Lab 6：Digital Baseband Transmission

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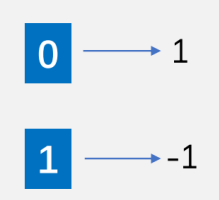
Introduction

1.Theoretical knowledge

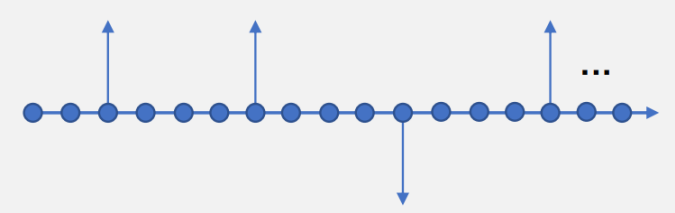
Symbol Mapping

In digital communication, the bit stream can not be transmitted directly. So, the bit stream needs to be mapped to some waveforms to transmit. The first step is to map the bit to symbol. For example, let symbol 1 represent bit 1 and let symbol -1 represent bit 0. This process is called symbol mapping. In this experiment, we use symbol 1 to represent bit 0 and use symbol -1 to represent bit 1.



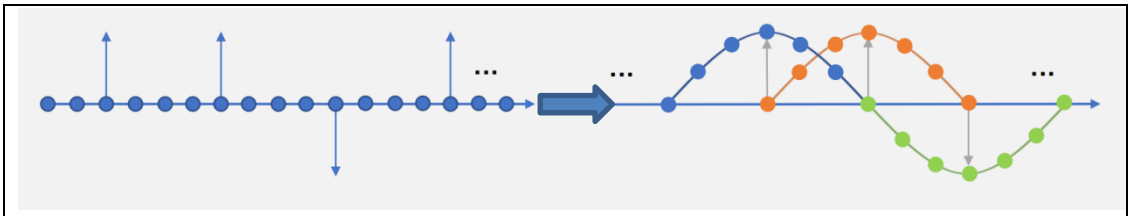
Interpolation - Up Sampling

In order to increase the internal between any two symbols, the up-sampling process is needed to do. In this experiment, the interpolation is executed as up-sampling, which means to insert some zeros between any two symbols during which the internal between the two waveforms to be transmitted is increased so that the interference between any two waveforms is reduced. This internal is equal to the up-sampling factor. We can change the up-sampling factor to change the internal to observe the influence of the value of internal.



Pulse Shaping

After symbol mapping, we need do the pulse shaping process to finally map the bit stream to waveforms. This process is finished by do convolution between the symbol stream and other function which usually include Sinc function and raised-cosine function. The resulting impulse, that is, the result of convolution, is to shift the above function waveforms to the position where the sign is not zero, and where the amplitude is the value of the sign multiplied by the peak value of the above function, thus forming a series of pulses alternating between positive and negative waveforms of above function.



Raised-Cosine Function

There are a variety of functions that are used in convolution operations, the raised-cosine function is one of the best functions. The conventional function used is Sinc function, but its trail is so large that that will influence the other signal in the pulse. So, raised- cosine function is put forward to reduce the value of the trail, the expression is based on the Sinc function and multiply the other term on Sinc function to make his tail decay faster. The expression change is as follows:

$$h(t)=\frac{\sin\frac{\pi}{T_S}t}{\frac{\pi}{T_S}t} \rightarrow h(t)=\frac{\sin \pi t/T_S}{\pi t/T_S}\cdot\frac{\cos \alpha\pi t/T_S}{1-4\alpha^2t^2/T_S^2}$$

Decimate

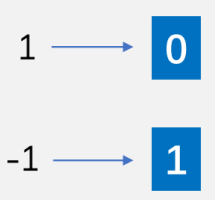
For the pulse transmitted, we need to do decimate operation namely sample. In this process, the system samples at the peak value of each pulse for subsequent detection and judgment, which means that it need to sample once a period, so the sampling period of this operation needs to be consistent with that of the up-sampling operation, that is, the down-sampling factor here needs to be equal to the up-sampling factor.

Detection

After the sampling operation, we need to judge whether it belongs to symbol 1 or symbol -1 according to the sampled value. In this experiment, this process is very simple. If the value at the sampling point is positive, the symbol is 1; if the value at the sampling point is negative, the symbol is -1.

Inverse Symbol Mapping

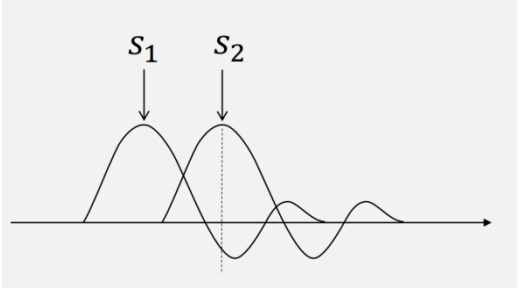
This is the latest step of the digital baseband communication which is to get the bit from the symbol. This the inverse operation of the previous operation: symbol mapping. In this experiment, if the symbol is 1, then the bit is mapped to 0, if the symbol is -1, then the bit is mapped to 1.



Inter-Symbol Interference (ISI)

ISI means that the symbol signal in pulse will have interference each other. As is shown in the figure, there will be a large overlap and influence between S1 and S2. As a result, the sampling value will be affected, and the positive value will be negative, resulting in errors in the final judgment, bit recovery failure and error

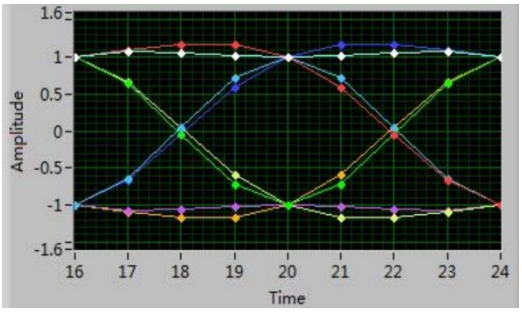
codes.



One of the reasons for ISI is that the convolution function that is usually used is the Sinc function, but the Sinc function has some problems, because the Sinc function that's out of the first period in the middle, which is its tail, is usually quite large, so the tail of one Sinc function is going to affect the other Sinc functions, which will cause increased interference between symbols in the pulse and it is not conducive to signal transmission and recovery. In order to reduce the influence of Sinc function tailing, three two methods are usually adopted. One is to increase the interval between two signals, that is, to increase the up-sampling factor in the previous step. However, the increase of up-sampling factor will reduce the transmission efficiency, so this method is not the best. The second method is to make that the maximum peak of other Sinc functions lies in the amplitude of 0 of other Sinc functions, so that the interference between each other can be reduced. But this method means to only the internal between two signal is Fixed value which is not effective. The third method is to use a better function that is raised-cosine function mentioned above so that its trailing is drastically reduced to minimize the impact on other signals.

