Lab 5：SDR Transmission

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Introduction

Basic Principle of Complex Baseband in FM Modulation and Demodulation

Modulation:

$$s_I(nT_S) = A_C \cos(2\pi \int k_f m(nT_S)dt)$$

$$s_Q(nT_S) = A_C \sin(2\pi \int k_f m(nT_S)dt)$$

$$s(nT_S) = s_I(nT_S) + js_Q(nT_S)$$

Demodulation:

$$2\pi \int k_f m(nT_S)dt = \arctan(\frac{s_Q(nT_S)}{s_I(nT_S)})$$

$$m(nT_S) = \frac{1}{2\pi k_f}\frac{d}{dt}\left[\arctan(\frac{s_Q(nT_S)}{s_I(nT_S)})\right]$$

with labview module to implement above equations, we can modulate and demodulate FM signal.

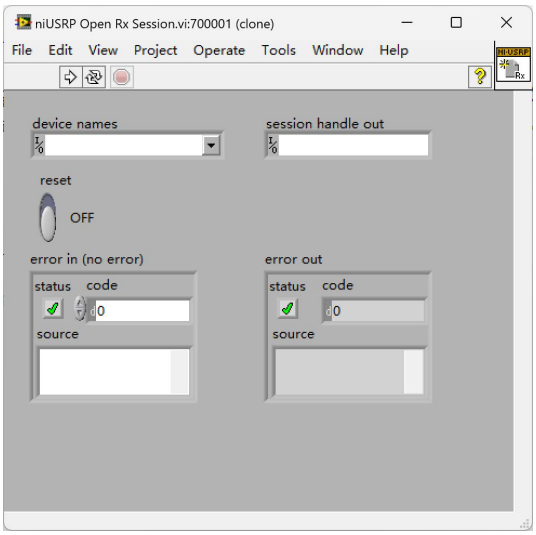
Basic Principle of USRP&RTLSDR

USRP is a general purpose soft-defined radio peripheral that can create various types of wireless communication systems.USRP can send modulated signals through the device.USRP can also capture the wireless signals into the software through the antenna.The captured signals can be processed in labview after ADC and after demodulation the raw signals can be obtained.USRP can also be used as an antenna to capture wireless signals into the software.USRP can be used as an antenna to capture wireless signals into the software.

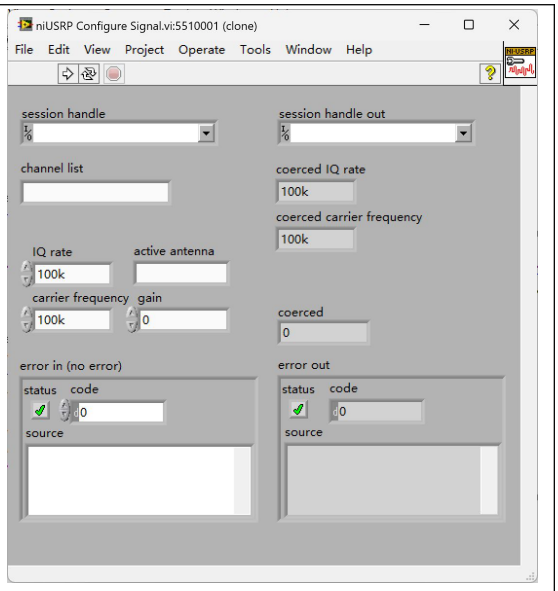
The RTL-SDR transmits raw I/Q signals to a PC via a USB interface, constituting a low-cost soft-defined radio platform.

LabVIEW Module

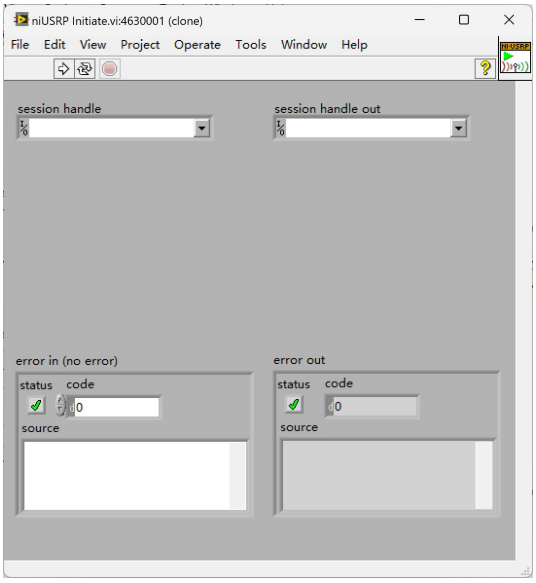
niUSRP



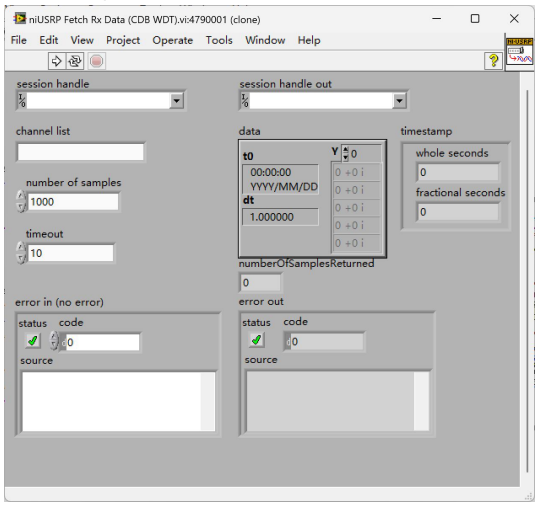
niUSRP Open Rx Session:
open the receiver



