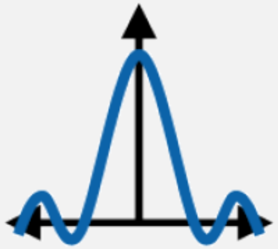
From Theory to Practice



Design Verification

Product Verification

Research/ Modeling ⇄ Design/ Simulation ⇄ Verification/ Validation ⇄ Manufacturing

南方科技大学 SOUTHERN UNIVERSITY OF SCIENCE AND TECHNOLOGY

Lab 5: Voice Transmission using USRP

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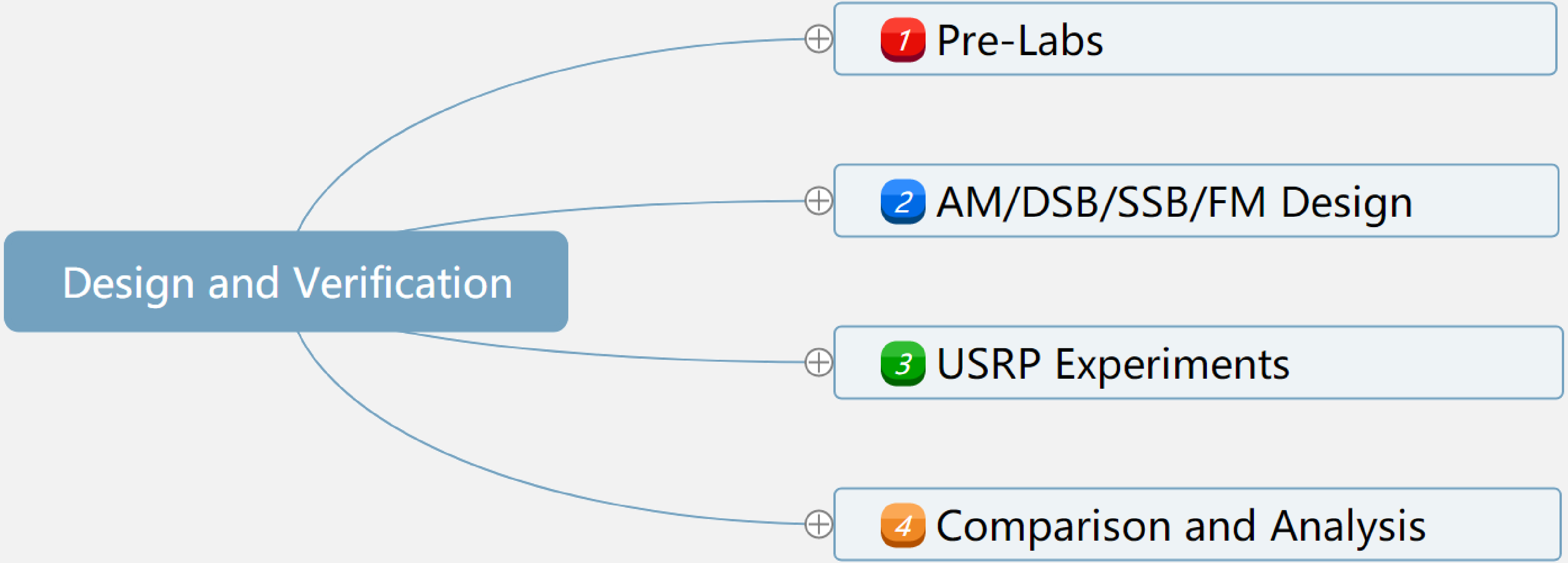
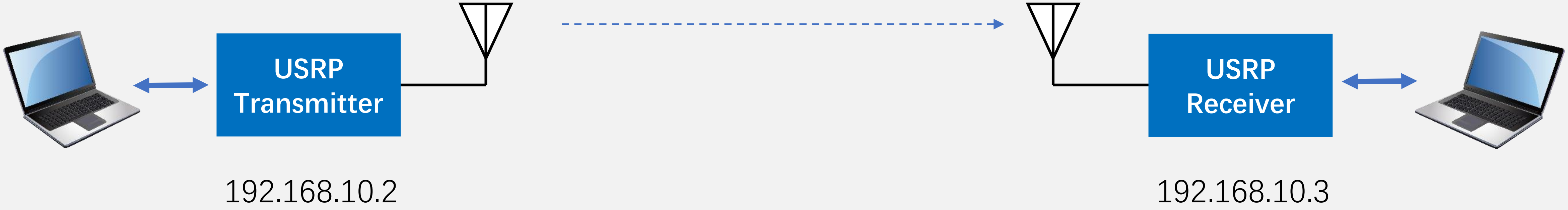
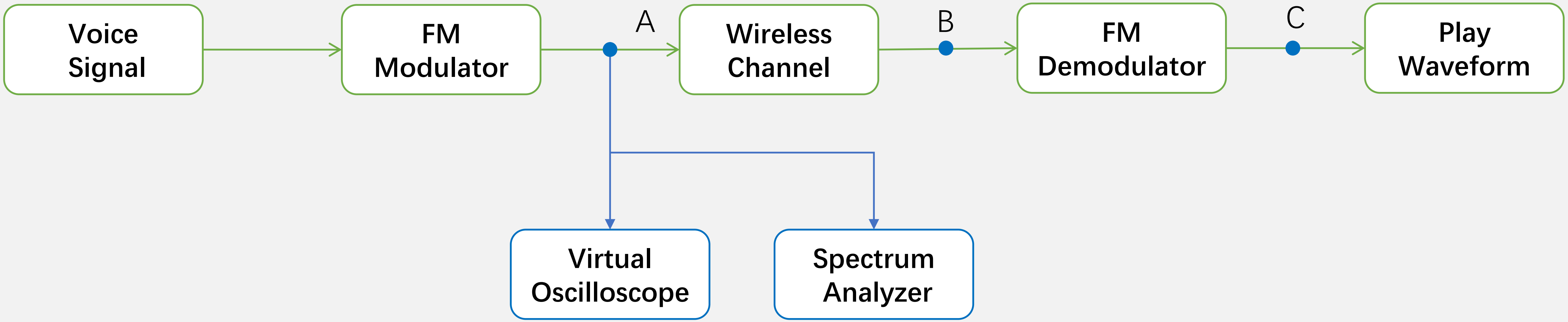

Design and Verification
1 Pre-Labs
2 AM/DSB/SSB/FM Design
3 USRP Experiments
4 Comparison and Analysis