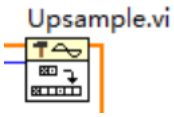
Eye Diagram

Eye diagram is a common analysis tool in digital communication system. It is a series of digital signals accumulated on a graph and displayed as a series of superimposed eye waveform, which contains a wealth of information. The influence of crosstalk and noise between codes can be observed from the eye diagram, reflecting the overall characteristics of digital signals, so as to estimate the pros and cons of the system. In this experiment, we can use the raised-cosine function as the convolution function, and then use the eye diagram to observe the interference between signals. By changing the alpha value, it can be found that the eye diagram will change. If the lines between the eye graph are more concentrated and there are fewer forks, it means that the interference between signals is reduced currently. The eye diagram of one of them is shown below:



2.LabView Module

Up-Sample Module

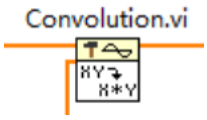


This module is to insert zero into the input sequence X by up-sampling factor. In this program, this module is to insert some zeros into the bits stream (1 and -1 sequence) after the symbol mapping. The up-sampling factor determines the number of zeros between samples. VI inserts 0 with number of the up-sampling factor - 1 between the two elements in sequence X. The up-sampling factor must be greater than 0. The default value is 1.

Sinc Pattern Module

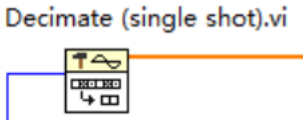
This module is to generate the Sinc function according to the input parameter. The first input parameter is the sample number of Sinc function, in this experiment this value is set to 65. The second input parameter is the delay duration which is time interval of the peak value of the Sinc function. In this experiment, this value is set to 3.2. The default value of sampling interval of this module is 0.1s.

Convolution Module



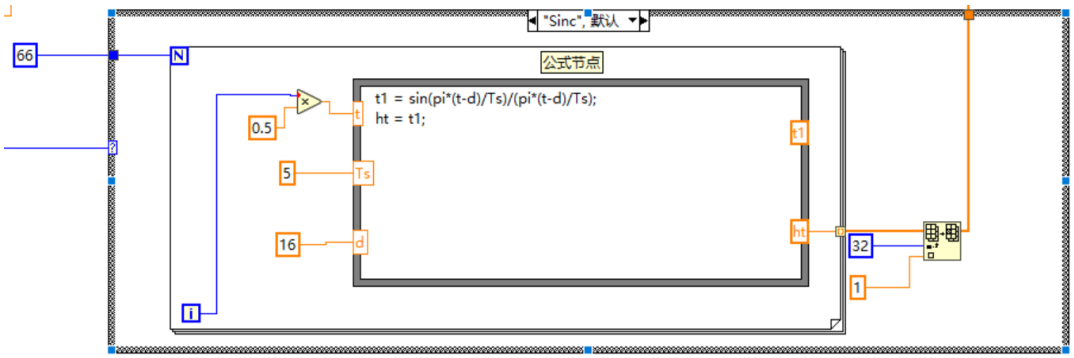
This module is used to do the convolution process. In this experiment, this module can calculate the result of the convolution between the sampled signal and the Sinc function to shape the pulse to transmit it.

Decimate Module



This module is used to do a down-sampling operation to decimate the signal which is to delete the zeros between the original sequence to recover the original signal. The first input parameter is the input sequence. The number of elements in the input sequence must be greater than the down-sampling factor. The second parameter is the down-sampling factor. The zeros that it removes are the ones that were added in the up-sampling module, so the parameters of the sampling factor here are the same as the parameters of the factor in the up-sampling module.

Formula Node Module



This module is used to generate arbitrary functions, just by writing code and function expressions in the corresponding block diagram which is similar to text programming, you can generate the desired function through input parameters and internal expressions. We can use it to generate the Sinc function by ourselves as well.

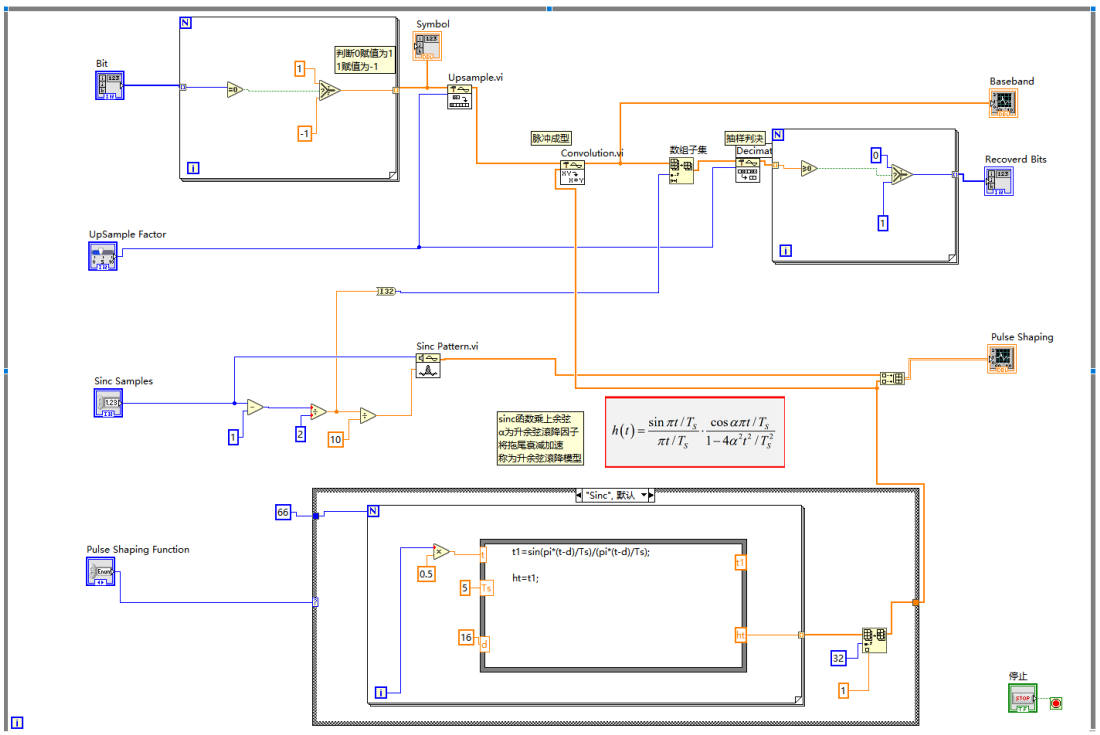
3.The Fundamental Principle of Pulse Shaping

Pulse shaping is an important part of digital baseband communication system. Its function is to map the bit stream into a series of pulse waveforms. Before the pulse shaping, the bit stream has been mapped to a series of symbol streams, and then it is only necessary to convolve a waveform function with the symbol stream to obtain the pulse. The symbol stream can be regarded as a series of impulse functions, whose convolution with a waveform function is to translate the waveform of the function to corresponding position, and multiply the amplitude by the corresponding sign value, so that a series of pulses of the convolution function can be obtained. This is pulse molding operation. Common convolution functions include Sinc function, rise and cosine function, etc.