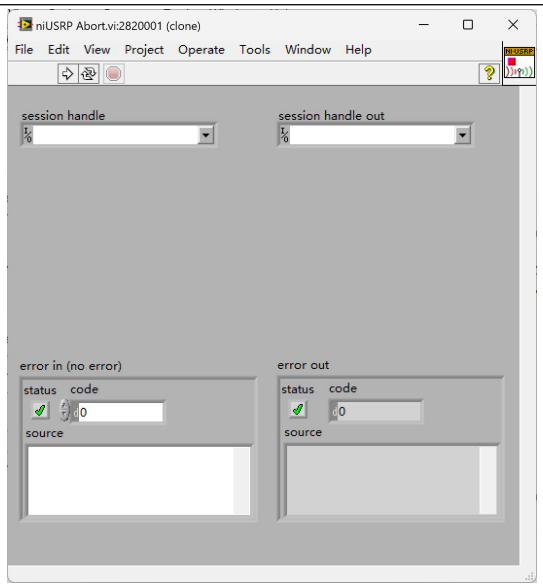
niUSRP Configure Signal:
configure IQ rate, carrier frequency, gain, coerced IQ rate, coerced carrier frequency, coerced gain, active antenna

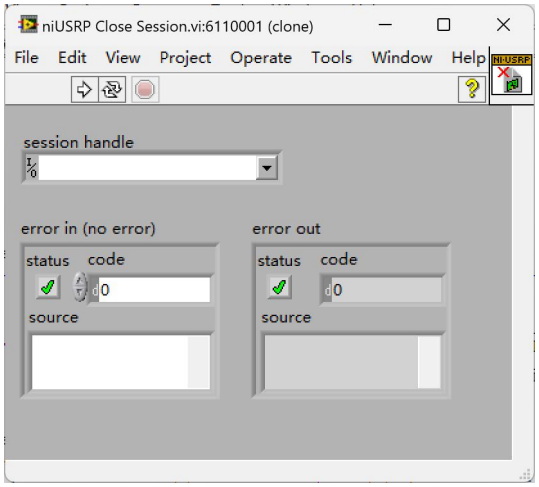


niUSRP Initiate:
initiate the USRP



niUSRP Fetch Rx Data:
choose a way(according to modulation way) to analyze the numbers

