SDR FM transceiver design

——Voice signal transmission based on USRP platform

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Theoretical basis and LabVIEW module

- Principles of FM modulation and demodulation
- Arc-tangent method
- Phase unwrapping module
- Waveform resampling module

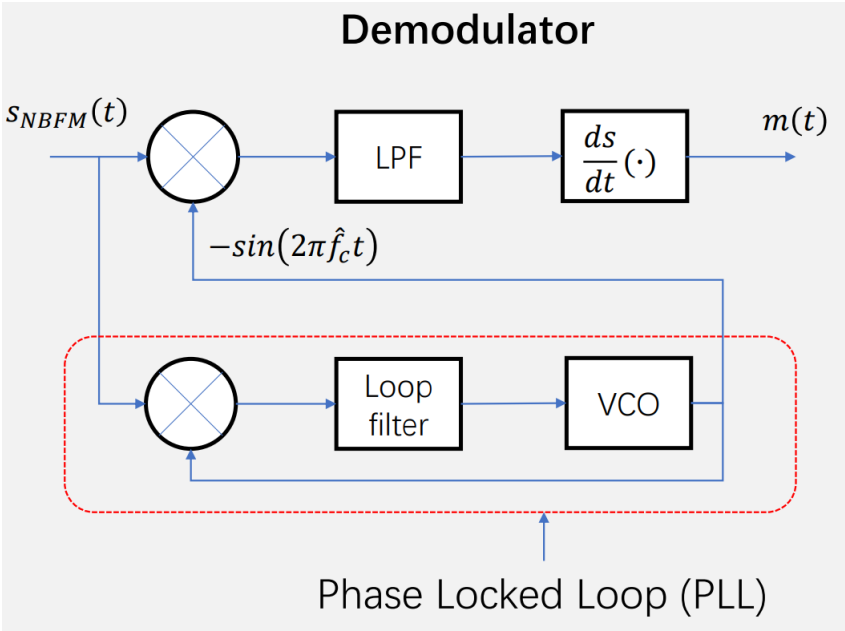
Principles of FM modulation and demodulation

$$f_{FM}(t) = A_c \cos[2\pi f_c t + 2\pi k_f \int_{-\infty}^{t} m(\tau)d\tau]$$

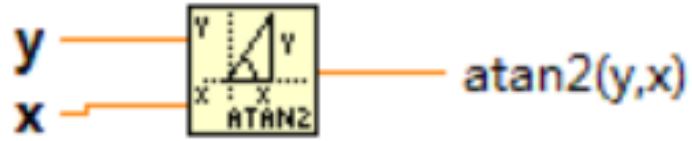
$$s_{FM}(t) = A_c \cos\left[2\pi k_f \int m(\tau)d\tau\right] \cos(2\pi f_c t) - A_c \sin\left[2\pi k_f \int m(\tau)d\tau\right] \sin(2\pi f_c t)$$

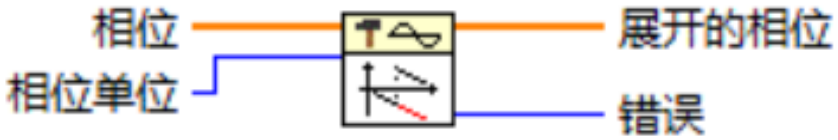
$$\cos(\beta \sin \omega_m t) \approx 1, \quad \sin(\beta \sin \omega_m t) \approx \beta \sin \omega_m t$$

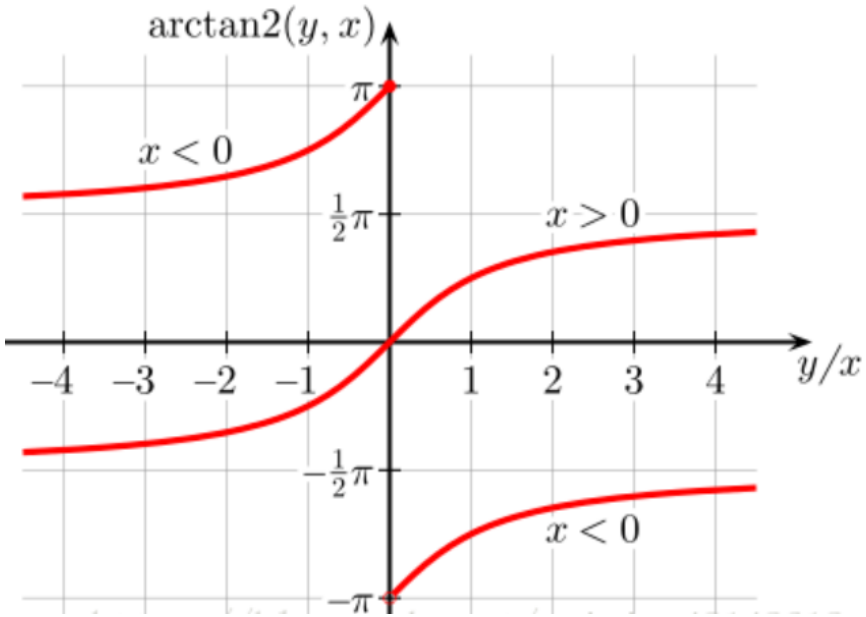
$$f_{NBFM}(t) \approx A_c[\cos \omega_c t - \beta \sin \omega_m t \sin \omega_c t]$$

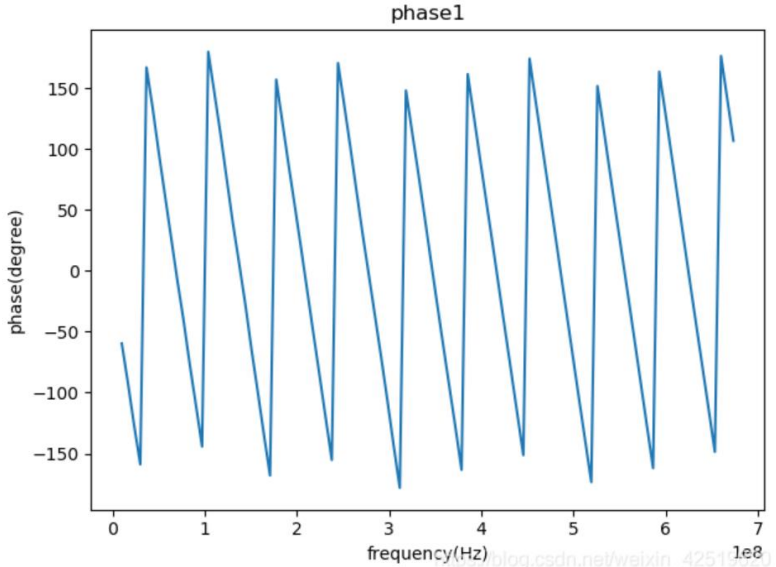


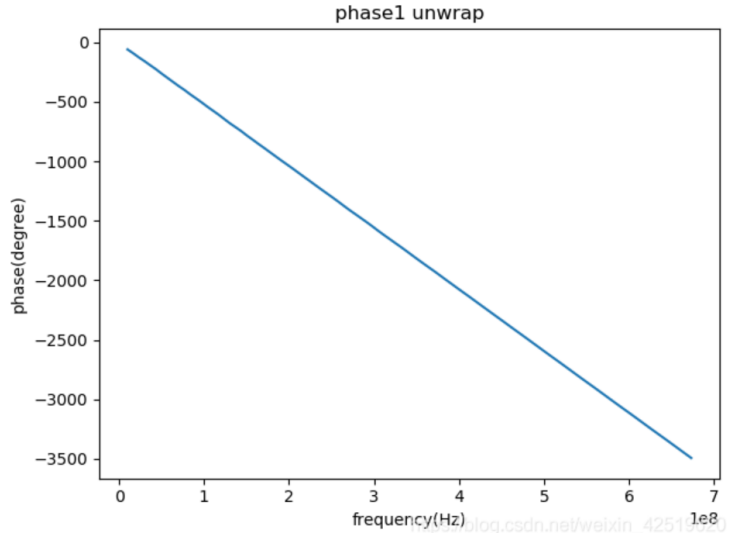
Arc tangent method, phase unwrapping module

