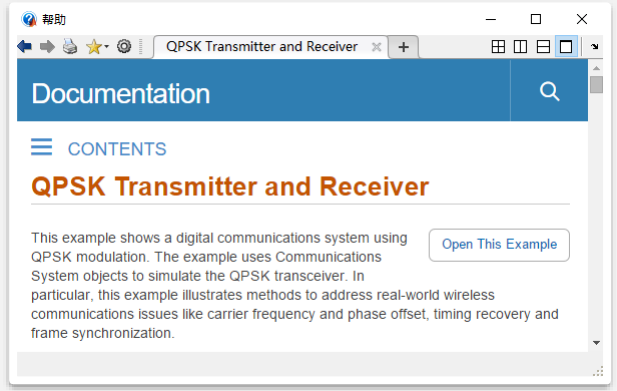


commQPSKTransmitterReceiver.m

commqpsktxrx_init

runQPSKSystemUnderTest

General simulation parameters
Tx parameters
Channel parameters
Rx parameters

QPSKTransmitter

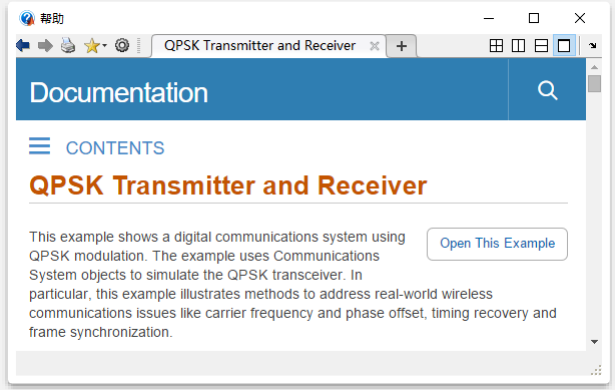
QPSKReceiver

QPSKChannel

createQPSKScopes

hTx
hRx
hChan
hScopes

for
step(hTx,…)
step(hRx,…)
step(hChan,…)
step(hScopes,…)
end



QPSKTransmitter

QPSKBitsGenerator

comm.QPSKModulator

dsp.FIRInterpolator

QPSKChannel

comm.PhaseFrequency Offset

dsp.VariableFractional Delay

comm.AWGNChannel

comm.CarrierSynchronizer

comm.SymbolSynchronizer

FrameFormation

QPSKReceiver

QPSKDataDecoder

comm.AGC

dsp.FIRDecimator

comm.PSKCoarseFrequ encyEstimator

comm.PhaseFrequencyOffset

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Communication Systems Design

Lab 3: Packet Transmission using USRP

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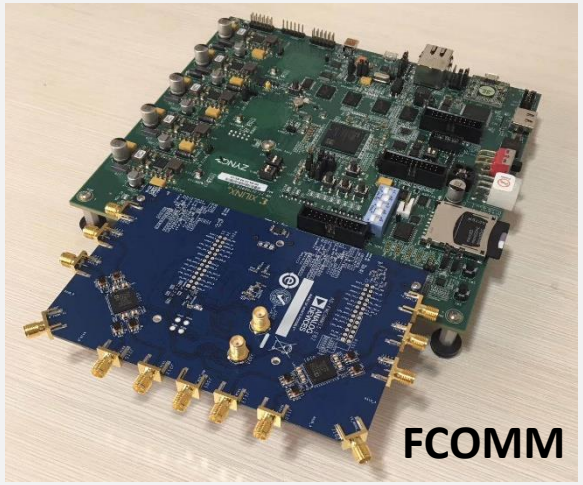
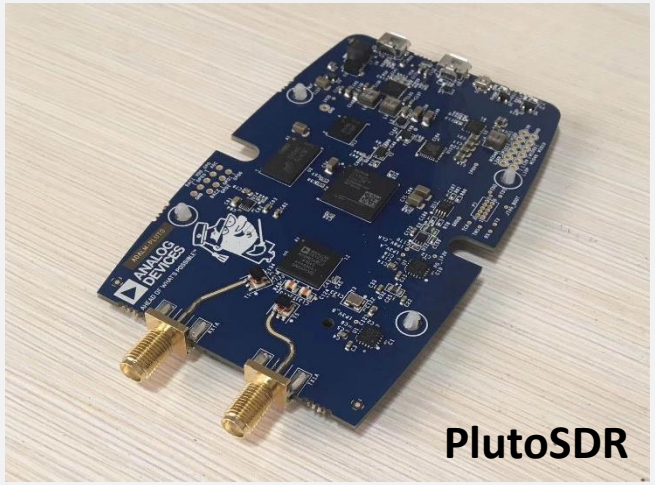
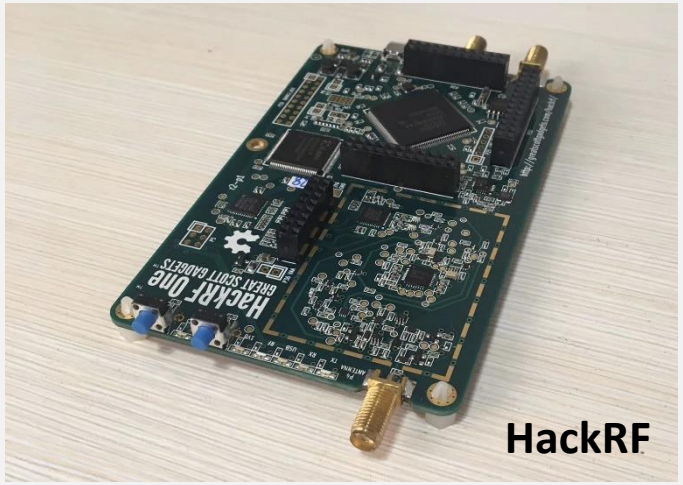
Electrical & Electronic Engineering
Southern University of Science and Technology

Software-Defined Radio (SDR)


FCOMM

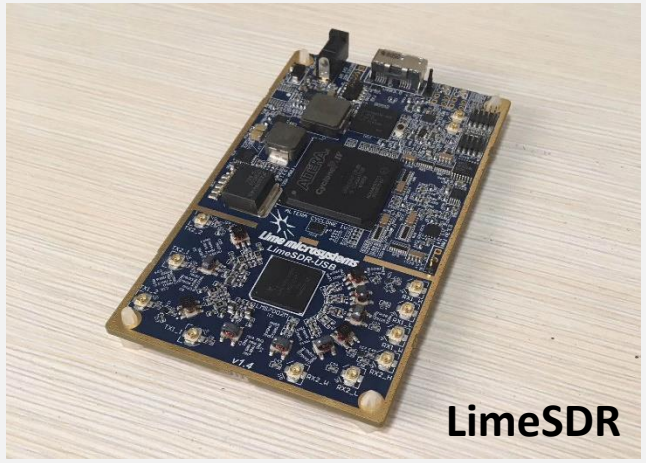


PlutoSDR



HackRF


USRP



LimeSDR

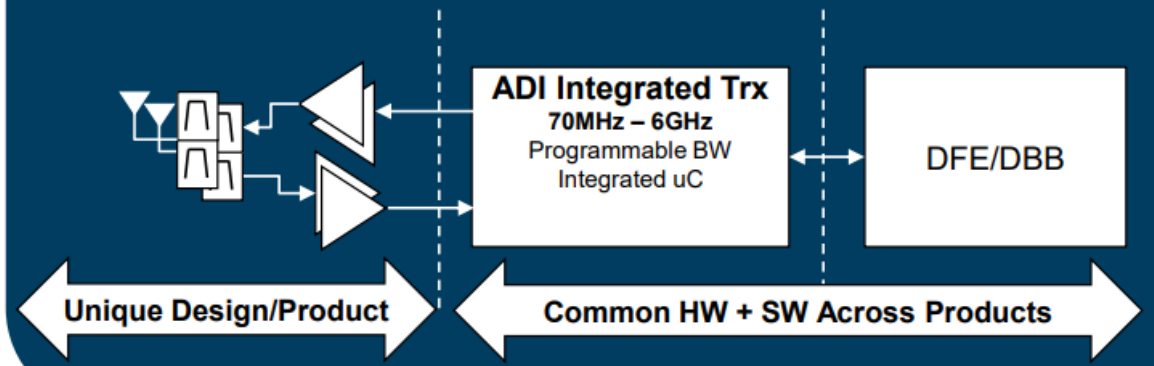

AD9361

Why SDR ？

Wideband RF Transceiver Benefits

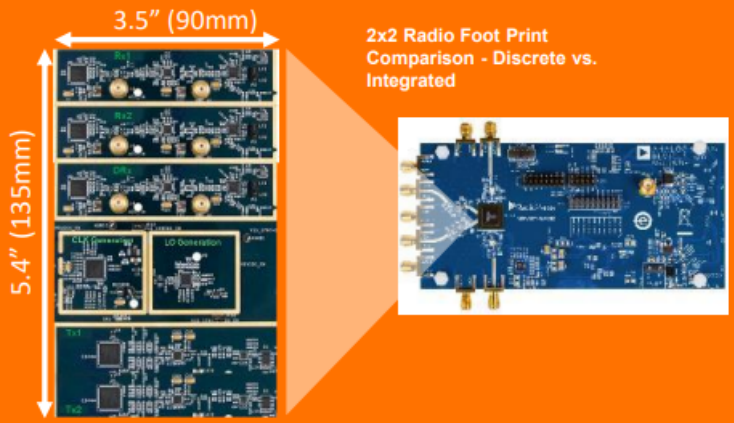
Highly Reconfigurable

Enables reduced time to market through common HW & SW Small Signal Radio Platform