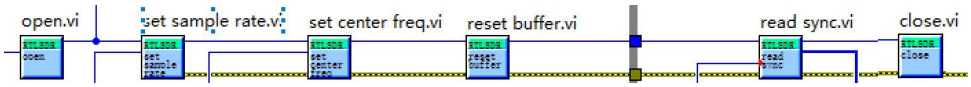




niUSRP Abort:
stop receive data from USRP

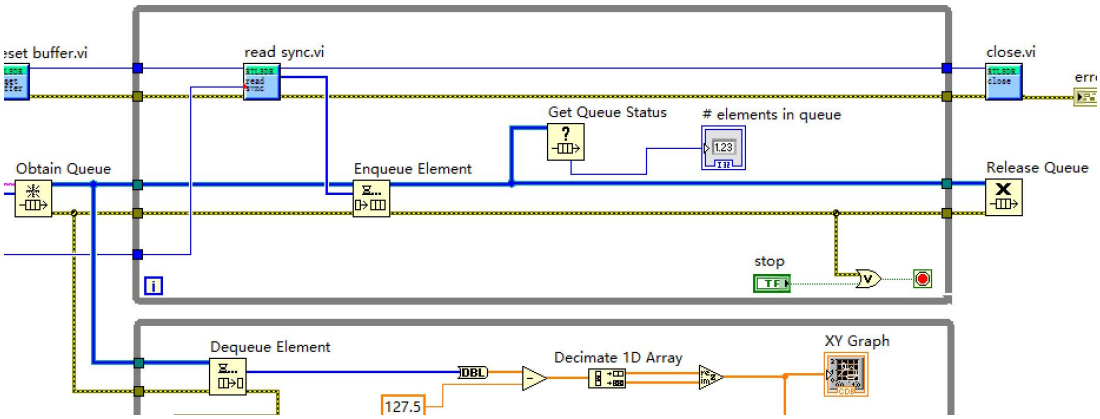
niUSRP Close Session:
close USRP

RTL-SDR Driver



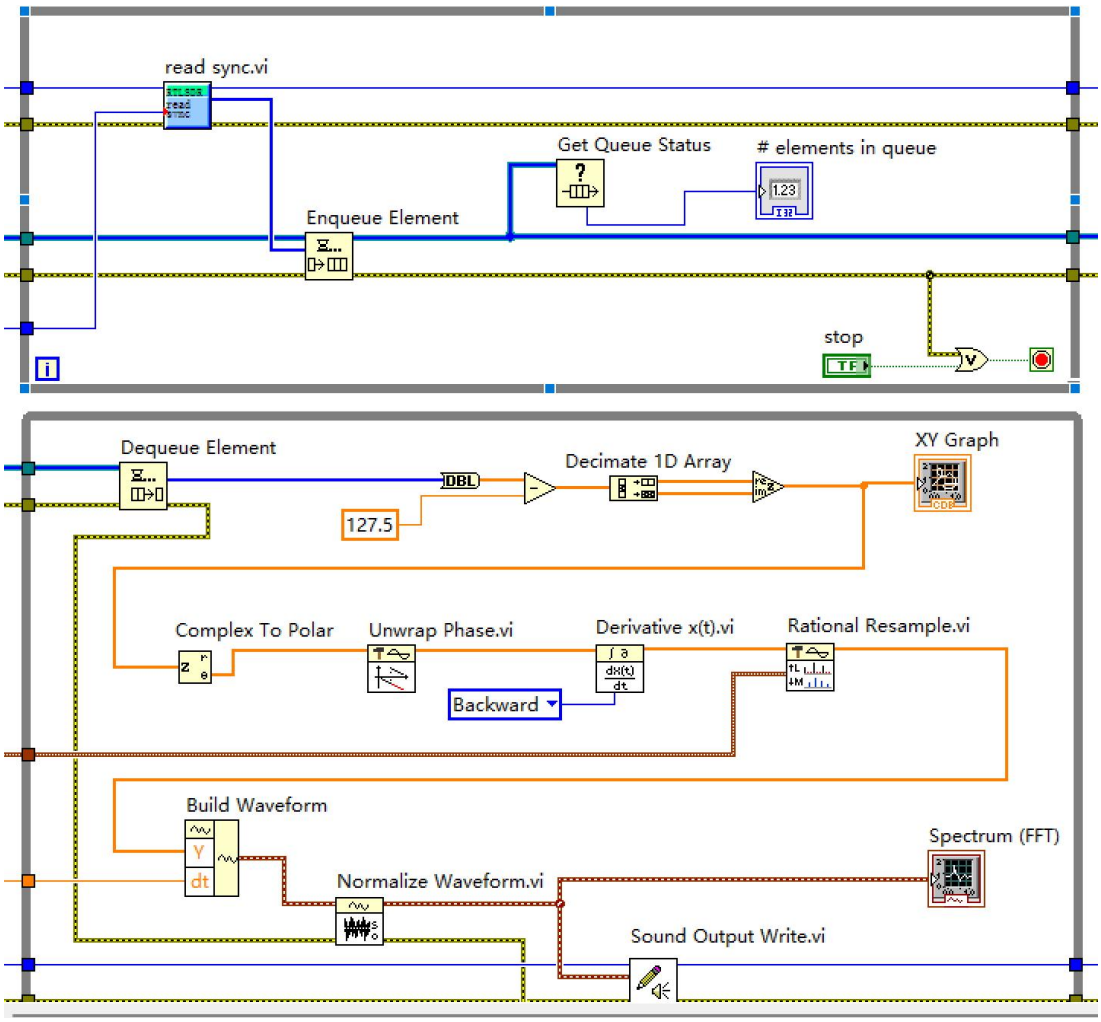
open the RTL-SDR , set parameters(sample rate, center frequency), reset buffer for analyzing, read the signal, close it.

Queue



obtain queue: choose a data type to obtain the queue
enqueue element: put elements into the queue
dequeue element: put elements out of the queue
release queue: put all elements out of the queue

Producer-Customer Structure



the upper one is producer, the lower one is customer

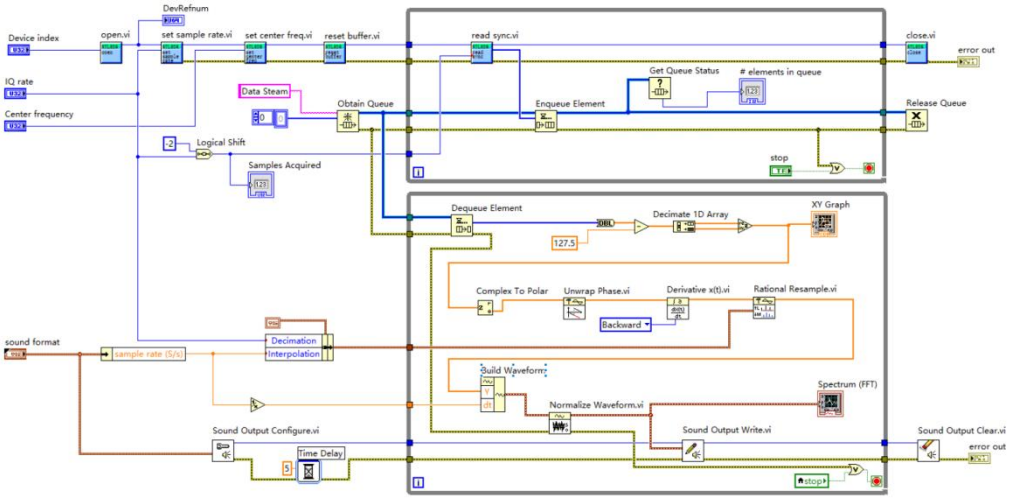
The producer-consumer pattern is a common concurrent programming pattern that has at its core a blocking queue for connecting producers and consumers. The producer is responsible for generating data and the consumer is responsible for consuming that data. Instead of communicating directly between the producer and consumer, they communicate through a blocking queue. After the producer produces the data, it directly throws the data to the blocking queue without waiting for the consumer to process it; the consumer takes the data from the blocking queue without looking for the producer for the data. In this way, the blocking queue is equivalent to a buffer, balancing the processing power of the producer and the consumer.