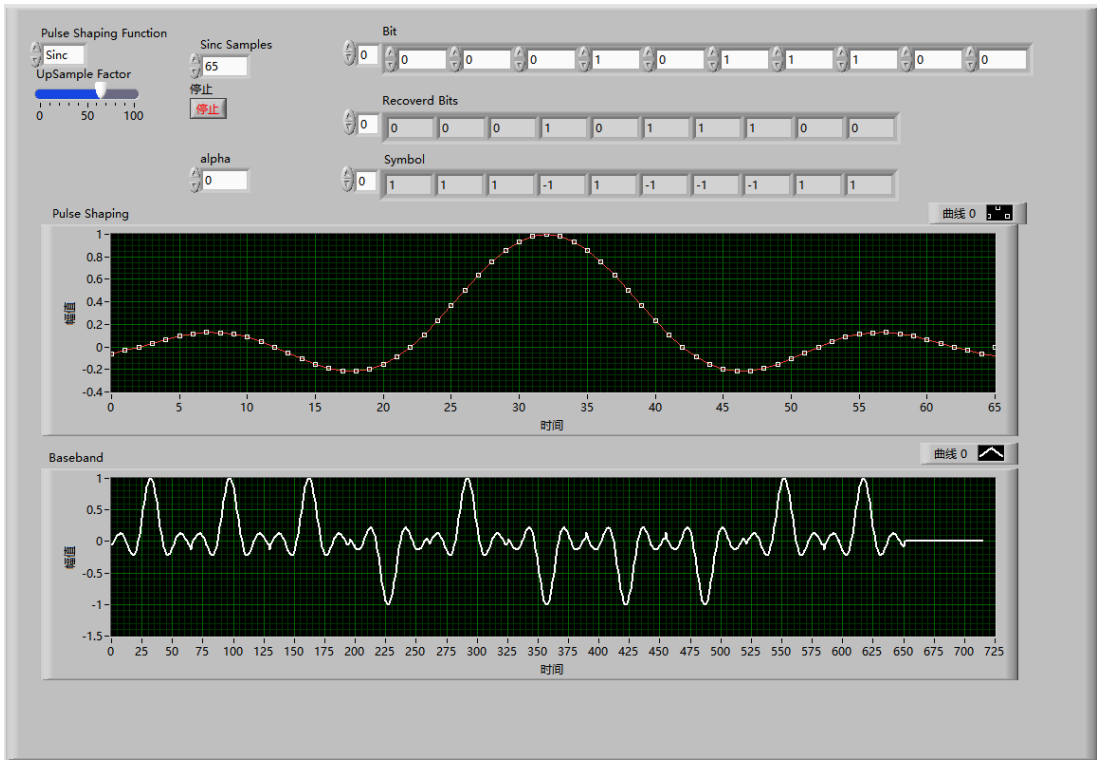
Lab results & Analysis：

1、Digital baseband transmission system simulation (based on formula nodes)