Highest Level of Integration

Enables higher density radio architectures e.g. M-MIMO

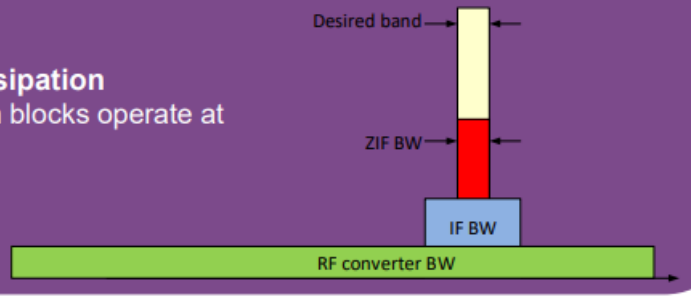


Lowest Power Consumption

Reduce thermal density, enable lower SWAP radios

Lowest possible power dissipation

- Highest power consumption blocks operate at minimum bandwidth



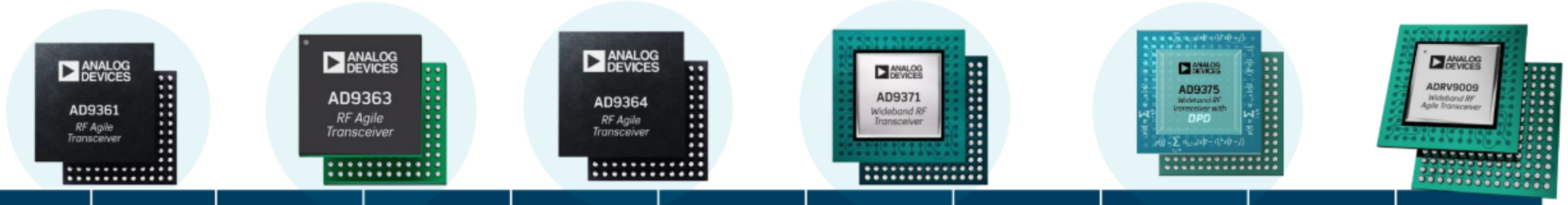
Lowest System Cost

Re-use of architecture used in handsets

- Components such as IF filters are eliminated
- RF filters are simplified enabled by the elimination of out-of-band images or aliases

ANALOG DEVICES
AHEAD OF WHAT'S POSSIBLE™

Wideband RF Transceiver Portfolio Released on RadioVerse™



Part #	Applications	Bandwidth	Functionality	RF Tuning Range	Rx Image Rejection*	Rx NF/IIP3**	Tx OIP3*	EVM	Package Size	Data Interface	Price
AD9361	3G/4G Picocell, SDR, Pt-Pt, Satcom, IoT Aggregator	56 MHz	2 Rx, 2 Tx	70 MHz to 6 GHz	50B	3dB/-14dBm	+19dBm	-40 dB	10 mm × 10 mm	CMOS/LVDS	$175
AD9364	3G/4G Picocell, SDR	56 MHz	1 Rx, 1 Tx	70 MHz to 6 GHz	50dB	3dB/-14dBm	+19dBm	-40 dB	10 mm × 10 mm	CMOS/LVDS	$130
AD9363	3G/4G Femtocell, UAV, Wireless Surveillance	20 MHz	2 Rx, 2 Tx	325 MHz to 3.8 GHz	50dB	3dB/-14dBm	+19dBm	-34 dB	10 mm × 10 mm	CMOS/LVDS	$80
AD9371	3G/4G Macro BTS, Massive MIMO, SDR	100MHx Rx, 250MHz Tx	2Tx, 2Rx Orx & SnRx	300 MHz to 6GHz	75dB	1.6dB/+2dBm	+27dBm	-40 dB	12 mm × 12 mm	6GHz JESD204B	$245
AD9375	3G/4G Small Cell, 3G/4G Massive MIMO	100MHx Rx, 250MHz Tx	2Tx, 2Rx Orx & SnRx	300 MHz to 6GHz	75dB	1.6dB/+2dBm	+27dBm	-40 dB	12 mm × 12 mm	6GHz JESD204B	$325
ADRV9009	3G/4G/5G TDD macro cell, Massive MIMO, Phased array radar	200MHx Rx, 450MHz Tx	2Tx, 2Rx Orx	75 MHz to 6GHz	75dB	1.6dB/+2dBm	+27dBm	-43 dB	12 mm × 12 mm	12GHz JESD204B	$319

* typical performance @ 2.6GHz
** AD9371 cascaded analysis with external LNA NF = 1.1dB, Gain = 19.5dB, IIP3 = 33dB (HMC8175A broadband LNA). Typical Performance @ 2.6GHz
** AD9361 assumes internal LNA, typical performance @ 2.6GHz

ANALOG DEVICES
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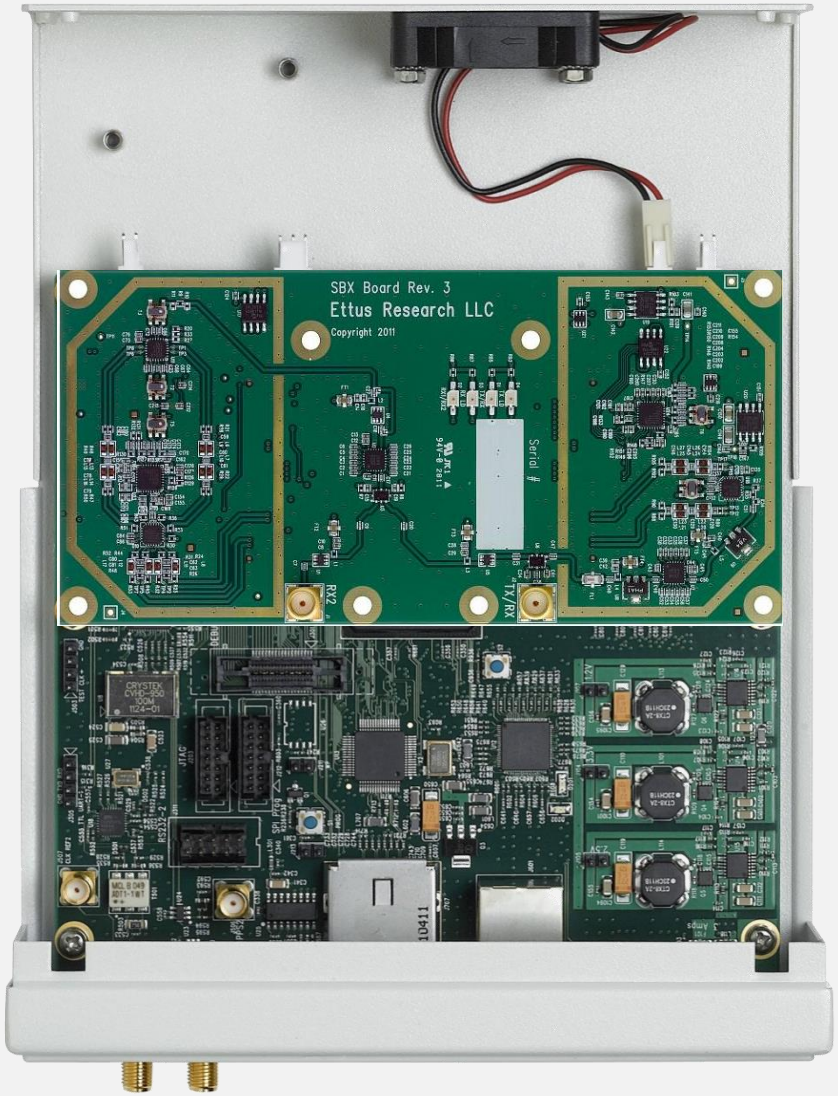
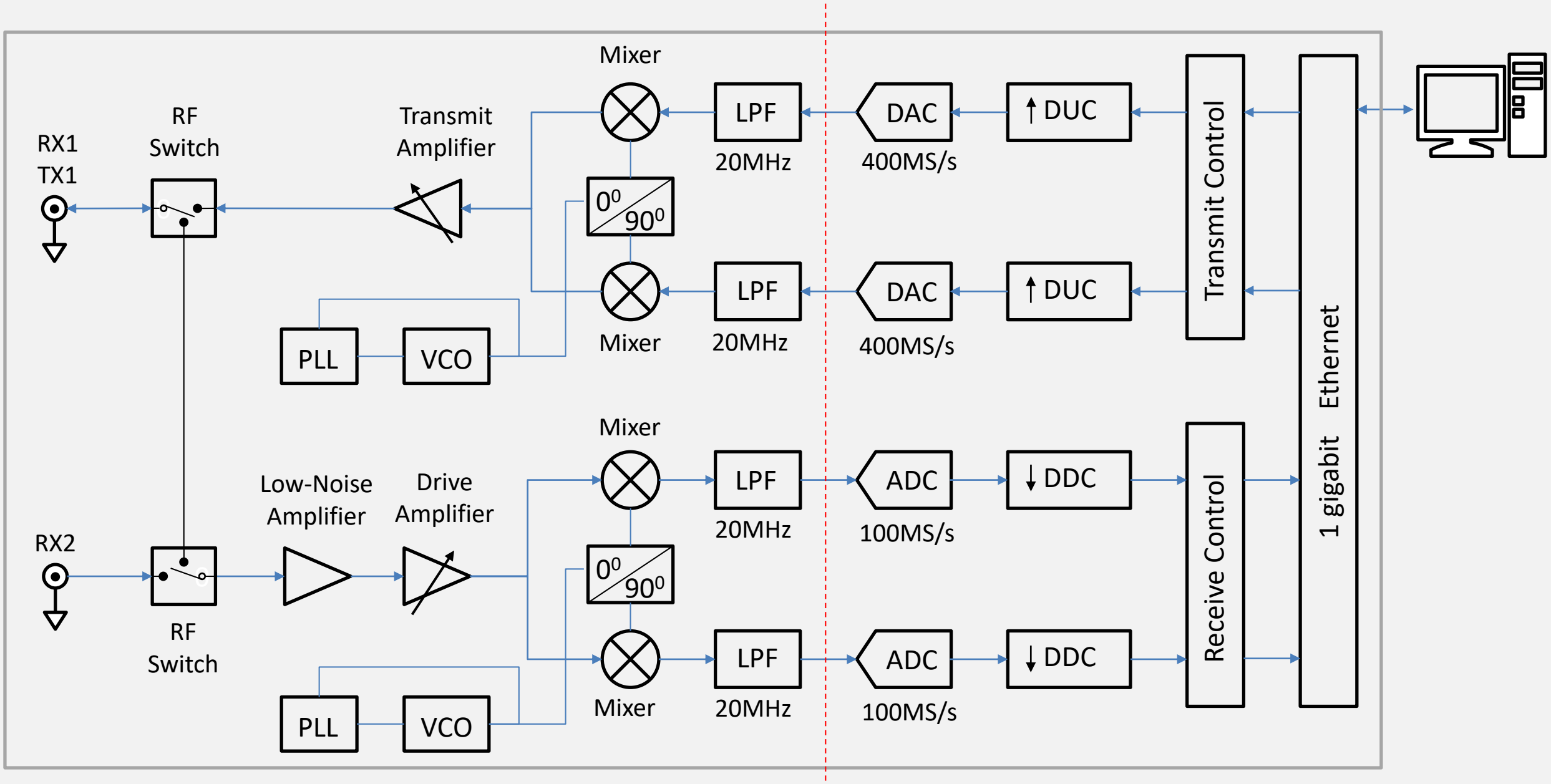
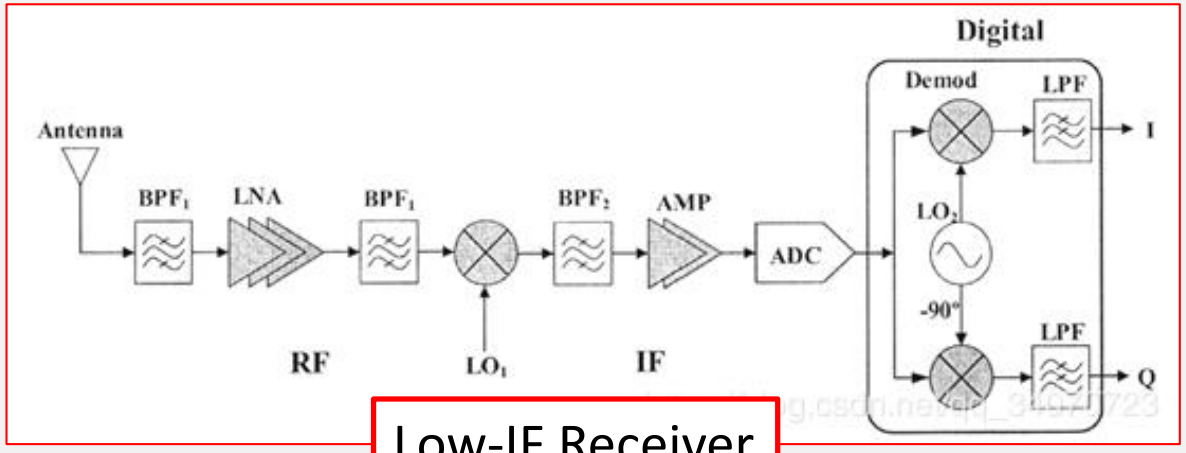