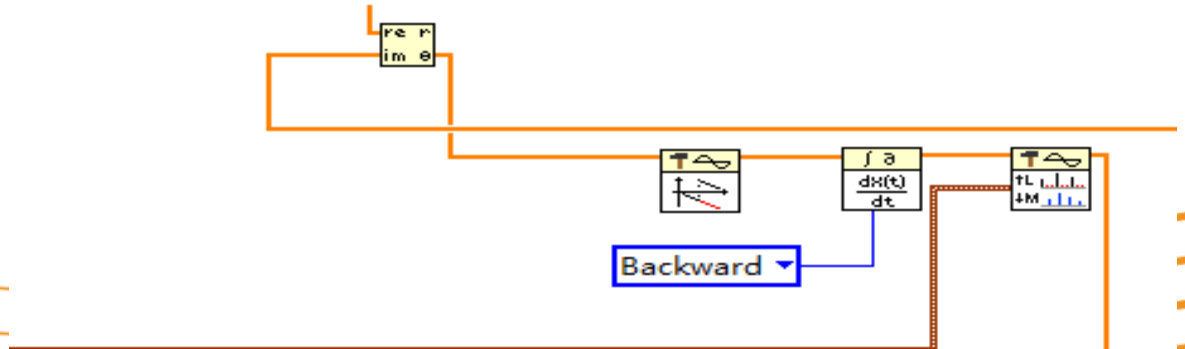




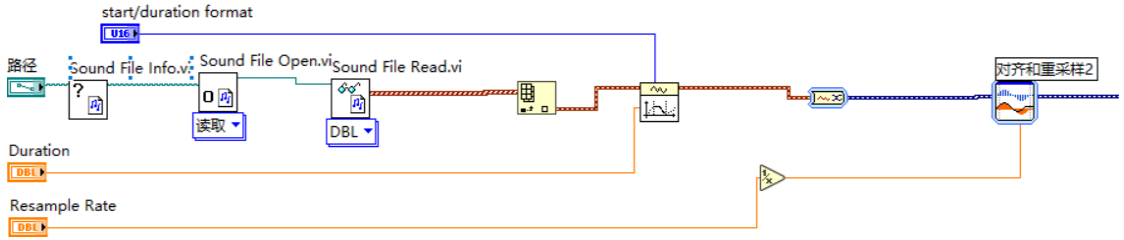




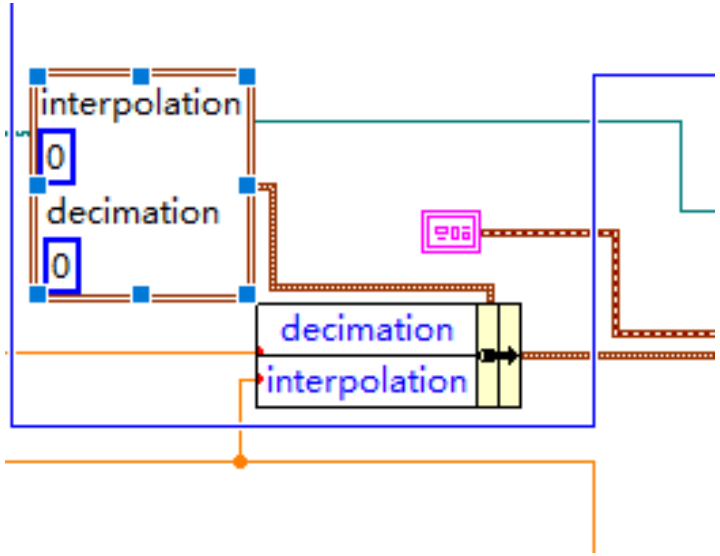


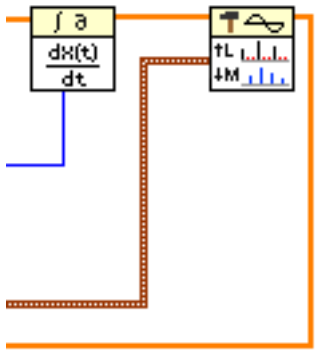


Waveform resampling module

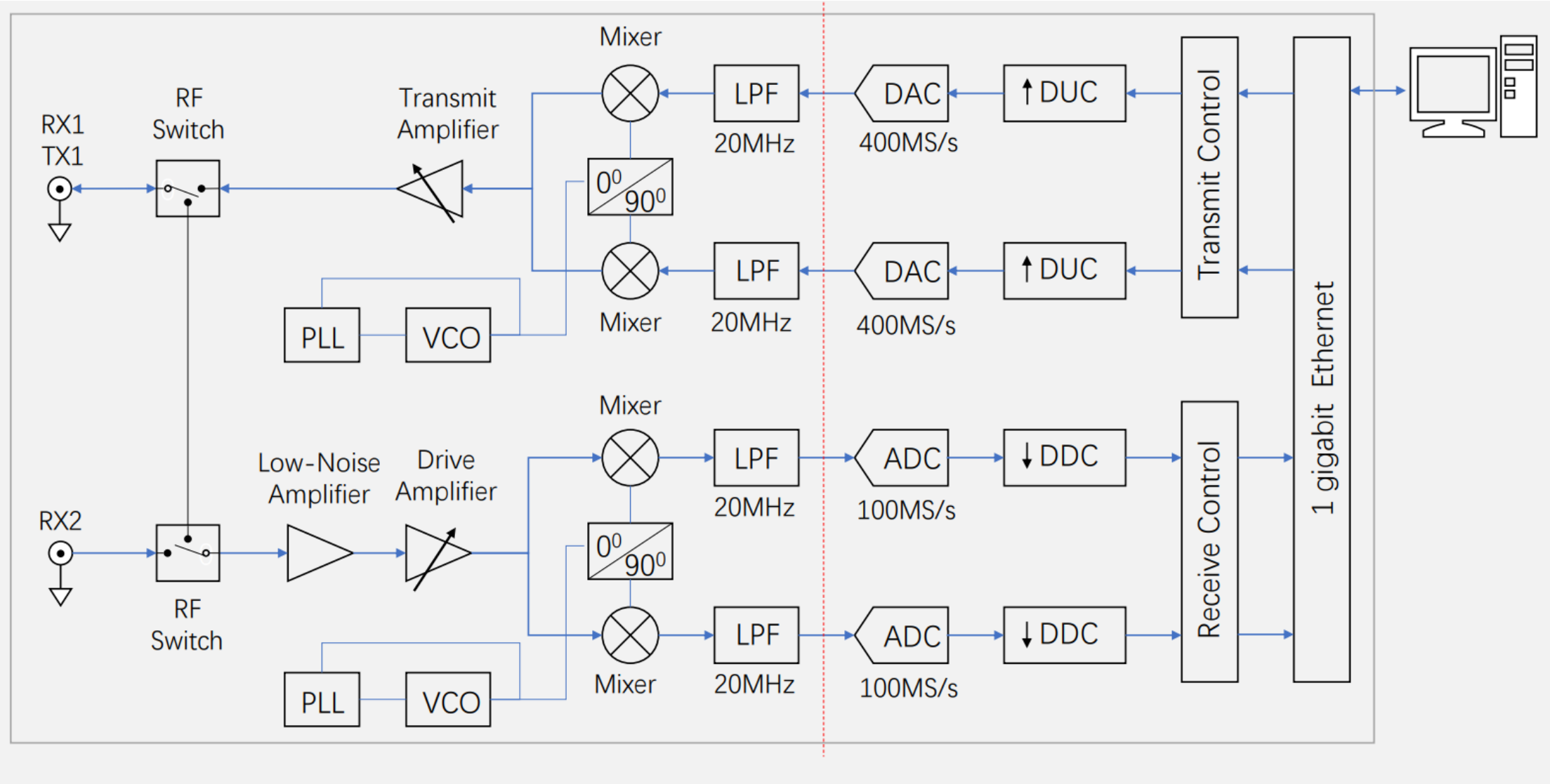


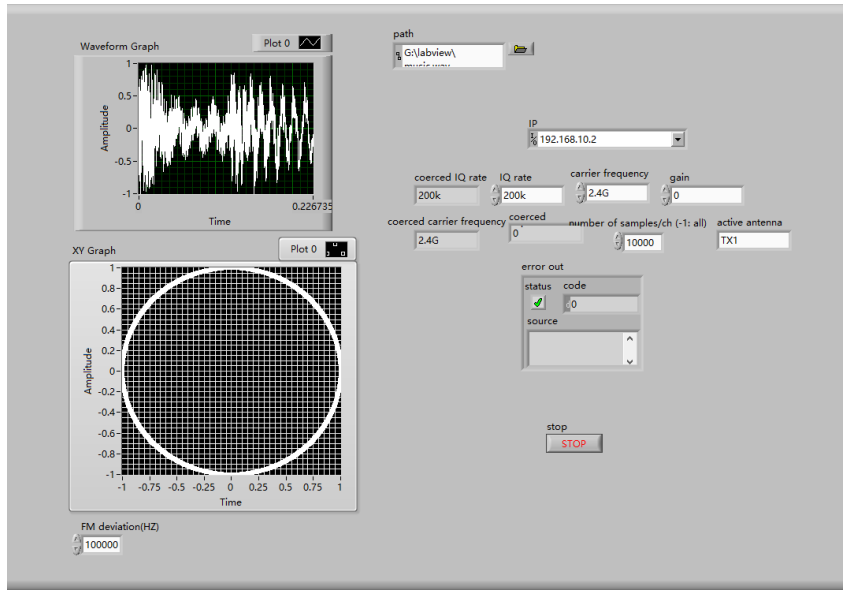
match the sample rate of others because only one sample rate is allowed in a system

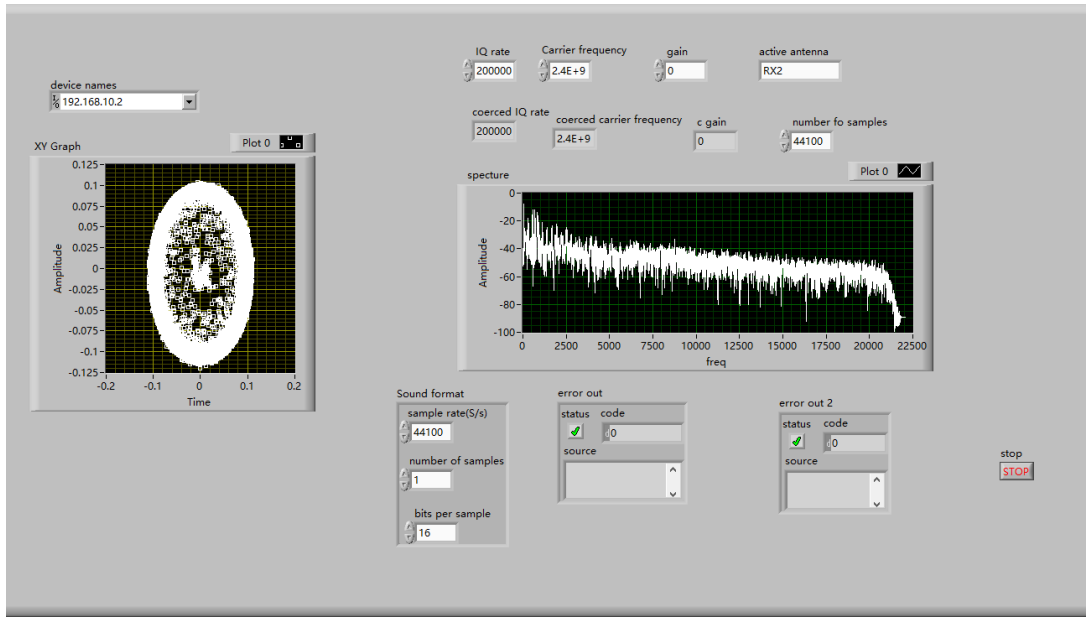


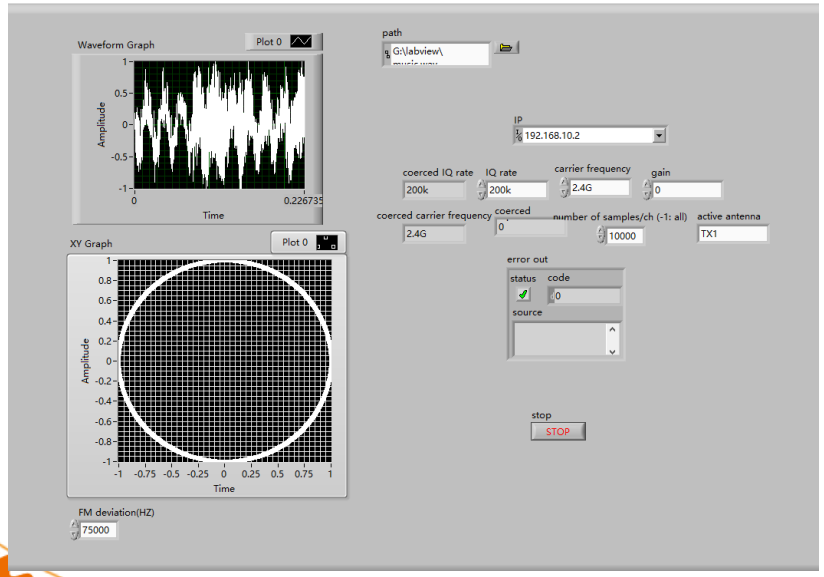


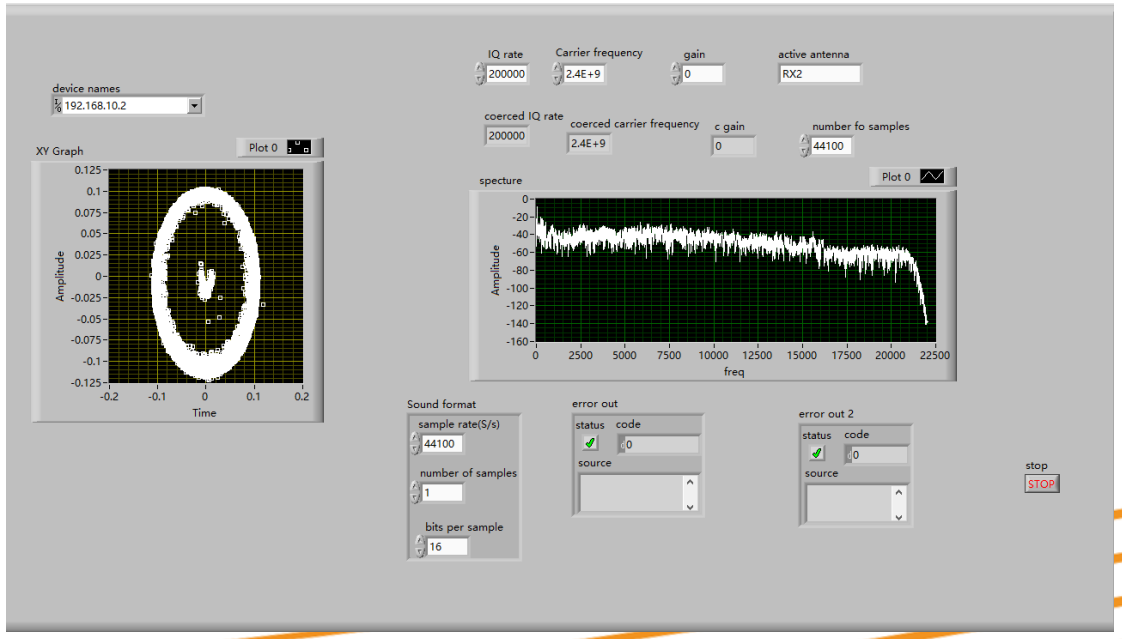
USRP Basic principle
(Universal Software Radio Peripheral)