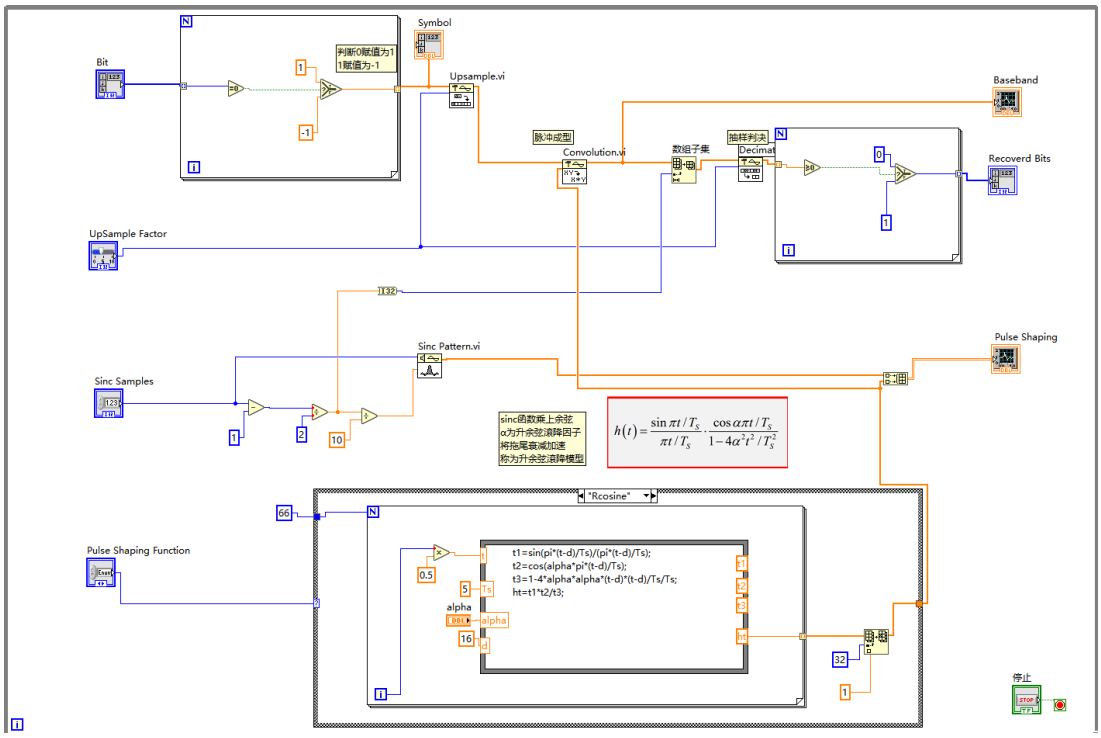
(1)Sinc Mapping



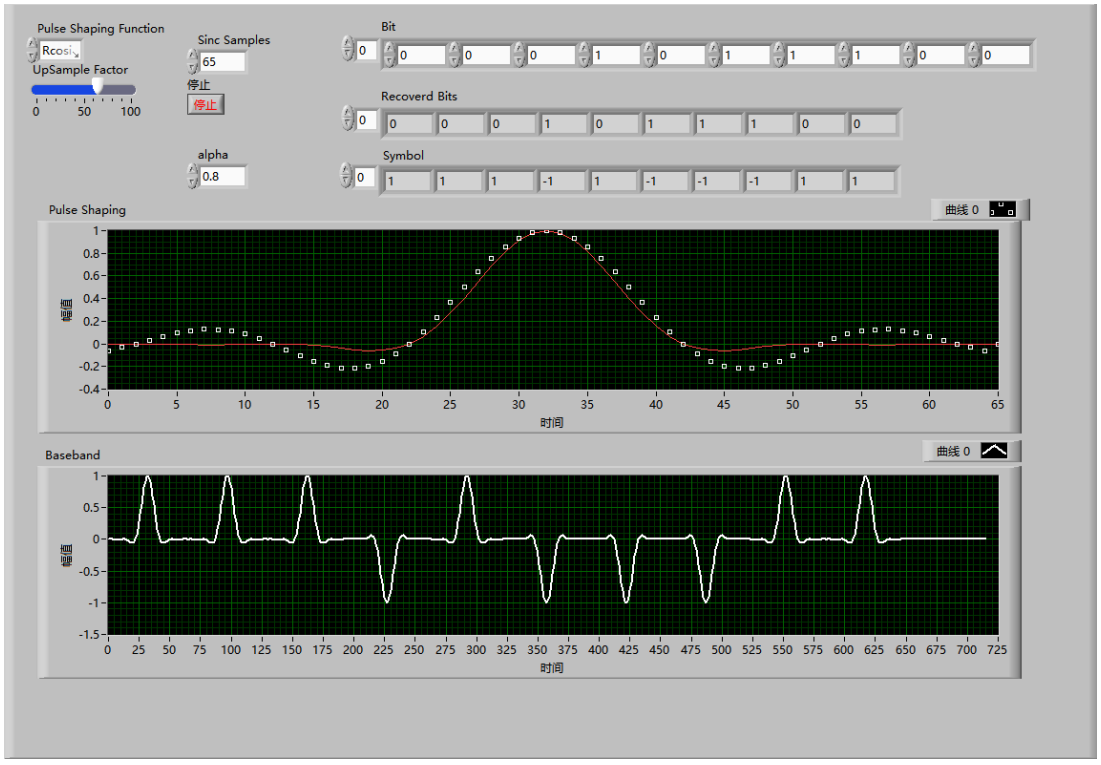
Result:



Ascending cosine roll-off function



Result：



Baseband digital signal transmission, first the bitstream to be transmitted is discriminant assignment, 0 is assigned to -1, 1 is assigned to 1, forming a series of pulse functions, and then up-sampling will expand the interval of the shock sequence, through mapping mapping, the convolution nature of the LTI system, convolution Sinc function, so that the original signal forms a column of equispaced

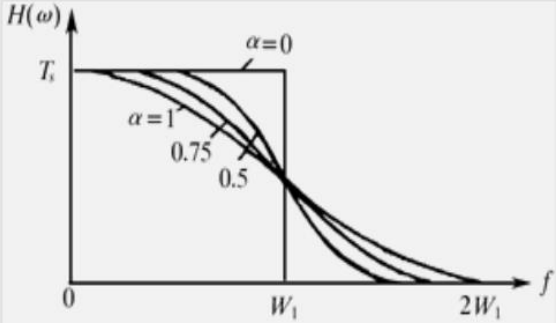
Sinc signals for analog signal transmission. The receiving end is down-sampled and then sampled to form an inverse process with the original digital signal modulation, and finally obtain the received bit stream. The result is shown in the figure.

2. Effect of rising cosine roll-off factor on the system (effect of ISI and bandwidth)

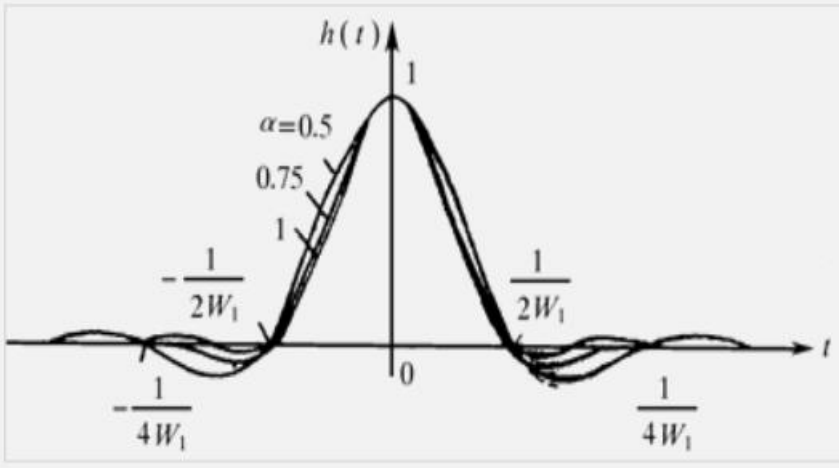
The original signal is mapped using the Sinc function, and if the up-sampling interval is not well controlled, the Sinc modulation between two adjacent bit signals will overlap. In other words, the smearing effect of the Sinc function can mislead the sampling decision, and a poor decision will produce inevitable errors.

$$h(t)=\frac{\sin \pi t / T_S}{\pi t / T_S} \cdot \frac{\cos \alpha \pi t / T_S}{1-4\alpha^2 t^2 / T_S^2}$$

$$H(\omega)=\begin{cases} T_S, & 0 \le |\omega| < \frac{(1-\alpha)\pi}{T_S} \\ \frac{T_S}{2}[1+\sin\frac{T_S}{2\alpha}(\frac{\pi}{T_S}-\omega)], & \frac{(1-\alpha)\pi}{T_S} \le |\omega| < \frac{(1+\alpha)\pi}{T_S} \\ 0, & |\omega| \ge \frac{(1+\alpha)\pi}{T_S} \end{cases}$$



Modify the modulation function to become an ascending cosine roll-off function, as shown in the figure.



