无线通信实验在线开放课程

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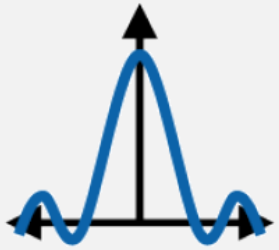
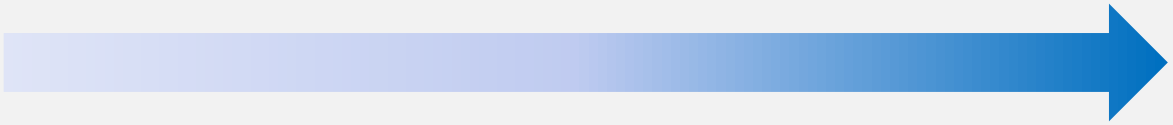
广东省教学质量工程建设项目

从理论到实践





Design Verification

Product Verification

Research/ Modeling

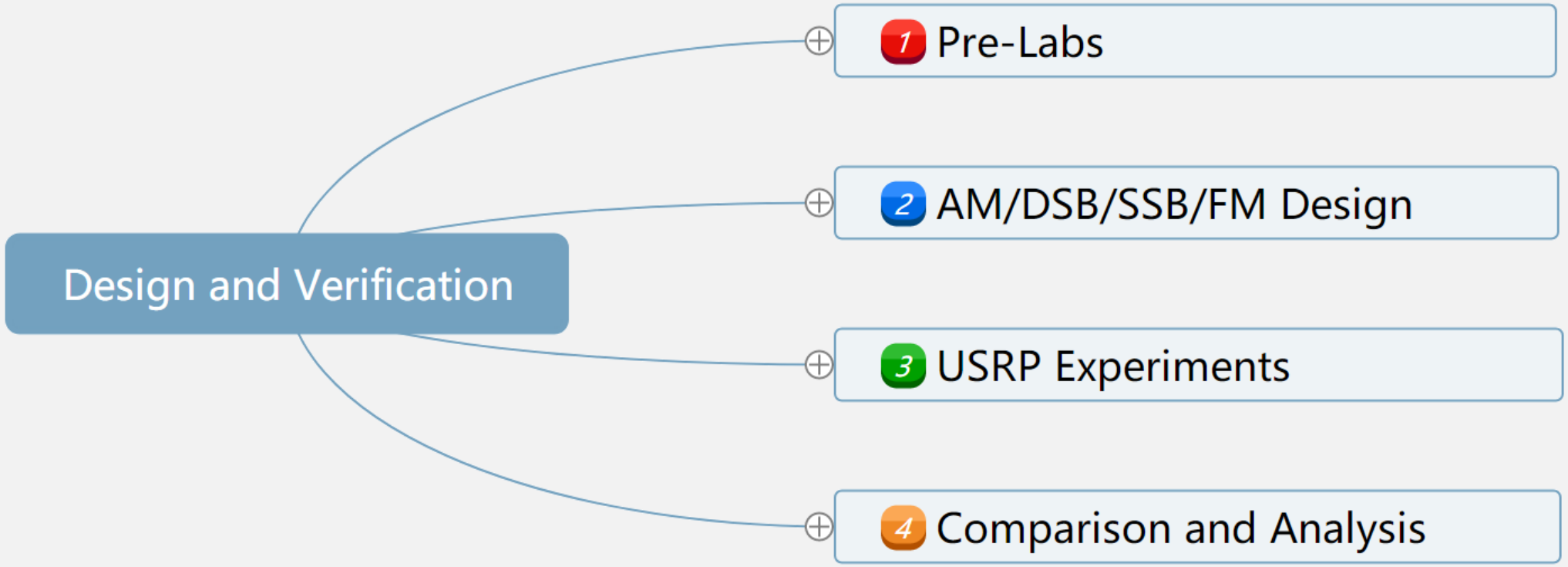
Design/ Simulation

Verification/ Validation

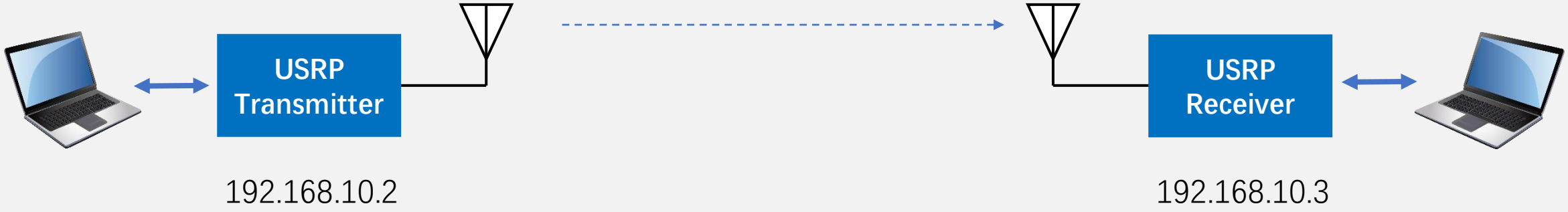
Manufacturing

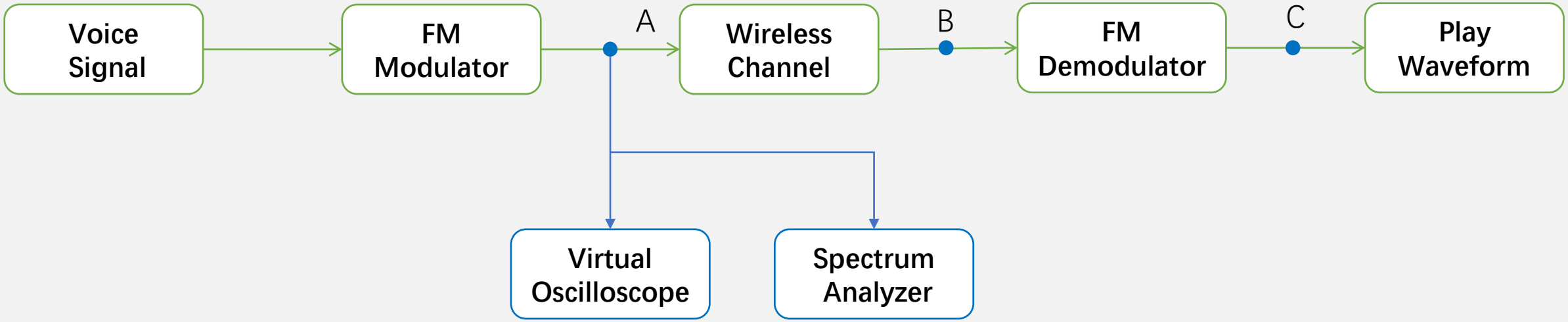
第八章

高性能软件无线电

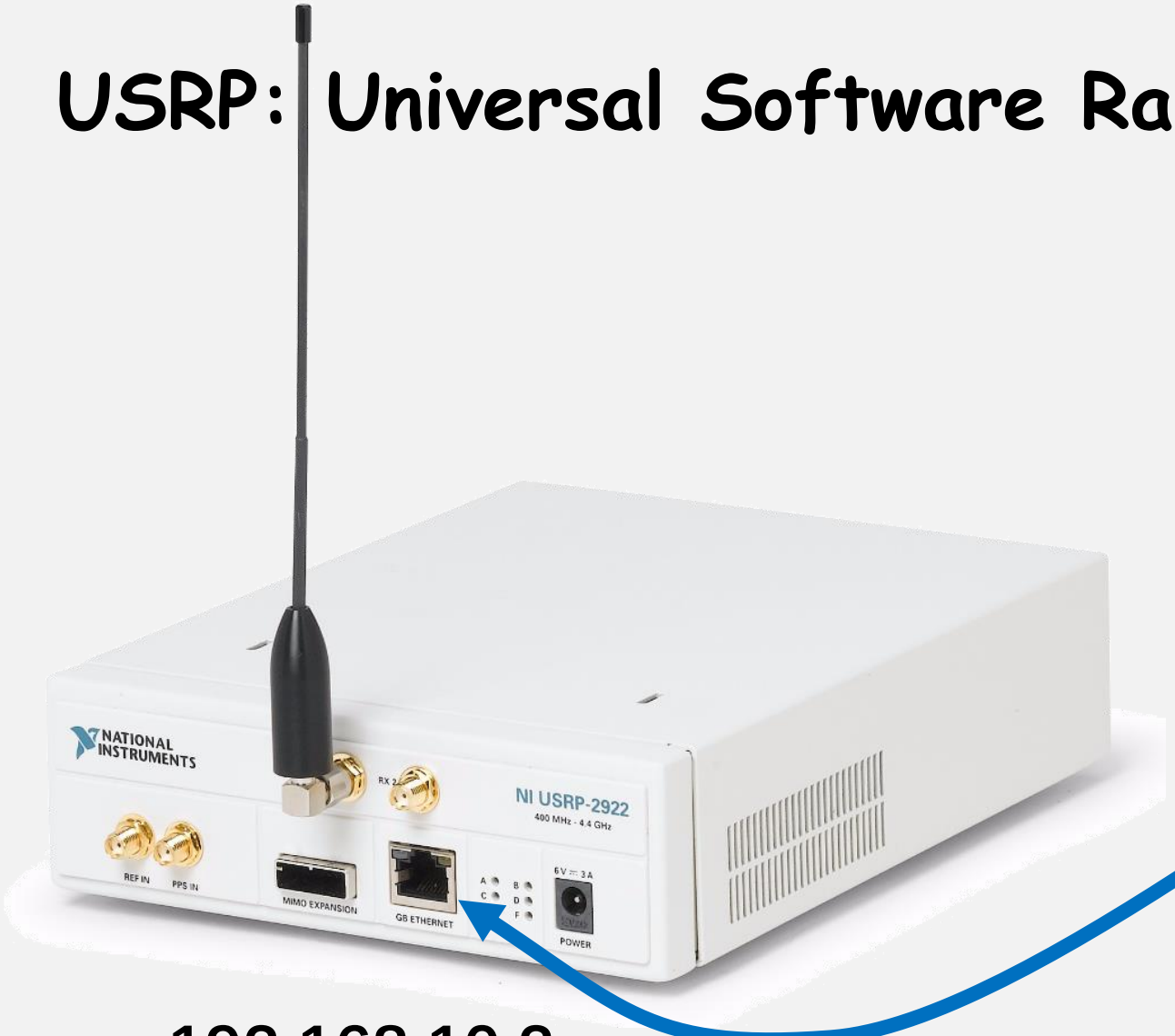

Design and Verification
1 Pre-Labs
2 AM/DSB/SSB/FM Design
3 USRP Experiments
4 Comparison and Analysis

