sending end can add redundant information to the packet, which the receiver can use to detect and correct errors in transmission.
PSK demodulator
A phase shift keying (PSK) demodulator is a device or module used in a digital communications system to convert a received phase-modulated signal back to digital data. It demodulates and decodes phase changes during transmission, thereby recovering the original digital data.
Receive signal: The PSK demodulator receives a phase-modulated signal from the channel. These signals may experience noise interference, attenuation, and distortion during transmission.
Phase demodulation: The PSK demodulator converts the phase change of the signal into discrete digital symbols by phase demodulating the received signal. The demodulation process involves detecting changes in phase and mapping each phase state to a corresponding numeric value.
Decoding symbols: Demodulated digital symbols are mapped back to the corresponding digital data. Depending on the PSK modulation scheme employed, the demodulator maps each digital symbol back to the corresponding binary digit or other digital representation.
Output digital data: The decoded digital data is provided to the receiving device or system for further processing or application
Synchronization
In digital carrier transmission, synchronization refers to the coordination of clock, phase, and frequency between the receiver and the transmitter to ensure proper demodulation and recovery of transmitted digital data.
Synchronization plays a crucial role in digital communication because there may be small differences in clock frequencies between the transmitter and receiver, resulting in the receiver not being able to accurately interpret and restore the transmitted signal. The goal of synchronization is to achieve accurate demodulation and data recovery by aligning the clock at the receiving end with the clock at the sending end through various techniques and algorithms.
Constellation chart
A constellation chart, also known as a constellation diagram or a signal space diagram, is a graphical representation of the signal points or symbols used in a digital communication system. It is commonly used in modulation schemes such as Quadrature Amplitude Modulation (QAM) and Quadrature Phase Shift Keying (QPSK).
In a constellation chart, each signal point represents a unique combination of amplitude and phase (for QAM) or phase (for QPSK). The chart typically consists of a grid or a set of axes, where the horizontal axis represents the in-phase component and the vertical axis represents the quadrature component of the signal. The signal points are plotted at specific locations on the chart based on their amplitude and phase values.

2.LabVIEW Model

1) MT Modulate PSK VI

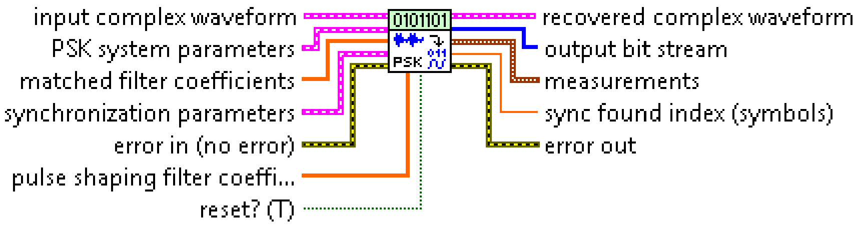
MT Modulate PSK VI is a module in LabVIEW, a graphical programming environment, designed to perform PSK modulation. With the MT Modulate PSK VI, users can specify the modulation parameters, such as the modulation order (e.g., BPSK, QPSK), the symbol rate, and the carrier frequency. The VI then takes the digital input data and maps it to the corresponding PSK symbols according to the selected modulation scheme. It generates the modulated signal by varying the phase of the carrier signal based on the PSK symbols. The MT Modulate PSK VI also allows users to configure additional parameters, such as the amplitude of the carrier signal and the choice of polar or non-polar PSK.



2) MT DeModulate PSK VI

MT DeModulate PSK VI is another module in LabVIEW that is used for demodulating PSK-modulated signals. It provides a comprehensive set of tools for recovering the original digital data from the received PSK signal.

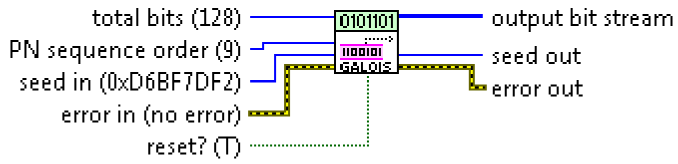
The MT DeModulate PSK VI takes the received PSK signal as input and performs signal processing operations to extract the phase information embedded in the signal. It employs various demodulation techniques, such as phase detection and symbol synchronization, to accurately demodulate the signal and recover the original data symbols.



3) MT Generate Bits (poly) VI

MT Generate Bits (poly) VI is a module in LabVIEW, a graphical programming environment, used to generate binary data sequences for digital communication systems. This VI allows users to create custom bit patterns by specifying a polynomial representation of the desired data sequence.

The MT Generate Bits (poly) VI provides flexibility in generating binary sequences by using a polynomial equation. Users can define the polynomial coefficients to represent the desired data pattern, allowing for the generation of complex and specific bit sequences. The VI outputs the generated binary data as a stream of bits, which can be used as input for modulation, encoding, or other signal processing tasks in a digital communication system.

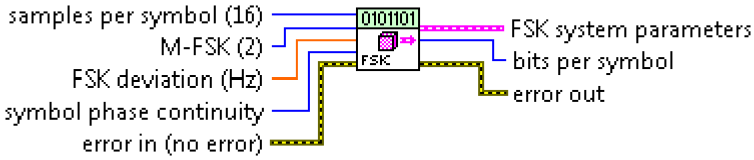


4) MT Generate System Parameters VI

MT Generate System Parameters VI is a module in LabVIEW used to set up and define the parameters of a digital communication system. This VI allows users to configure essential system parameters required for the operation of the communication system.

The MT Generate System Parameters VI enables users to specify parameters such as the carrier frequency, symbol rate, modulation type (e.g., BPSK, QPSK), and coding scheme. Users can also define other system-specific parameters, including channel characteristics, noise levels, and synchronization methods. By customizing these parameters, users can create a system that matches their specific communication requirements.

The output of the MT Generate System Parameters VI is a set of system parameters that can be used as input for other modules or VIs in LabVIEW for further signal processing and analysis.

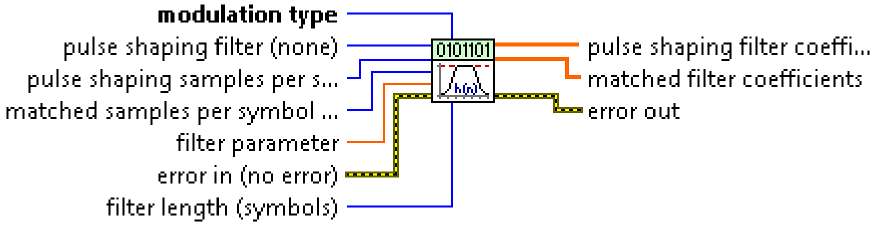


5) MT Generate Filter Coefficients VI

MT Generate Filter Coefficients VI is a module in LabVIEW used to generate filter coefficients for digital filters. This VI provides a convenient and efficient way to design and create filter coefficients based on user-defined filter specifications.

With the MT Generate Filter Coefficients VI, users can specify filter parameters such as filter type (e.g., low-pass, high-pass, band-pass), cutoff frequency, filter order, and desired filter characteristics (e.g., pass-band ripple, stop-band attenuation). The VI then calculates the filter coefficients using various filter design algorithms, such as windowing, Parks-McClellan, or least squares methods.

The generated filter coefficients can be used to implement digital filters for tasks such as signal filtering, equalization, or modulation/demodulation in a digital communication system.

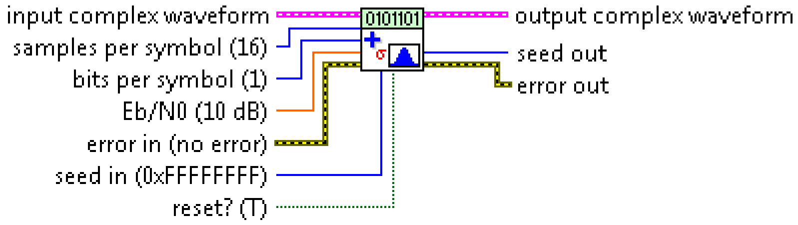


6) MT Add AWGN VI

MT Add AWGN VI is a module in LabVIEW used to simulate the addition of Additive White Gaussian Noise (AWGN) to a digital signal. AWGN is a commonly encountered type of noise in communication systems, and this VI allows users to evaluate the effects of noise on their signals.