ISI:

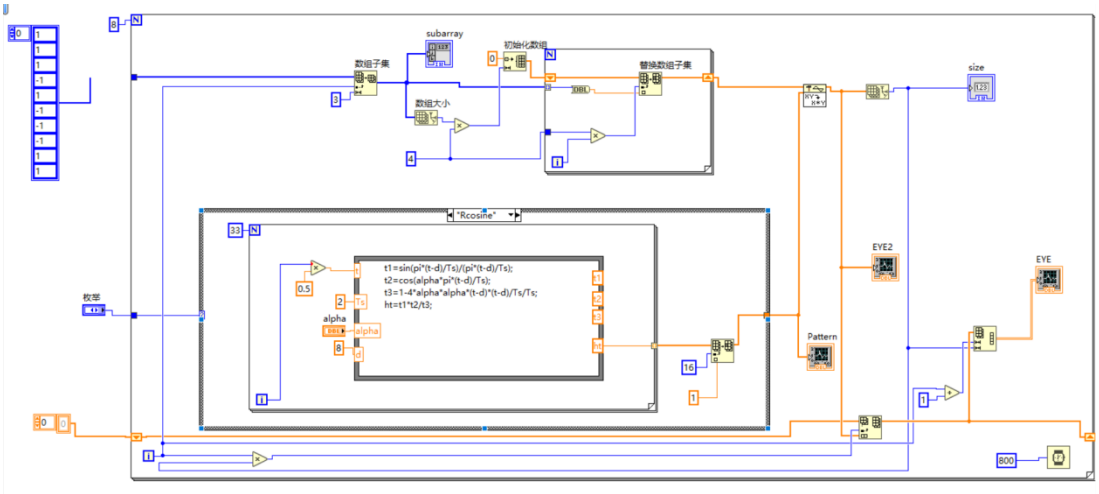
The tailing of the original Sinc function is unchanged because of multiplication of cos, and the decreasing effect of the function is intensified due to the increasing denominator, and the tailing can decay to 0 faster, without occupying more time domains.

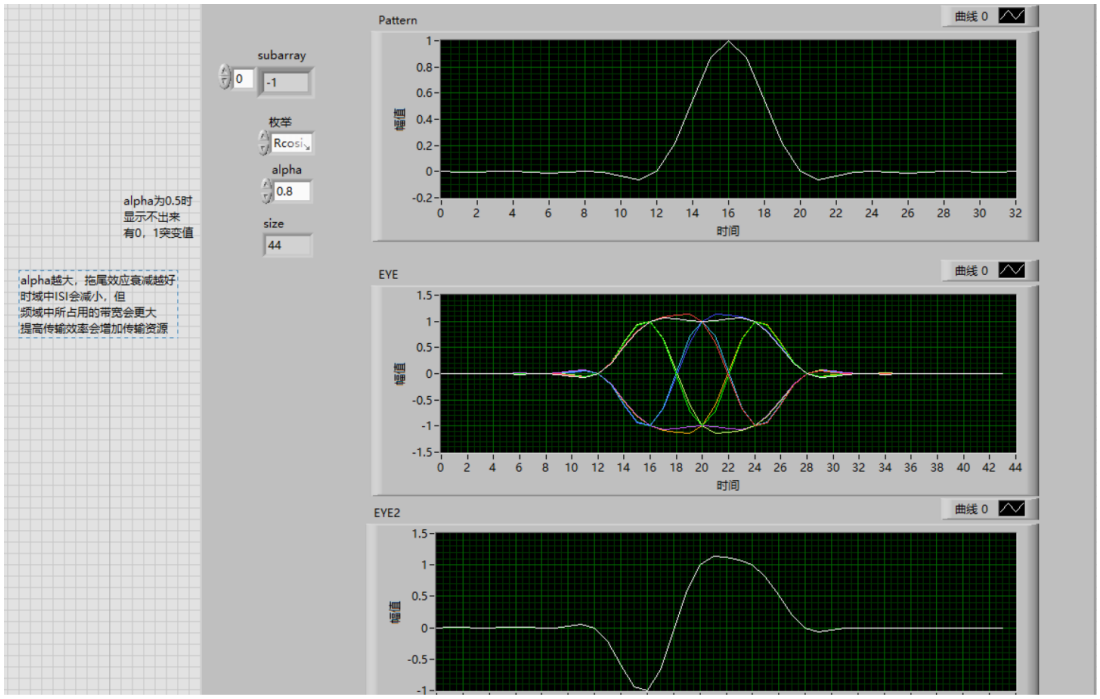
BW in freq:

Through the formula we can deduce W=(1+alpha) w_0, the original bandwidth multiplied by a coefficient becomes the current bandwidth, in the frequency band will occupy more resources, the larger the alpha, the larger the bandwidth in the frequency domain, the maximum to 2w_0.