Waveform Graph
Plot 0
Amplitude
Time
path
G:\labview\
IP
192.168.10.2
coerced IQ rate
200k
IQ rate
200k
carrier frequency
2.4G
gain
0
coerced carrier frequency
2.4G
coerced
0
number of samples/ch (-1: all)
10000
active antenna
TX1
XY Graph
Plot 0
error out
status
code
0
source
stop
STOP
FM deviation(HZ)
100000


device names
192.168.10.2
XY Graph
Plot 0
Amplitude
Time
IQ rate
200000
Carrier frequency
2.4E+9
gain
0
active antenna
RX2
coerced IQ rate
200000
coerced carrier frequency
2.4E+9
c gain
0
number fo samples
44100
specture
Plot 0
freq
Sound format
sample rate(S/s)
44100
number of samples
1
bits per sample
16
error out
status
code
0
source
error out 2
stop
STOP


Waveform Graph
Plot 0
Amplitude
Time
path
G:\labview\
IP
192.168.10.2
coerced IQ rate
200k
IQ rate
200k
carrier frequency
2.4G
gain
0
coerced carrier frequency
2.4G
coerced
0
number of samples/ch (-1: all)
10000
active antenna
TX1
XY Graph
Plot 0
error out
status
code
0
source
stop
STOP
FM deviation(HZ)
75000


device names
192.168.10.2
XY Graph
Plot 0
Amplitude
Time
IQ rate
200000
Carrier frequency
2.4E+9
gain
0
active antenna
RX2
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0
number fo samples
44100
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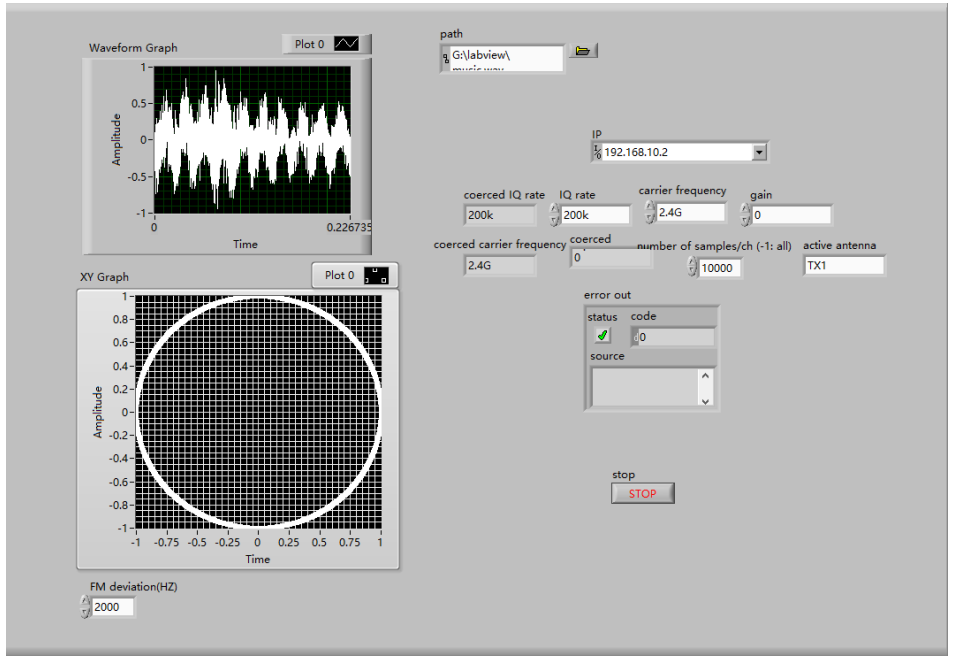
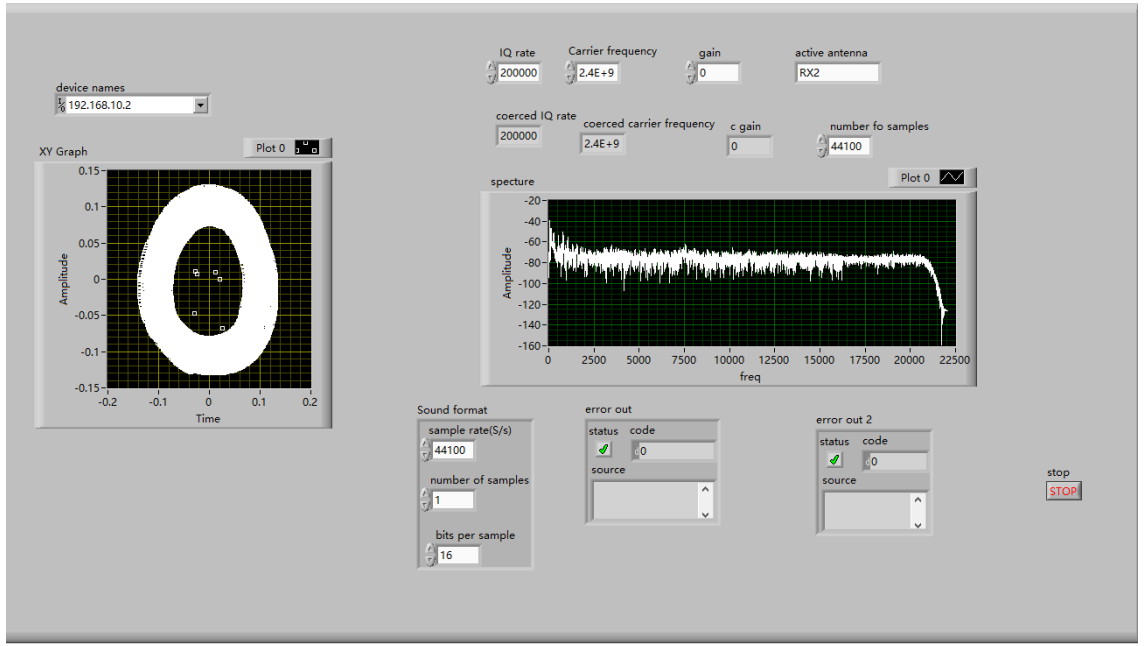
Plot 0
freq
Sound format
sample rate(S/s)
44100
number of samples
1
bits per sample
16
error out
status
code
0
source
error out 2
stop
STOP


Waveform Graph
Plot 0
Amplitude
Time
path
G:\labview\
IP
192.168.10.2
coerced IQ rate
200k
IQ rate
200k
carrier frequency
2.4G
gain
0
coerced carrier frequency
2.4G
coerced
0
number of samples/ch (-1: all)
10000
active antenna
TX1
XY Graph
Plot 0
error out
status
code
0
source
stop
STOP
FM deviation(HZ)
2000


device names
192.168.10.2
XY Graph
Plot 0
Amplitude
Time
IQ rate
200000
Carrier frequency
2.4E+9
gain
0
active antenna
RX2
coerced IQ rate
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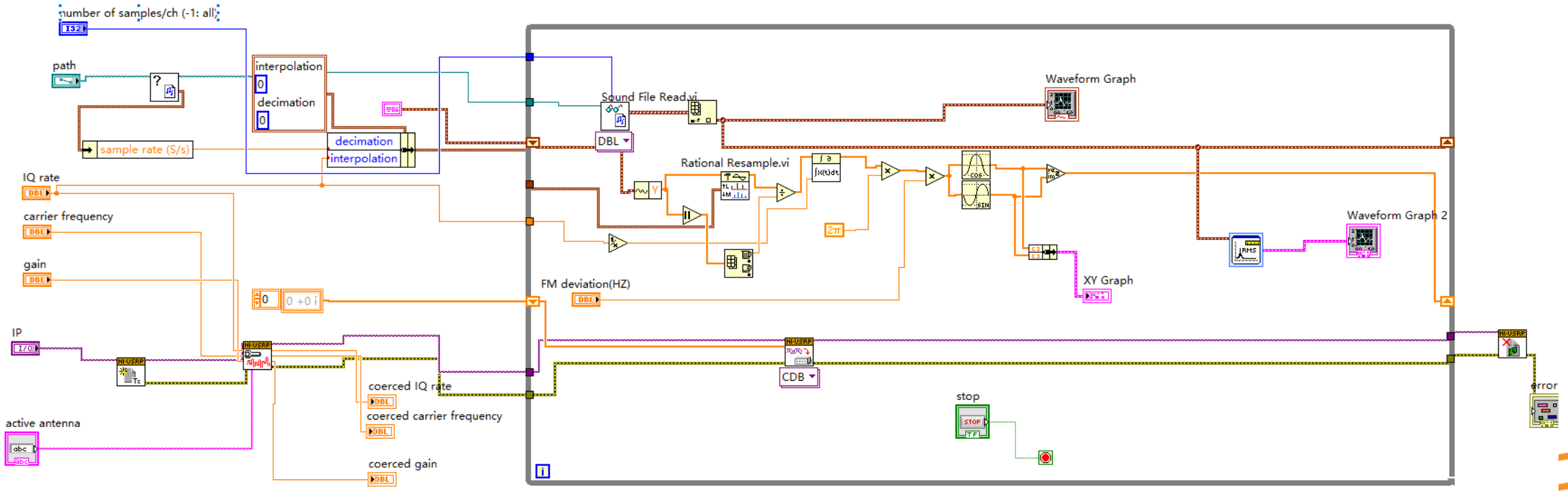
coerced carrier frequency
2.4E+9
c gain
0
number fo samples
44100
specture
Plot 0
Amplitude
freq
Sound format
sample rate(S/s)
44100
number of samples
1
bits per sample
16
error out
status
code
0
source
error out 2
status
code
0
source
stop
STOP