Lab results & Analysis:

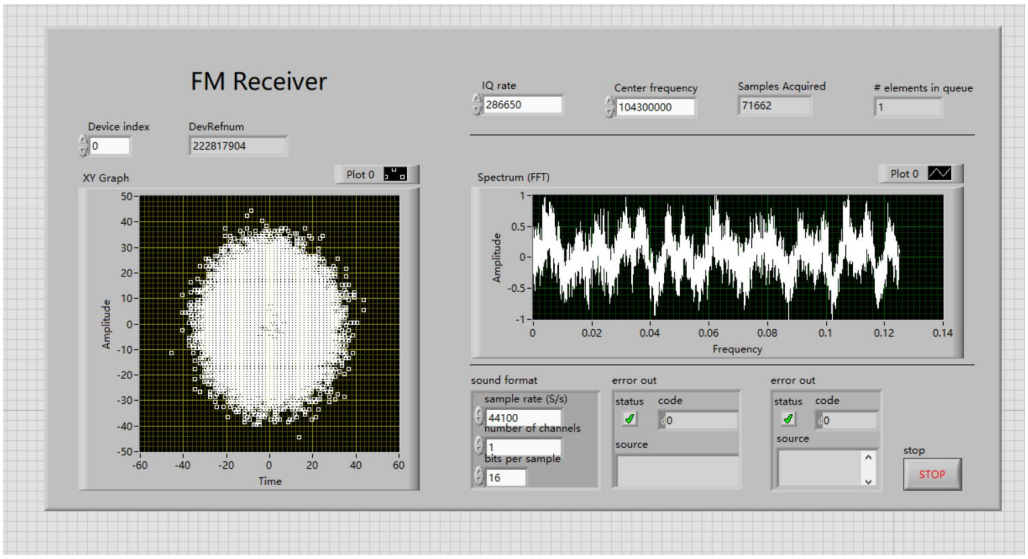
FM demodulation block diagram

1. RTLSDR

Block diagram

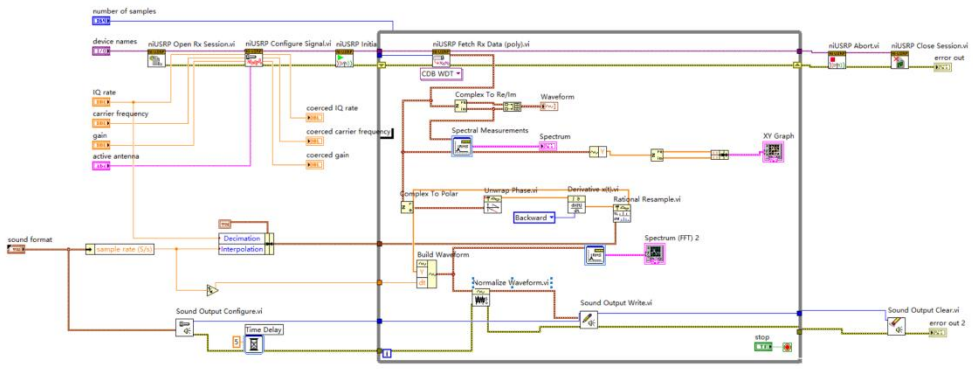


Simulation result

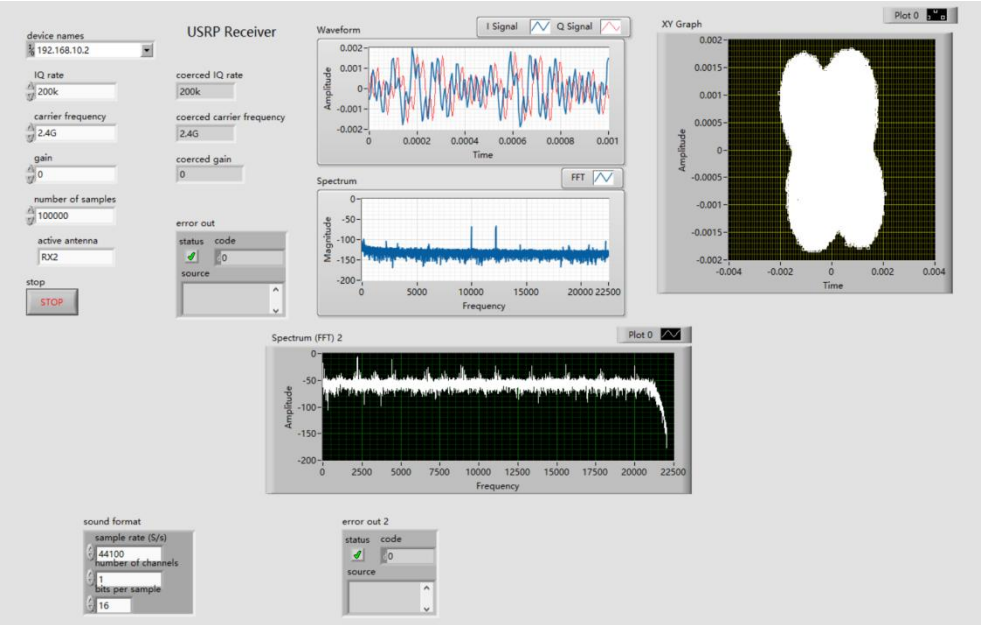


2. USRP

Block diagram



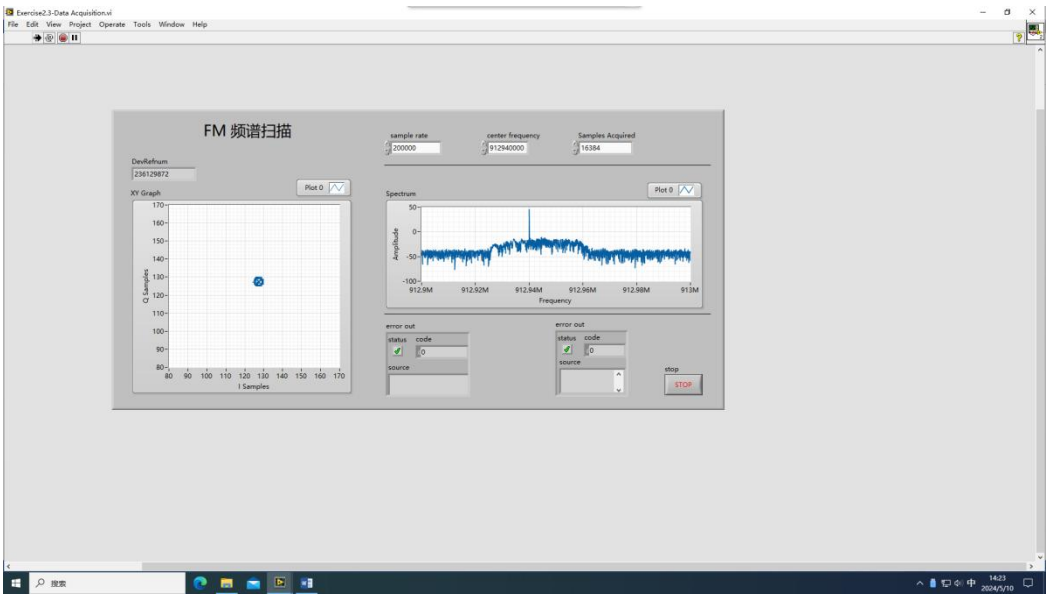
Simulation result



Factors affecting the FM modulation system

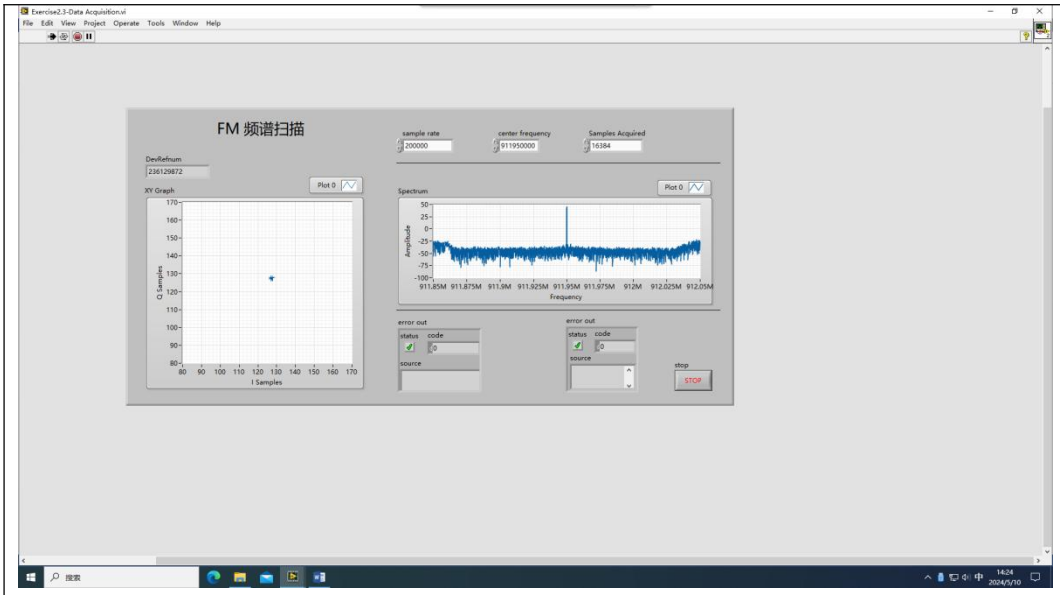
frequency offset

Song



Signal at 912.94 MHz

Music

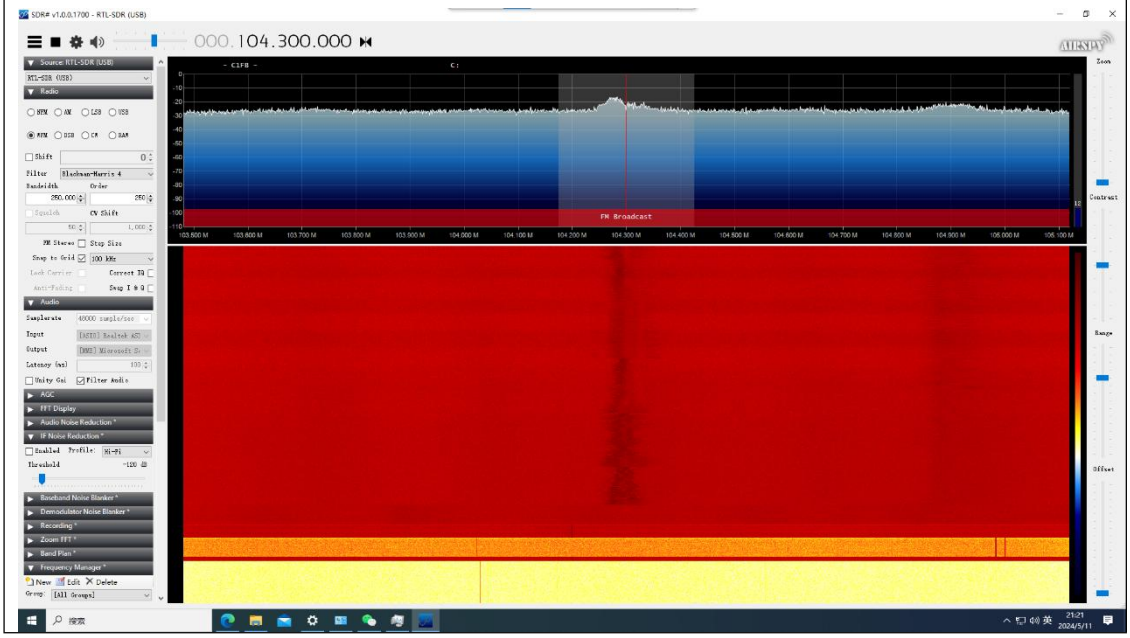


Signal at 911.95 MHz

Since the transmitter transmits at an integer multiple of 1M, the RTLSDR frequency offsets are considered to be 0.06MHz and 0.05MHz respectively.

Effect of receiver frequency bias on FM modulation: in FM modulation, information is transmitted by changing the frequency of the carrier. If the frequency of the receiver does not match the transmission frequency (i.e., there is a frequency bias), it may lead to frequency misinterpretation in the demodulation process, which makes the demodulated signal different from the original signal and produces distortion.

Bottom Noise and FM Signal Bandwidth



Signal Bandwidth

The band highlighted in the graph is the FM broadcast signal at 104.300 MHz. FM broadcast signals typically have a wide bandwidth, typically 200 kHz. this can be seen directly on the horizontal axis of the spectrum in the graph, where the signal broadens around the centre frequency of 104.300 MHz.