The MT Add AWGN VI takes the input digital signal and applies AWGN with user-defined parameters such as noise power or signal-to-noise ratio (SNR). The VI generates random Gaussian noise samples and adds them to the input signal, simulating the noise that can degrade the signal during transmission or reception.

By adjusting the parameters of the MT Add AWGN VI, users can simulate different levels of noise and observe the resulting signal degradation. This module is valuable for testing and optimizing communication systems in the presence of realistic noise conditions, allowing users to make informed design decisions and enhance system performance.

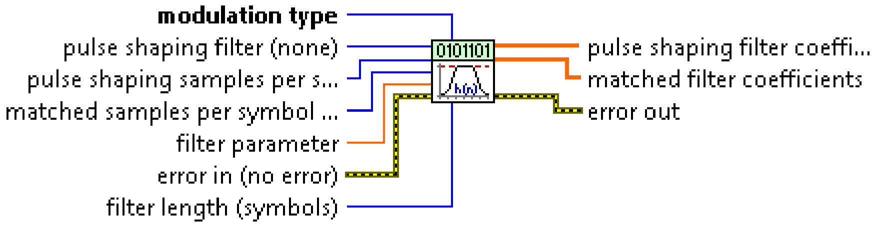


7) MT Generate Synchronization Parameters VI

MT Generate Synchronization Parameters VI is a module in LabVIEW used to generate and configure synchronization parameters for digital communication systems. This VI allows users to define and optimize parameters related to synchronization, which is crucial for accurate signal detection and demodulation.

The MT Generate Synchronization Parameters VI enables users to set parameters such as timing synchronization, carrier frequency synchronization, and symbol timing recovery. These parameters can be customized based on specific system requirements and signal characteristics. The VI provides options for different synchronization algorithms, such as matched filtering, correlation, or maximum likelihood estimation.

By using the MT Generate Synchronization Parameters VI, users can fine-tune the synchronization process to ensure reliable and accurate signal detection, demodulation, and data recovery in digital communication systems.

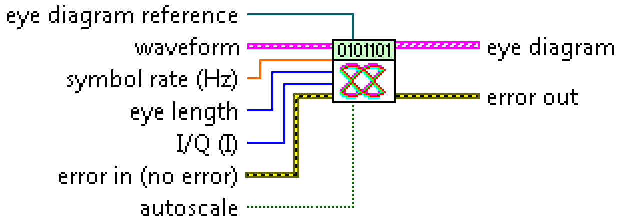


8) MT Format Eye Diagram VI

MT Format Eye Diagram VI is a module in LabVIEW used for visualizing and analyzing the eye diagram of a digital communication system. The eye diagram provides a graphical representation of signal quality, including noise, distortion, and timing jitter.

The MT Format Eye Diagram VI takes the received digital signal as input and processes it to generate the eye diagram. It samples the signal at different time instants and plots the sampled values on a graph. By repeating this process for multiple signal periods, an eye-shaped pattern is formed, which represents the overlapped waveforms of the signal.

The eye diagram allows users to evaluate various system parameters, such as signal quality, timing offset, and noise margin. It provides insights into the integrity of the transmitted signal, making it easier to detect and diagnose issues related to synchronization, distortion, or noise.



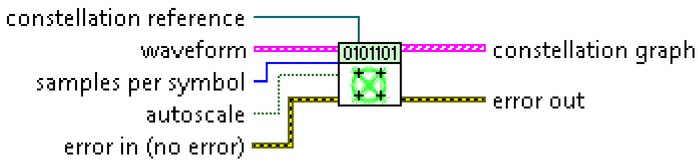
9) MT Format Constellation VI

MT Format Constellation VI is a module in LabVIEW used to visualize and analyze the constellation diagram of a modulated signal in a digital communication system. The constellation diagram displays the amplitude and phase relationships of the signal's symbols.

The MT Format Constellation VI takes the received modulated signal as input and processes it to generate the constellation diagram. It maps the received symbols onto a two-dimensional graph, where the x-axis represents the in-phase component and the y-axis represents the quadrature component. Each symbol is plotted as a point on the graph, indicating its amplitude and phase.

The constellation diagram provides valuable information about the signal quality, such as signal distortion, noise interference, and symbol spacing. It helps users analyze and optimize modulation and demodulation schemes, identify performance issues, and evaluate the overall system performance.

By using the MT Format Constellation VI, users can visually examine and interpret the characteristics of the modulated signal, enabling effective troubleshooting and improvement of digital communication systems.



3.Fundamentals of synchronization

Sender clock: In digital communication systems, the sender uses a local clock to generate and schedule data. The clock on the sending end is the system's base clock, which determines the rate and time interval of data transfer.

Clock signal transmission: The clock signal at the sending end needs to be transmitted to the receiving end along with the data so that the receiver can use the same clock reference for decoding. This can be achieved by embedding the clock signal into the data, or by using specialized clock signal lines or protocols.

Receiver clock recovery: The receiver synchronizes with the clock at the sending end by recovering the clock signal from the received signal. The receiving side uses clock recovery techniques, such as a phase-locked loop (PLL) or frequency-locked loop (FLL), to extract clock information from the received signal and adjust the local clock to align with the sender.

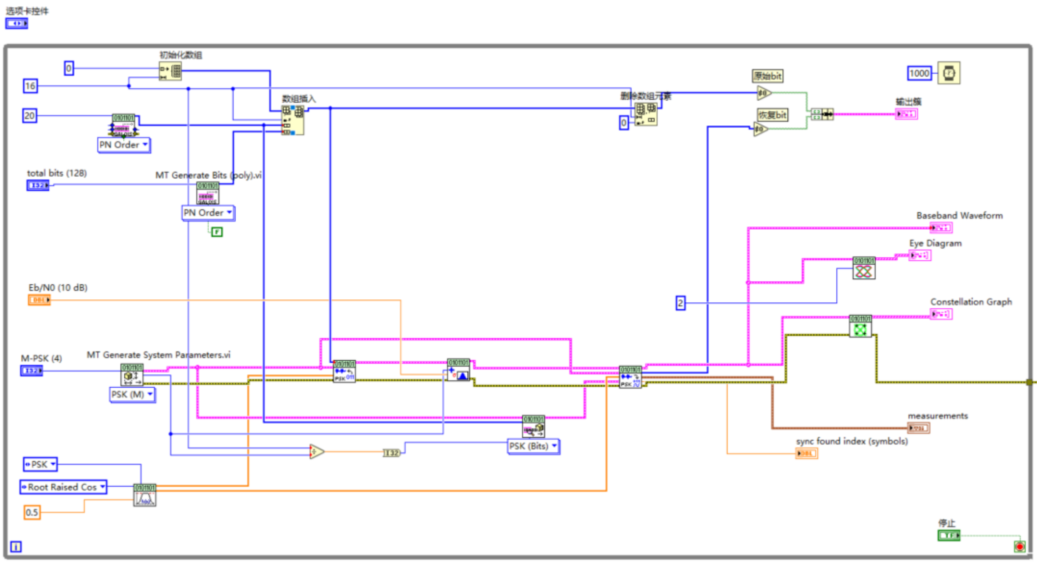
Phase and frequency synchronization: In addition to clock synchronization, the receiver needs to maintain phase and frequency consistency with the transmitter. Phase synchronization is when the receiver adjusts the phase of the received signal to match the

phase of the transmitter. Frequency synchronization is when the receiver corrects the frequency of its local oscillator to match the frequency of the transmitter.
Synchronization algorithms and feedback: Achieving synchronization typically involves the use of specific algorithms and feedback mechanisms to continuously adjust the clock, phase, and frequency at the receiving end. These algorithms can be estimated and adjusted based on the characteristics of the received signal to minimize clock skew, phase error, and frequency drift.