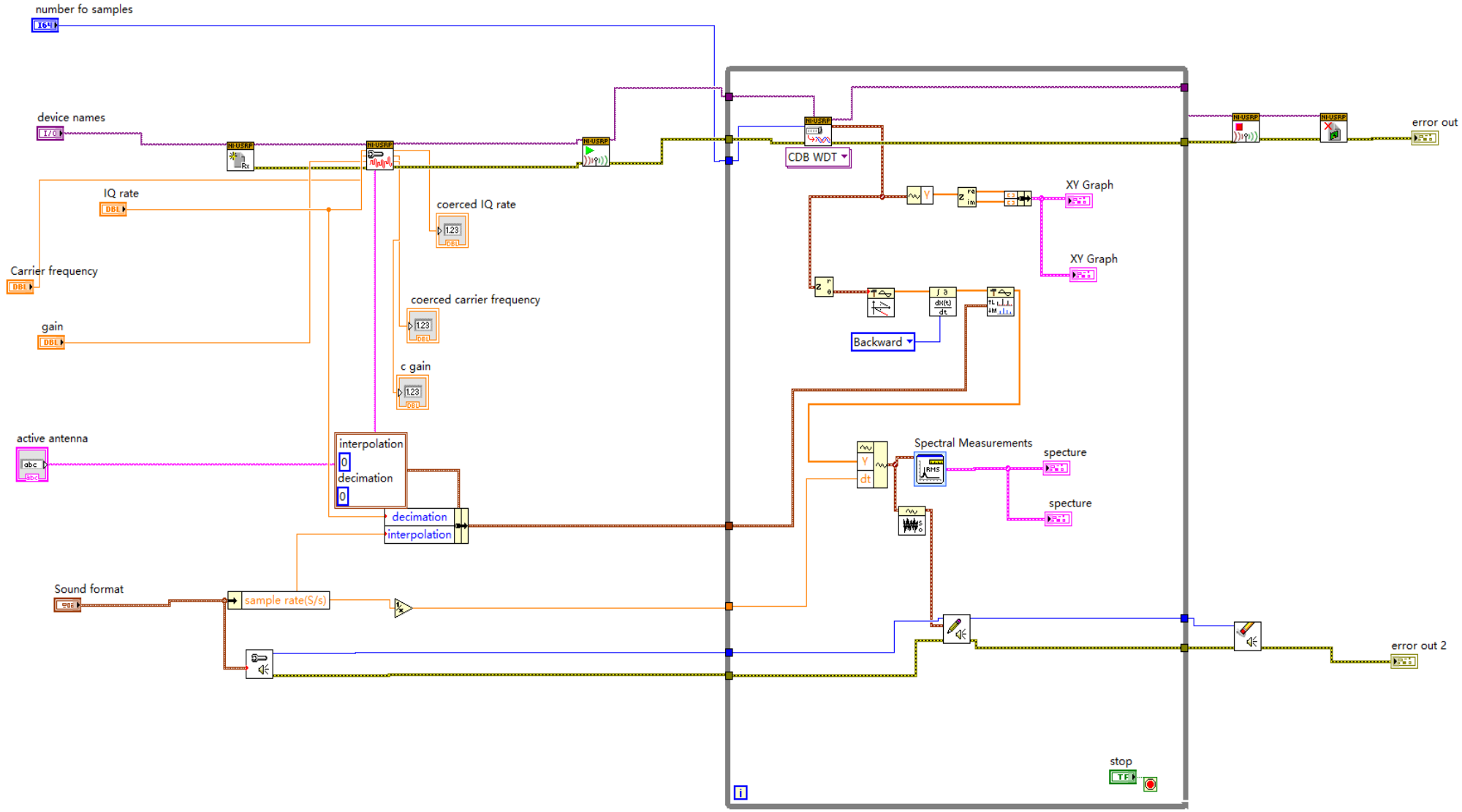
Program block diagram

TX:

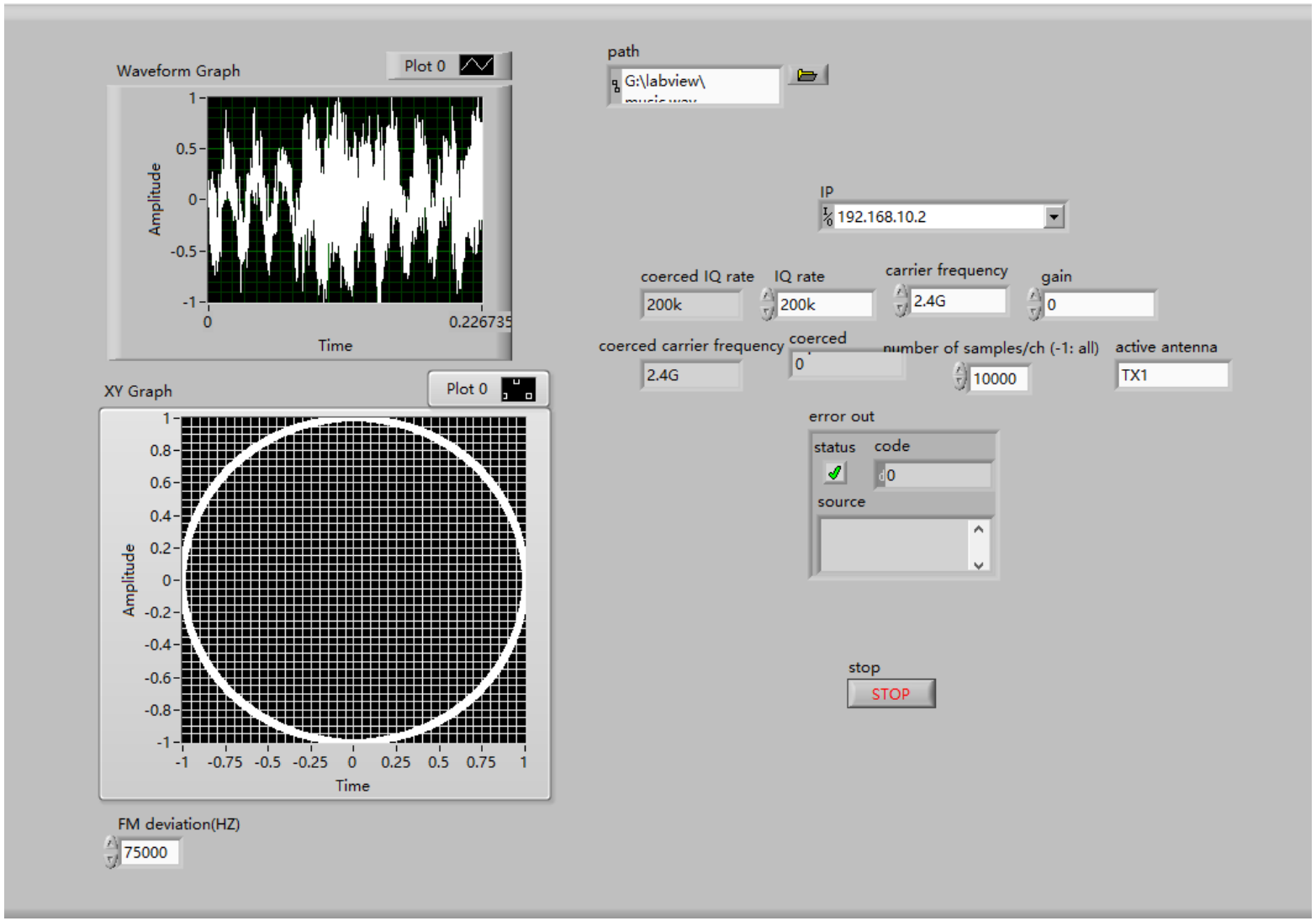


Program block diagram

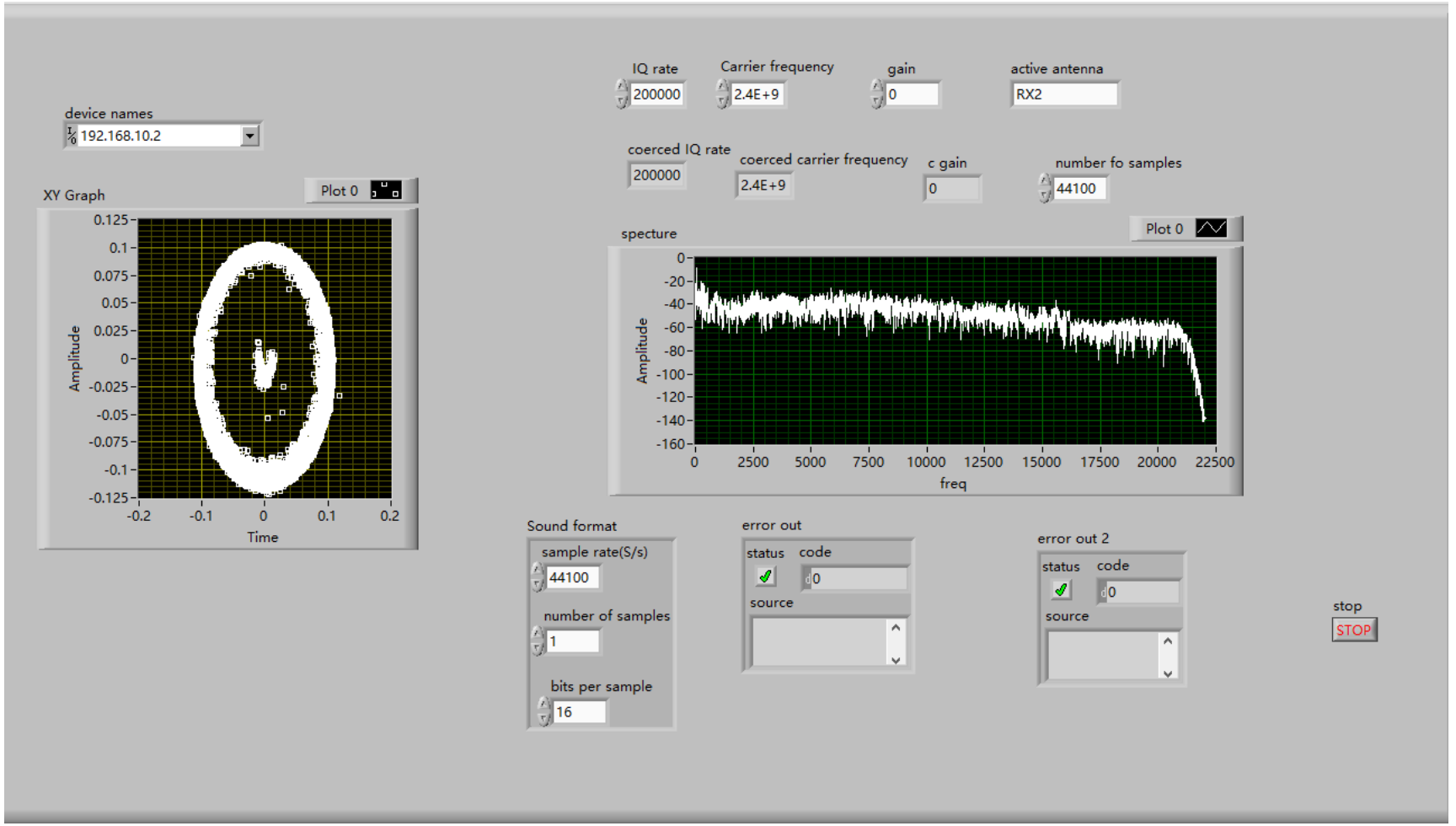
RX:



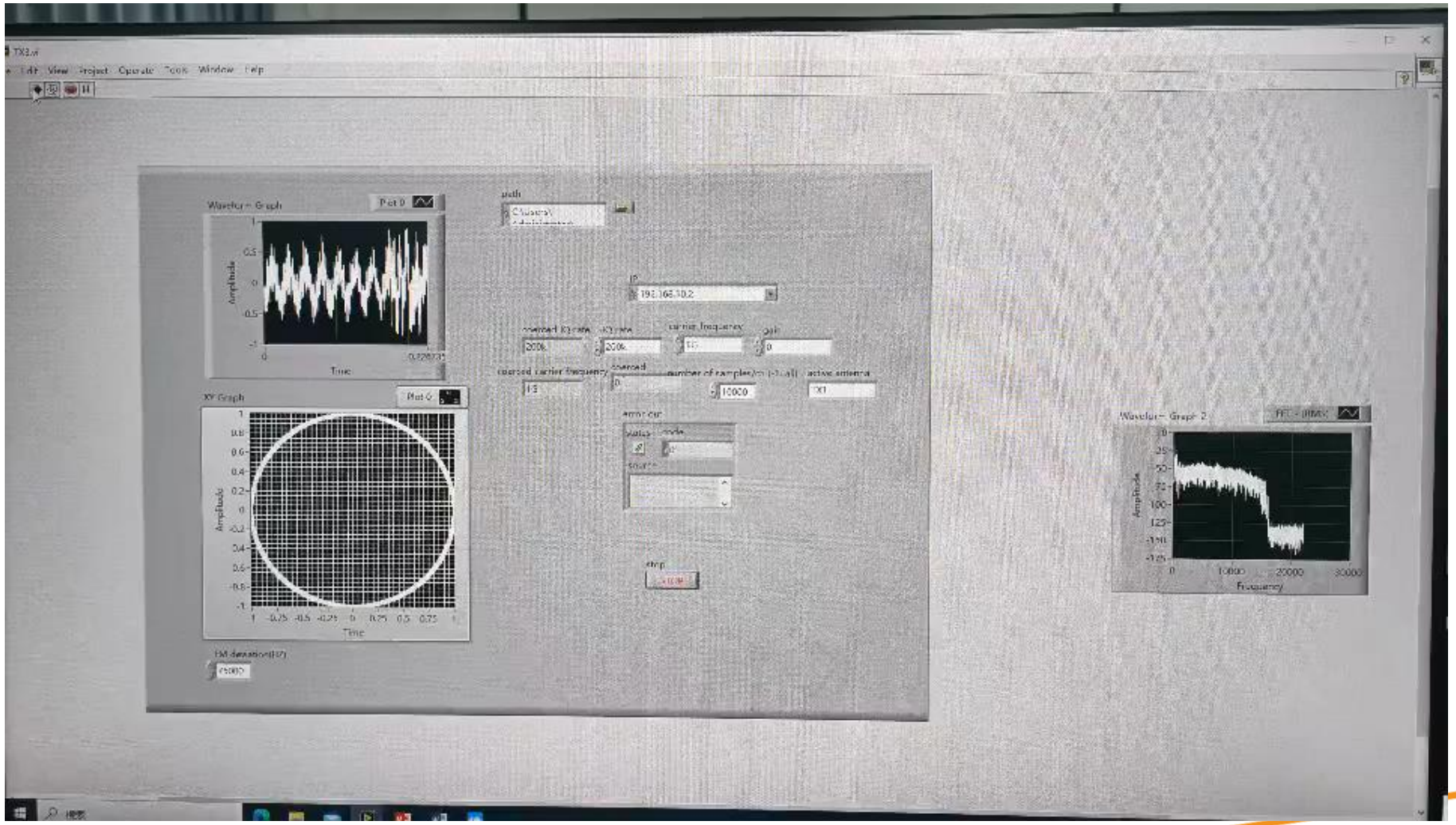
Demonstration effect



Demonstration effect



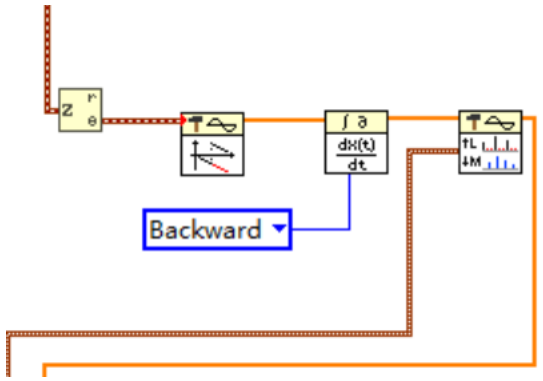
Demonstration effect



Extension section： Low cost implementation

Theoretical analysis:

Integrator module

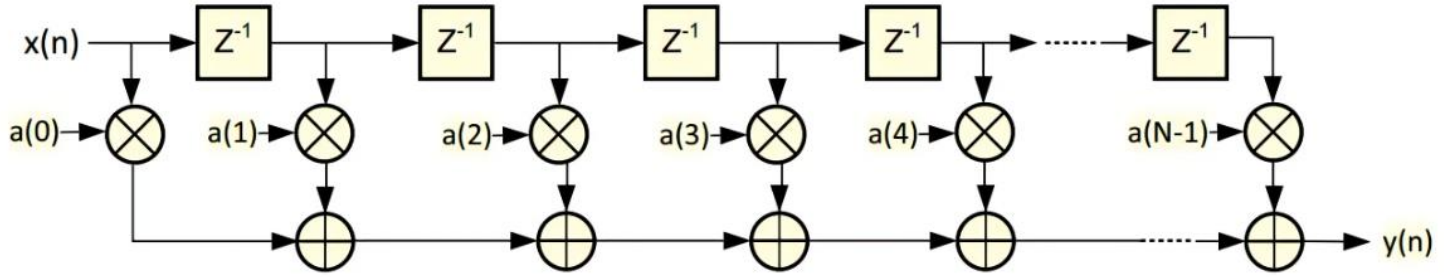


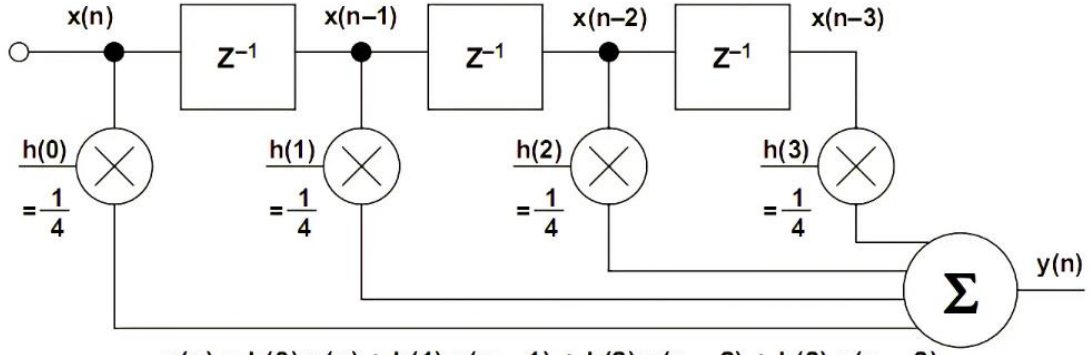
Differential process: $\frac{dx(t)}{dt} \xrightarrow{discretization} \frac{x[n]-x[n-1]}{1}$

Extension section： Low cost implementation

FIR filter

$$y(k) = \sum_{n=0}^{N-1} a(n)x(k-n) \quad k = 0, 1, \ldots$$





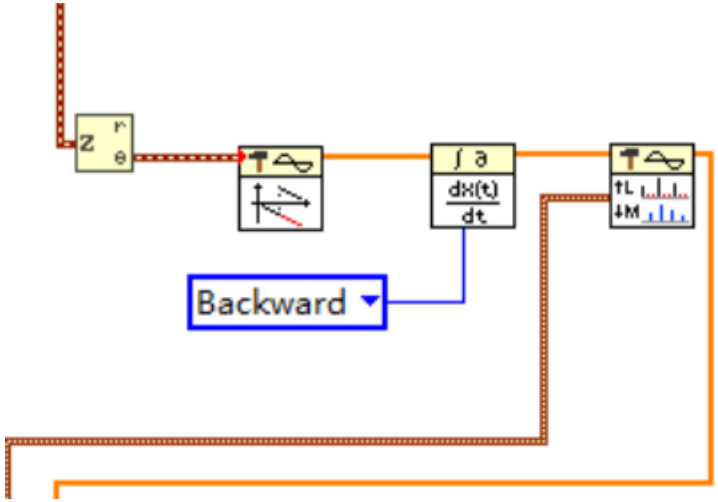
$$y(n) = h(0)\,x(n) + h(1)\,x(n-1) + h(2)\,x(n-2) + h(3)\,x(n-3)$$

$$= \frac{1}{4}x(n) + \frac{1}{4}x(n-1) + \frac{1}{4}x(n-2) + \frac{1}{4}x(n-3)$$

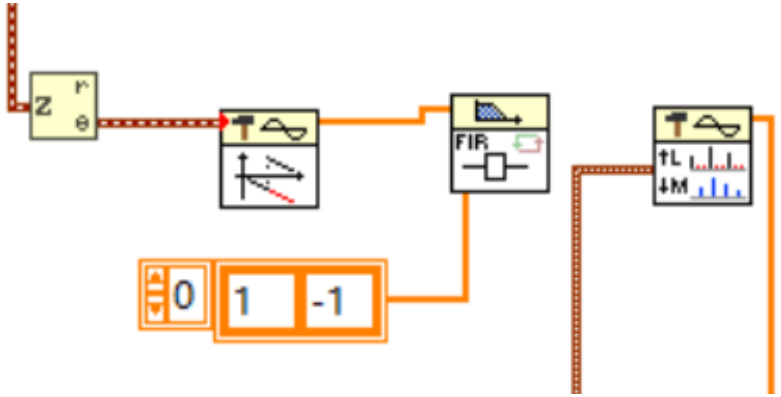
$$= \frac{1}{4}\left[x(n) + x(n-1) + x(n-2) + x(n-3)\right]$$

For N-Point Moving Average Filter: $y(n) = \frac{1}{N}\sum_{k=0}^{N-1} x(n-k)$

Extension section： Low cost implementation



Integrator module



FIR filter

Extension section： Low cost implementation

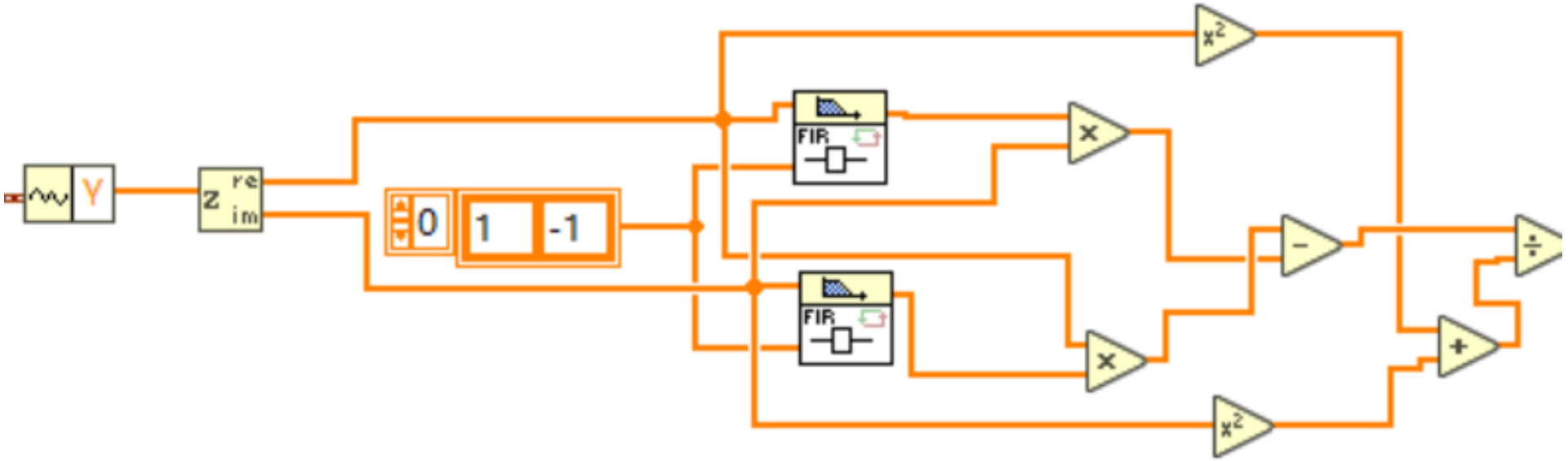
Theoretical analysis:

$$m(t) = \frac{d[\arctan\left(\frac{Q(t)}{I(t)}\right)]}{dt} = \frac{I(t)\frac{dQ(t)}{dt} - Q(t)\frac{dI(t)}{dt}}{I^2(t)+Q^2(t)}$$

$$m(n) = \frac{I(n)[Q(n)-Q(n-1)]-Q(n)[I(n)-I(n-1)]}{I^2(n)+Q^2(n)}$$

$$= \frac{I(n-1)Q(n)-I(n)Q(n-1)}{I^2(n)+Q^2(n)}$$

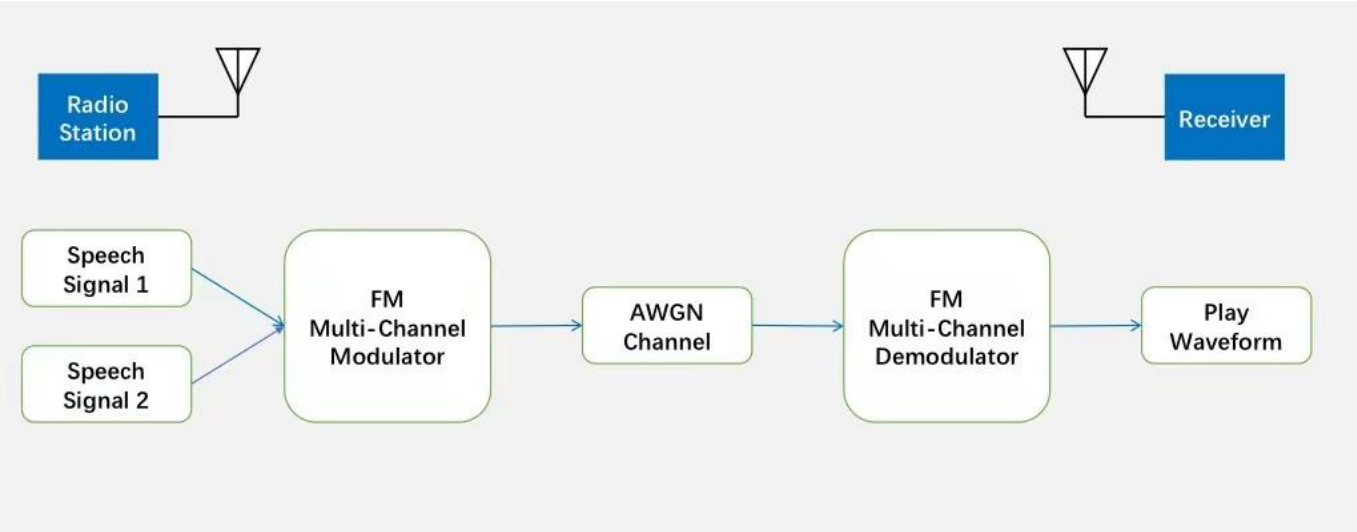
Extension section： Low cost implementation

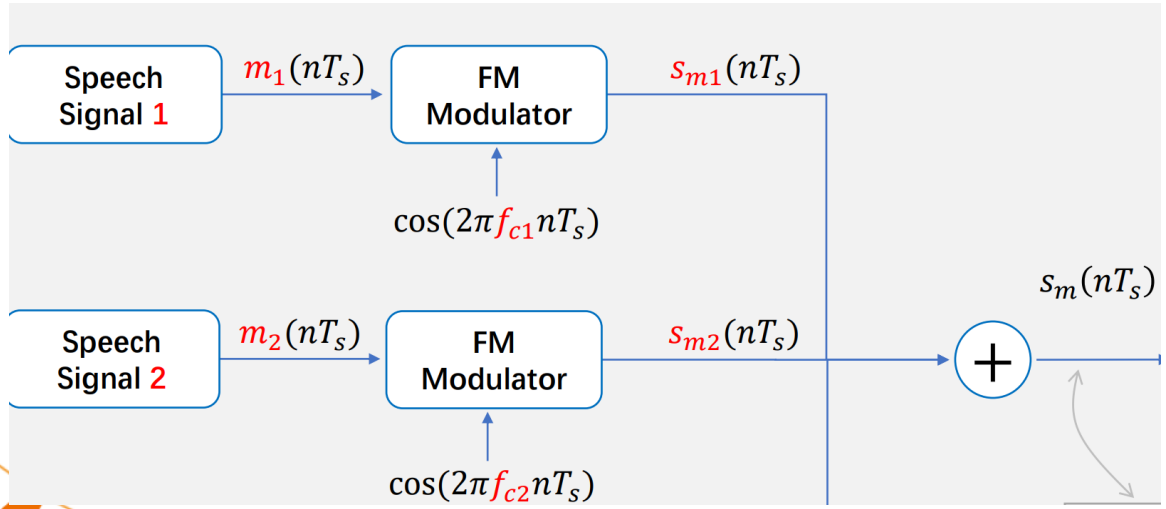


Two FIR filter

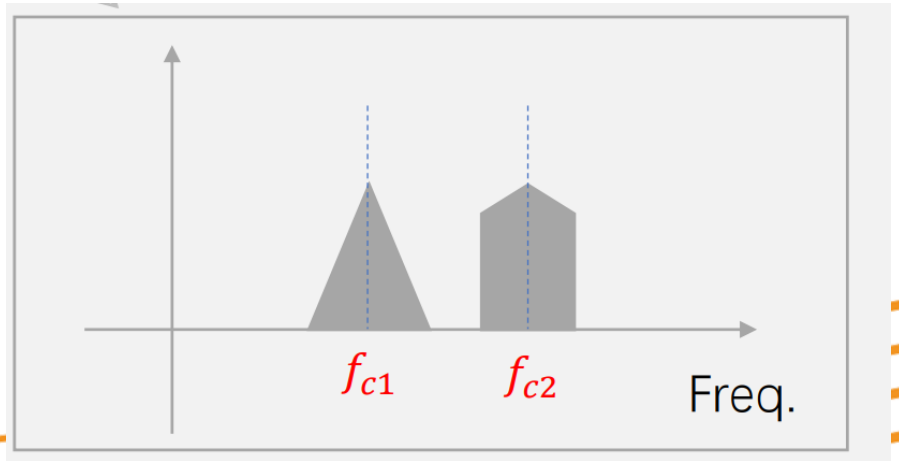
Extension section： FM multi-channel design

Theoretical analysis





frequency domain



Extension section： FM multi-channel design

Theoretical analysis

$$s(nT_s) = cos[2\pi f_c t + 2\pi \int k_f m(nT_s)dt]$$

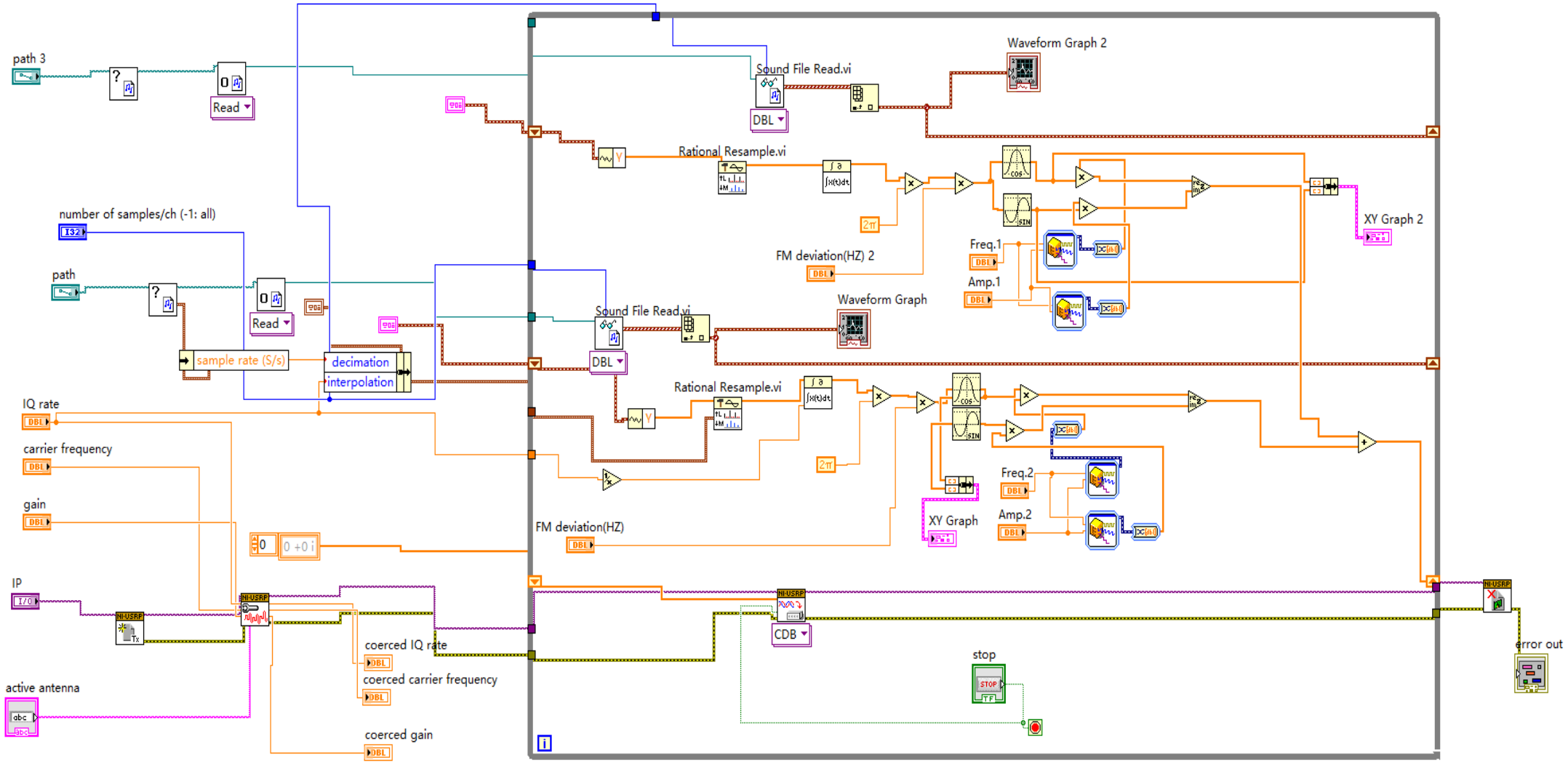
$$s_I(nT_s) = A_c cos(2\pi \int k_f m(nT_s)dt)$$