Demo: Voice Transmission using USRP

System Model

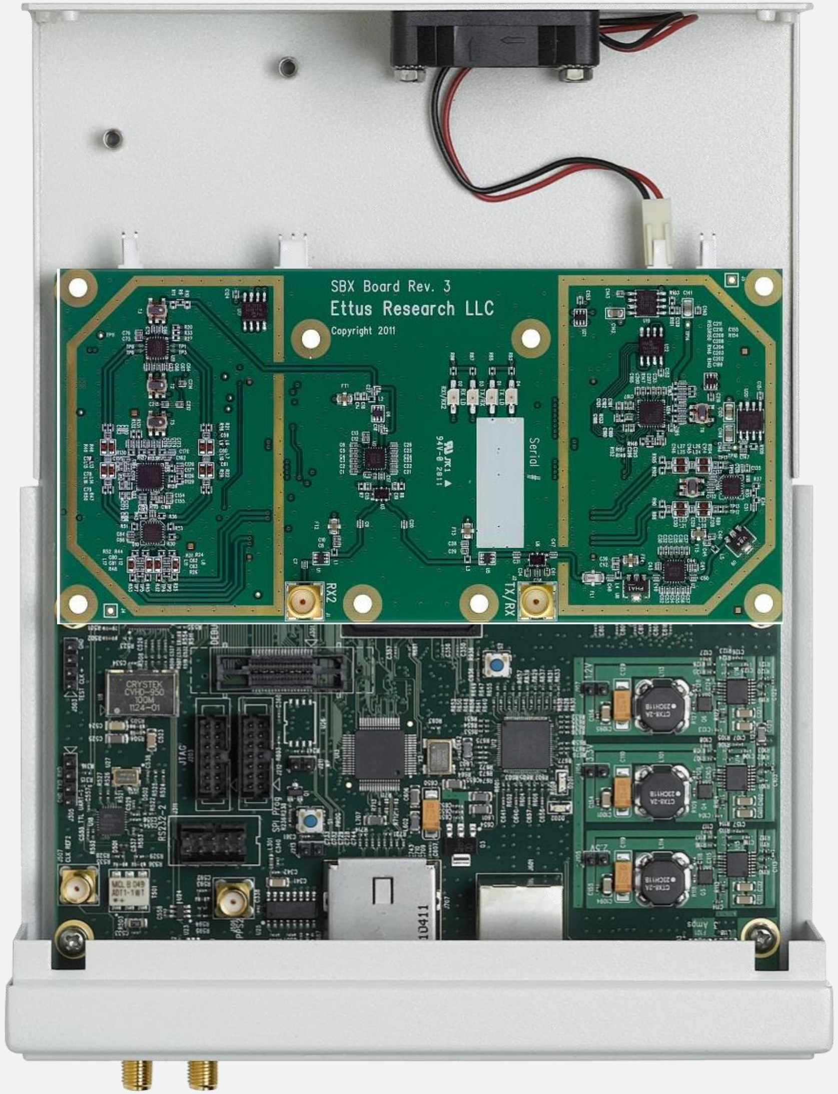




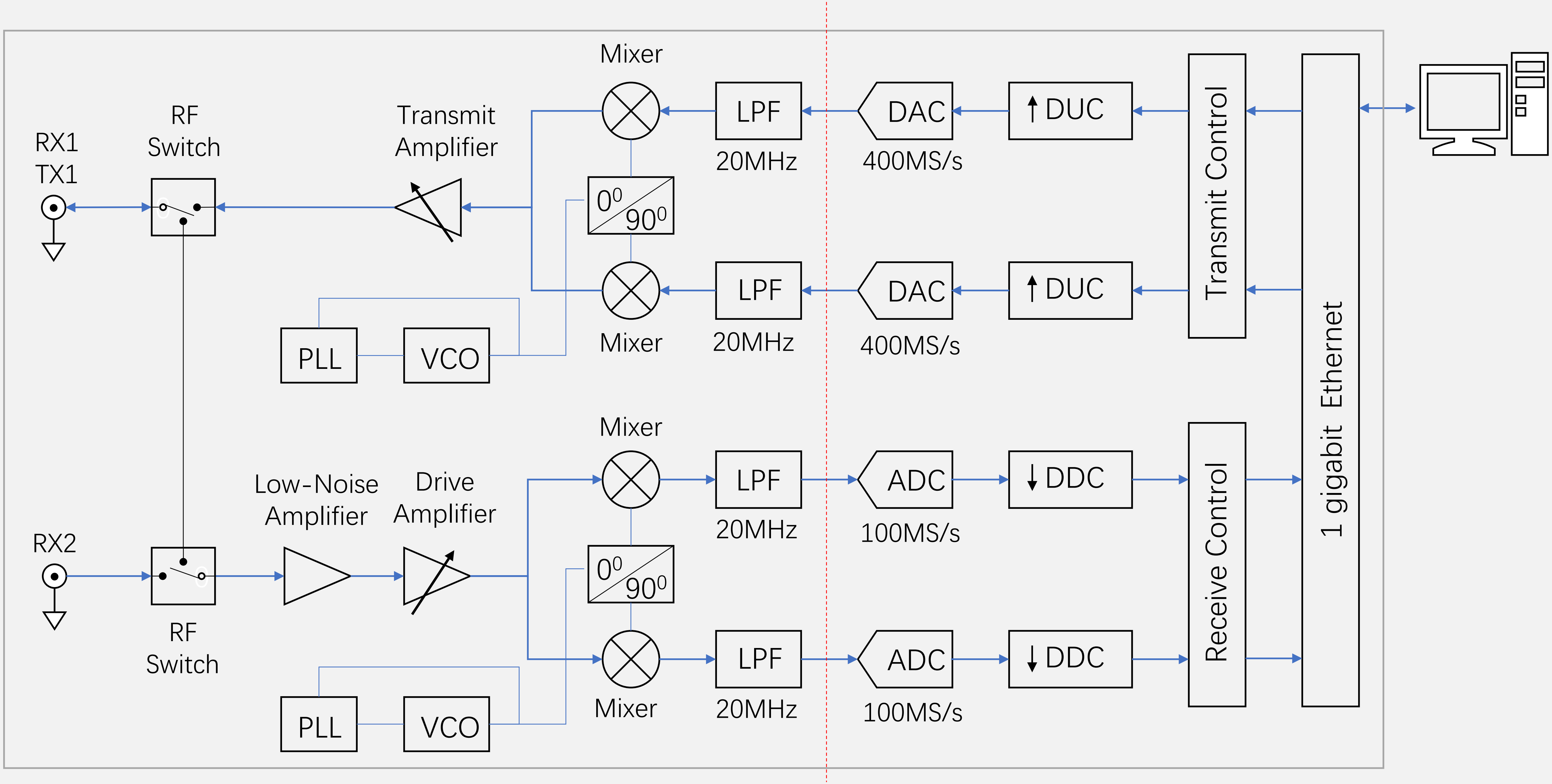
USRP: Universal Software Radio Peripheral

NATIONAL INSTRUMENTS

Ettus Research
A National Instruments Brand



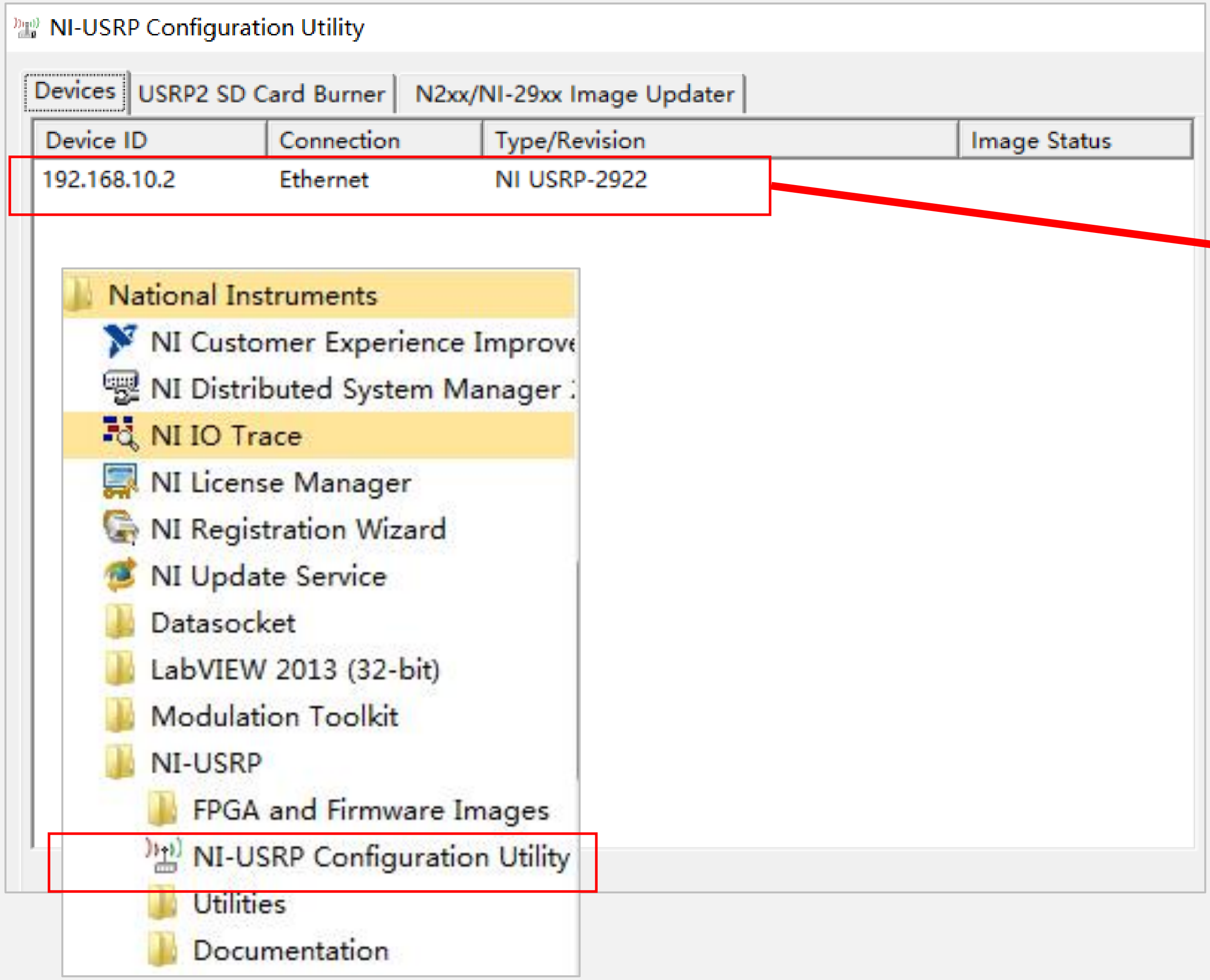
Daughter board	Frequency range
SBX	400 - 4400MHz
WBX	50 - 2200MHz
XCVR2450	2400 - 2500MHz
Basic	1 - 250MHz

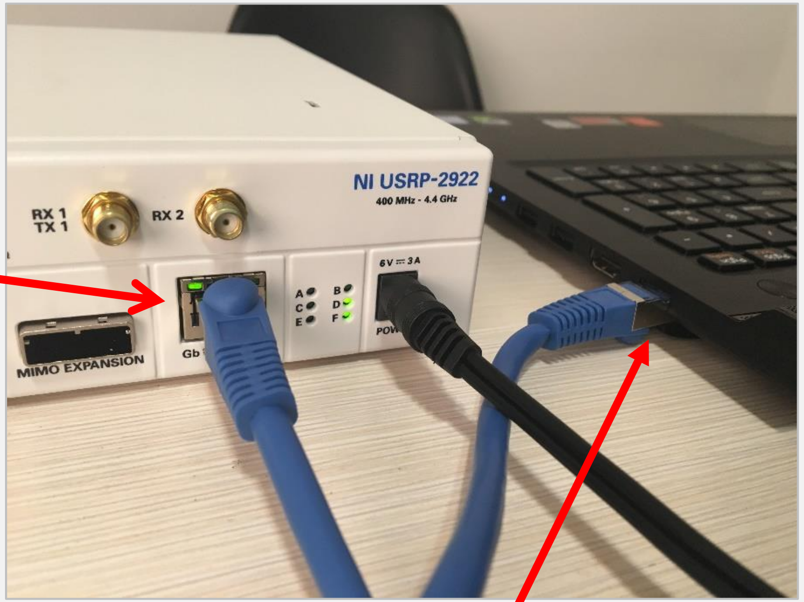


Mixer
RF
Switch
Transmit
Amplifier
LPF
DAC
↑DUC
Transmit Control
RX1
TX1
20MHz
400MS/s
0⁰
90⁰
LPF
DAC
↑DUC
PLL
VCO
Mixer
20MHz
400MS/s
1 gigabit Ethernet
Mixer
Low-Noise
Amplifier
Drive
Amplifier
LPF
ADC
↓DDC
20MHz
100MS/s
RX2
0⁰
90⁰
Receive Control
RF
Switch
LPF
ADC
↓DDC
PLL
VCO
Mixer
20MHz
100MS/s