Lab results & Analysis:

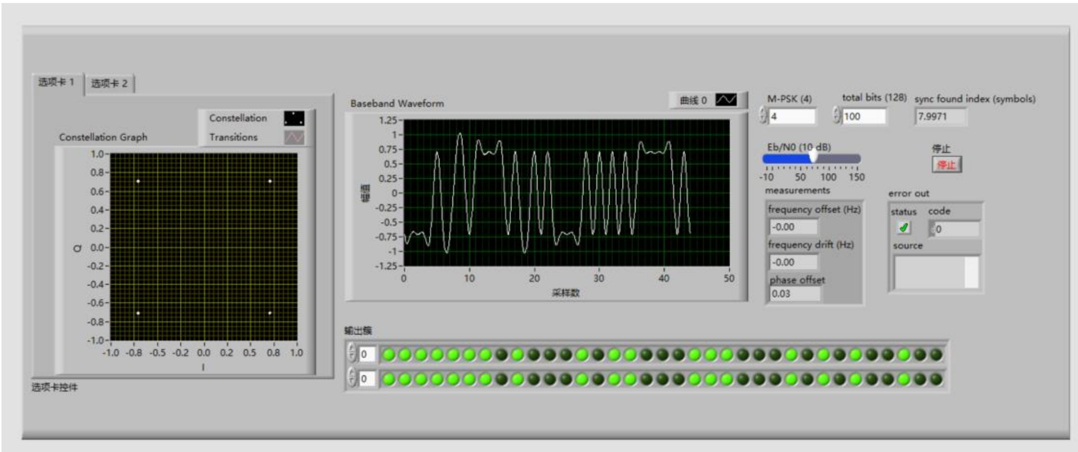
1. Digital Passband Transmission System Simulation Q-PSK (Bit Transmission)

Program block diagram:

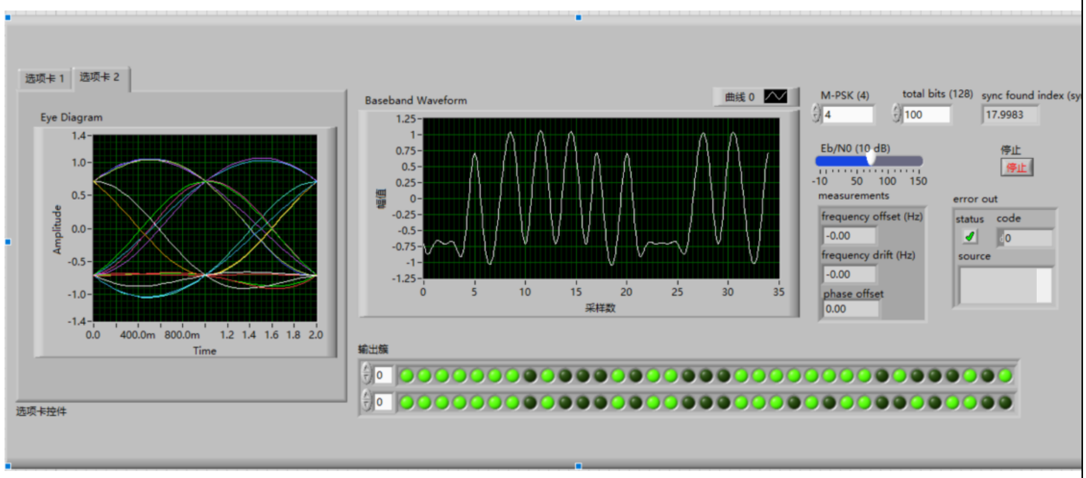


Simulation result:

(1) Constellation chart

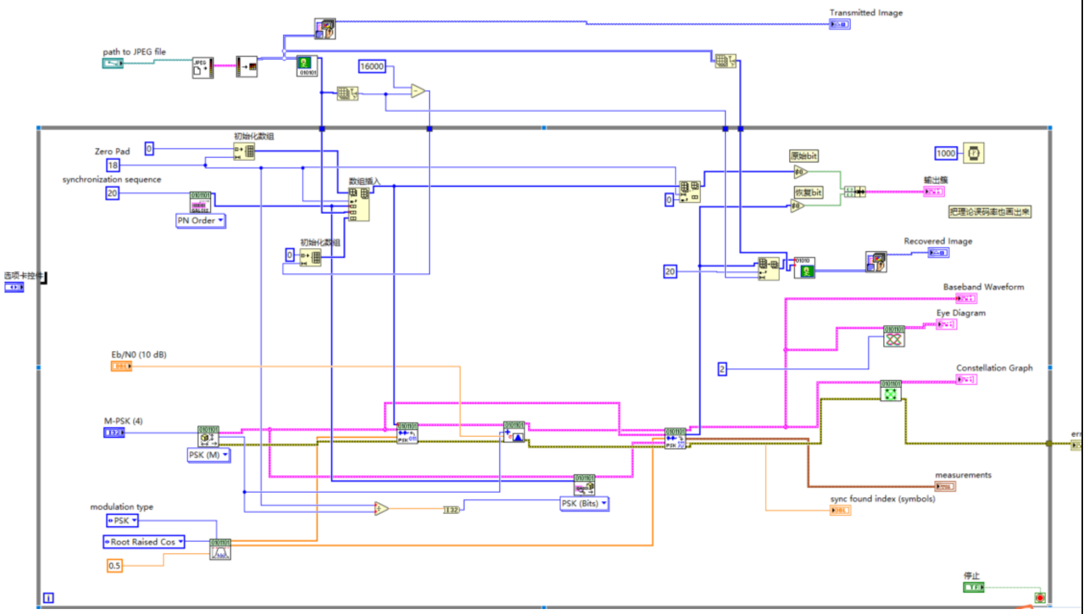


(2) Eye diagram



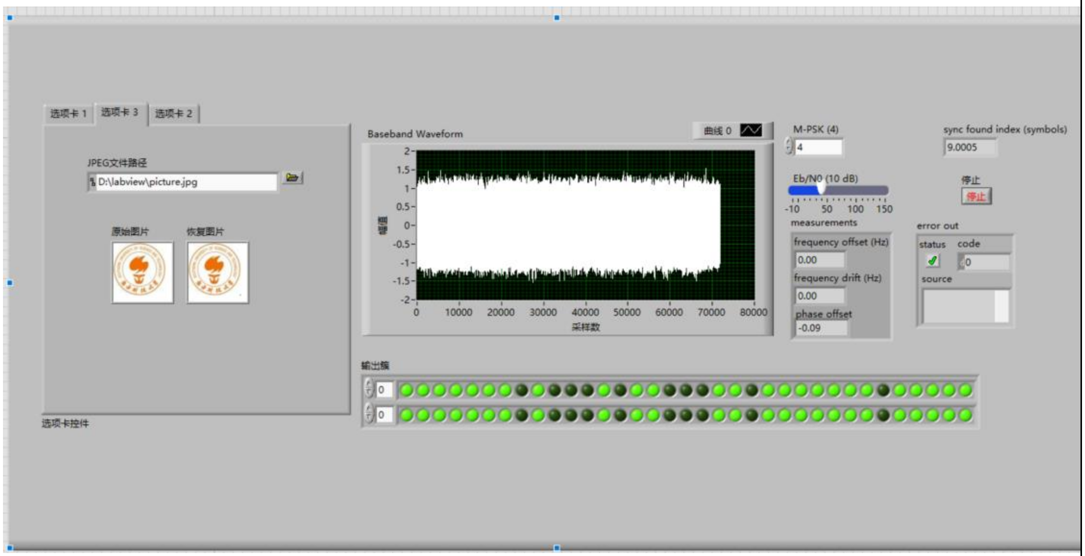
2. Digital Passband Transmission System Simulation Q-PSK (Image transmission)

Program block diagram:



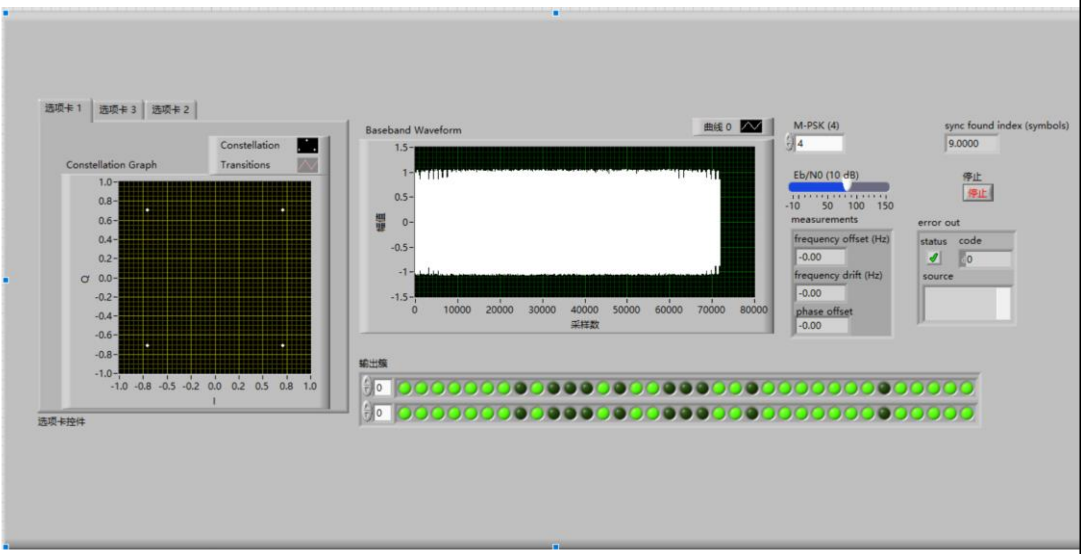
Simulation result:

(1) Effect of recovering

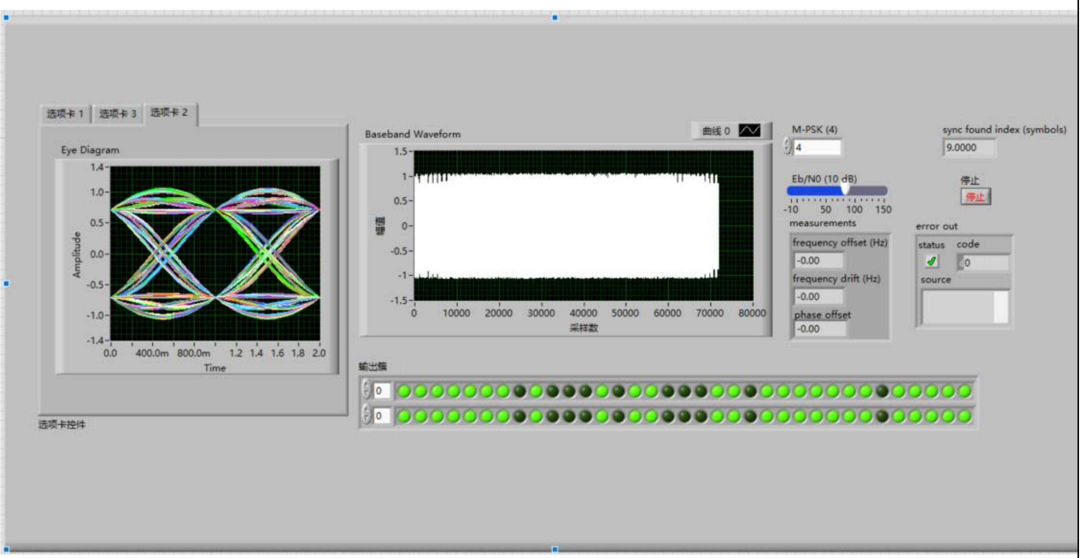


As can be seen from the result above, the picture can be recovered well.

(2) The Constellation chart:

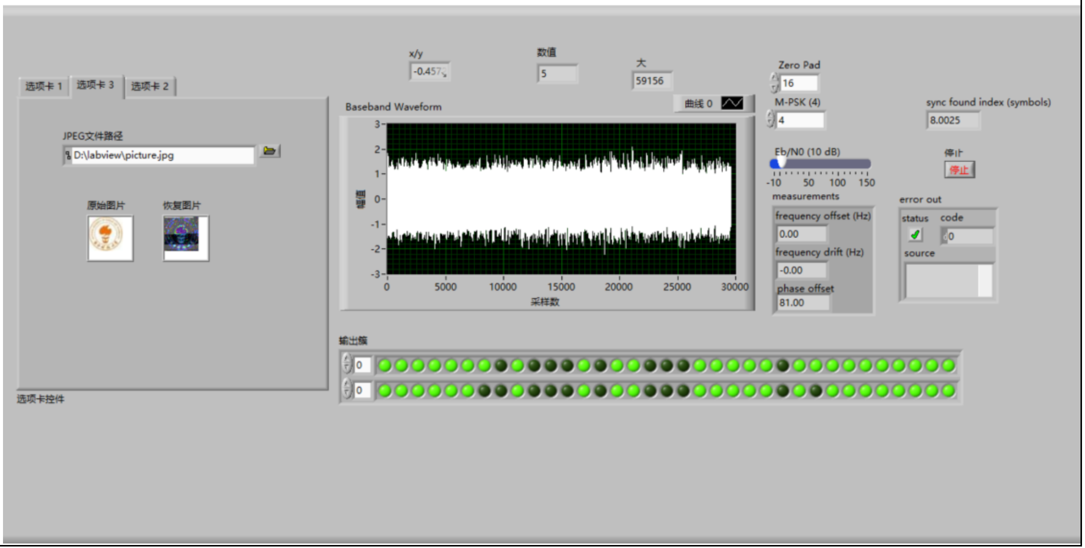


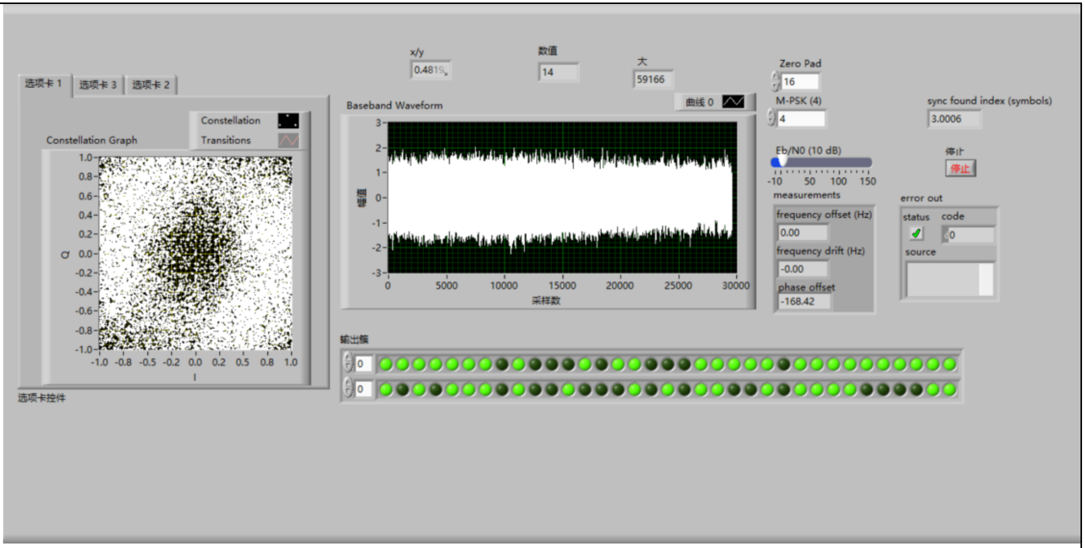
(2) Eye diagram



3. Effects of modulation order and EbN0 on the system:

The modulation order and EbN0 have a big impact on the performance of the system.
In the above experimental simulation, by reducing the signal-to-noise ratio of the system Eb/N0, it can be seen that with the decrease of the signal-to-noise ratio, the recovery effect of the system will decline, and the picture cannot be fully recovered at this time, and there will be a lot of noise points in the constellation map and messy lines on the eye map, which indicates that the performance of the system will be seriously affected when the signal-to-noise ratio is less than a certain value.