3.Simulation of the formation process of the eye diagram

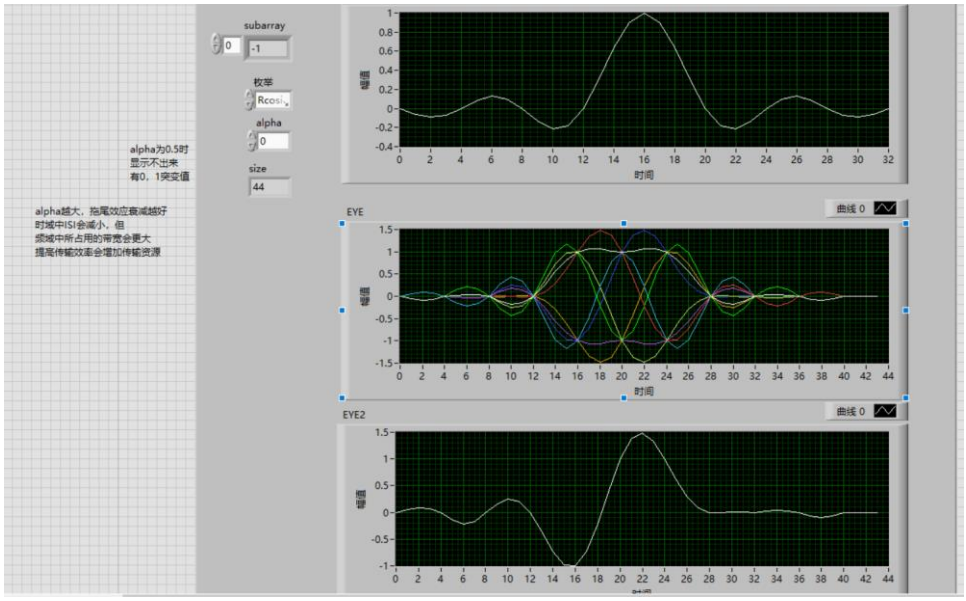
Diagram



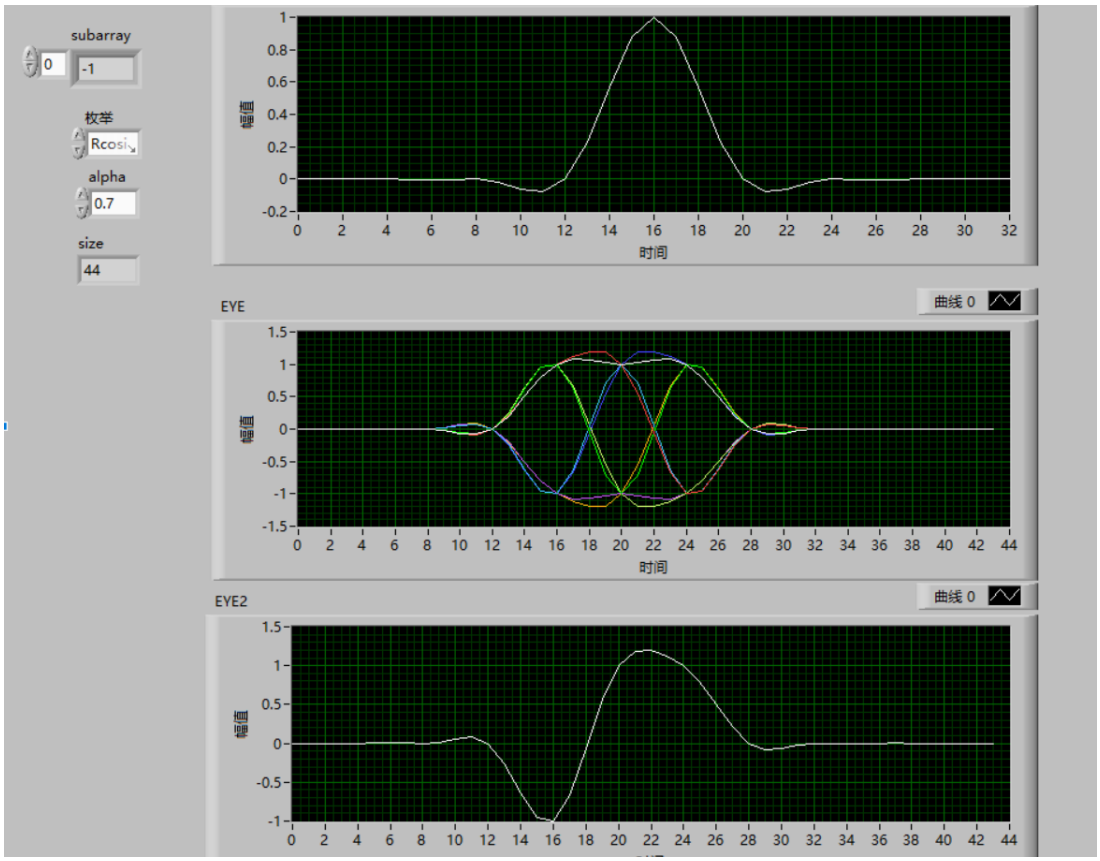


The eye diagram is to superimpose each of the ascending cosine roll-off functions after convolution with the impact function, and the waveforms formed are all placed in a waveform graph, forming the shape of an eye as a whole.

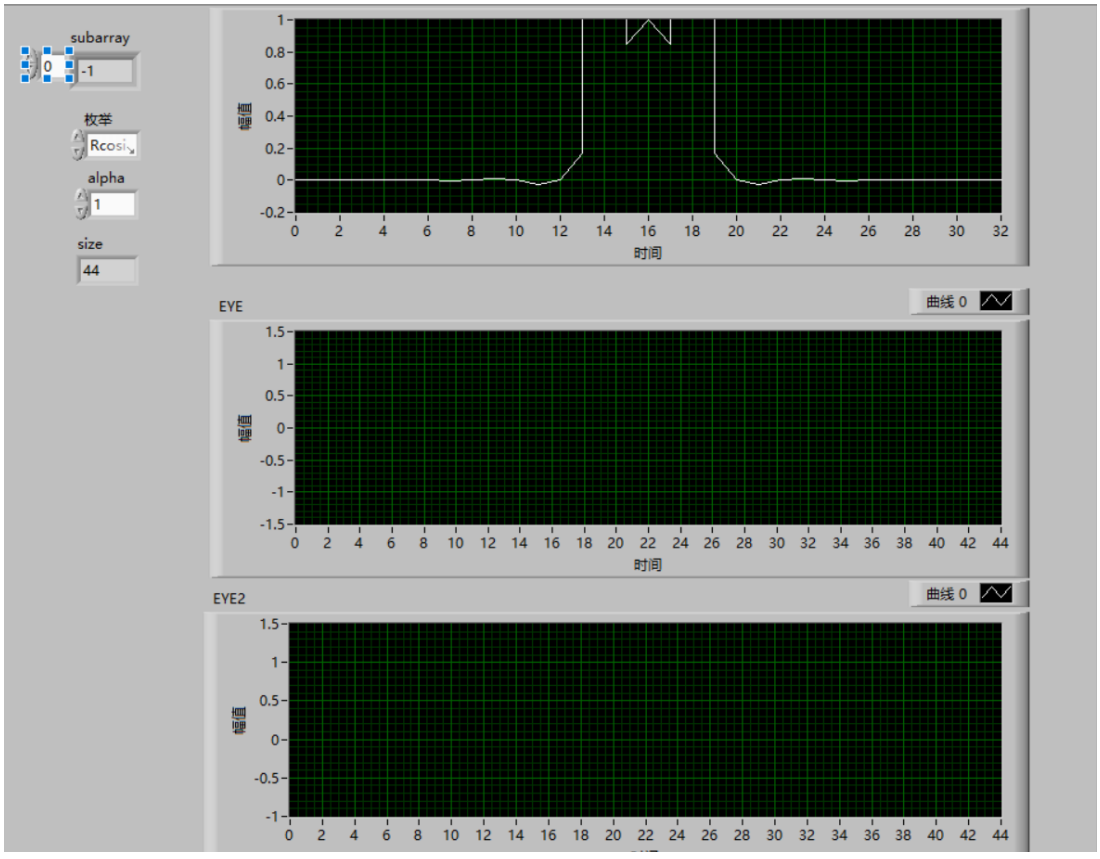
4. Eye diagram under different cosine roll-off factor conditions