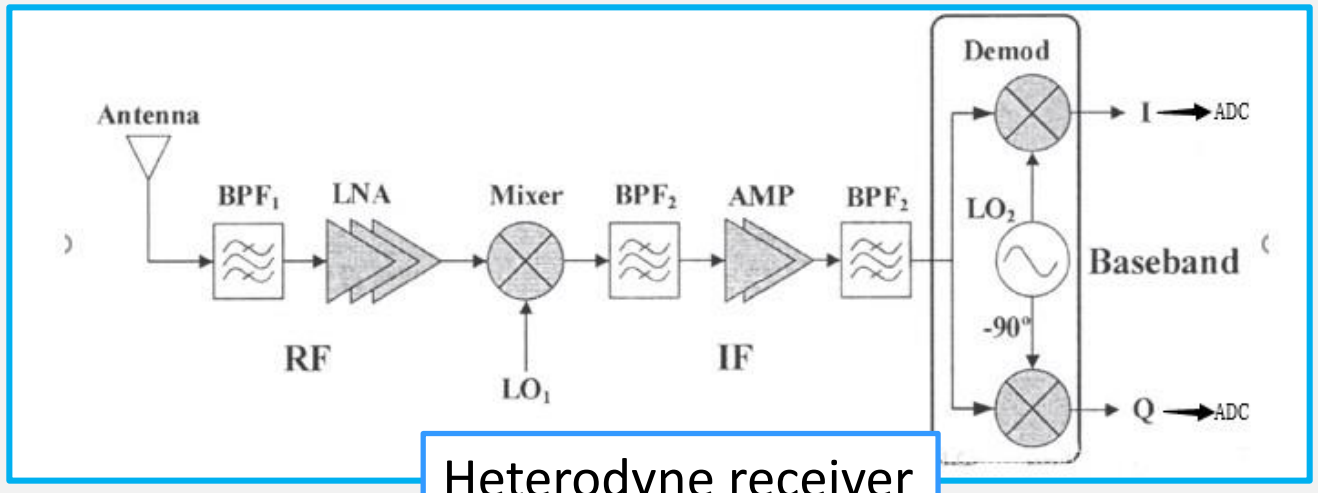
USRP

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

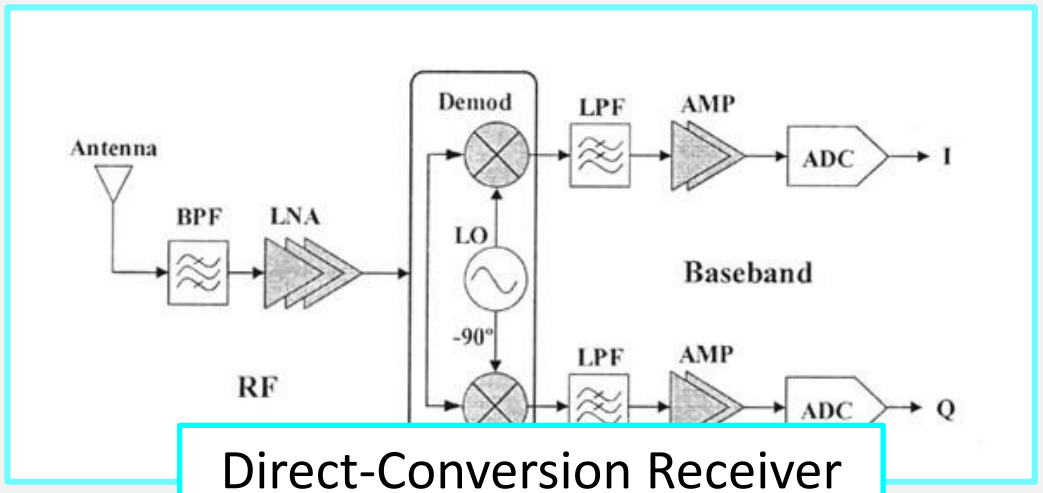

RX1
TX1
RF
Switch
Transmit
Amplifier
Mixer
LPF
20MHz
DAC
400MS/s
DUC
Transmit Control
1 gigabit Ethernet
0⁰
90⁰
PLL
VCO
Mixer
LPF
20MHz
DAC
400MS/s
DUC
RX2
Low-Noise
Amplifier
Drive
Amplifier
RF
Switch
Mixer
LPF
20MHz
ADC
100MS/s
DDC
Receive Control
0⁰
90⁰
PLL
VCO
Mixer
LPF
20MHz
ADC
100MS/s
DDC