Demo: Transmit a signal

Find USRP

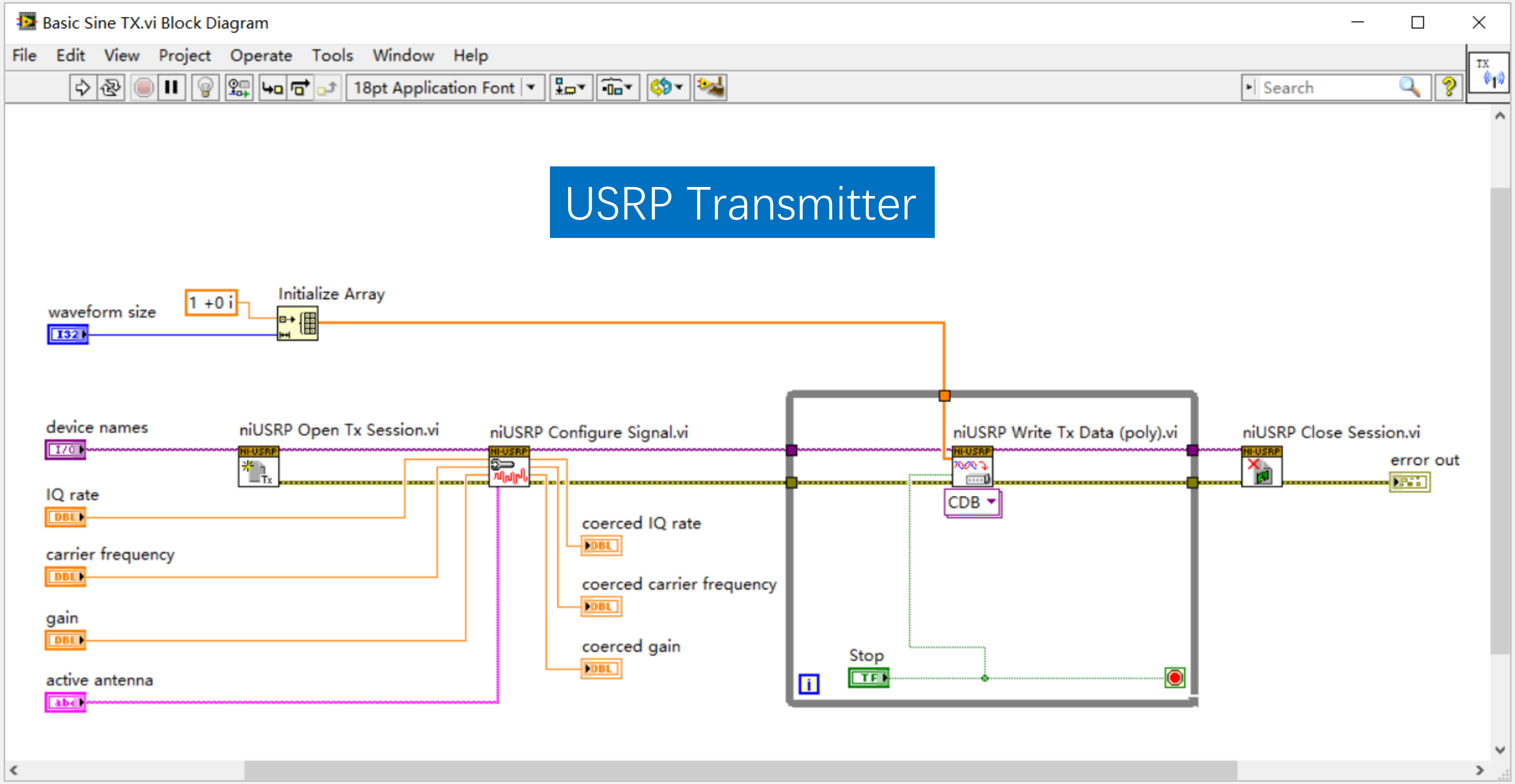




Host computer's IP:
192.168.10.1

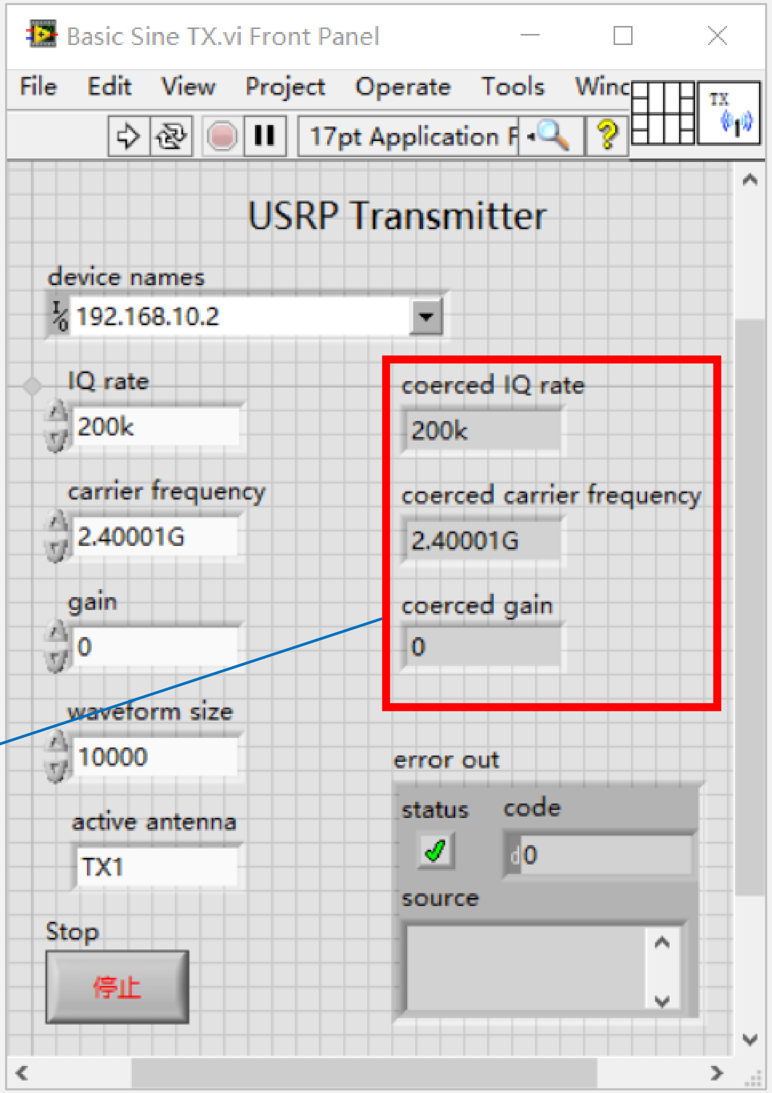
Programming for Transmitter

Block Diagram of the Transmitter

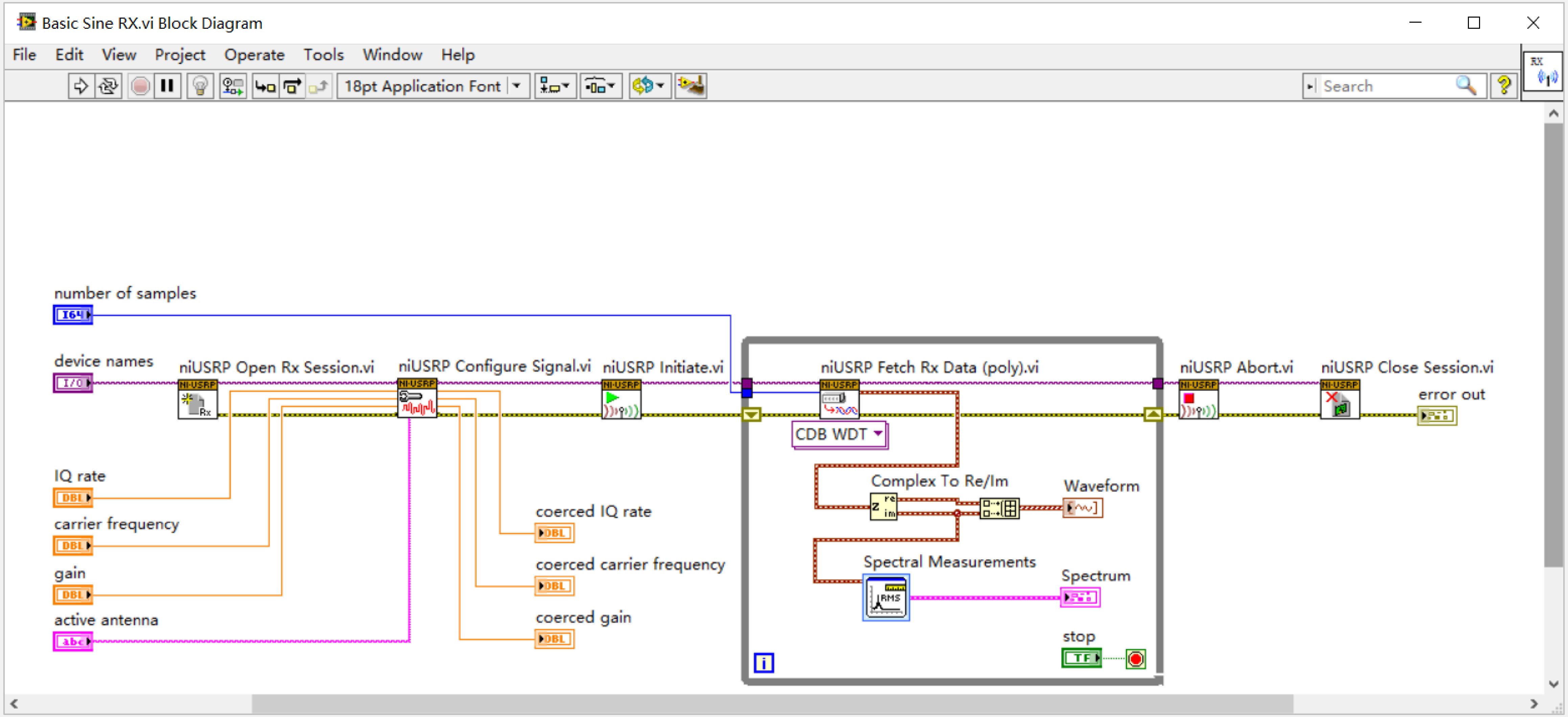


Configuration Parameters in Front Panel

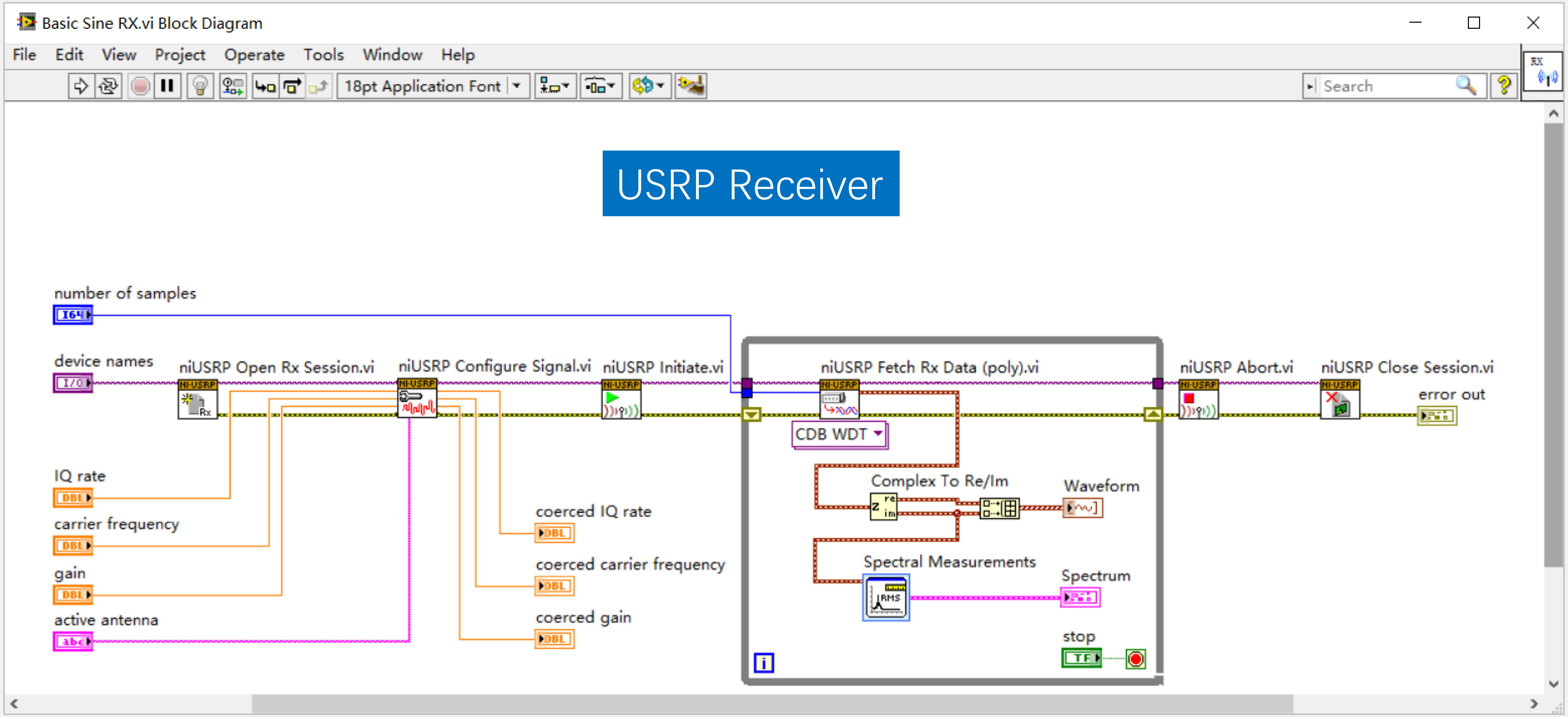
Parameters	Value
Device names	192.168.10.2
Carrier frequency	2.40001GHz
IQ rate (samples/s)	200k
Gain (dB)	0
Waveform size	10000
Data	1+0i
Active antenna	Tx1



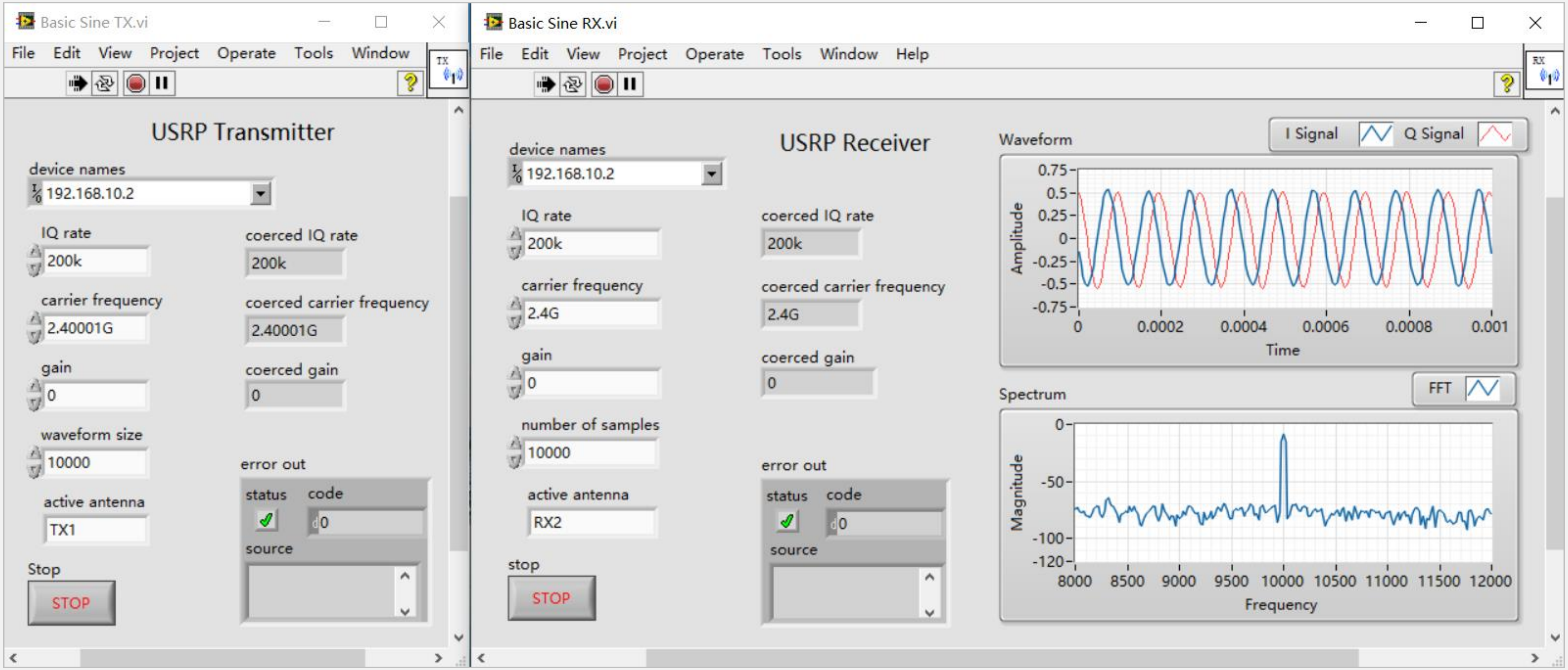
Actual value


Basic Sine RX.vi Block Diagram
File Edit View Project Operate Tools Window Help