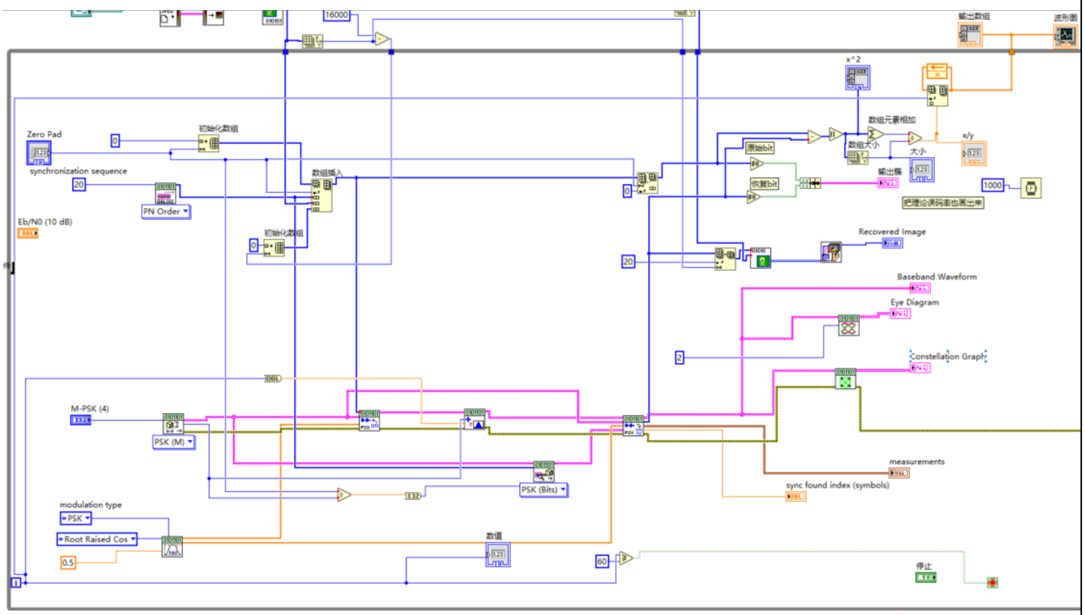


The order of PSK also has a great impact on the system. When the order of PSK is smaller, it can be found that the running time of the program is longer and the feeling of stutter is heavier. This is because the smaller the order of PSK means that the bit data processed at each time is less, so the total processing process is longer. With the increase of order, the running rate also increases, but at the same time, it can be found that the anti-interference ability of the system is small, which means that a higher signal-to-noise ratio is needed to ensure the recovery effect of bit. This is because the higher the order, the more bits are processed at once, and an error in any one of them will cause an error in all of them. In a word, the lower the order, the slower the processing speed, but the stronger the anti-jamming ability, and the higher the order, the faster the processing speed, but the less anti-jamming ability.

In order to better compare the anti-interference ability of the system under different orders, we can draw the relationship curve of bit error rate with signal-to-noise ratio under different orders of the system, so that we can get an intuitive feeling.

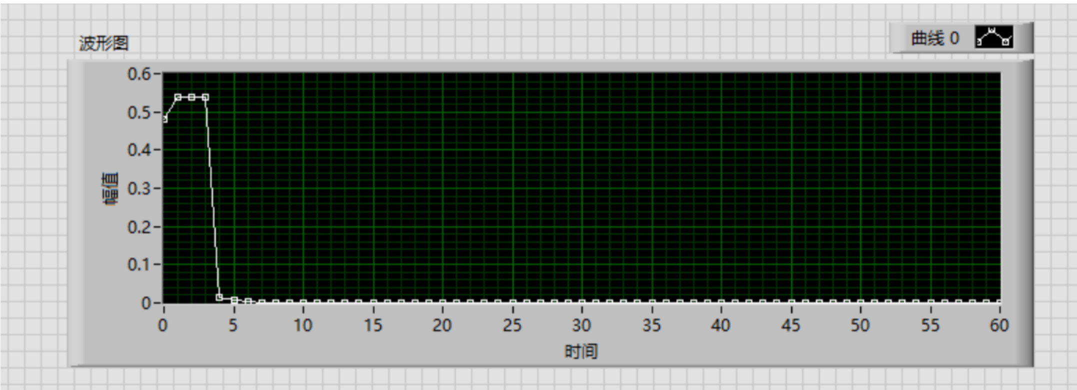
We take the signal-to-noise ratio from 1 to 60, calculate the bit error rate under different orders and save it in an array, and draw the corresponding curves of different arrays into a waveform graph. The bit error rate is calculated by subtracting the recovered bit array and the original bit digit bit by bit, then taking the absolute value, and then summing it to get the bit error rate.

Its program block diagram is as follows:

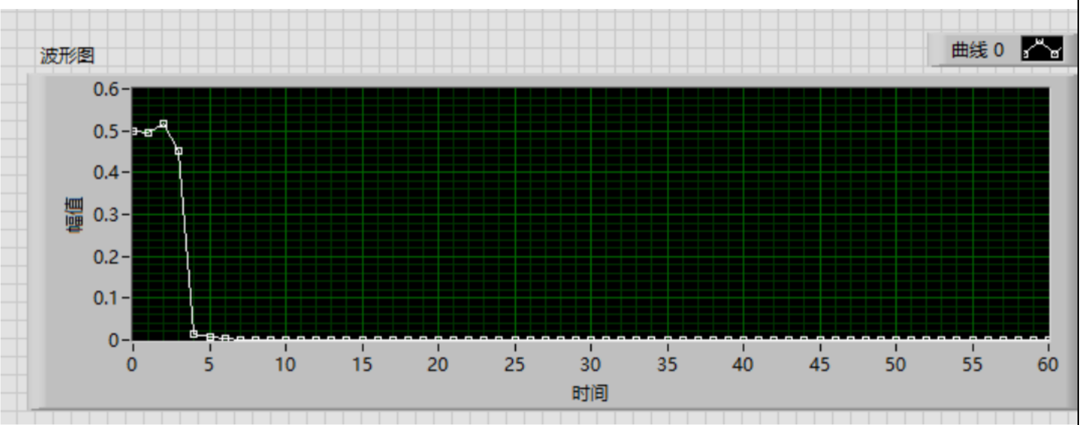


Each order corresponds to the following diagram:

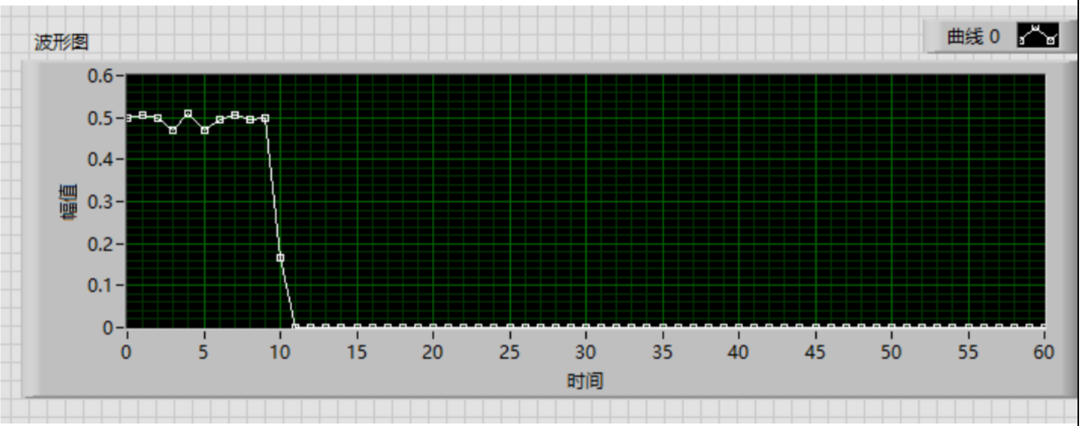
BPSK:



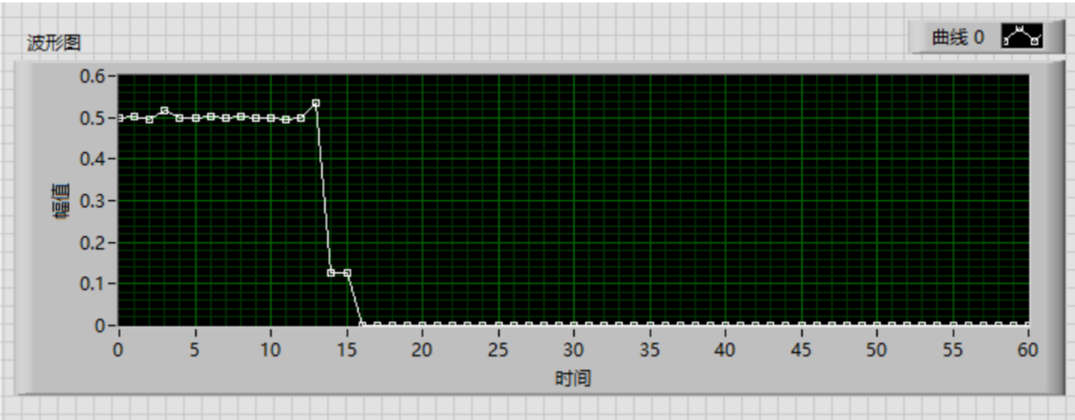
QPSK：



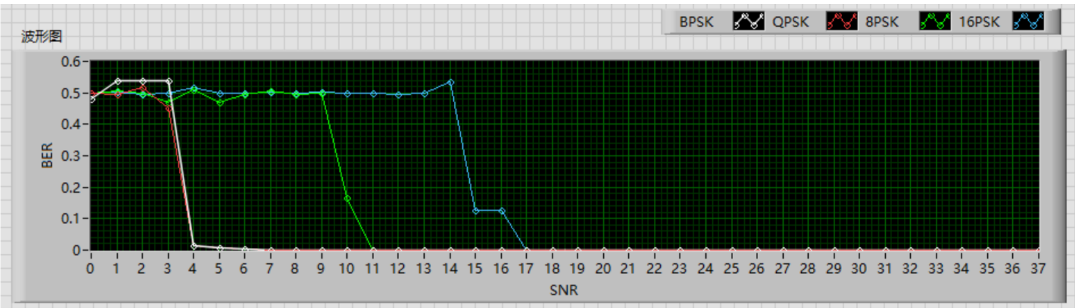
8PSK:



16PSK:



Draw the above into the same waveform diagram, the effect is as follows:



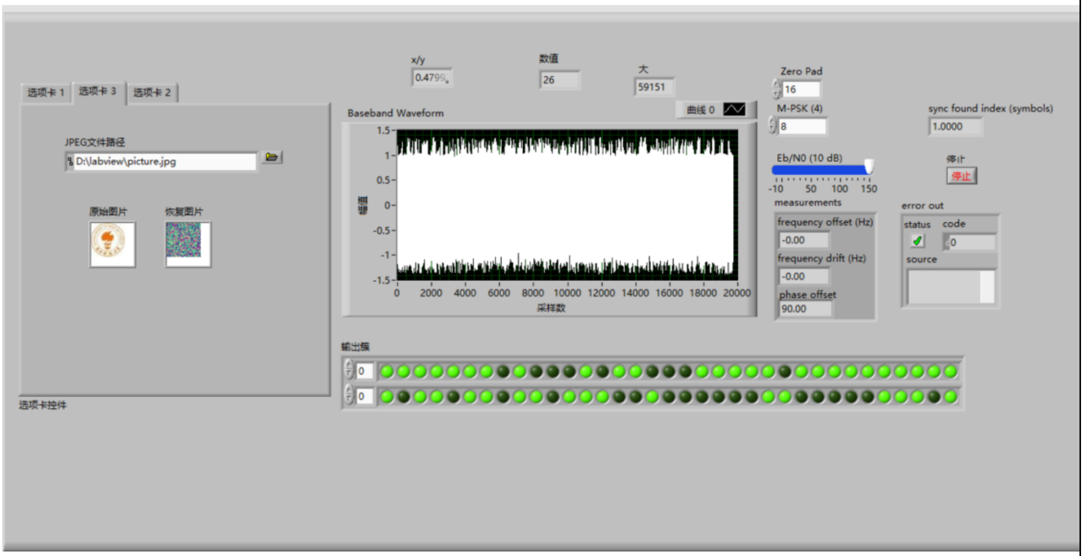
As can be seen from the figure, when the system is BPSK or QBSK, the bit error rate is approximately 0 when the signal-to-noise ratio is 6; when the system is 8PSK, the bit error rate is approximately 0 when the signal-to-noise ratio reaches 11; when the system is 16PSK, the bit error rate is approximately 0 when the signal-to-noise ratio reaches 17; this indicates that with the increase of order, The anti-noise capability of the system does gradually decrease.

4. Extension

(1) Digital Passband Transmission System Simulation 8-PSK (Image transmission)

If we change the above simulation to 8PSK, we only need to change the MPSK order to 8. At this time, also note that we need to change the zero pad to 12, so that the original

image can be displayed normally and restored.
If zero pad is not modified, it will be impossible to recover the original image, regardless of the signal-to-noise ratio.

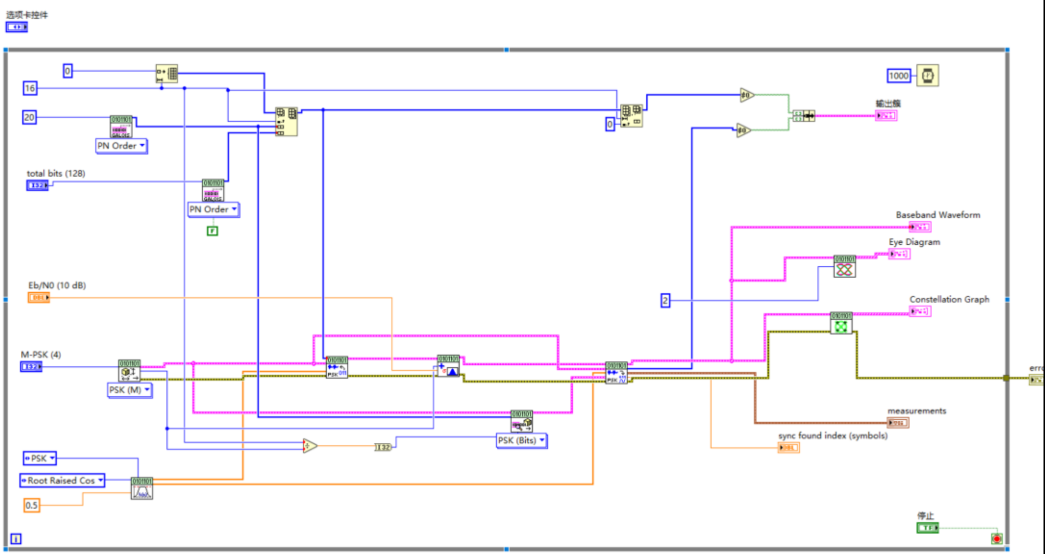


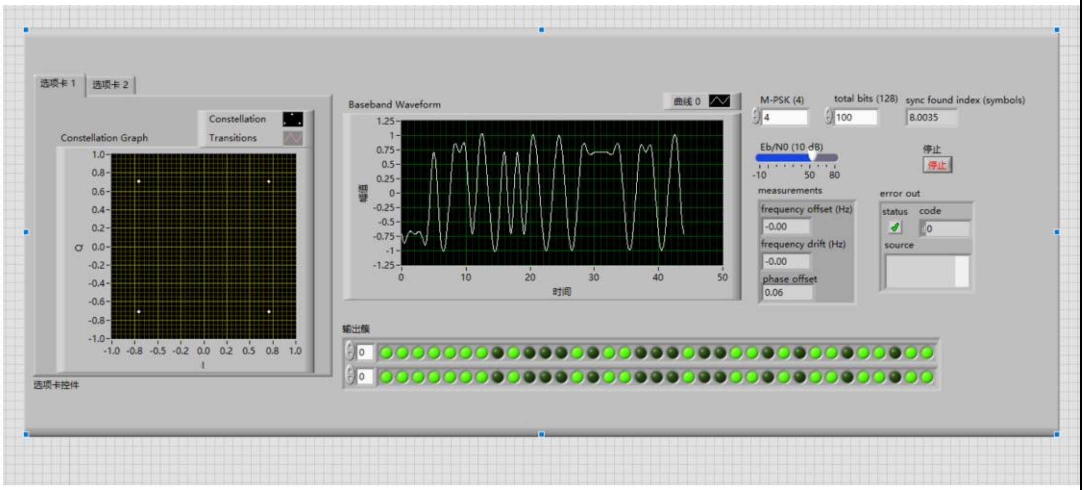
(2) Advantages and disadvantages of digital passband transmission systems