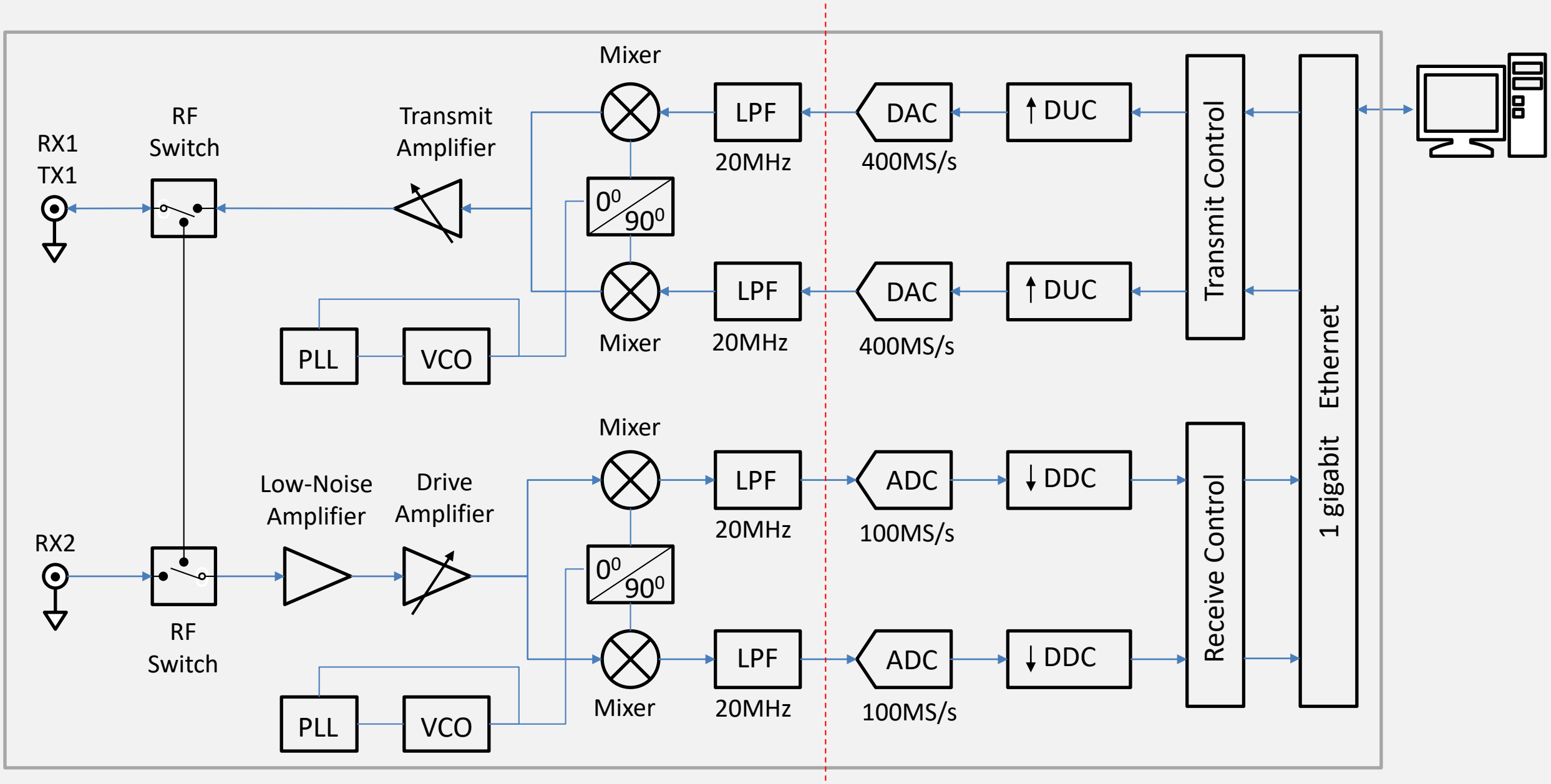
Low-IF Receiver



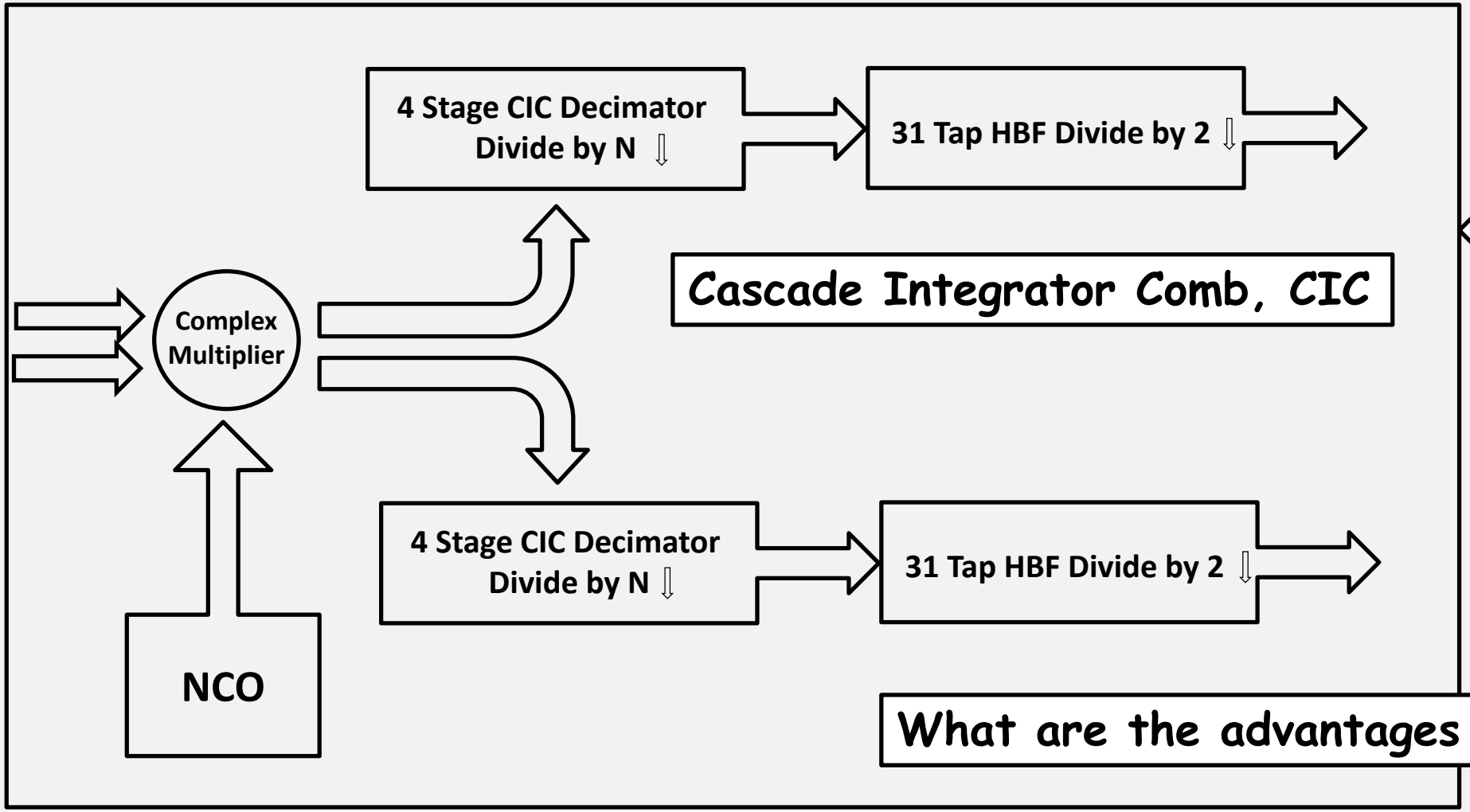
Heterodyne receiver



Direct-Conversion Receiver


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
Low-Noise
Amplifier
Drive
Amplifier
RF
Switch
Mixer
LPF
20MHz
ADC
100MS/s
DDC
Receive Control
0⁰
90⁰
PLL
VCO
Mixer
LPF
20MHz
ADC
100MS/s
DDC