18pt Application Font
Search
number of samples
device names
niUSRP Open Rx Session.vi
niUSRP Configure Signal.vi
niUSRP Initiate.vi
niUSRP Fetch Rx Data (poly).vi
niUSRP Abort.vi
niUSRP Close Session.vi
error out
CDB WDT
IQ rate
carrier frequency
gain
active antenna
coerced IQ rate
coerced carrier frequency
coerced gain
Complex To Re/Im
Waveform
Spectral Measurements
Spectrum
stop

Block Diagram of the Receiver



Configuration Parameters in Front Panel



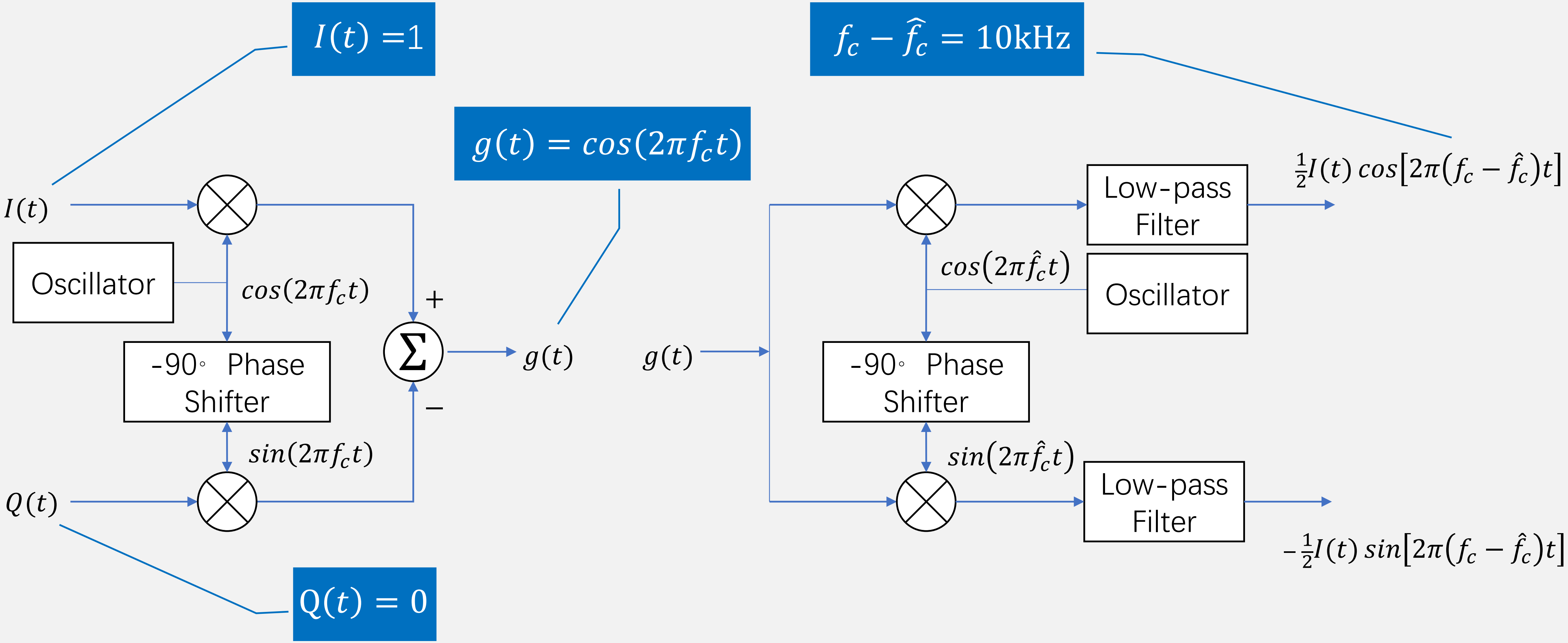
Complex Baseband

$$s(t) = a(t)cos[2\pi f_c t + \varphi] \longrightarrow s_l(t) = s_I(t) + js_Q(t)$$