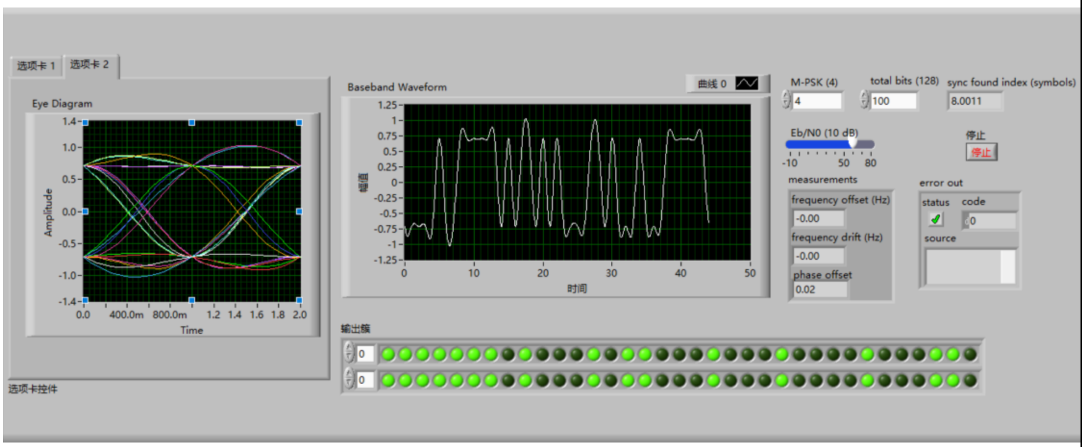
Advantages: Digital transmission systems provide better signal quality compared to analog systems. They can effectively mitigate noise and distortion, resulting in improved clarity and reliability of the transmitted data. Digital passband transmission systems can be easily scaled up to accommodate increasing data demands. By employing different modulation schemes and encoding techniques, the system can adapt to varying transmission requirements and support higher data rates.
Disadvantages: Implementing a digital passband transmission system requires a complex infrastructure involving sophisticated equipment and protocols. This complexity can lead to higher implementation and maintenance costs. Digital systems are susceptible to interference from various sources, such as electromagnetic interference and channel impairments. Adequate measures need to be taken to mitigate these interferences and maintain reliable communication.
Social application value: Digital passband transmission systems form the backbone of modern telecommunications networks. They enable high-quality voice and video communication, internet access, and other data services, facilitating global connectivity and information exchange. The IoT (Internet of Things) relies on digital transmission systems to connect and exchange data between various devices and sensors. These systems facilitate the seamless integration of smart homes, smart cities, industrial automation, and other IoT applications.