系统模型


USRP
Transmitter
USRP
Receiver
192.168.10.2
192.168.10.3


Voice
Signal
FM
Modulator
A
Wireless
Channel
B
FM
Demodulator
C
Play
Waveform
Virtual
Oscilloscope
Spectrum
Analyzer

USRP: Universal Software Radio Peripheral

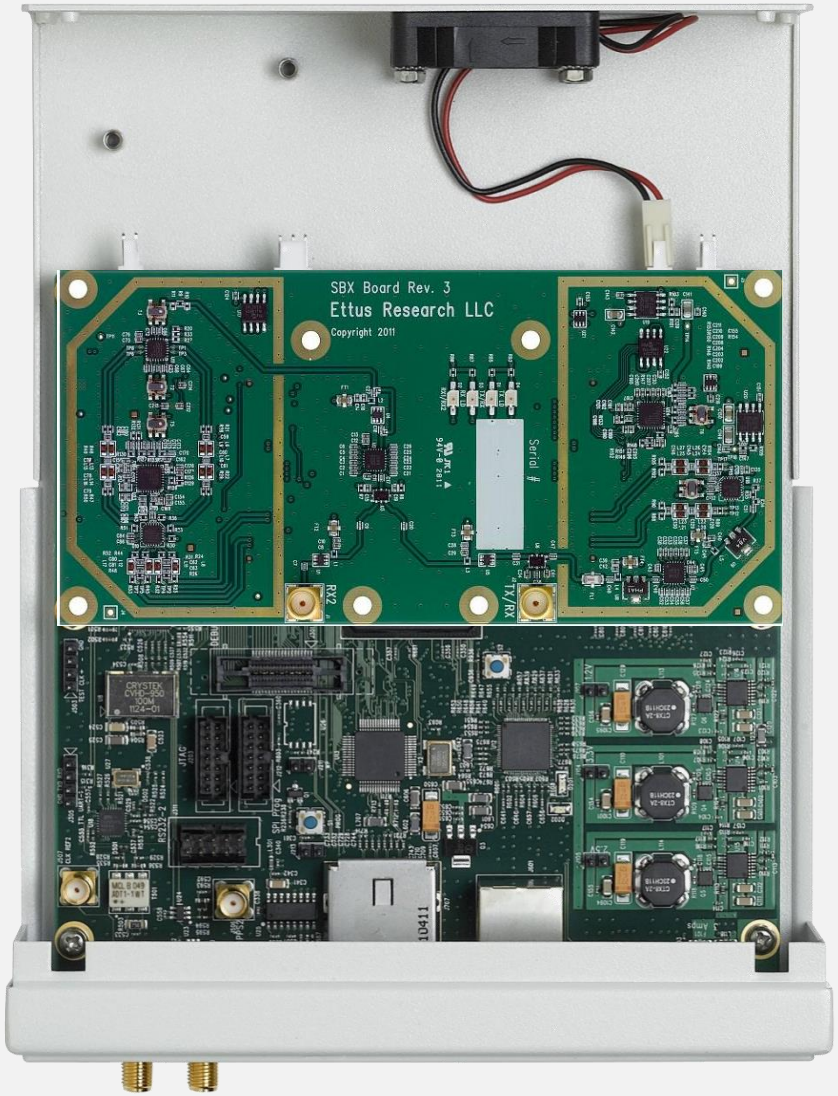


192.168.10.1

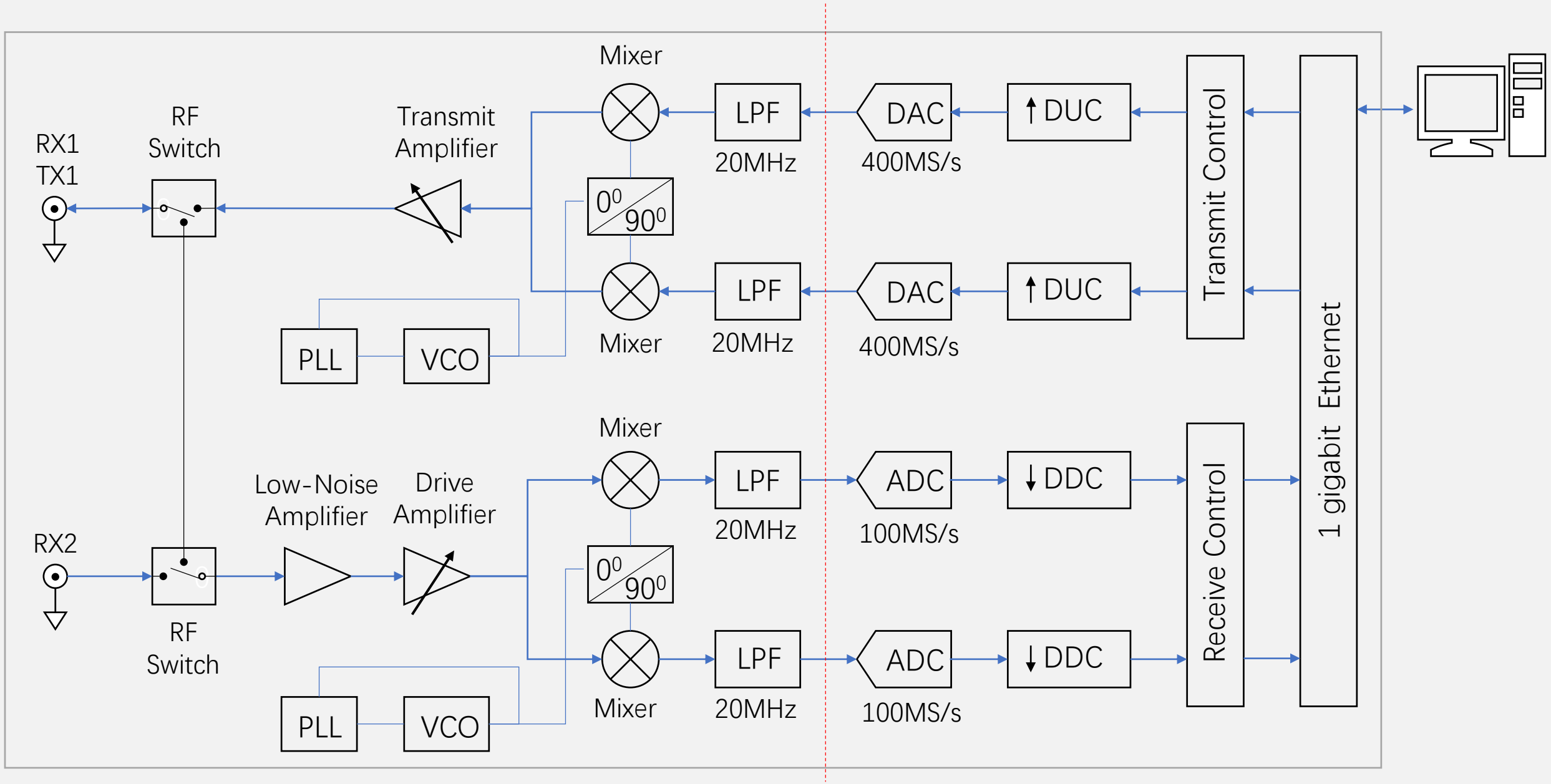
192.168.10.2

NATIONAL INSTRUMENTS

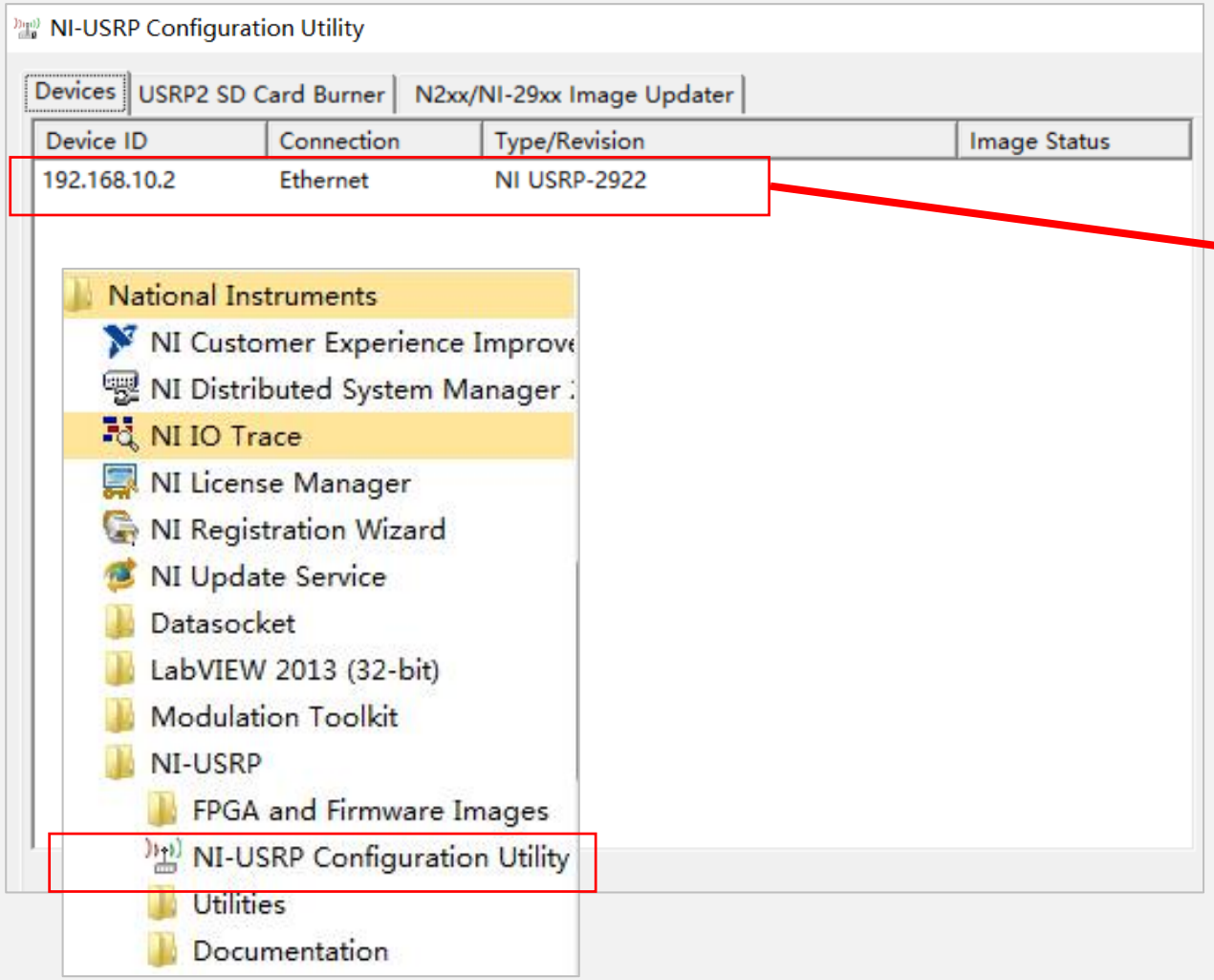
Ettus Research™
A National Instruments Brand

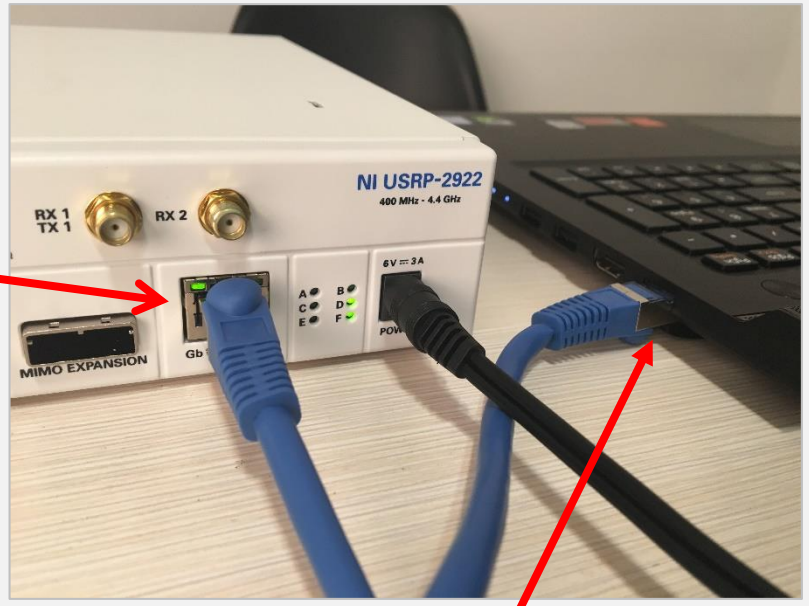


Daughter board	Frequency range
SBX	400 - 4400MHz
WBX	50 - 2200MHz
XCVR2450	2400 - 2500MHz
Basic	1 - 250MHz