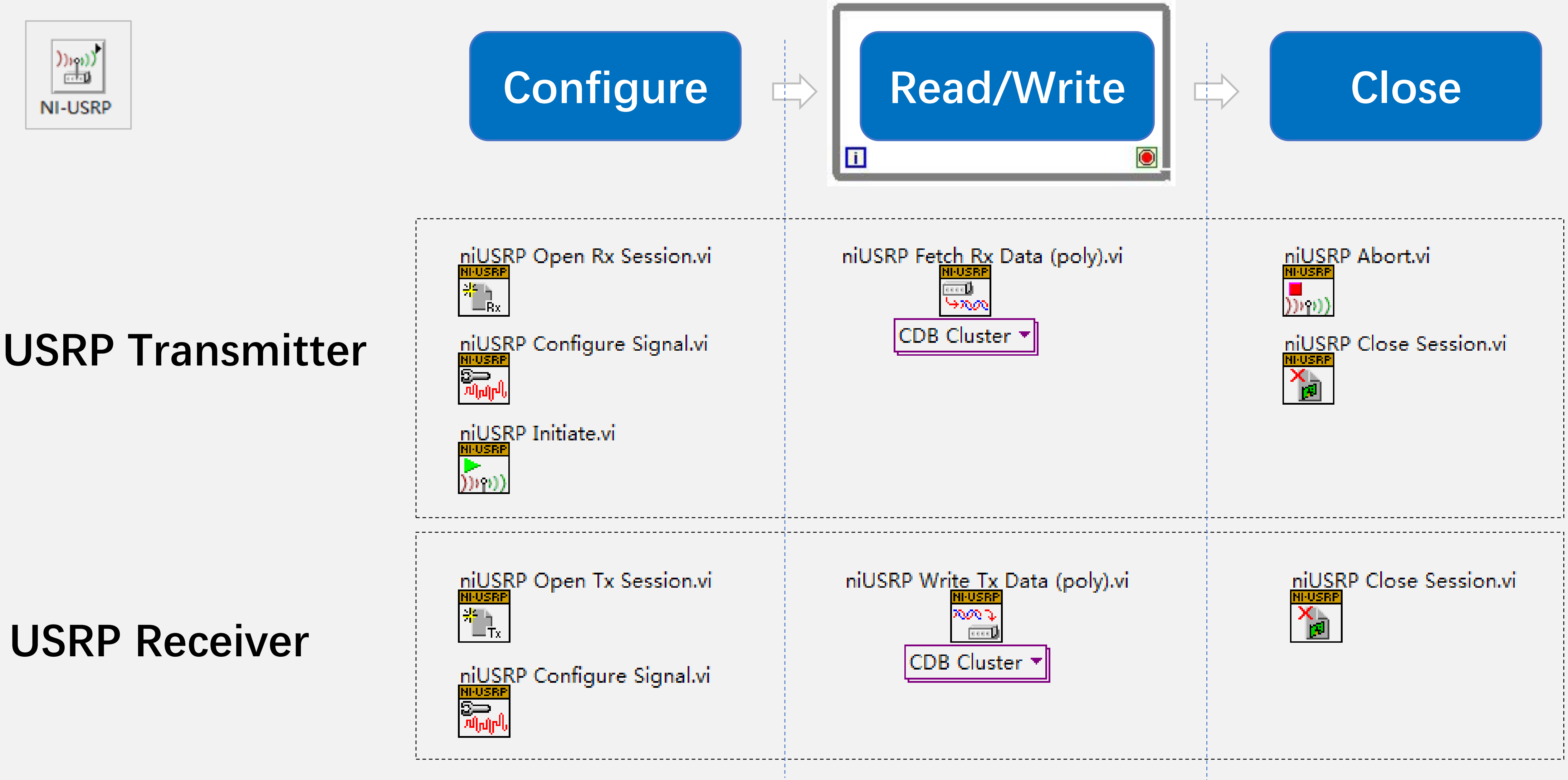
$$s_I(t) = a(t)cos(\varphi)$$

$$s_Q(t) = a(t)sin(\varphi)$$

How to Interpret the Results ?



Most-used USRP functions



Demo: Voice Transmission using USRP

Complex Baseband

$$s(t) = a(t)cos[2\pi f_c t + \varphi]$$

$$s_I(t) = a(t)cos(\varphi)$$

$$s_Q(t) = a(t)sin(\varphi)$$

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

Complex Baseband

Baseband

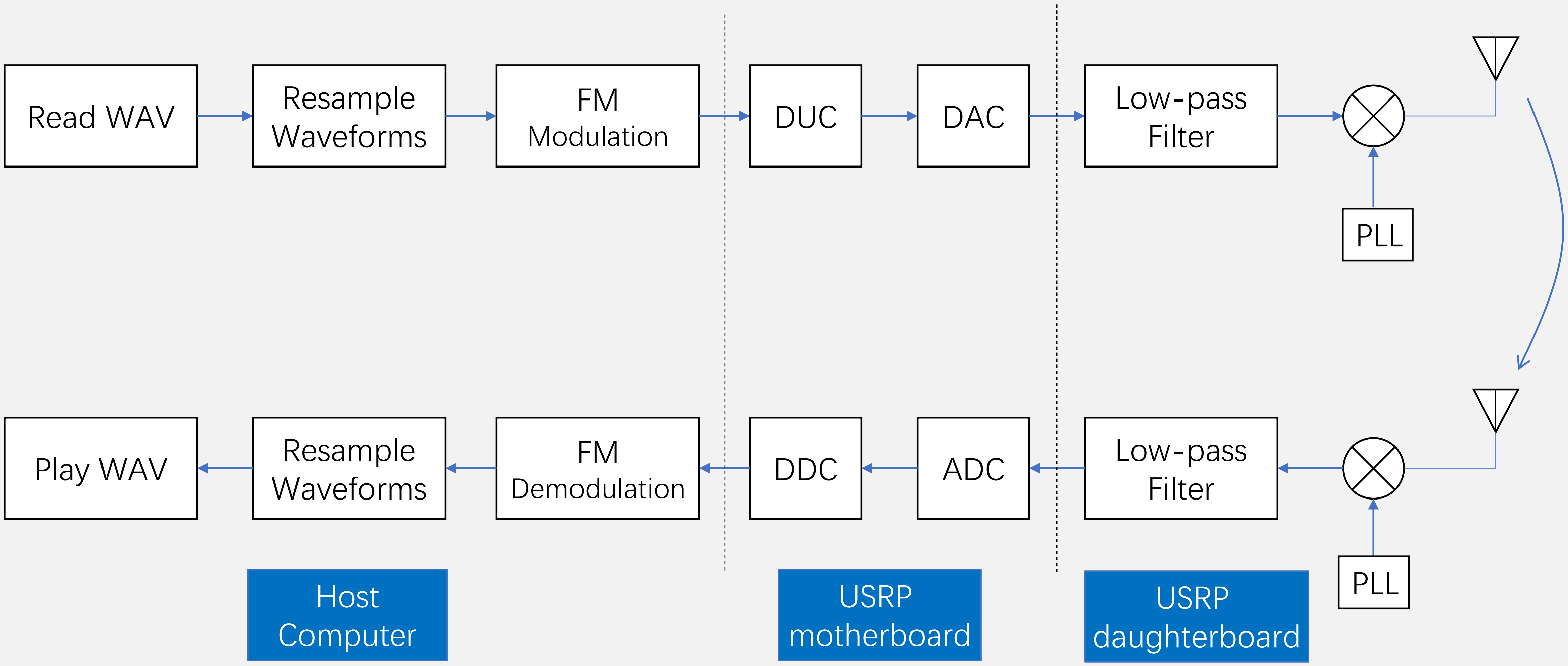
$$s(nT_s) = cos[2\pi f_c t + 2\pi \int k_f m(nT_s)dt]$$