DDC architectures

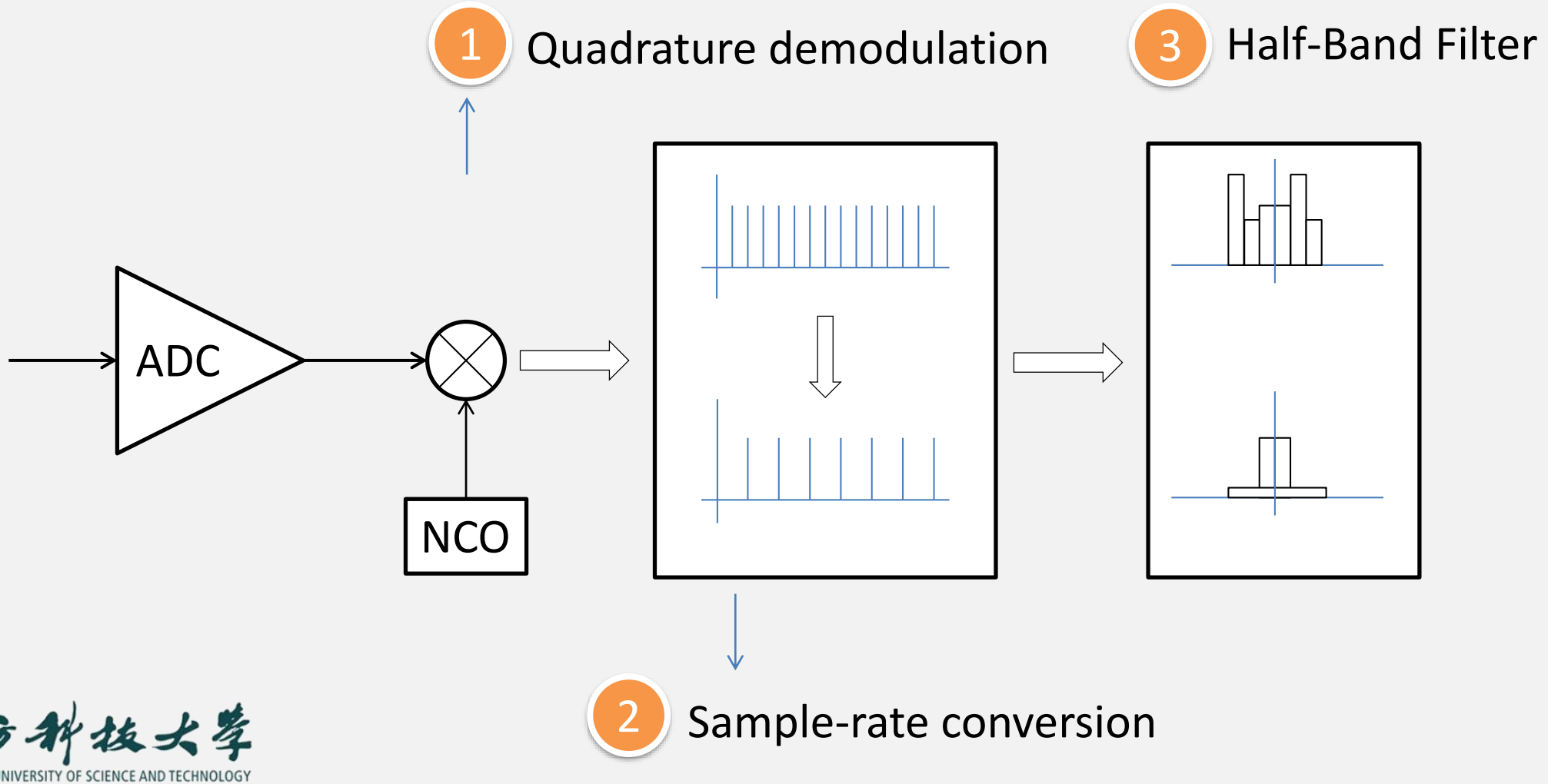


Cascade Integrator Comb, CIC

XILINX FPGA

What are the advantages of CICs in the DDC ?

Digital Down Converter



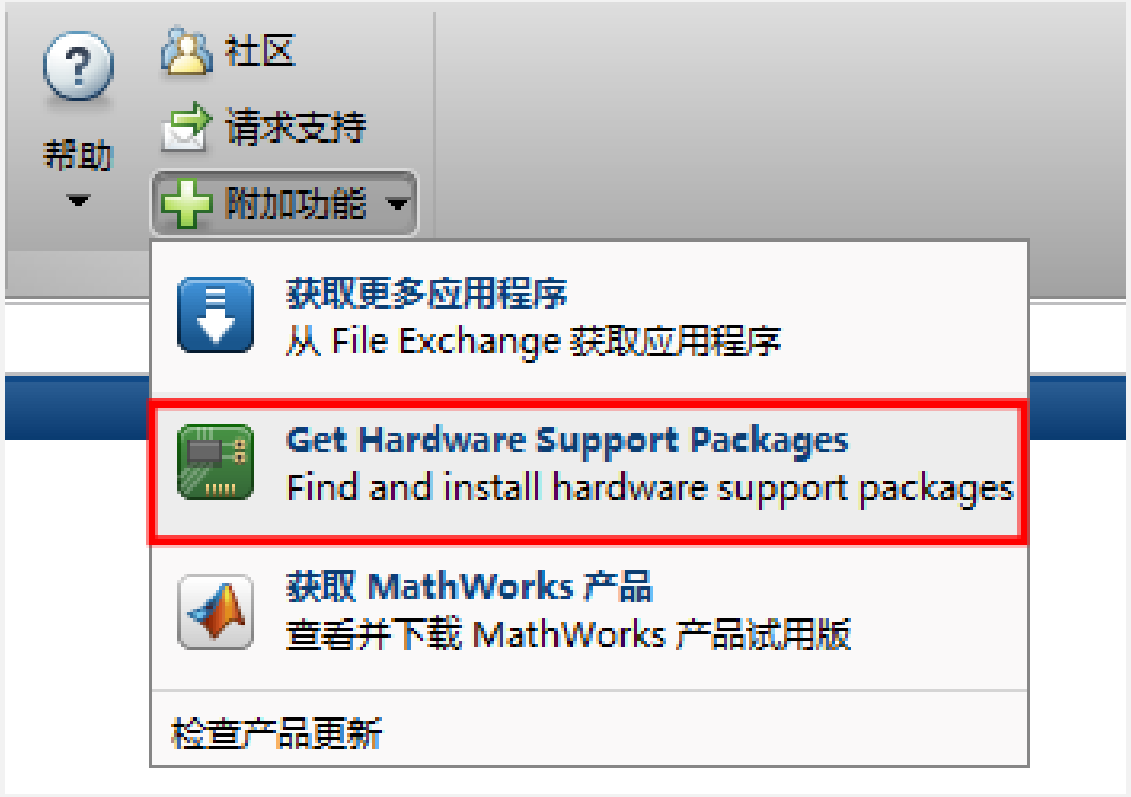
USRP Connection

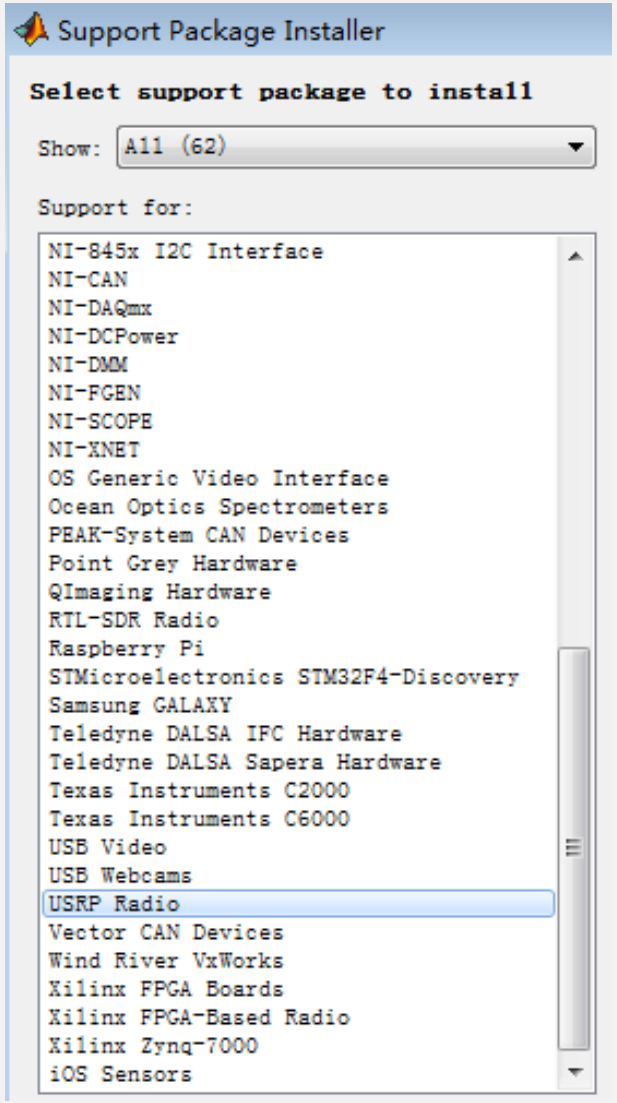
“Here, then, we have, in the very beginning, the groundwork for something more than a mere guess.”
- Edgar Allan Poe, The Gold Bug

5 steps to connect a USRP

- Step 1. Install Support Package for USRP® Radio
- Step 2. Configure Host Computer
- Step 3. Verify Hardware Connection
- Step 4. Load FPGA and firmware images for USRP® radio
- Step 5. Verify MATLAB Connection to USRP® Radio