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

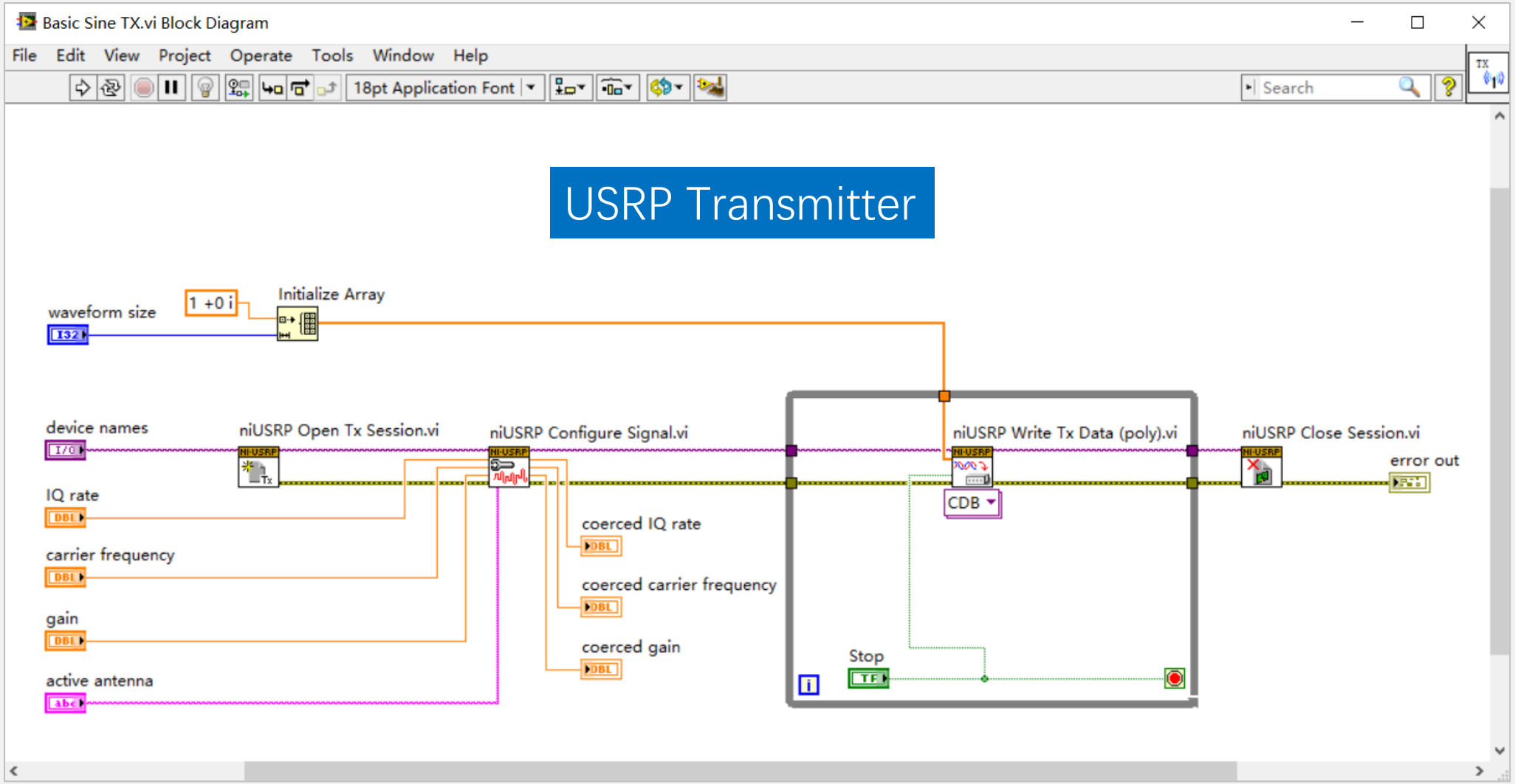
查找 USRP





Host computer's IP:
192.168.10.1

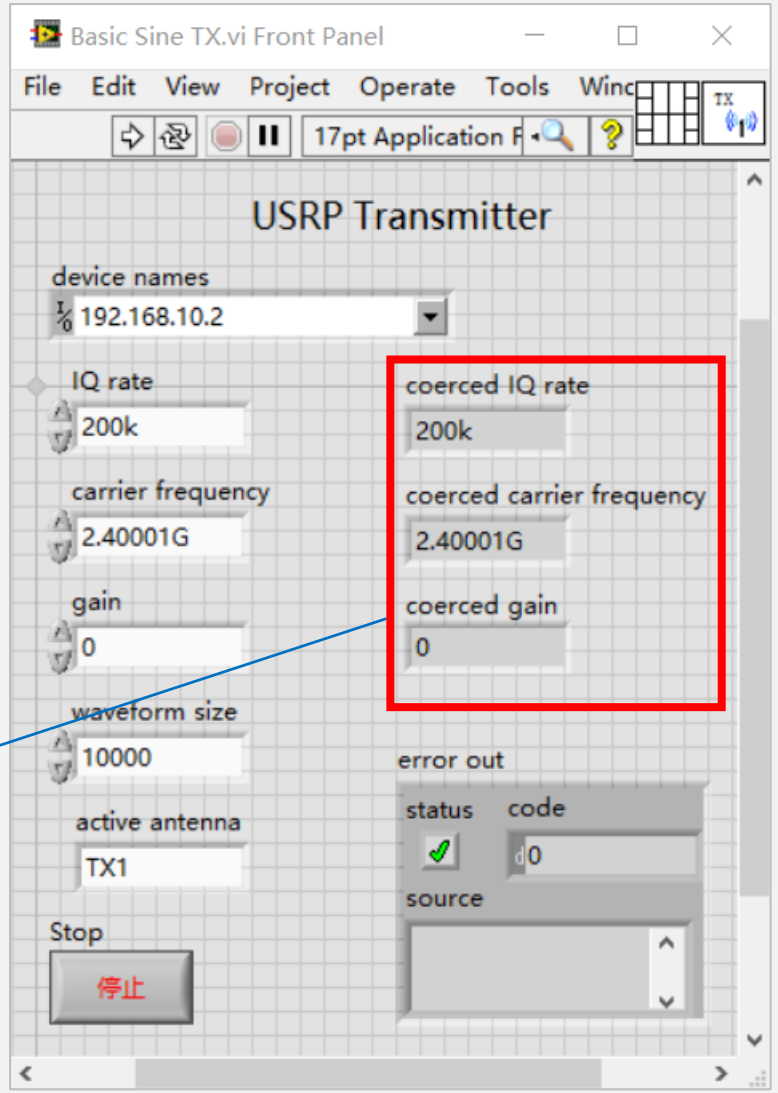
发射机程序框图


Basic Sine TX.vi Block Diagram
File Edit View Project Operate Tools Window Help
18pt Application Font
Search
TX
USRP Transmitter
waveform size
I32
1 +0 i
Initialize Array
device names
I/O
niUSRP Open Tx Session.vi
niUSRP Configure Signal.vi
niUSRP Write Tx Data (poly).vi
niUSRP Close Session.vi