Bottom Noise

The bottom noise in the graph can be seen on both sides of the signal peak. The effect of the level of bottom noise on FM demodulation is mainly seen in the SNR. The lower the base noise, the higher the SNR, which means that the quality of the signal is better and the demodulated audio signal is clearer.

Influence

The influence of the noise floor and the signal bandwidth on FM demodulation is mainly expressed through the SNR. If the noise floor is too high, the quality of the received signal may deteriorate due to a poor signal-to-noise ratio, even though the bandwidth is sufficient. In FM broadcasting, the ideal situation is to have a clear signal peak and a low level of noise floor, which ensures the quality and clarity of the audio output.

Advantages and disadvantages of FM modulation system

Advantages

Highly resistant to interference:

FM modulation is insensitive to variations in the amplitude of the signal, which means it is effectively resistant to amplitude noise, such as electrostatic interference and other environmental noise. This feature allows FM modulation to maintain signal quality in complex electromagnetic environments.

Excellent sound quality:

Thanks to its immunity to interference, FM broadcasting is able to provide a higher quality audio output, which is particularly important for music and voice transmissions, making broadcast content clearer and easier to understand.

Mature technology and widely available equipment:

FM technology has been in widespread use for many years, the associated transmitter and receiver equipment is well-produced and relatively low-cost, and the user interface is often simple and easy to use.

Disadvantages

Spectral inefficiency:

FM modulation is less spectrally efficient than some of the newer modulation techniques, such as digital modulation. It requires a wider bandwidth to transmit information, which can be a disadvantage today when spectrum resources are tight.

Equipment and operating costs:

While receiving equipment is relatively inexpensive, high-quality FM transmitting equipment can be costly, especially for high-power transmissions. In addition, there is some technical support and expense required to operate and maintain such equipment.

Inability to carry more information:

FM modulation transmits a limited amount of data compared to digital signals, which limits its use in data-intensive applications.

Social application value

Radio services:

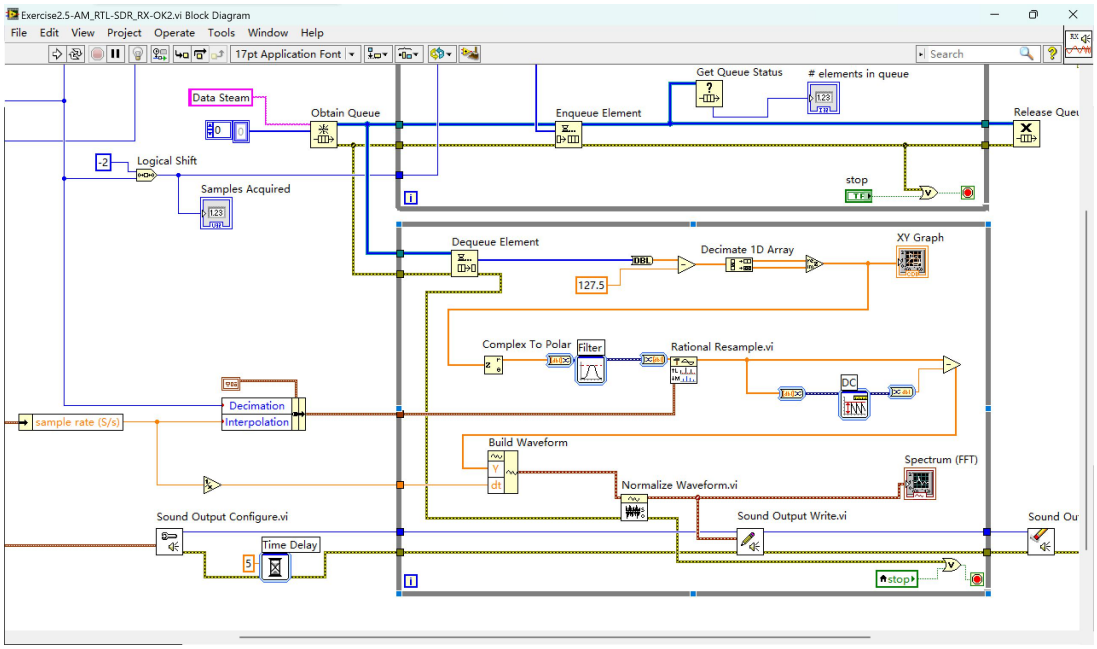
FM radio is one of the most popular applications in the world, providing not only music and entertainment content, but also an important distribution channel for news, weather forecasts, traffic information and emergency alerts.