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

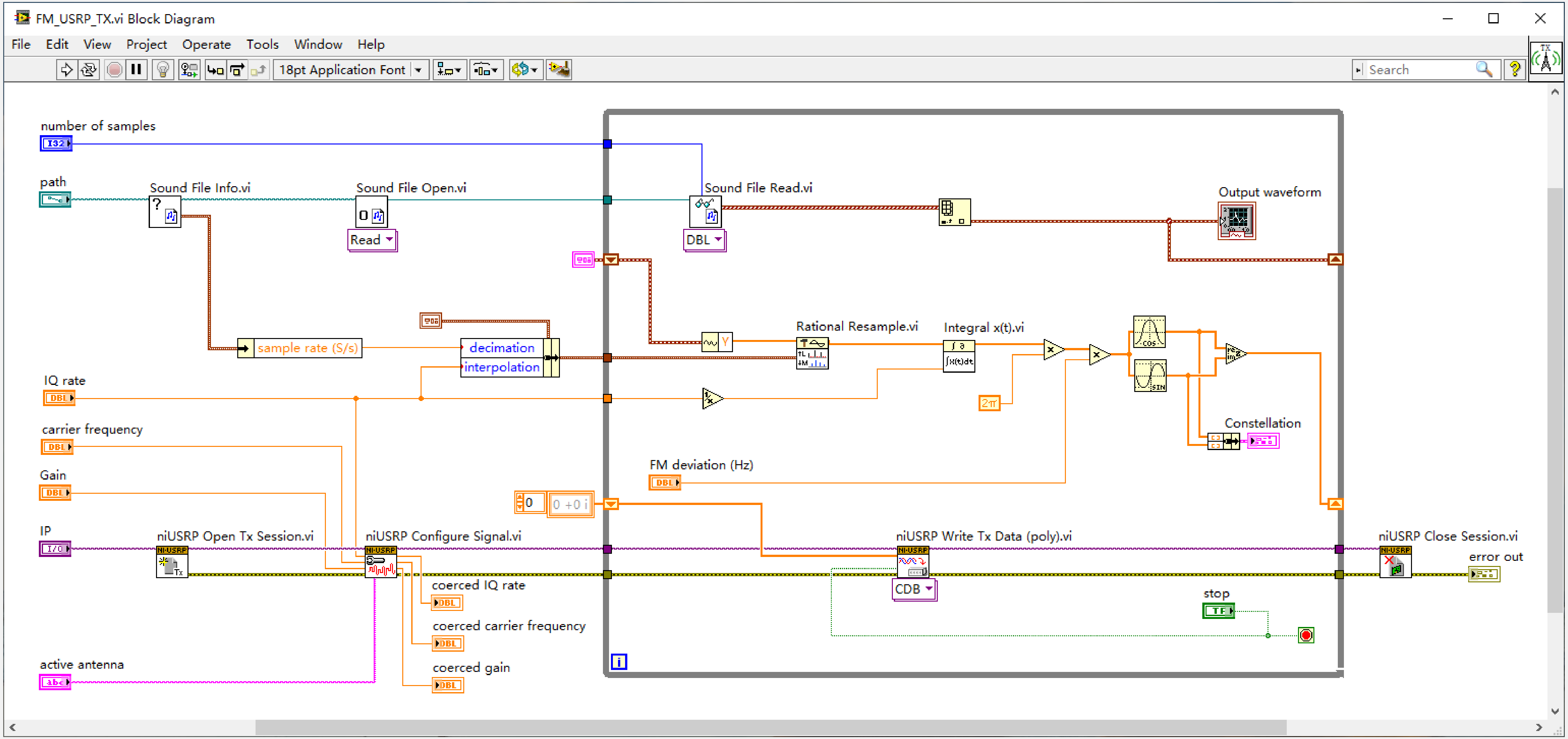
$$s_Q(nT_s) = A_c sin(2\pi \int k_f m(nT_s)dt)$$

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

FM Complex Baseband



Read WAV
Resample Waveforms
FM Modulation
DUC
DAC
Low-pass Filter
PLL
Play WAV
Resample Waveforms
FM Demodulation
DDC
ADC
Low-pass Filter
PLL
Host Computer
USRP motherboard
USRP daughterboard



FM_USRP_TX.vi Block Diagram
File Edit View Project Operate Tools Window Help
18pt Application Font
Search
number of samples
path
Sound File Info.vi
Sound File Open.vi
Sound File Read.vi
Read
DBL
Output waveform
sample rate (S/s)
decimation
interpolation
Rational Resample.vi
Integral x(t).vi
IQ rate
carrier frequency
Gain
IP
active antenna
2π
Constellation
FM deviation (Hz)
0 +0 i
niUSRP Open Tx Session.vi
niUSRP Configure Signal.vi
niUSRP Write Tx Data (poly).vi
niUSRP Close Session.vi
CDB
error out
coerced IQ rate
coerced carrier frequency
coerced gain
stop

Complex Baseband

Baseband

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

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

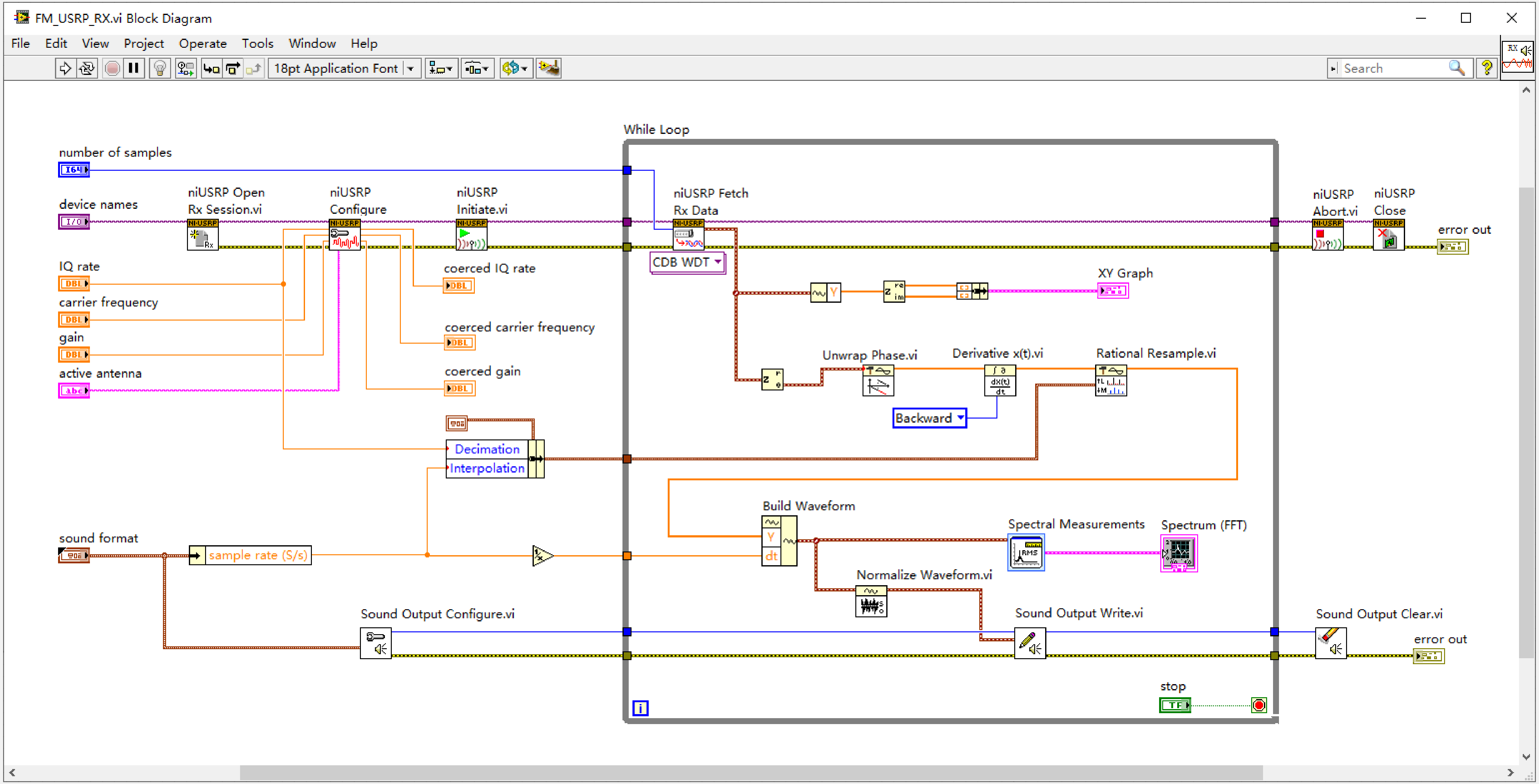
$$s_Q(nT_s) = A_c sin(2\pi \int k_f m(nT_s)dt)$$