error out
IQ rate
DBL
carrier frequency
DBL
gain
DBL
active antenna
Abc
coerced IQ rate
DBL
coerced carrier frequency
DBL
coerced gain
DBL
CDB
Stop
TF
i

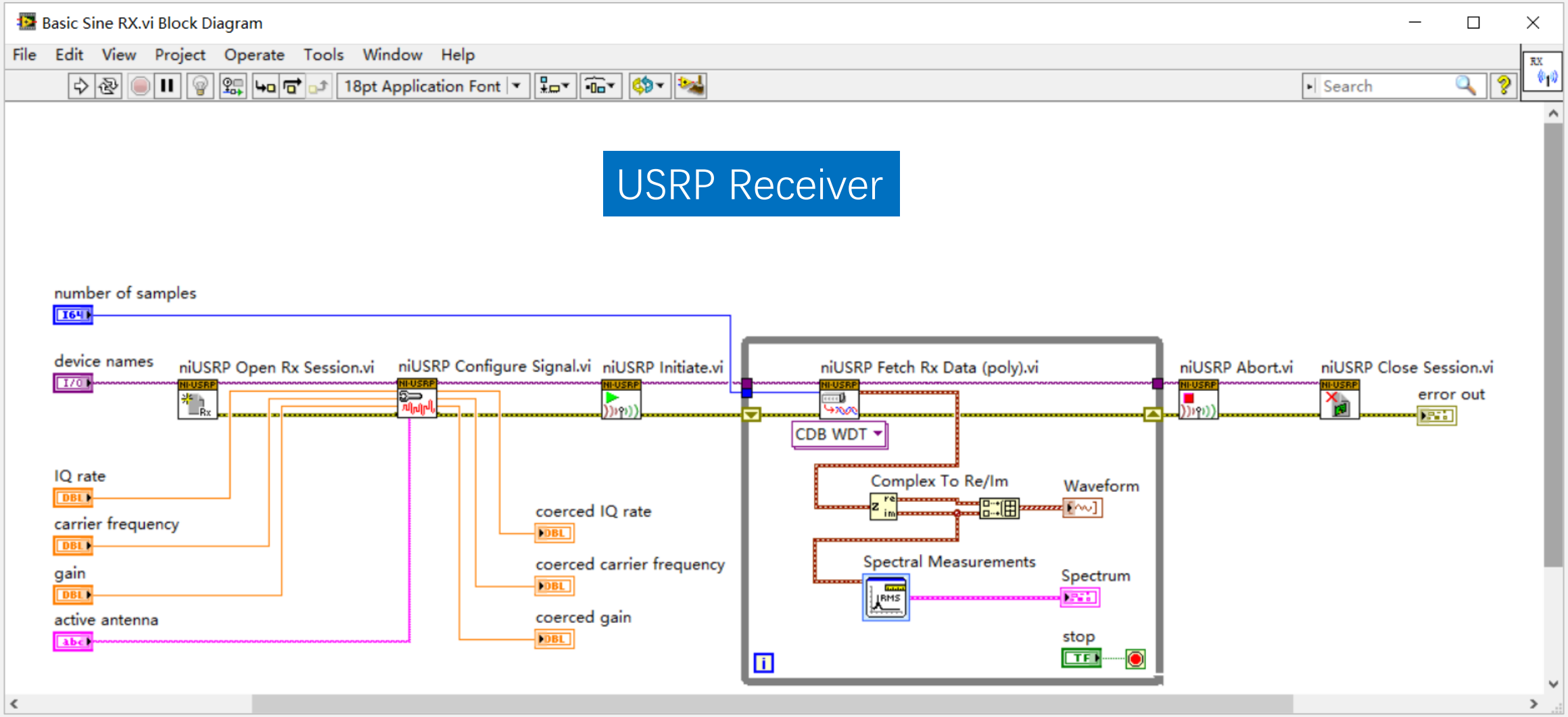
前面板

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

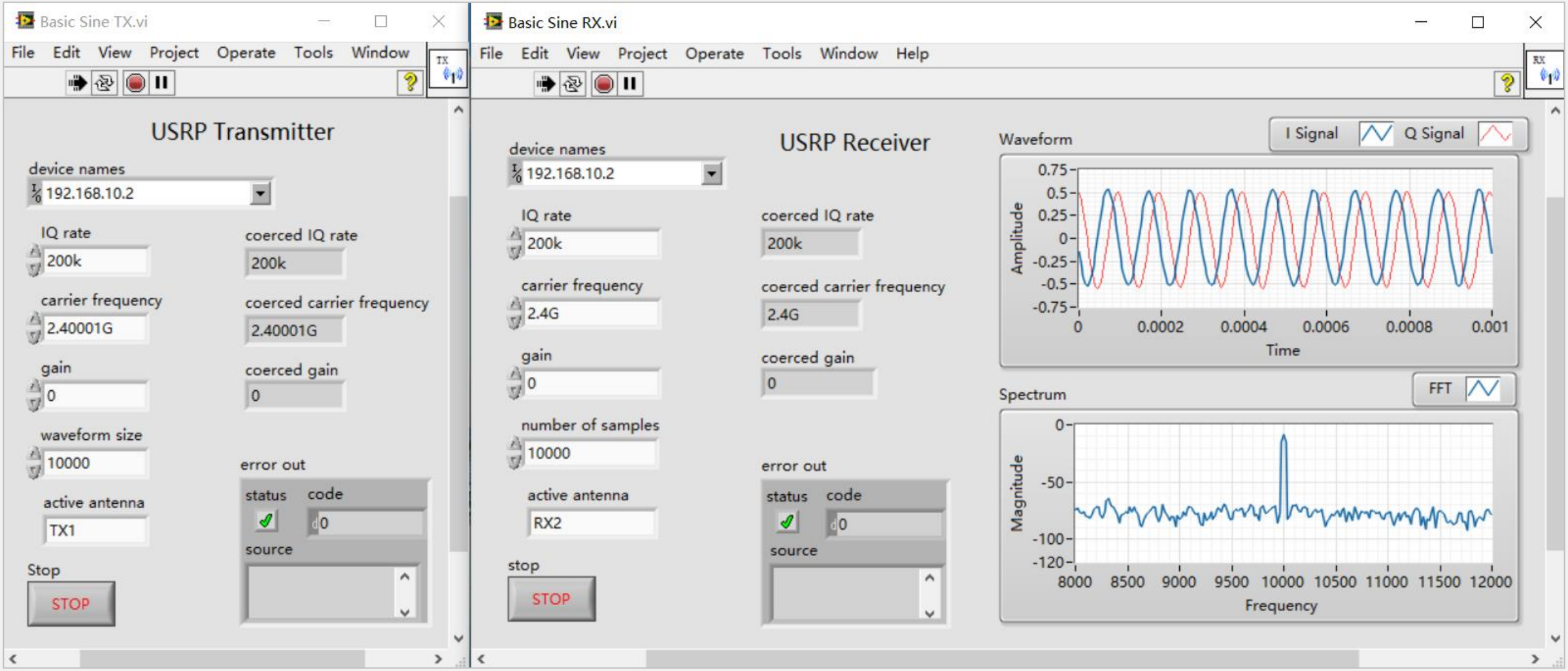
Actual value



接收机程序框图


Basic Sine RX.vi Block Diagram
File Edit View Project Operate Tools Window Help
18pt Application Font
Search
USRP Receiver
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