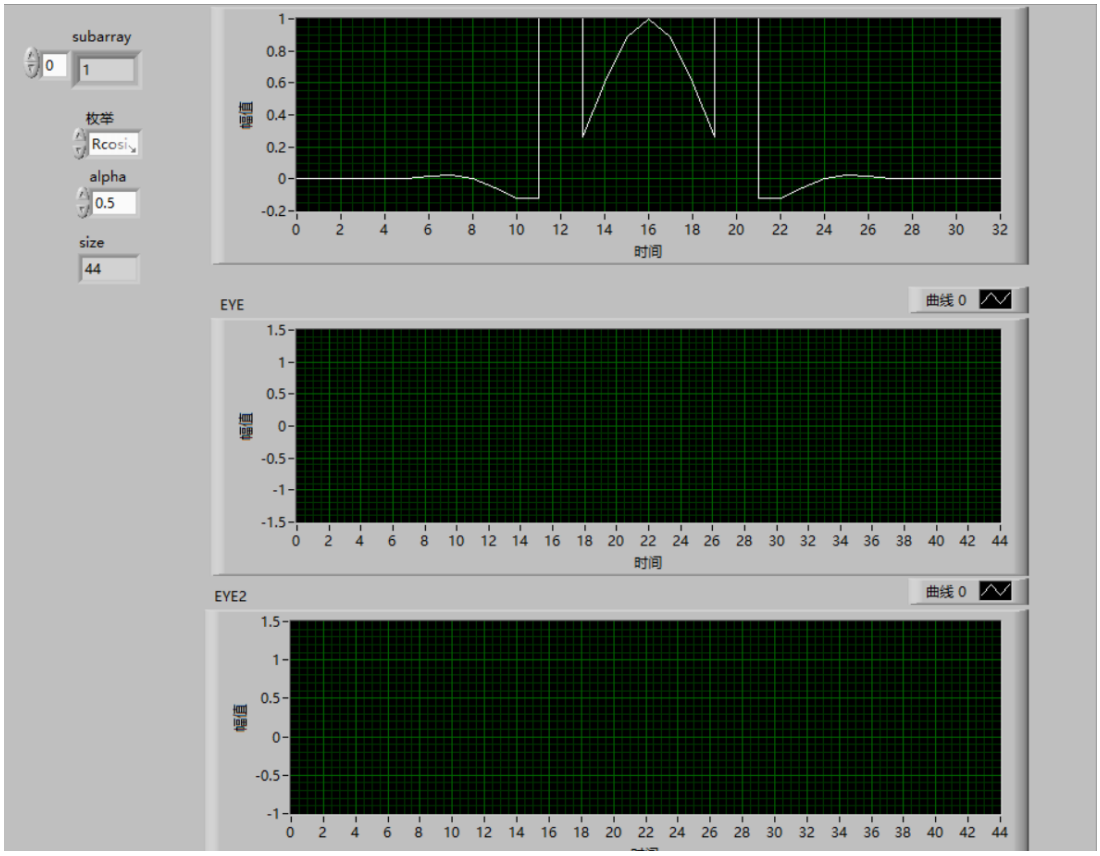


When alpha=0, the eye diagram effect is not good, and the ISI overlap is serious



At alpha=0.7, ISI is significantly reduced





When alpha=0.5 or 1, the eye picture cannot be drawn, because the input of t is only an integer, and the rising cosine roll-off function will only produce a 0,1 mutation, and the waveform modulation cannot be completed. The denominator of the rising cosine may be 0.Mutations are produced

5. Advantages and disadvantages of digital baseband transmission systems

Advantages: The use of the rising cosine roll-off function can effectively reduce ISI, complete the transmission of the digital signal base band, improve the transmission efficiency, and obtain a better receiving signal. In some wired channels with low-pass characteristics, such as twisted pairs, cables, when the transmission distance is not too far, the digital baseband signal can be transmitted directly without modulation

Disadvantages: occupy more baseband bandwidth, improve transmission cost, in the rising cosine roll-off model, the larger the alpha, the better the attenuation of the tailing effect, the ISI in the time domain will decrease, but the bandwidth occupied in the frequency domain will be larger, and improving the transmission efficiency will increase the transmission resources. Moreover, the decoder must be designed to be more accurate, otherwise it is easy to produce decision errors, which greatly reduces SNR.

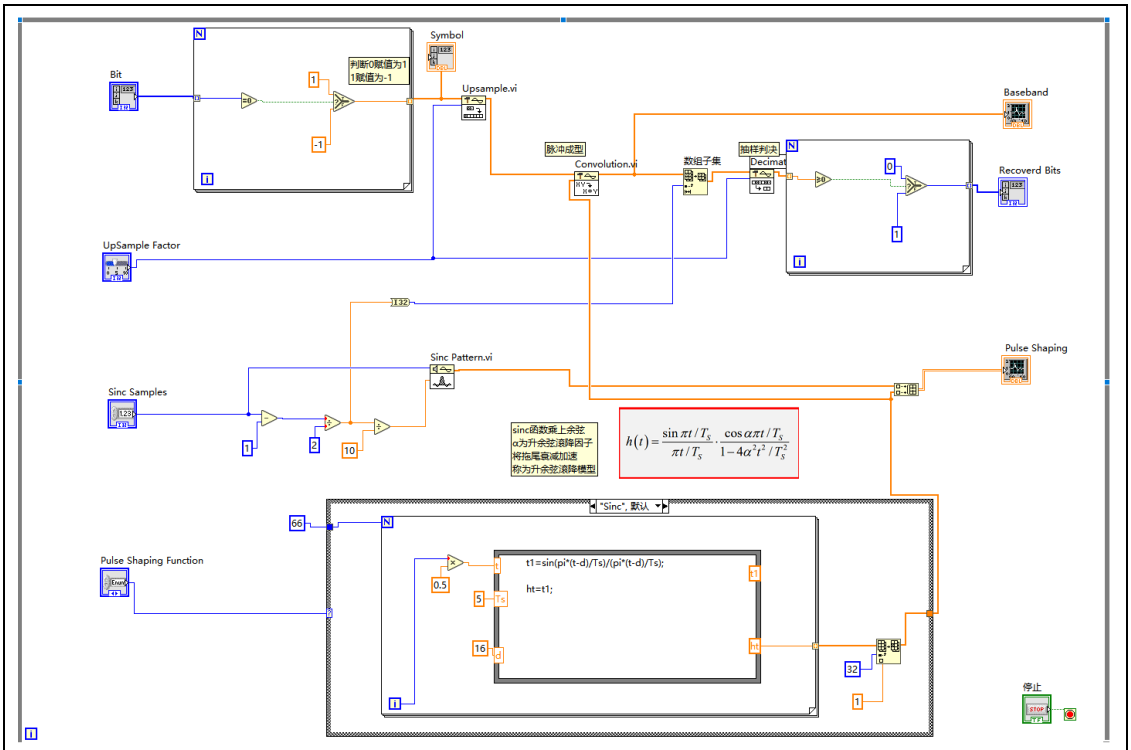
Social application value: The original digital signal that has not been modulated, such as the binary sequence output by the computer, the binary code of various texts,