Emergency Communications:

During natural disasters or other emergencies, when other means of communication may fail, FM modulation is able to continue to provide critical communication services due to its stability and wide range of receiving devices.

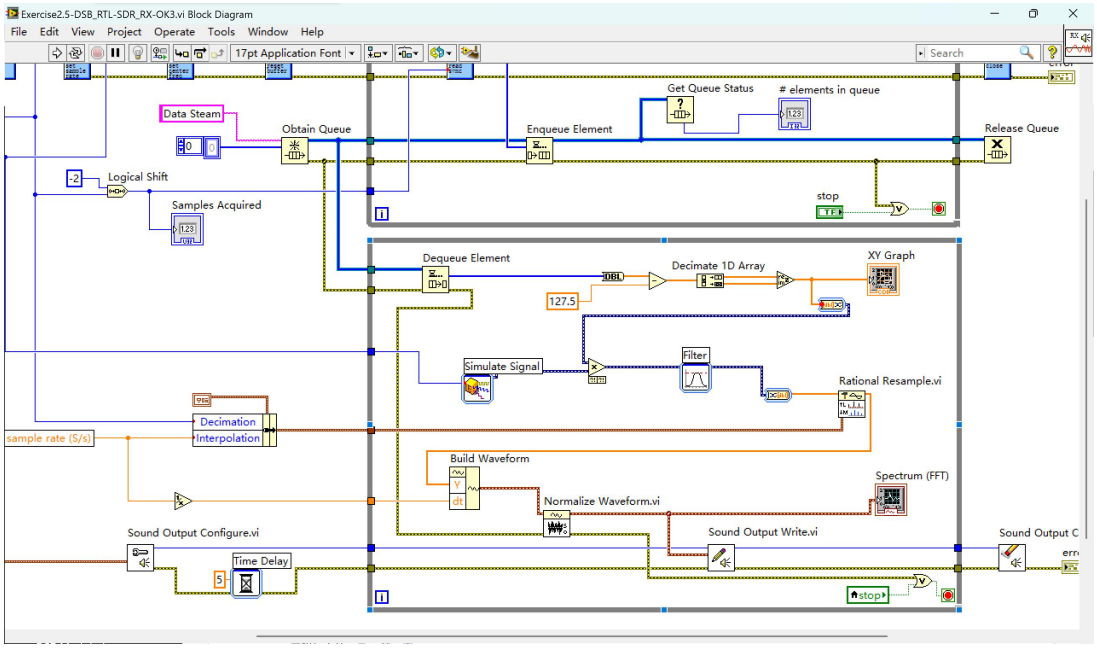
Extension

RTL-SDR AM Demodulation



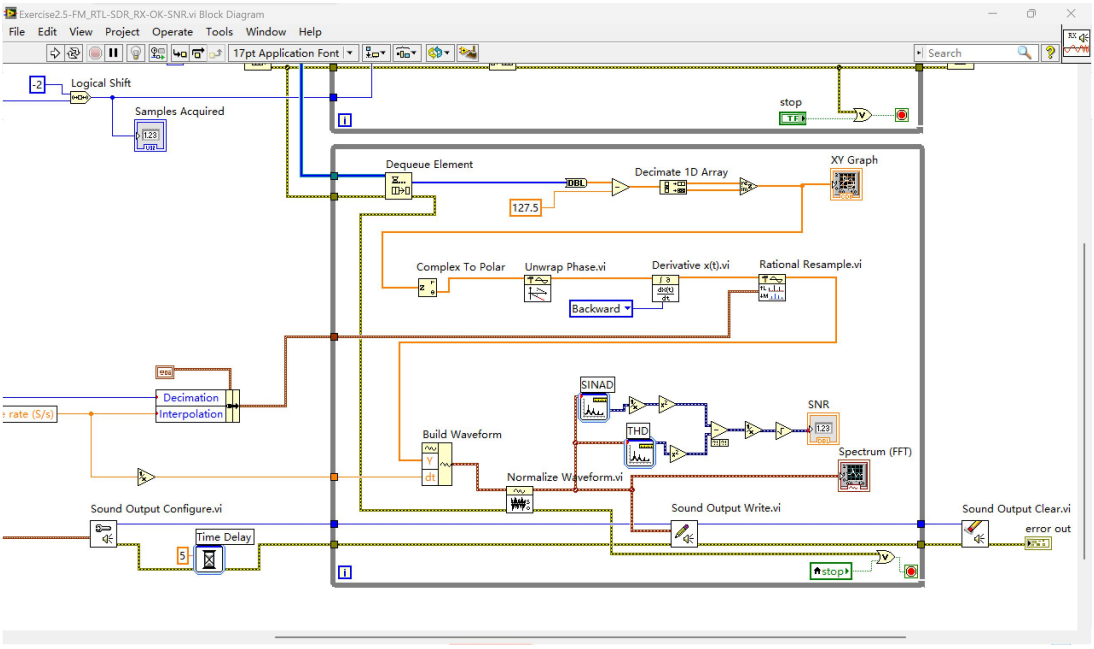
For AM signal, we can take the envelope of it, and then take the direct component off, then the signal is demodulated.