前面板

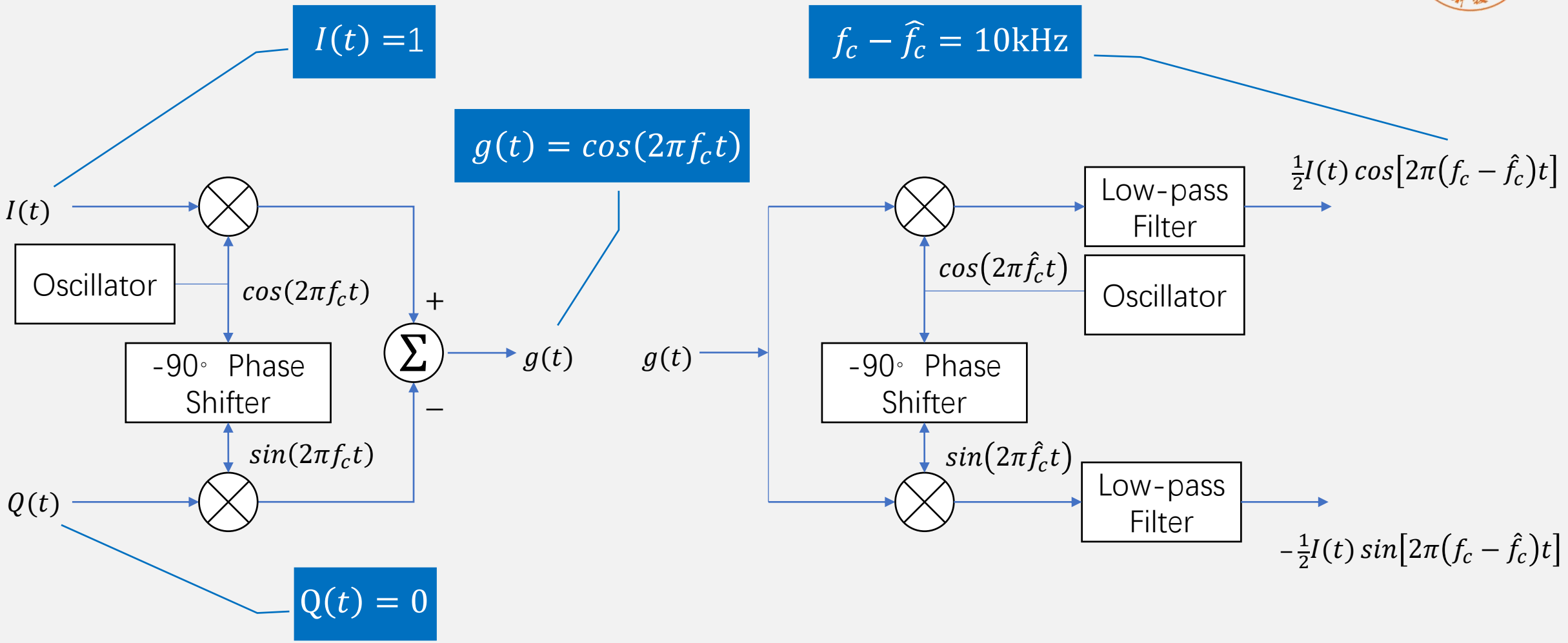

Basic Sine TX.vi
File Edit View Project Operate Tools Window
USRP Transmitter
device names
192.168.10.2
IQ rate
200k
coerced IQ rate
200k
carrier frequency
2.40001G
coerced carrier frequency
2.40001G
gain
0
coerced gain
0
waveform size
10000
error out
status
code
0
source
active antenna
TX1
Stop
STOP
Basic Sine RX.vi
File Edit View Project Operate Tools Window Help
USRP Receiver
device names
192.168.10.2
IQ rate
200k
coerced IQ rate
200k
carrier frequency
2.4G
coerced carrier frequency
2.4G
gain
0
coerced gain
0
number of samples
10000
error out
status
code
0
source
active antenna
RX2
stop
STOP
Waveform
I Signal
Q Signal
Amplitude
0.75
0.5
0.25
0
-0.25
-0.5
-0.75
0
0.0002
0.0004
0.0006
0.0008
0.001
Time
Spectrum
FFT
Magnitude
0
-50
-100
-120
8000
8500
9000
9500
10000
10500
11000
11500
12000
Frequency

复基带信号

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

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

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


$I(t)$ =1
$g(t) = cos(2\pi f_c t)$
$f_c - \hat{f}_c = 10\text{kHz}$
$I(t)$
Oscillator
$cos(2\pi f_c t)$
-90° Phase Shifter
$sin(2\pi f_c t)$
$Q(t)$
+
−
Σ
$g(t)$
$g(t)$
Low-pass Filter
$\frac{1}{2}I(t)\,cos[2\pi(f_c - \hat{f}_c)t]$
$cos(2\pi\hat{f}_c t)$
Oscillator
-90° Phase Shifter
$sin(2\pi\hat{f}_c t)$
Low-pass Filter
$-\frac{1}{2}I(t)\,sin[2\pi(f_c - \hat{f}_c)t]$
Q(t) = 0

USRP驱动函数

Configure

Read/Write

Close

USRP Transmitter

niUSRP Open Rx Session.vi

niUSRP Configure Signal.vi

niUSRP Initiate.vi

niUSRP Fetch Rx Data (poly).vi

CDB Cluster

niUSRP Abort.vi

niUSRP Close Session.vi

USRP Receiver

niUSRP Open Tx Session.vi

niUSRP Configure Signal.vi

niUSRP Write Tx Data (poly).vi

CDB Cluster

niUSRP Close Session.vi

复基带信号

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

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

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

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

Complex Baseband

Baseband

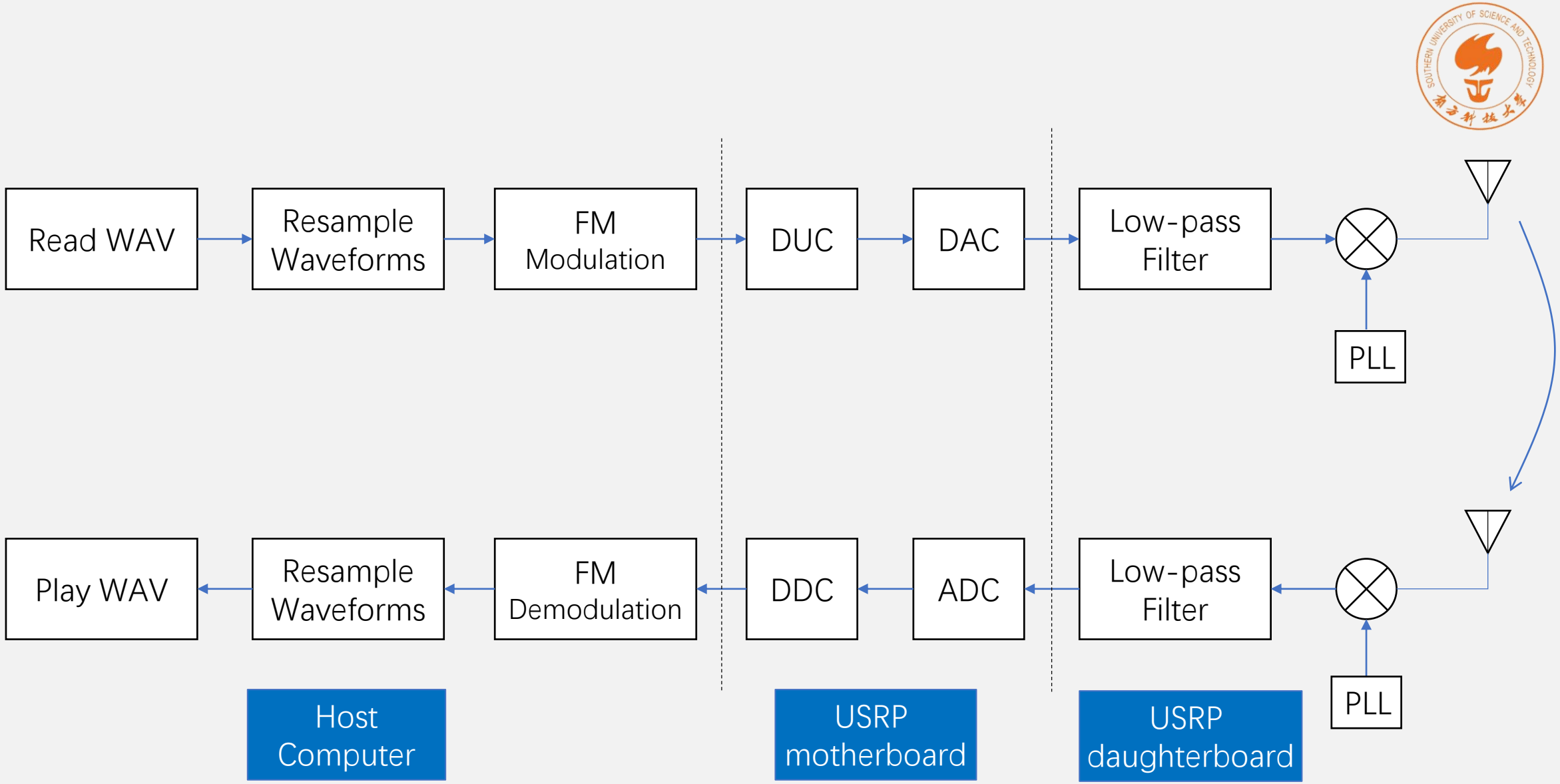
$$s(nT_s) = cos[2\pi f_c t + 2\pi \int k_f m(nT_s)dt]$$