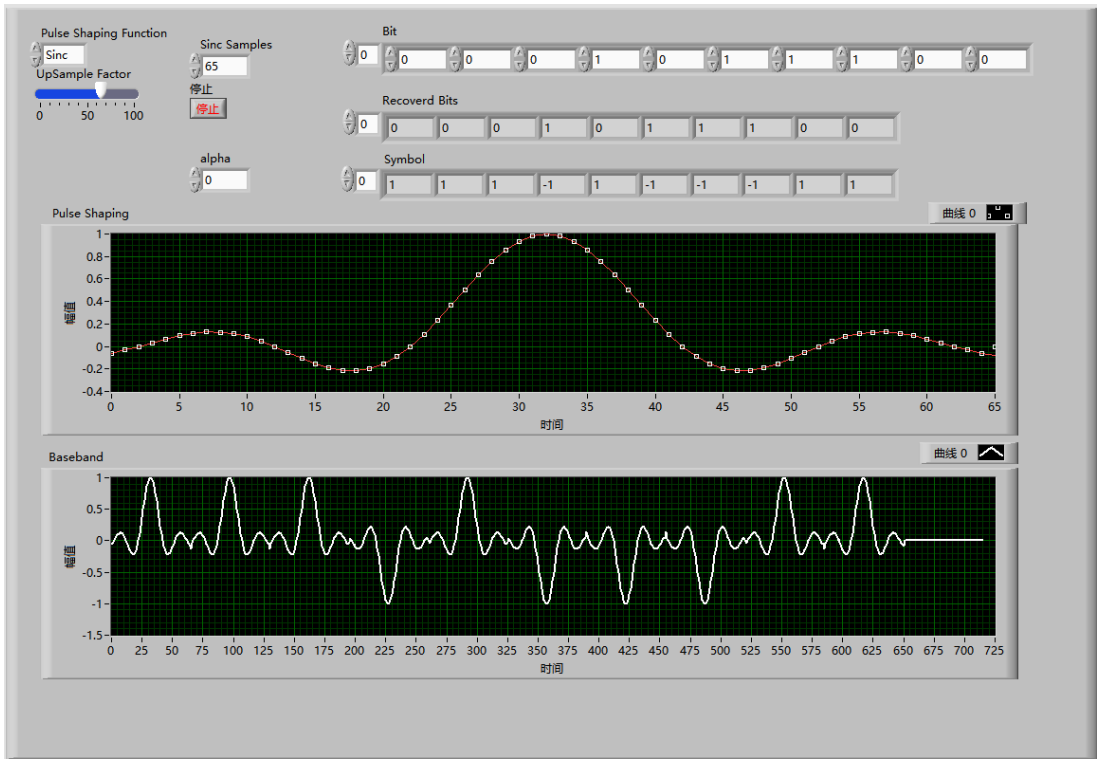
numbers, and images, the code output by the telex machine, the code output by the PCM mode and the M mode, etc., are all digital baseband signals. The main characteristics of digital baseband signals: The bandwidth of the signal spectrum is basically concentrated near the zero spectrum. A digital baseband transmission system is a system used to transmit baseband signals. Baseband transmission system is used to use telex machines for direct telegraph communication over short distances, or to directly transmit PCM signals over long distances by relay. Because the baseband transmission system has an irreplaceable role in the digital transmission system, its application scope has also penetrated into all aspects of life and technology such as network communication, satellite communication and measurement and control, mobile phone communication, digital television, digital telephone and other aspects of life and technology with the development of technology, and has increasingly become the key technology in the digital communication transmission system.

First: It is because many problems of digital baseband systems are also problems that must be considered by frequency band transmission systems. Two: With the development of digital communication technology, baseband transmission also has a rapid development trend, which is not only used for low-speed data transmission, but also for high-speed data transmission; Three: Theoretically, any linearly-modulated frequency band transmission system can always be replaced by an equivalent baseband carrier modulation system.

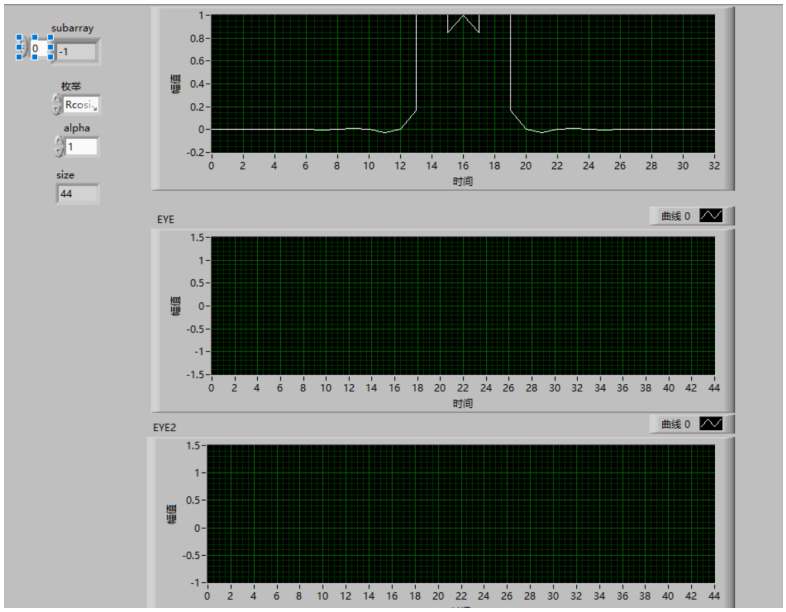
Experience

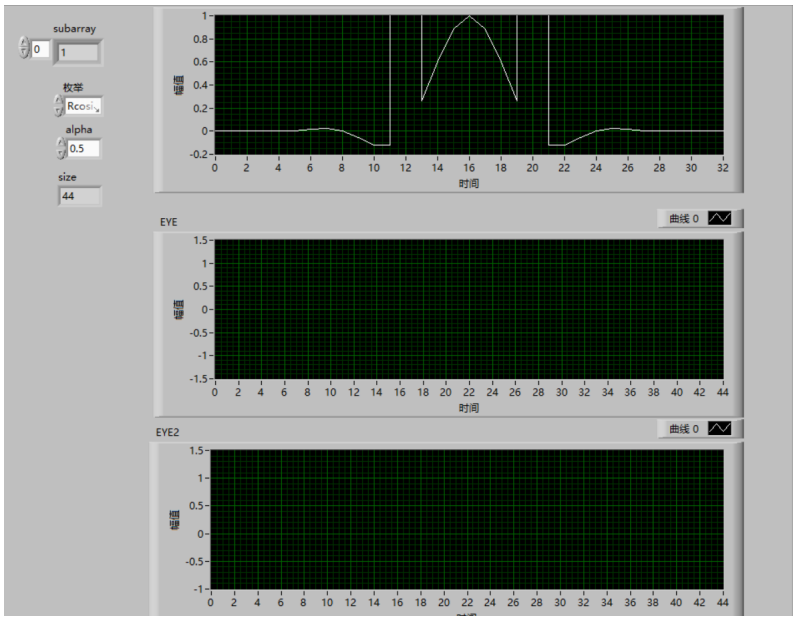
1. **Screenshots of class submissions**





2.Problems we meet





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3.Contribution

We two finish the whole LabVIEW program together. Song Yihang finish the Analysis of Factors Affecting Digital Baseband Transmission System. The introduction and analysis of the advantages and disadvantages of Digital Baseband Transmission system were completed, and its social application value was elaborated by Zhang Haodong.

Contribution ratio :50%,50%

Score	97