Step 1. Install Support Package for USRP® Radio





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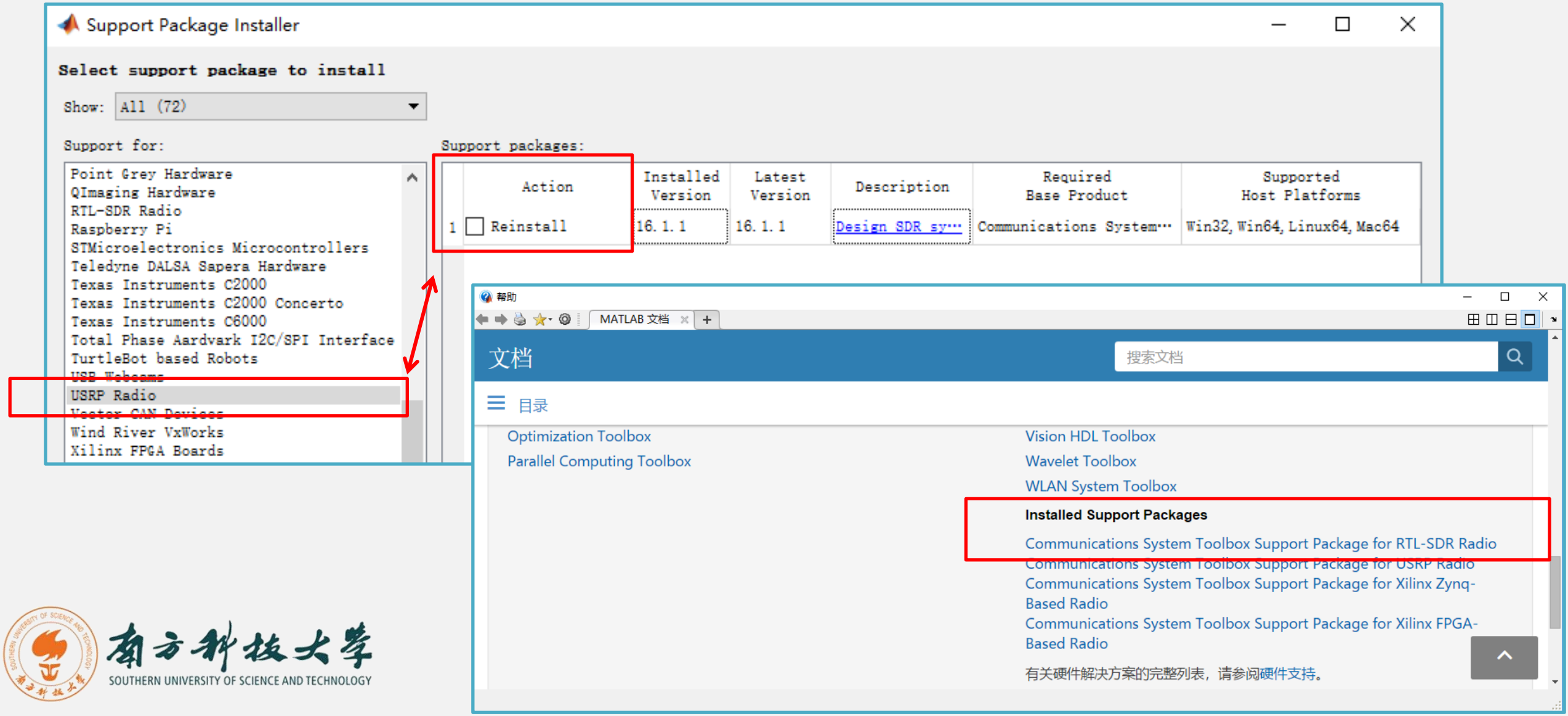
Successful Installation



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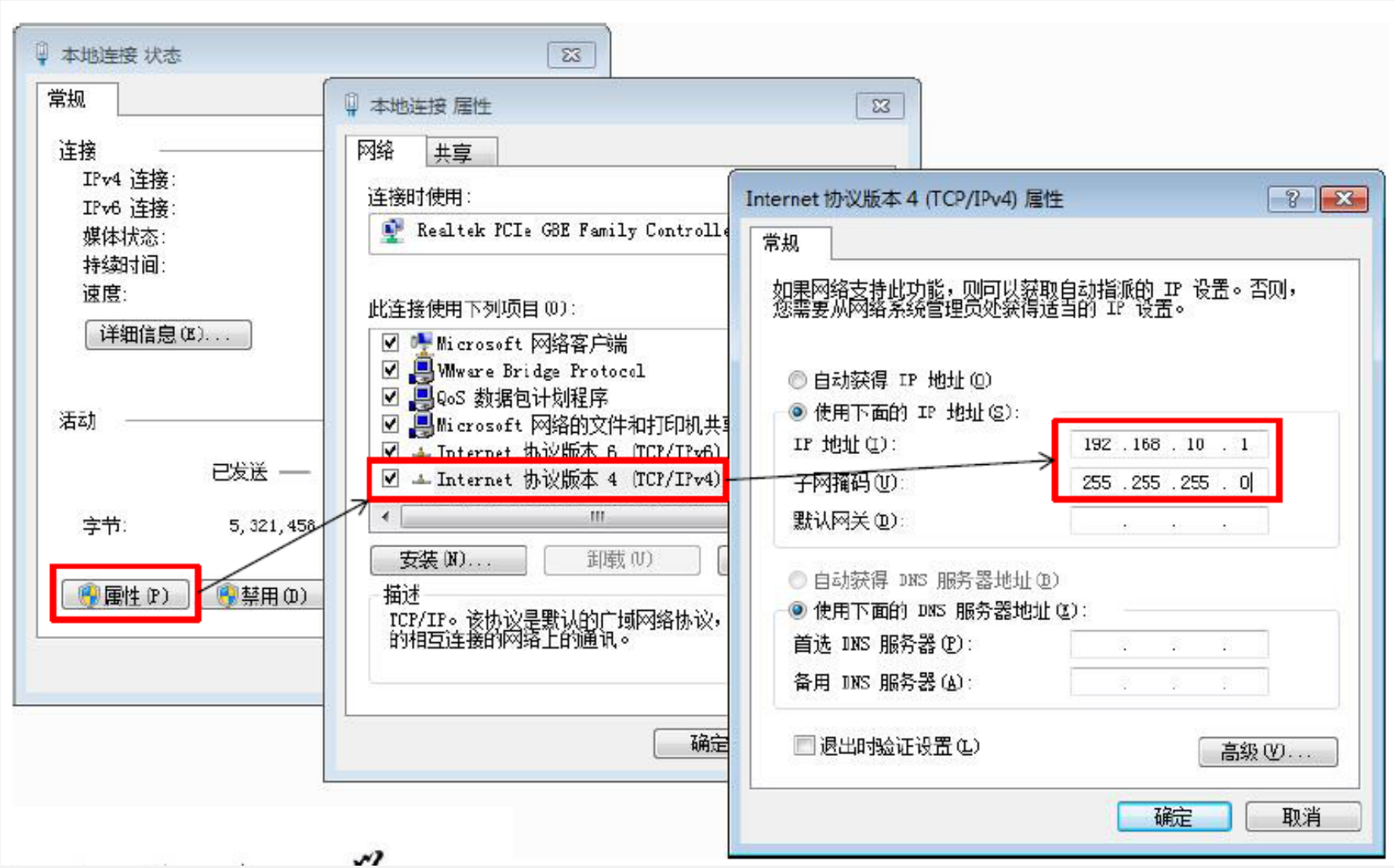
Step 2. Configure Host Computer



Step 3. Verify Hardware Connection

>>ping 192.168.10.2

Step 4. Load FPGA and firmware images for USRP® radio

```
>> sdruload('Device','n210_r4')
```

命令行窗口

```
>> sdruload('Device', 'n210_r4')
---------- begin libuhd driver construction output ----------
---------- begin libuhd status message output ----------
Opening a USRP2/N-Series device...
---------- end libuhd status message output ----------
---------- begin libuhd status message output ----------
Current recv frame size: 1472 bytes
---------- end libuhd status message output ----------
---------- begin libuhd status message output ----------
Current send frame size: 1472 bytes
```

命令行窗口

```
to n210_r4 device at 192.168.10.2. Would you like to continue? [yes/no]: yes

Writing images using usrp_simple_net_burner.py ...

==== Start messages from third party application ====
USRP-N2XX found.
Hardware type: n210_r4
Flash size: 4194304
Sector size: 65536

Begin FPGA write: this should take about 1 minute...
Erasing 1572864 bytes at 1572864
Writing image
Verifying data
Read back 1311644 bytes
Success.
Time elapsed: 52.356000 seconds



Begin firmware write: this should take about 1 second...
Erasing 31744 bytes at 3145728
Writing image
Verifying data
Read back 16383 bytes
Success.
Time elapsed: 1.173000 seconds



==== End messages from third party application ====
```

Step 5. Verify MATLAB Connection to USRP® Radio

```
>> findsdru
```

```
ans =

    IPAddress: '192.168.10.2'
       Status: 'Success'
```

```
>> probesdru
```

```
--------------------------------------------------
/
|       RX Dboard: A
|   ID: SBX (0x0054)
|   Serial: F3D7CA
|     ----------------------------------------------
|    /
|    |       RX Frontend: 0
|    |   Name: SBXv3 RX
|    |   Antennas: TX/RX, RX2, CAL
|    |   Sensors: lo_locked
|    |   Freq range: 400.000 to 4400.000 Mhz
|    |   Gain range PGA0: 0.0 to 31.5 step 0.5 dB
|    |   Connection Type: IQ
|    |   Uses LO offset: No
|     ----------------------------------------------
|    /
|    |       RX Codec: A
|    |   Name: ads62p44
|    |   Gain range digital: 0.0 to 6.0 step 0.5 dB
|    |   Gain range fine: 0.0 to 0.5 step 0.1 dB
--------------------------------------------------
```