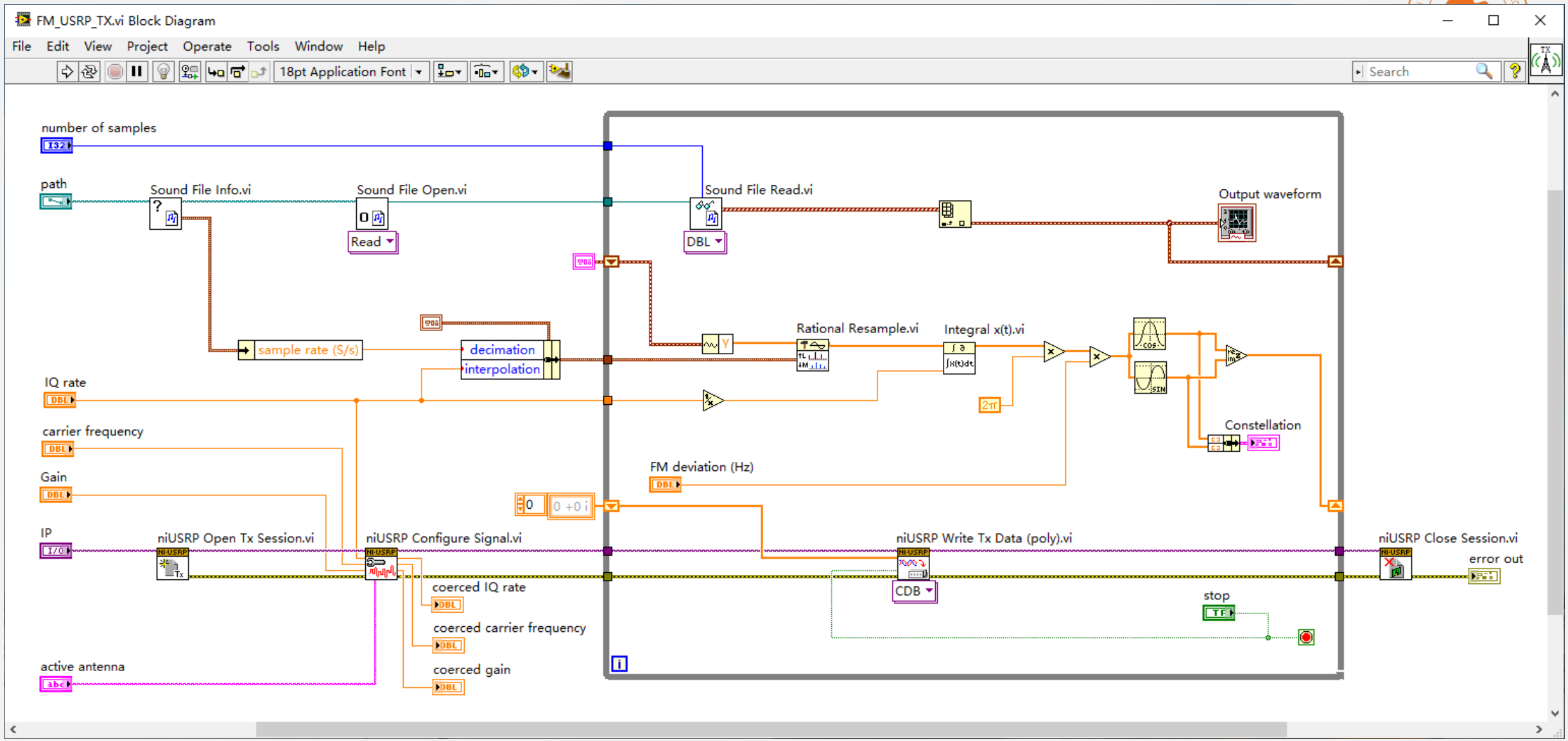
$$s_I(nT_s) = A_c cos(2\pi \int k_f m(nT_s)dt)$$

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

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

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
Read
Sound File Read.vi
DBL
Output waveform
sample rate (S/s)
decimation
interpolation
Rational Resample.vi
Integral x(t).vi
IQ rate
carrier frequency
Gain
Constellation
FM deviation (Hz)
IP
niUSRP Open Tx Session.vi
niUSRP Configure Signal.vi
niUSRP Write Tx Data (poly).vi
CDB
niUSRP Close Session.vi
error out
stop
coerced IQ rate
coerced carrier frequency
coerced gain
active antenna

复基带信号

Baseband

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

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

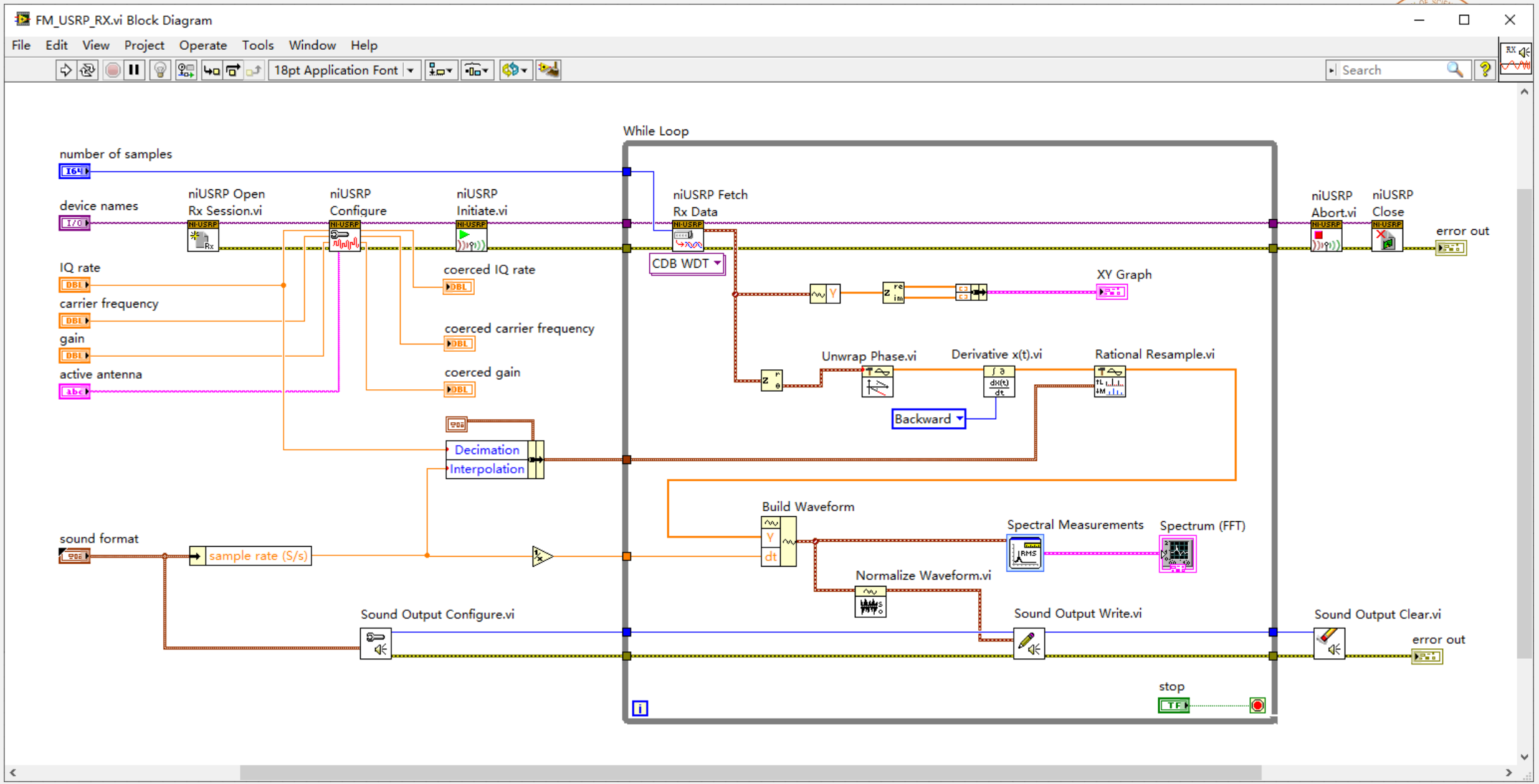
$$s_Q(nT_s) = A_c sin(2\pi \int k_f m(nT_s)dt)$$

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

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

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

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
niUSRP Abort.vi
niUSRP Close
error out
IQ rate
carrier frequency
gain
active antenna
coerced IQ rate
coerced carrier frequency
coerced gain
CDB WDT
XY Graph
Unwrap Phase.vi
Derivative x(t).vi
Rational Resample.vi
Backward
Decimation
Interpolation
sound format
sample rate (S/s)
Build Waveform
Spectral Measurements
Spectrum (FFT)
Normalize Waveform.vi
Sound Output Configure.vi
Sound Output Write.vi
Sound Output Clear.vi
error out
stop