RTL-SDR DSB Demodulation



For DSB signal, after multiplying carrier signal and filter, we can demodulate it.

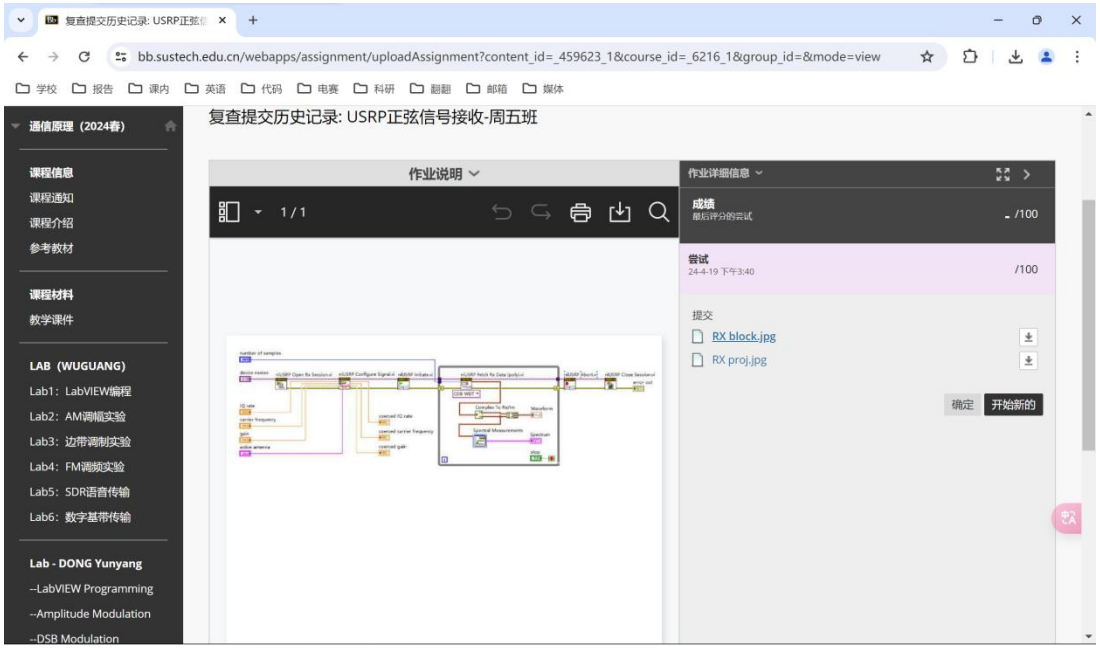
SNR



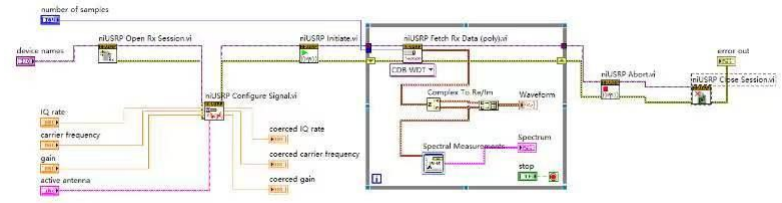
According to NI official website, $SNR \approx ((THD+N)^2 - THD^2)^{-\frac{1}{2}}$

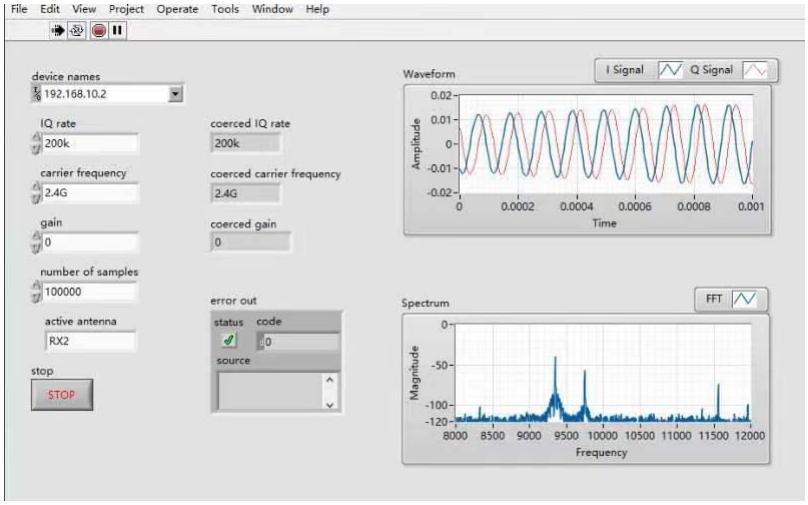
Screenshot of class submission

Ying Yiwen



Chen Weiyu





Experience

We learned about the transmitter and receiver of USRP, demodulation of AM,DSB,FM signal in RTL-SDR, ways to find the signal center frequency.

Contributions

Ying Yiwen: Basic program design, introduction, extension
Chen Weiyu: Basic program design, analysis

Score	100/100