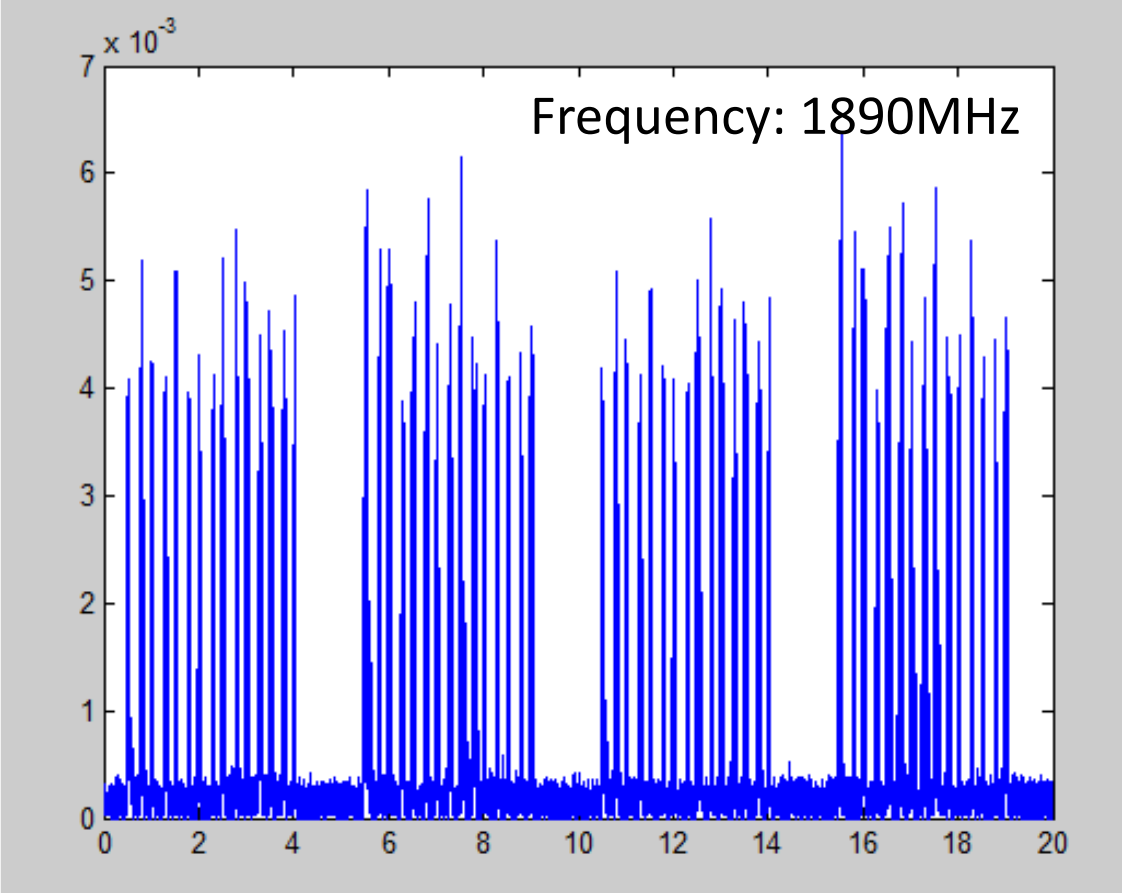
```
命令行窗口
--------------------------------------------------
/
|       Device: USRP2 / N-Series Device
|   --------------------------------------------------
|  /
|  |       Mboard: N210r4
|  |   hardware: 2577
|  |   mac-addr: 00:80:2f:0a:d8:aa
|  |   ip-addr: 192.168.10.2
|  |   subnet: 255.255.255.255
|  |   gateway: 255.255.255.255
|  |   gpsdo: none
|  |   serial: F3C1F3
|  |   FW Version: 12.3
|  |   FPGA Version: 10.0
|  |
|  |   Time sources: none, external, _external_, mimo
|  |   Clock sources: internal, external, mimo
|  |   Sensors: mimo_locked, ref_locked
|  |     ----------------------------------------------
|  |    /
|  |    |       RX DSP: 0
|  |    |   Freq range: -50.000 to 50.000 Mhz
|  |     ----------------------------------------------
|  |    /
|  |    |       RX DSP: 1
|  |    |   Freq range: -50.000 to 50.000 Mhz
|  |     ----------------------------------------------
```

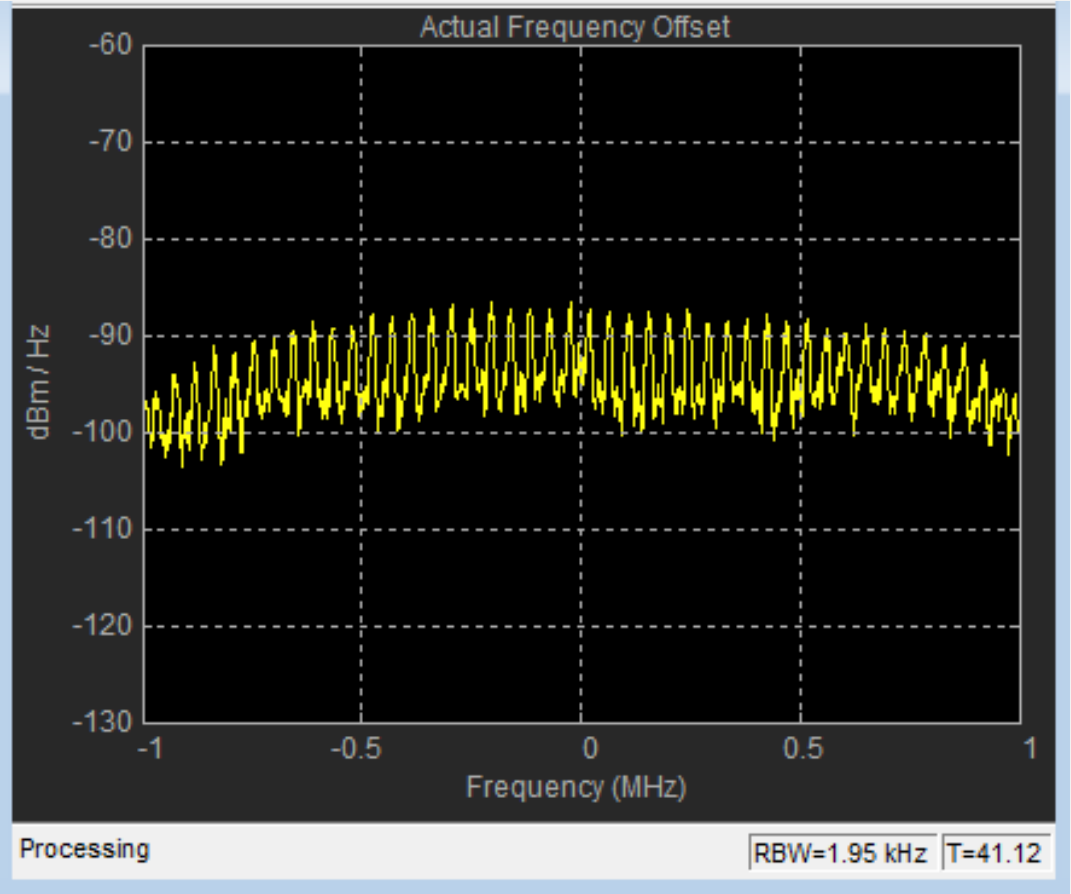
>> help sdru

命令行窗口

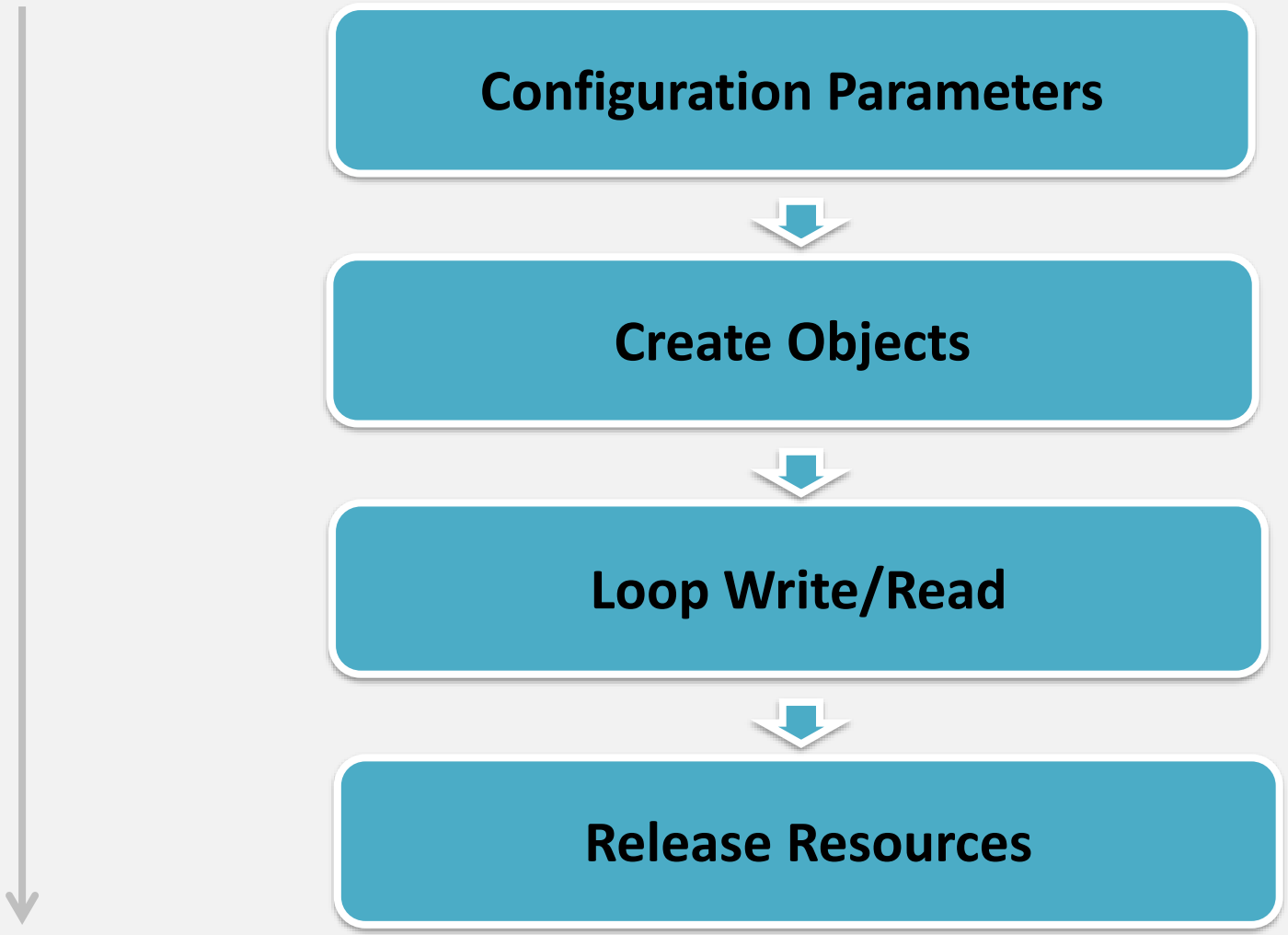
```
>> help sdru
  Communications System Toolbox Support Package for USRP(R) Radio

  Documentation for USRP(R) Radio

  Functions
    findsdru             - Find USRP(R) radios connected to host computer and report status
    getSDRuDriverVersion - UHD(R) driver version on the host computer
    probesdru            - Detailed USRP(R) radio information
    sdruexamples         - Open index of USRP(R) Radio examples
    sdruload             - FPGA and firmware image loader for USRP(R) radios
    setsdruip            - Set USRP(R) radio IP address
  System Objects
    comm.SDRuTransmitter - Send data to the USRP(R) Radio
    comm.SDRuReceiver    - Receive data from the USRP(R) Radio
  Blocks
    sdrulib              - Open the block library for USRP(R) Radio

  USRP, USRP2, UHD, and Ettus Research are trademarks of National Instruments Corp.
```