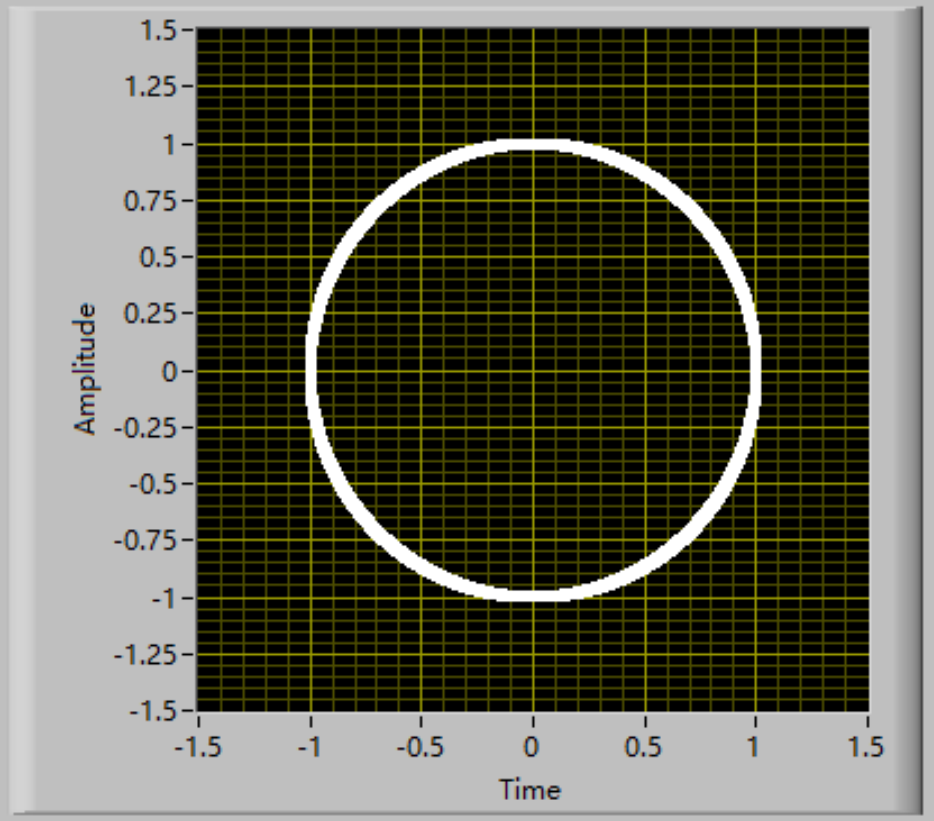
FM Transmitter

IP
192.168.10.2

path
D:\File\let it go.wav

Constellation

Plot 0



IQ rate
200k

carrier frequency
2.4G

Gain
0

active antenna
TX1

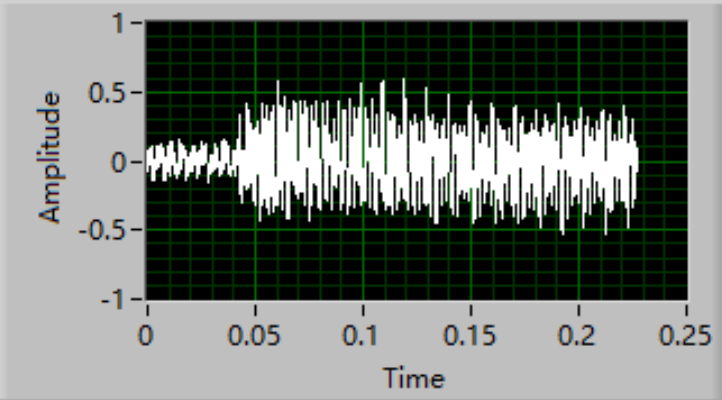
coerced IQ rate
200k

coerced carrier frequency
2.4G

coerced gain
0

number of samples
10000

Output waveform



error out

status

code
0

source

FM deviation (Hz)
75000
0
20000
40000
60000
80000
100000

stop
STOP

FM Receiver

device names
192.168.10.2

IQ rate
200k

carrier frequency
2.4G

gain
0

active antenna
RX2

coerced IQ rate
200k

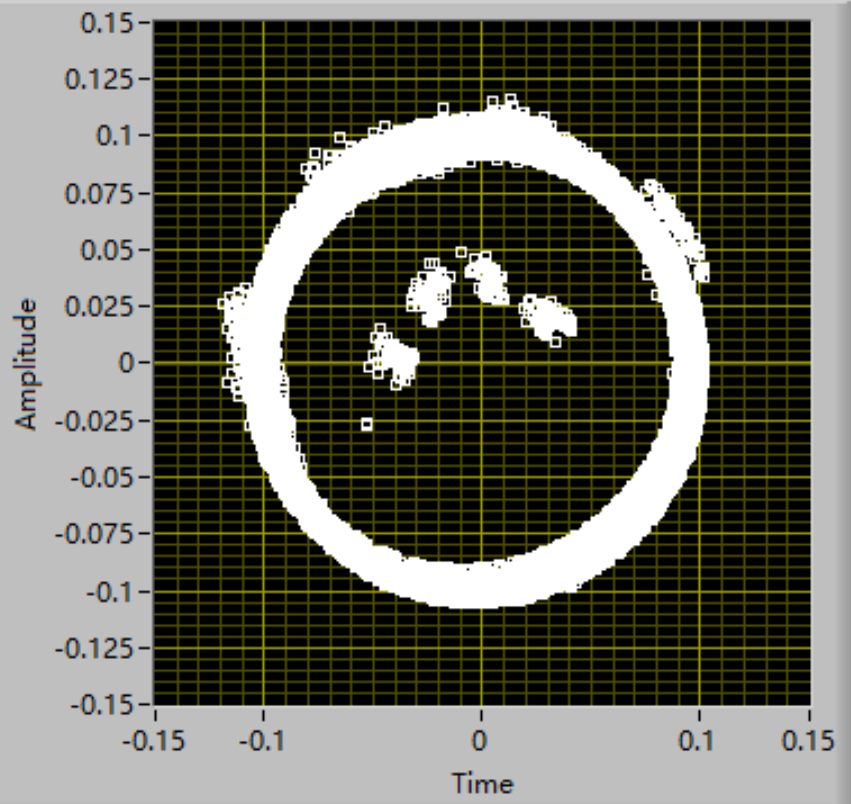
coerced carrier frequency
2.4G

coerced gain
0

number of samples
44100

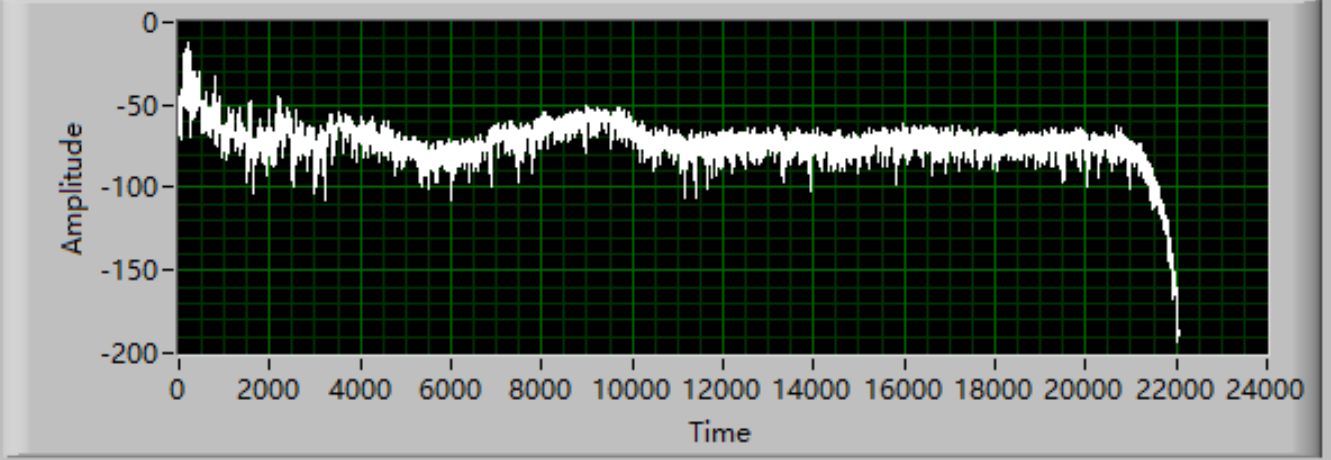
XY Graph

Plot 0



Spectrum (FFT)