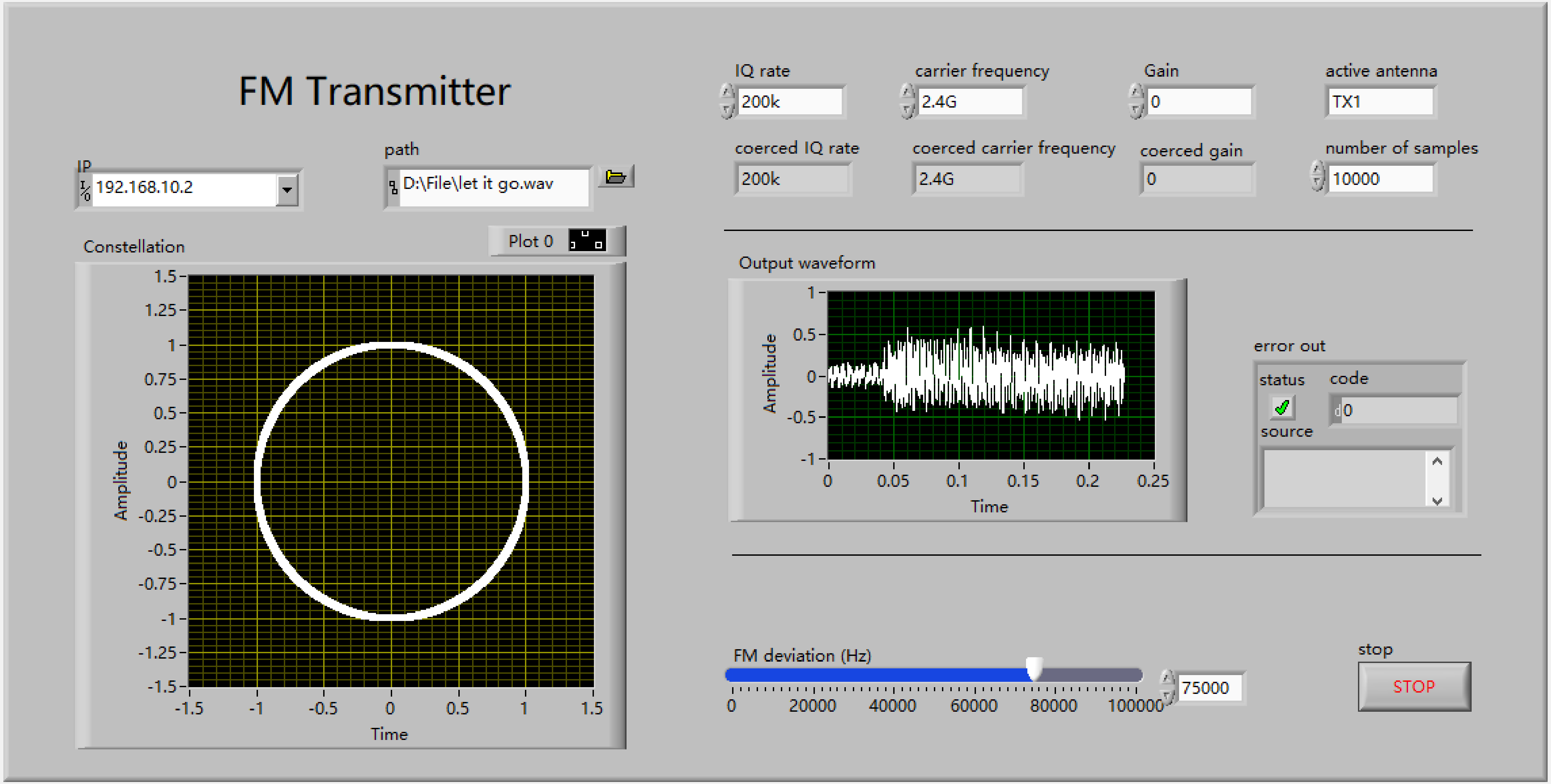
$$s_l(nT_s) = s_I(nT_s) + js_Q(nT_s)$$

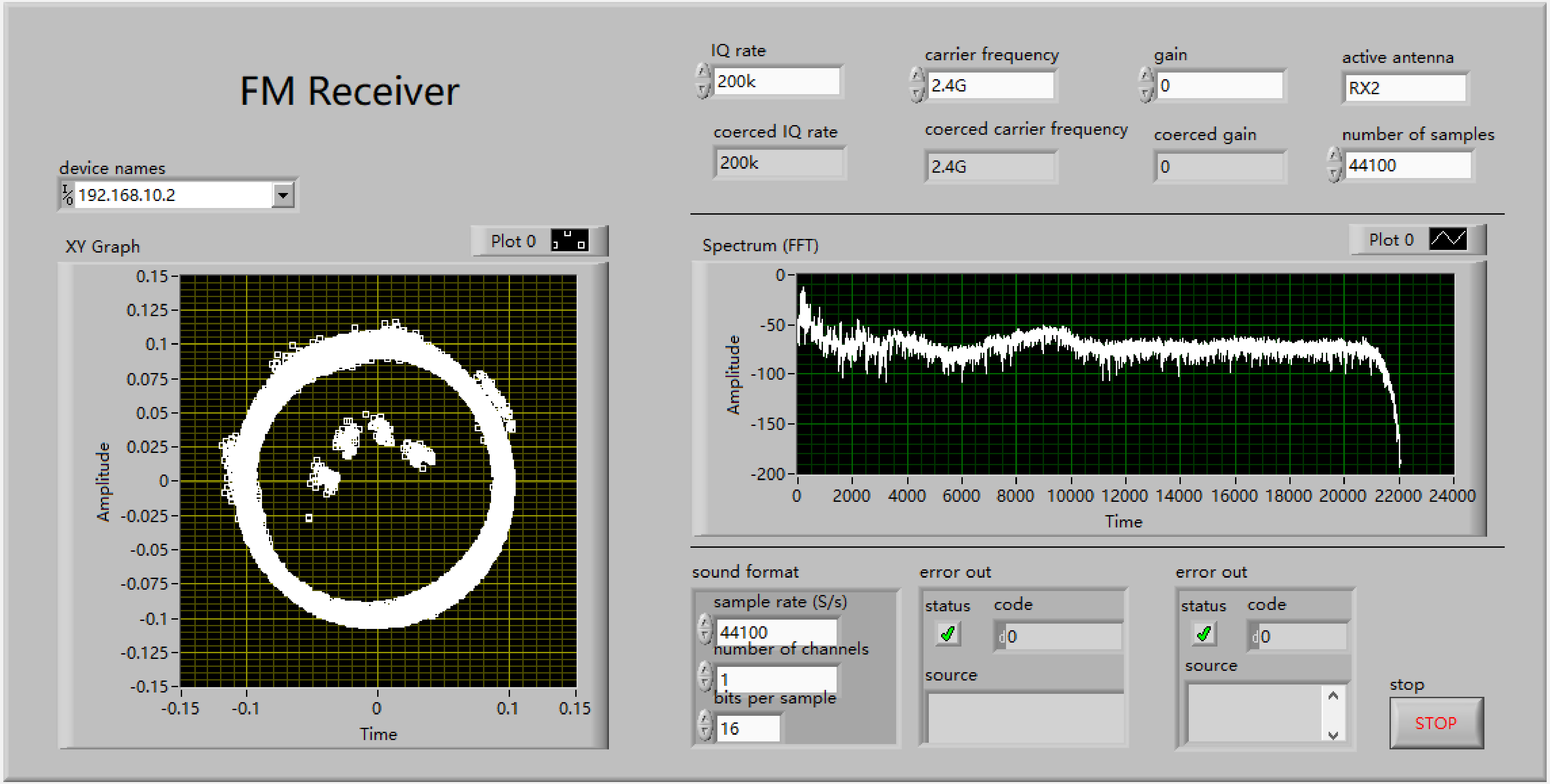
$$2\pi \int k_f m(nT_s)dt = atan\left(\frac{s_Q(nT_s)}{s_I(nT_s)}\right)$$

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

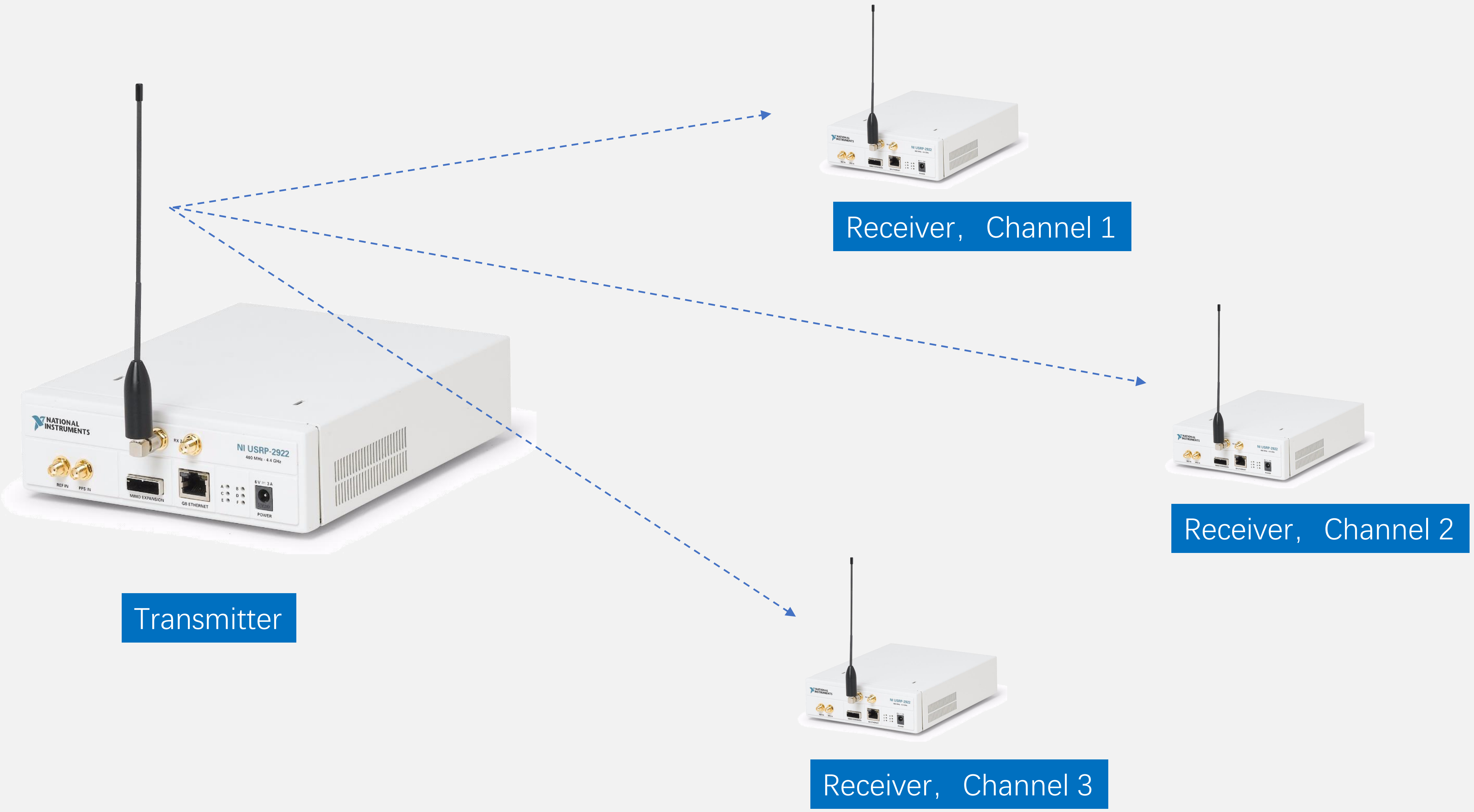
FM Complex Baseband


FM_USRP_RX.vi Block Diagram
File Edit View Project Operate Tools Window Help
18pt Application Font
Search
While Loop
number of samples
device names
niUSRP Open Rx Session.vi
niUSRP Configure
niUSRP Initiate.vi
niUSRP Fetch Rx Data
CDB WDT
niUSRP Abort.vi
niUSRP Close
error out
IQ rate
carrier frequency
gain
active antenna
coerced IQ rate
coerced carrier frequency
coerced gain
XY Graph
Unwrap Phase.vi
Derivative x(t).vi
Rational Resample.vi
Backward
Decimation
Interpolation
Build Waveform
Spectral Measurements
Spectrum (FFT)
sound format
sample rate (S/s)
Normalize Waveform.vi
Sound Output Configure.vi
Sound Output Write.vi
Sound Output Clear.vi
error out
stop