$$s_Q(nT_s) = A_c sin(2\pi \int k_f m(nT_s)dt)$$

$$s_l(nT_s) = s_I(nT_s) + js_Q(nT_s)$$

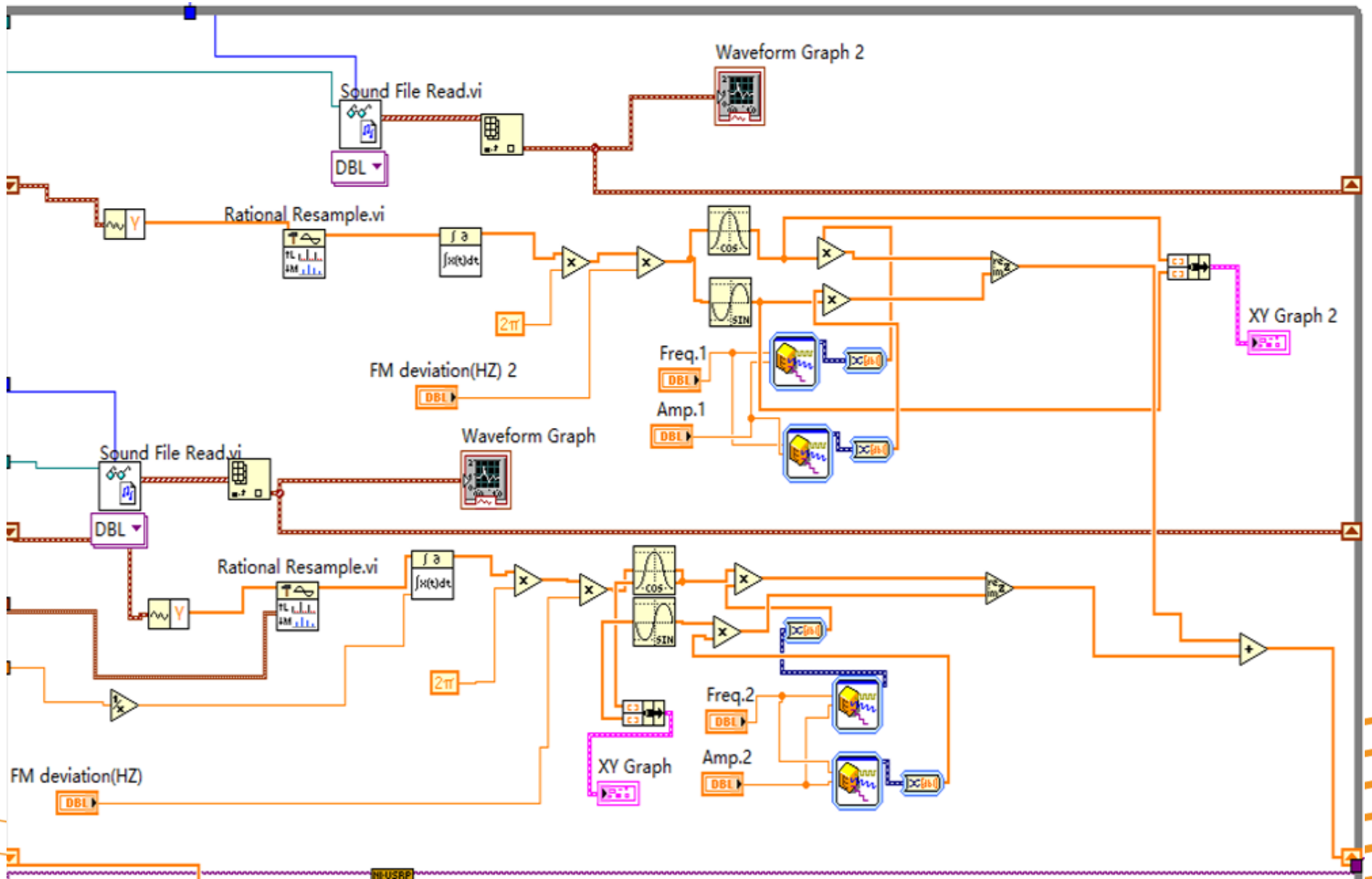
Extension section： FM multi-channel design

TX:



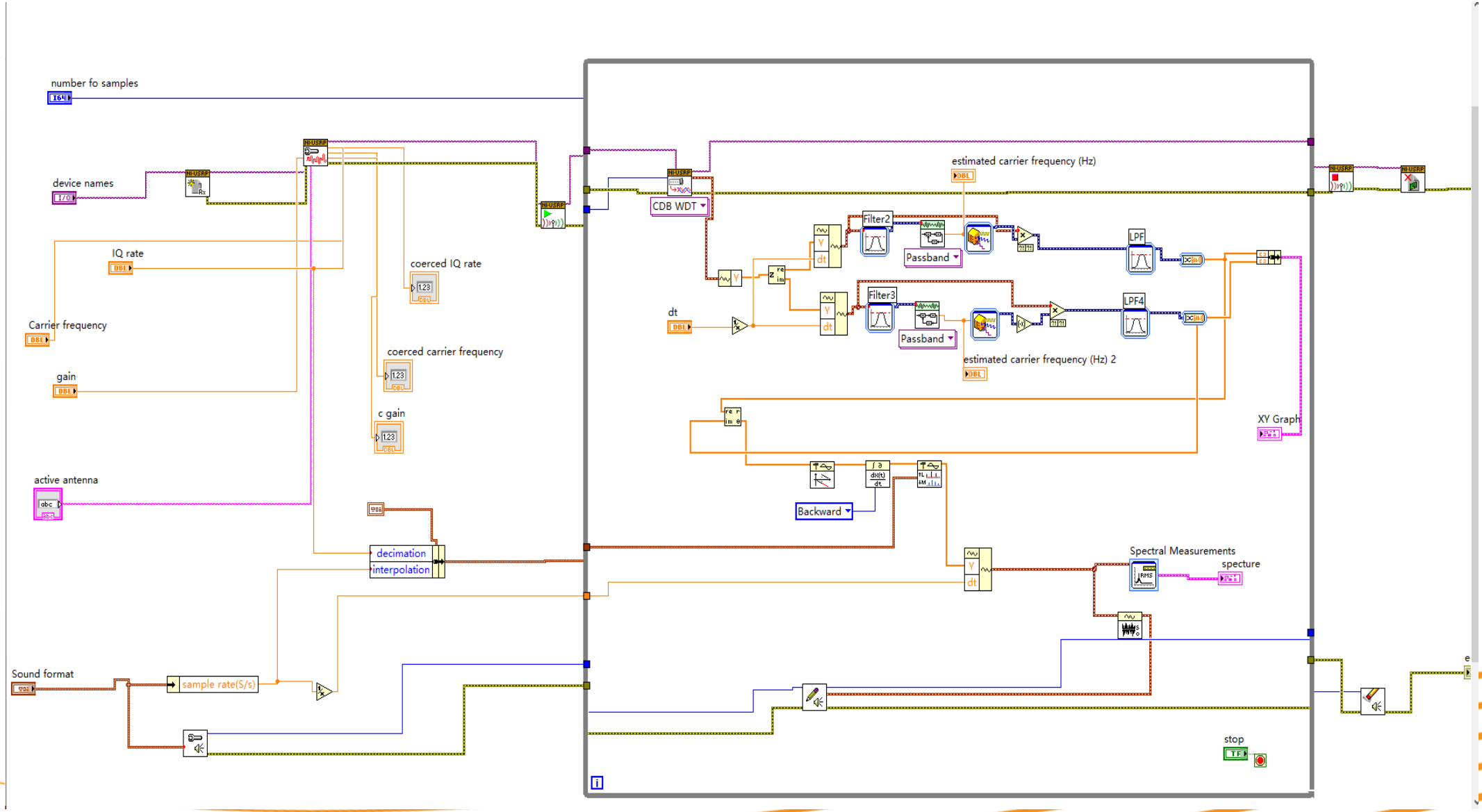
Extension section： FM multi-channel design

TX:



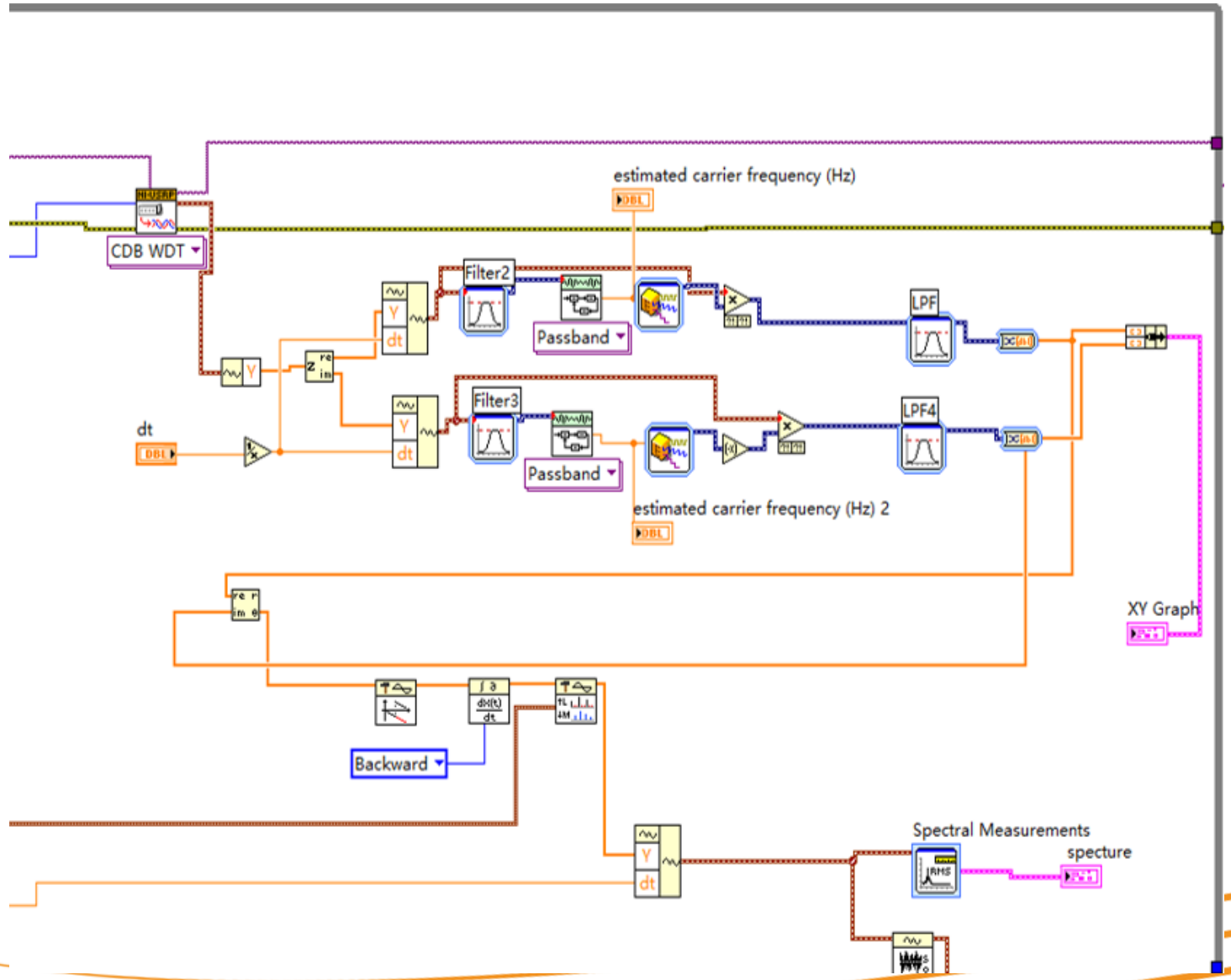
Extension section： FM multi-channel design

RX:

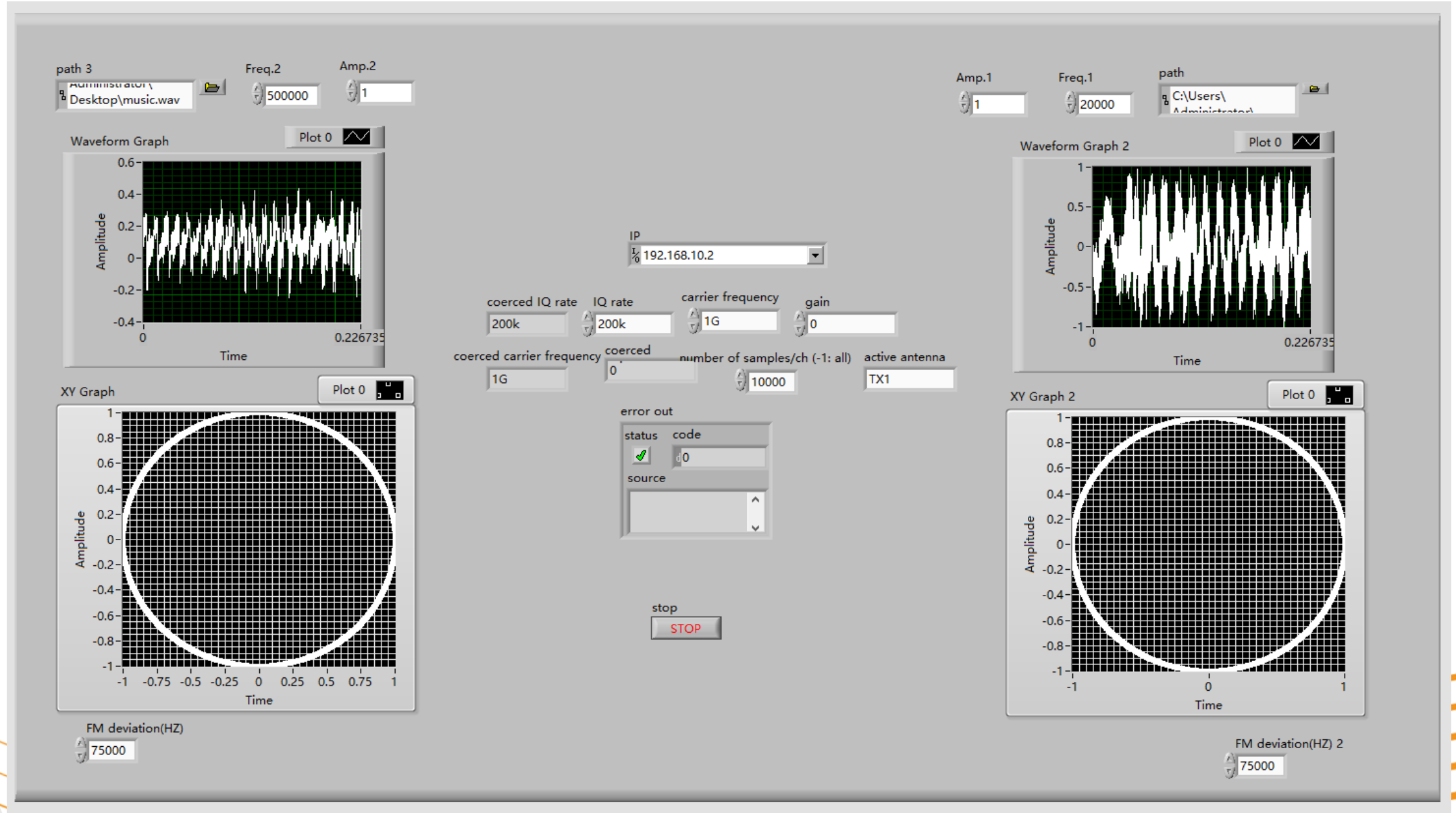


Extension section： FM multi-channel design

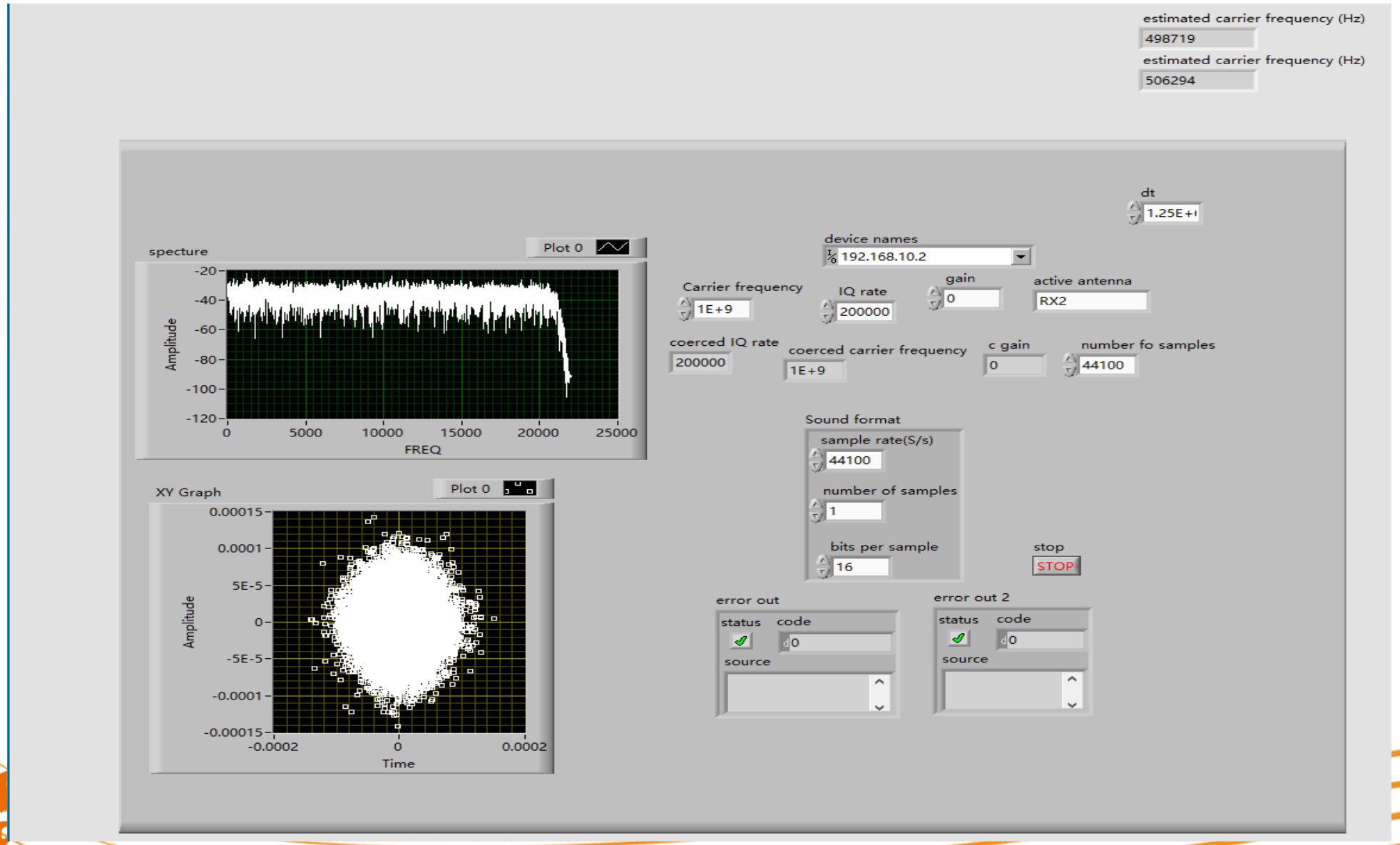
RX:



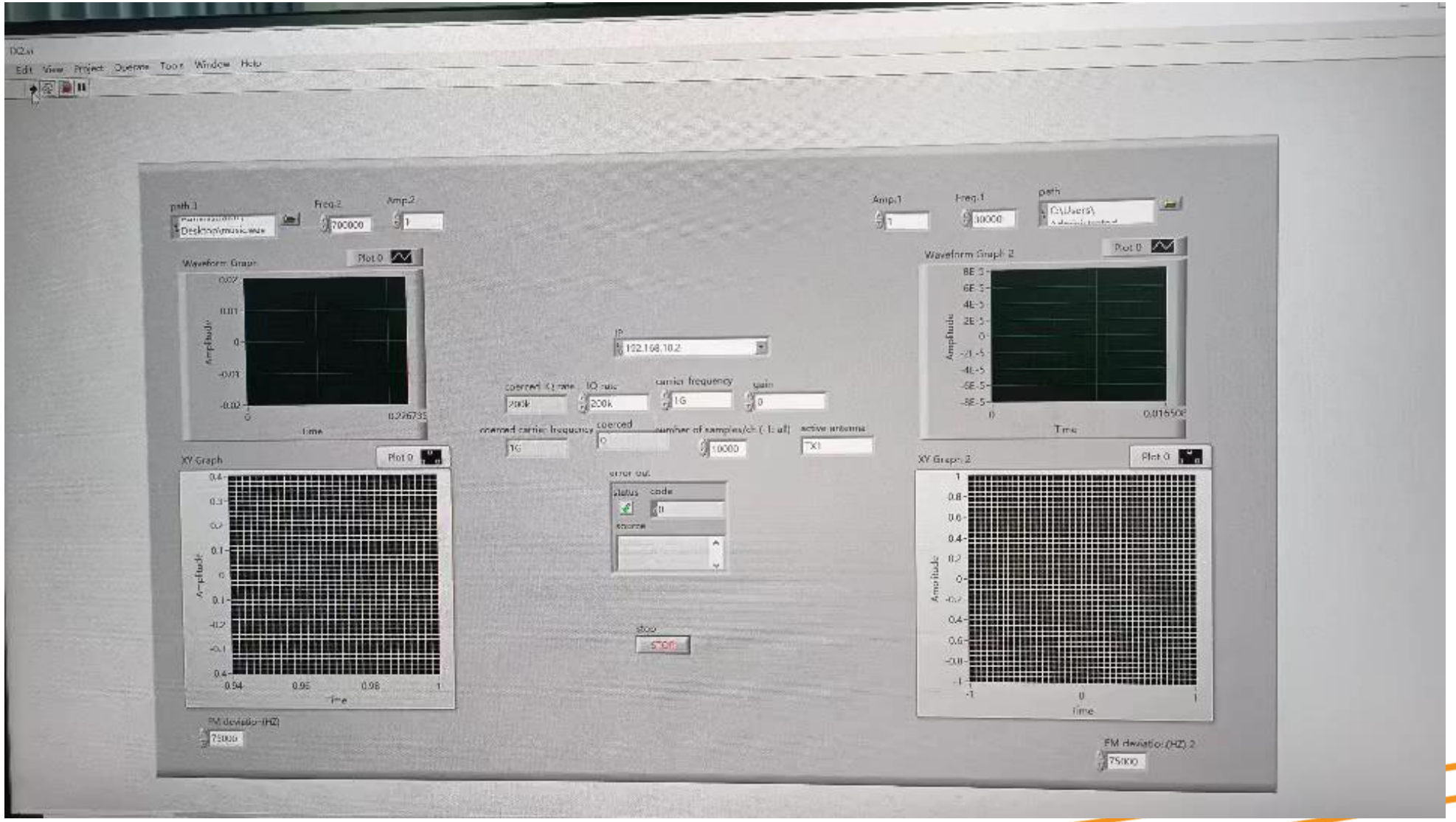
Demonstration effect



Demonstration effect



Demonstration effect



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Thanks for your listening