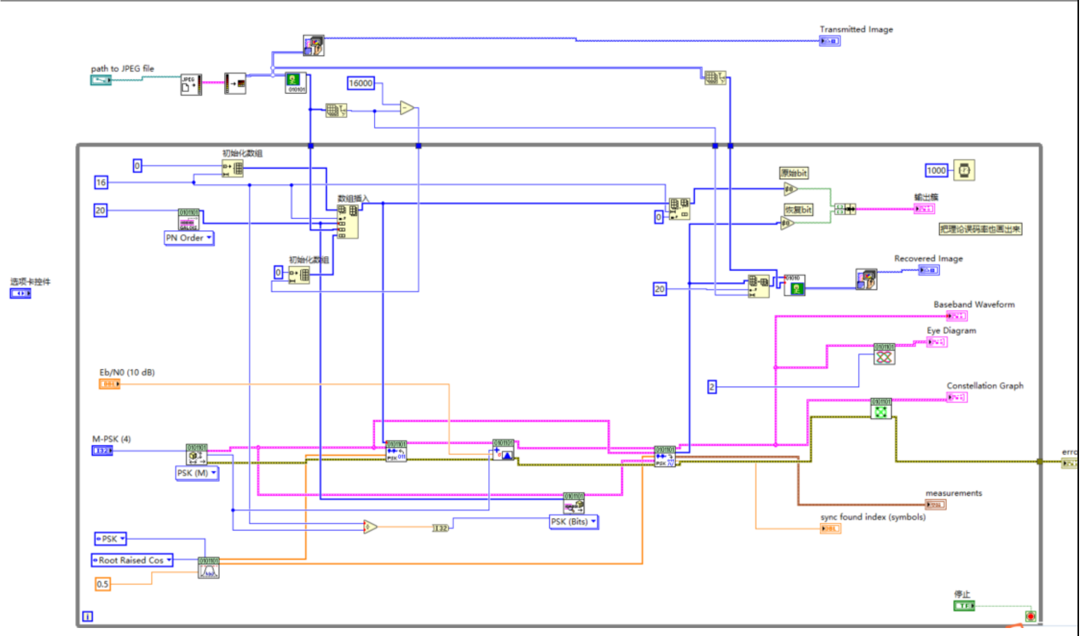
Experience

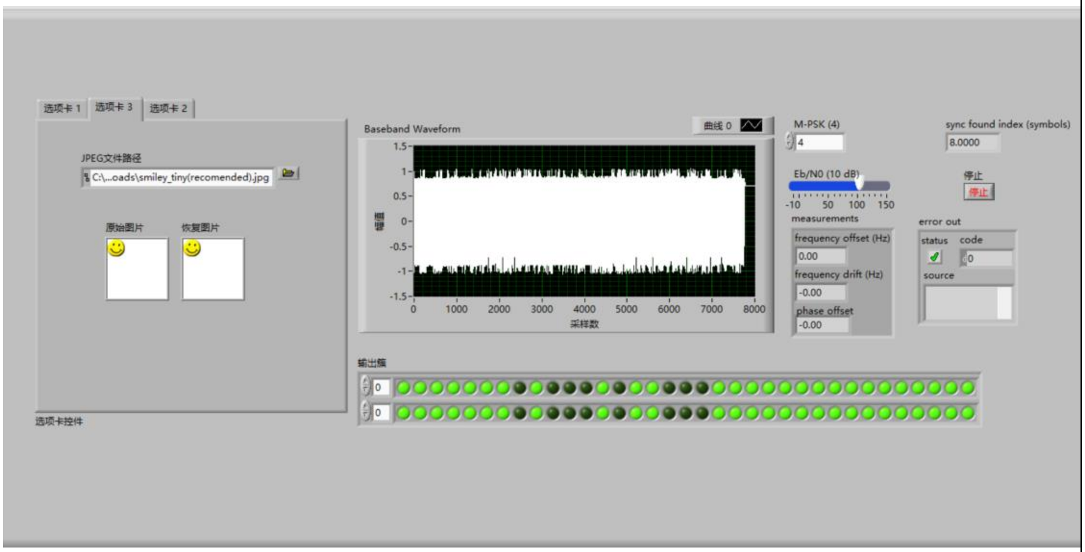
1. Screenshots of class submissions

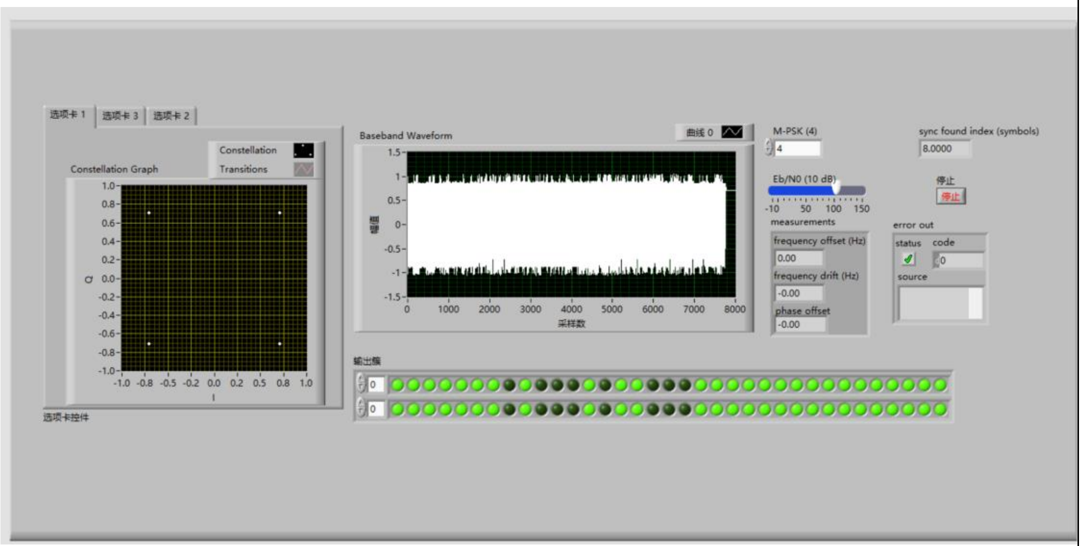


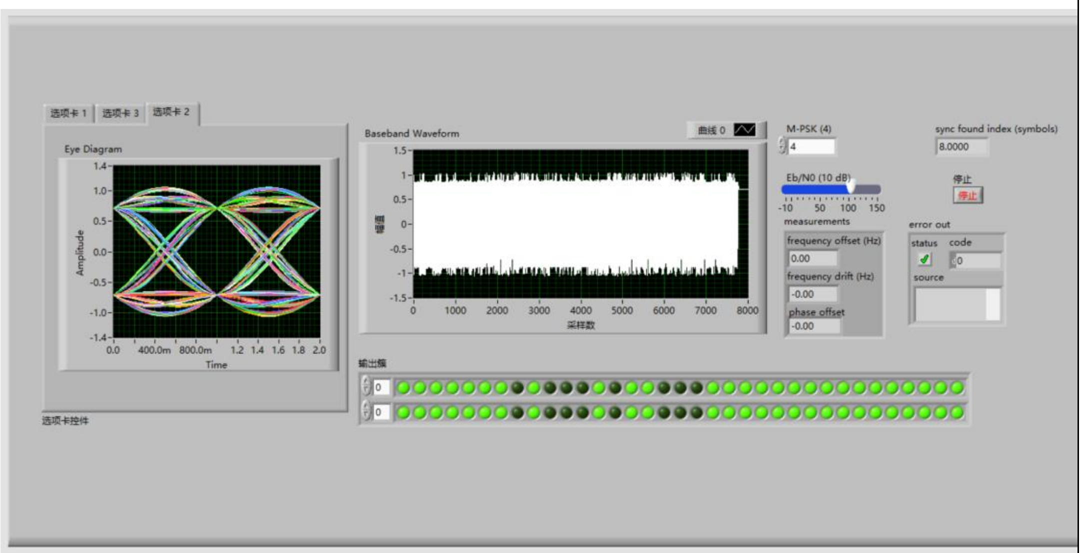

选项卡 1
选项卡 2
Constellation Graph
Constellation
Transitions
Baseband Waveform
曲线 0
时间
M-PSK (4)
total bits (128)
sync found index (symbols)
8.0035
Eb/N0 (10 dB)
停止
measurements
frequency offset (Hz)
frequency drift (Hz)
phase offset
error out
status
code
source
输出帧
选项卡控件


选项卡 1
选项卡 2
Eye Diagram
Amplitude
Time
Baseband Waveform
曲线 0
时间
M-PSK (4)
total bits (128)
sync found index (symbols)
8.0011
Eb/N0 (10 dB)
停止
measurements
frequency offset (Hz)
frequency drift (Hz)
phase offset
error out
status
code
source
输出帧
选项卡控件


path to JPEG file
Transmitted Image
16000
初始化数组
数组插入
PN Order
选项卡控件
添加bit
恢复bit
输出帧
1000
Recovered Image
Baseband Waveform
Eye Diagram
Constellation Graph
Eb/N0 (10 dB)
M-PSK (4)
PSK (M)
PSK (Bits)
PSK
Root Raised Cos
measurements
sync found index (symbols)
停止



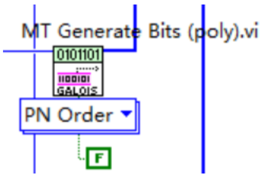




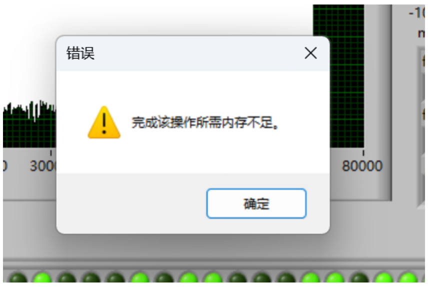
2. Problems we meet

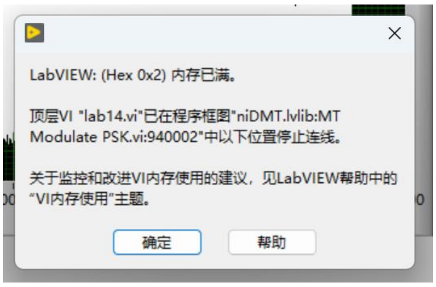
(1) During the simulation of the system of bit transmission, we found that MT Generate

Bits(poly).vi module of MT Generate Bit (poly). The option must be set to FALSE. If it is set to TRUE, the system will not be able to recover the original bit properly. This may be because if it is set to TRUE, the bit stream will be fixed and not generated in real time. If this parameter is set to F, bit streams are continuously generated for transmission.

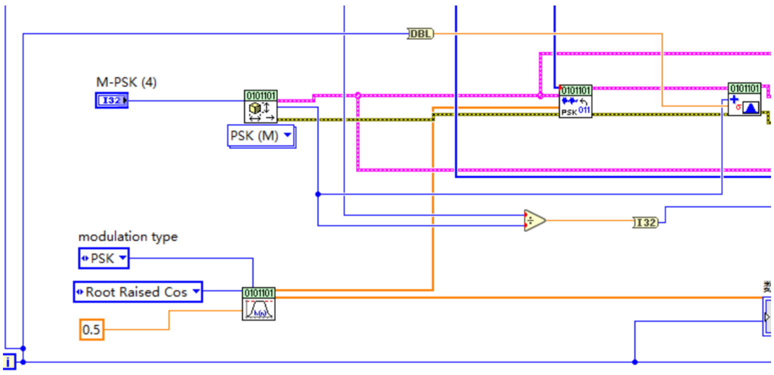


(2) When transferring pictures, the system cannot transmit pictures with too large pixels. When the pictures are too large, the system will report an error indicating that the labview memory is not enough at this time, so we need to adjust the size of the original pictures and reduce the amount of bit data to be transmitted.





(3) When studying the relationship between bit error rate and signal-to-noise ratio, we directly imported the index number i of the for cycle into the module as the signal-to-noise ratio. Later, we found that there would be some problems in system simulation, and the original bit could not be recovered normally. After exploration, we found that at this time, i needed to be converted into double type and transmitted to the module, so that the module could work normally.



(4) When drawing the relation graph between bit error rate and signal-to-noise ratio, we found that the relation graph generated by each operation would change, and the image generated by observation was not strictly decreasing, but there were many jumps and spikes. We guessed that there was a random state in the case of bit error, that is, there was chance, so the relation graph we got was not accurate. By increasing the amount of bit data, it may be possible to reduce the occurrence and influence of this random state to some extent.

(5) We also found an interesting phenomenon, when the system is BPSK, the value of zero pad can be whatever it is, which will not have a great impact on the system performance. When the system is QBSK, the value of zero pad must be a multiple of 2, otherwise it will have a great impact on the system performance. When the system is 8PSK, The value of zero pad must be a multiple of 3; otherwise, the system will be greatly affected. When the system is 16PSK, the value of zero pad must be a multiple of 4; otherwise, the system will be greatly affected. We suspect that this is probably because MPSK processes log2 (M) bits at a time, so it must be set to an integral multiple of log2 (M) so that it doesn't mess up by processing bits in groups.

3.Contribution

We two finish the whole LabVIEW program together. Zhang Haodong finish the Analysis of Factors Affecting Digital Passband Transmission System and plot the graph. The introduction and its social application value was elaborated by Song Yihang.

Contribution ratio :50%,50%

Score	97