Plot 0



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

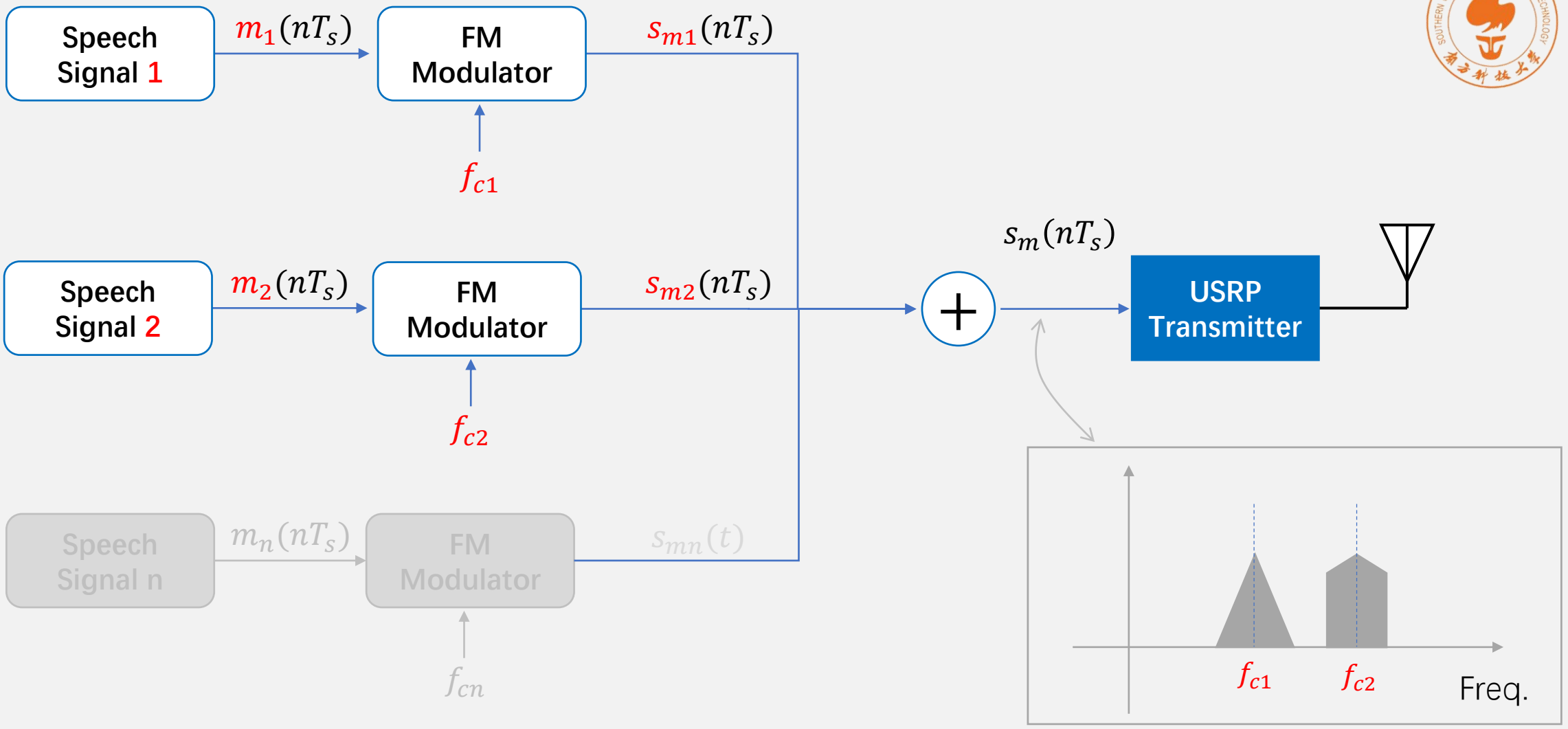
STOP

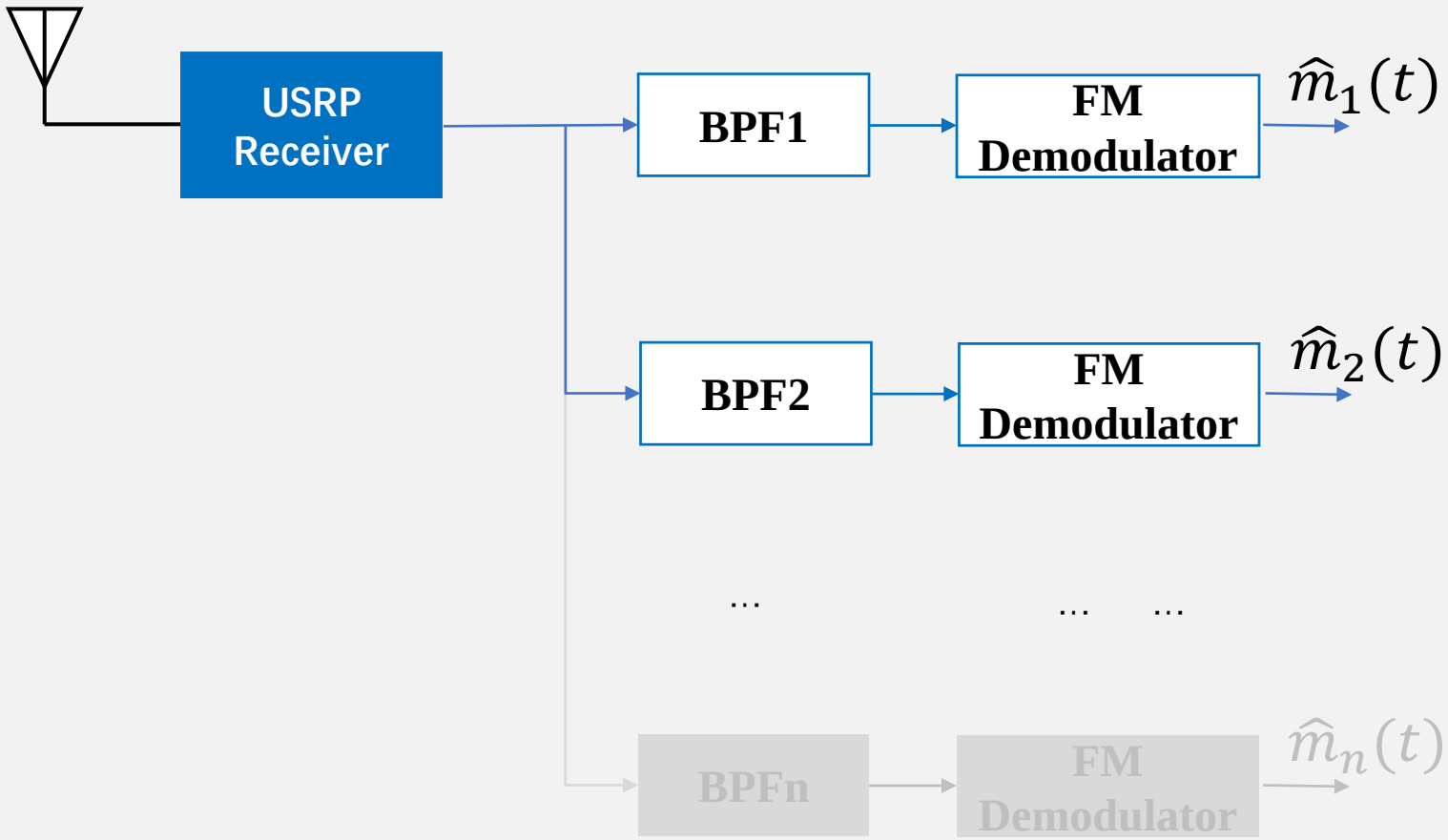
Transmitter

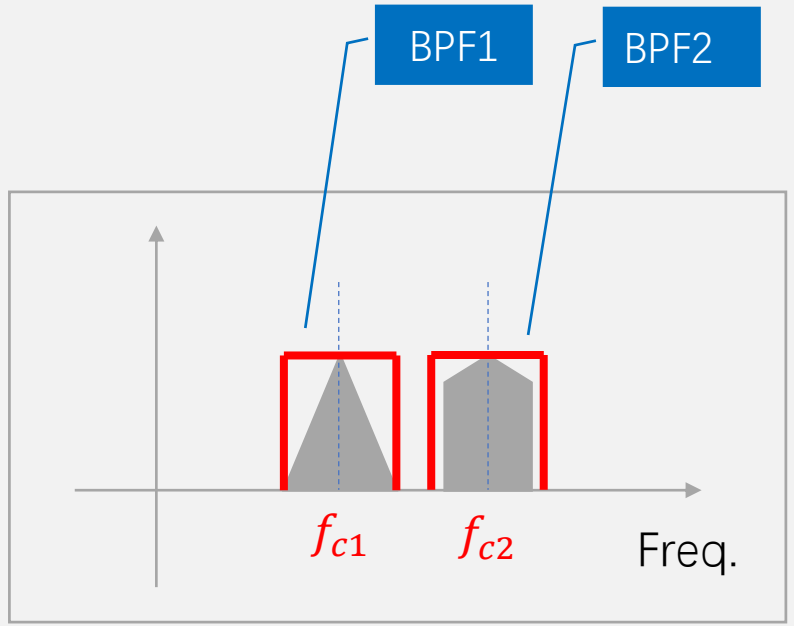
Receiver， Channel 1

Receiver， Channel 2

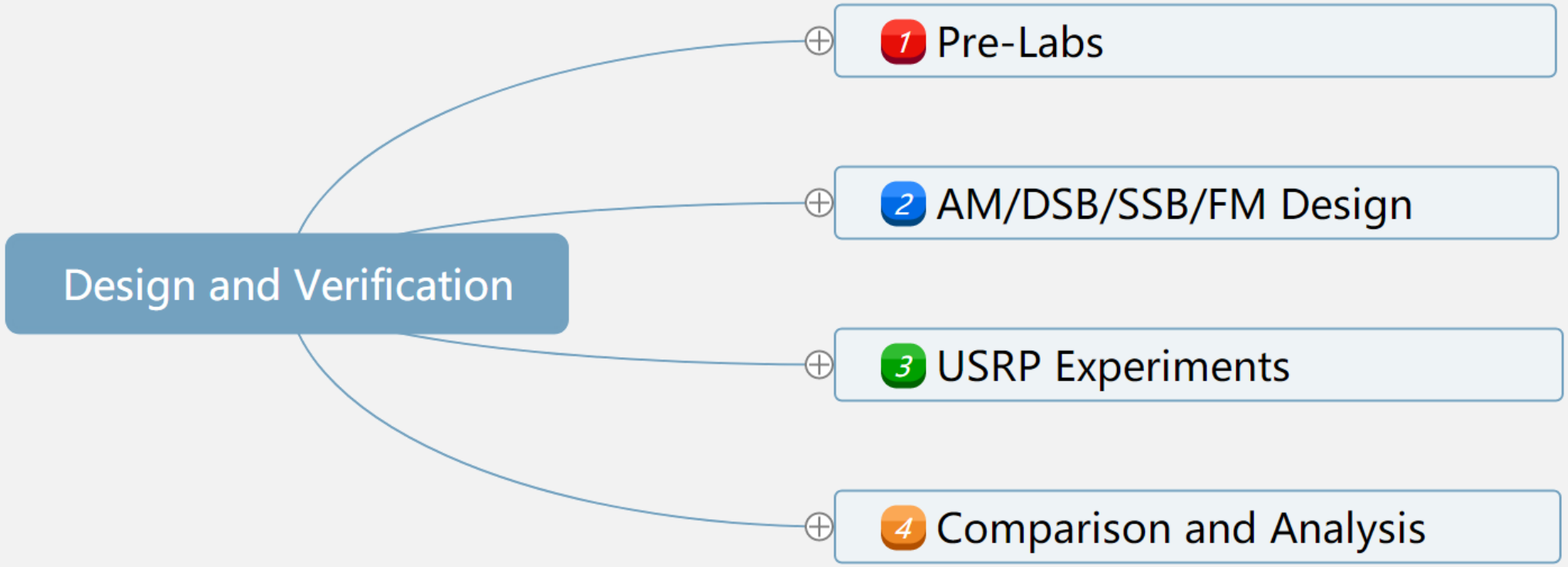
Receiver， Channel 3


Speech Signal 1
$m_1(nT_s)$
FM Modulator
$s_{m1}(nT_s)$
f_{c1}
Speech Signal 2
$m_2(nT_s)$
FM Modulator
$s_{m2}(nT_s)$
f_{c2}
Speech Signal n
$m_n(nT_s)$
FM Modulator
$s_{mn}(t)$
f_{cn}
+
$s_m(nT_s)$
USRP Transmitter
f_{c1}
f_{c2}
Freq.


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.

Summary


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

- Question ?

【通信新说】