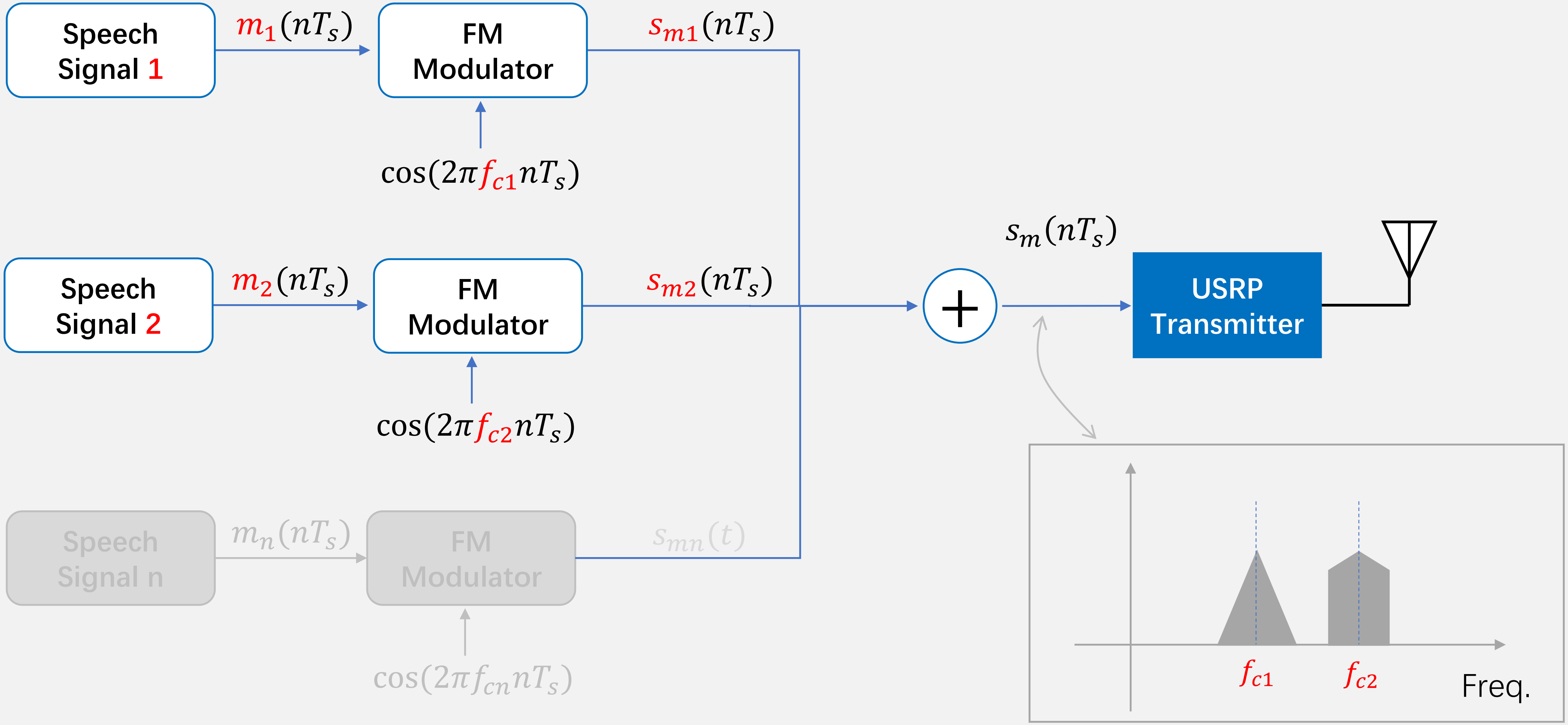

FM Transmitter
IP
192.168.10.2
path
D:\File\let it go.wav
Constellation
Plot 0
Amplitude
Time
IQ rate
200k
carrier frequency
2.4G
Gain
0
active antenna
TX1
coerced IQ rate
200k
coerced carrier frequency
2.4G
coerced gain
0
number of samples
10000
Output waveform
Amplitude
Time
error out
status
code
0
source
FM deviation (Hz)
0 20000 40000 60000 80000 100000
75000
stop
STOP


FM Receiver
device names
192.168.10.2
XY Graph
Plot 0
0.15
0.125
0.1
0.075
0.05
0.025
0
-0.025
-0.05
-0.075
-0.1
-0.125
-0.15
Amplitude
-0.15
-0.1
0
0.1
0.15
Time
IQ rate
200k
carrier frequency
2.4G
gain
0
active antenna
RX2
coerced IQ rate
200k
coerced carrier frequency
2.4G
coerced gain
0
number of samples
44100
Spectrum (FFT)
Plot 0
0
-50
-100
-150
-200
Amplitude
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
22000
24000
Time
sound format
sample rate (S/s)
44100
number of channels
1
bits per sample
16
error out
status
code
0
source
error out
status
code
0
source
stop
STOP

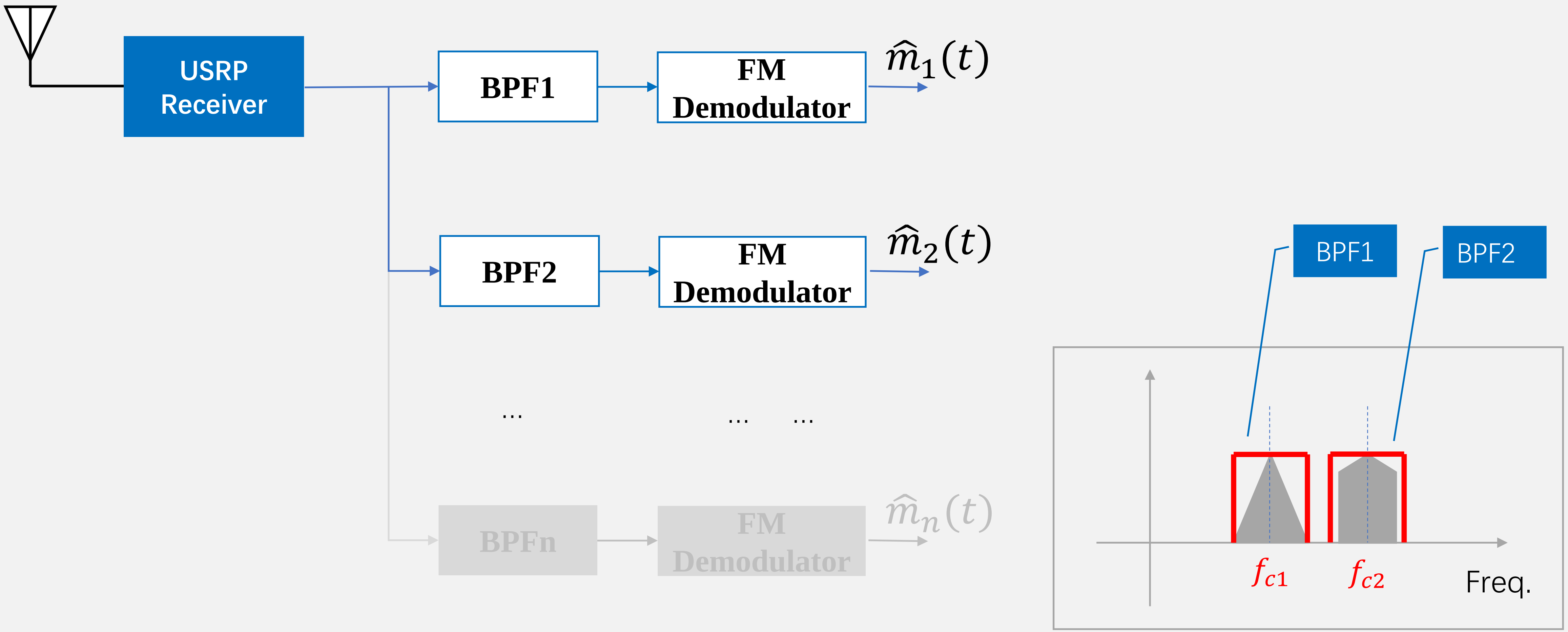
Demo: Multi Channel System



Receiver， Channel 1
Receiver， Channel 2
Transmitter
Receiver， Channel 3



$$s_m(nT_s) = A_c\big(1 + k_{a1} m_1(nT_s)\big)\cos(2\pi f_{c1} nT_s) + A_c\big(1 + k_{a2} m_2(nT_s)\big)\cos(2\pi f_{c2} nT_s)$$


USRP
Receiver
BPF1
FM
Demodulator
$\hat{m}_1(t)$
BPF2
FM
Demodulator
$\hat{m}_2(t)$
...
... ...
BPFn
FM
Demodulator
$\hat{m}_n(t)$
BPF1
BPF2
f_{c1}
f_{c2}
Freq.

Discussion and Research

- 1. Implementation of the FM Receiver with the Pre-recorded signal.
- 2. How to design the multi-channel system ?
- 3. How to implement the FM receiver by DLL ?
- 4. Design a User Interface (UI).
- 5. Implementation with Producer-Consumer Design Pattern.
- 6. 2-3 Students work as a group, Presentation and Report.

Summary

- Design and Verification
  1. Pre-Labs
  2. AM/DSB/SSB/FM Design
  3. USRP Experiments
  4. Comparison and Analysis

- **Question ?**