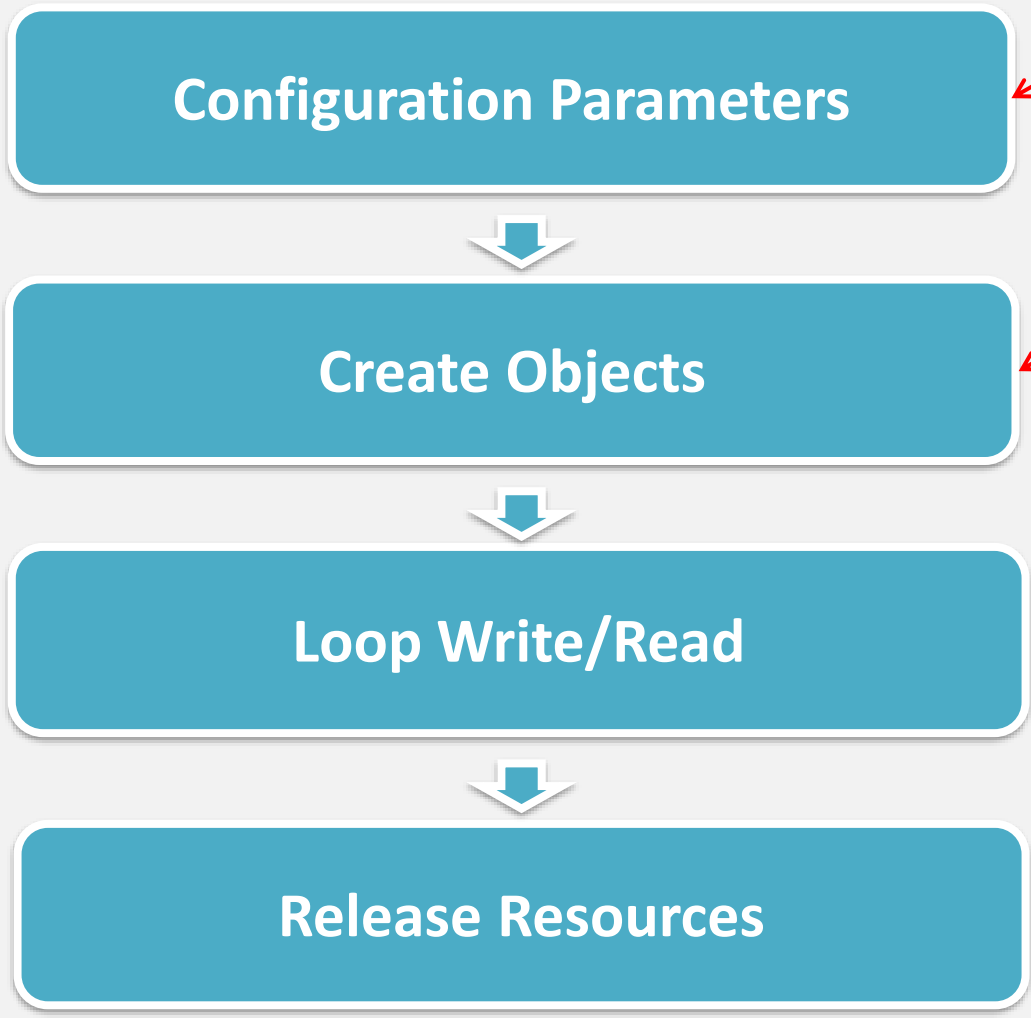
Frequency Scanning





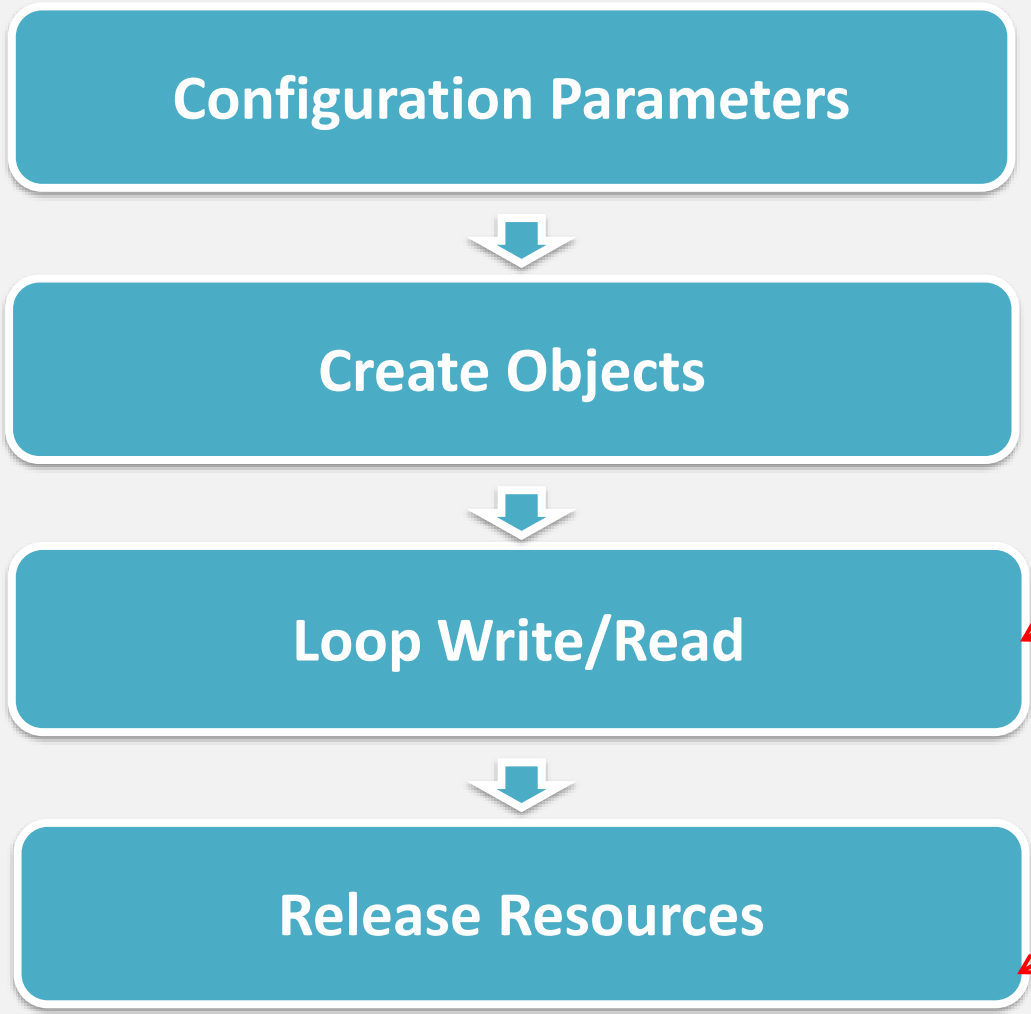
Flow Graph


Configuration Parameters
Create Objects
Loop Write/Read
Release Resources




```
fc              = 1890e6; % Center frequency (Hz)
FrontEndSampleRate = 2e6;     % Samples per second
FrameLength       = 40000;
```

```
hSDRu = comm.SDRuReceiver('192.168.10.2', ...
        'CenterFrequency',      fc, ...
        'Gain',                 30, ...
        'DecimationFactor',     50, ...
        'SampleRate',           FrontEndSampleRate, ...
        'FrameLength',          FrameLength, ...
        'OutputDataType',       'double');

hSpectrum = dsp.SpectrumAnalyzer(...
        'Name',            'Actual Frequency Offset',...
        'Title',           'Actual Frequency Offset', ...
        'SpectrumType',    'Power density',...
        'FrequencySpan',   'Full', ...
        'SampleRate',      FrontEndSampleRate, ...
        'YLimits',         [-130,-60],...
        'SpectralAverages', 50, ...
        'FrequencySpan',   'Start and stop frequencies', ...
        'StartFrequency',  -1000e3, ...
        'StopFrequency',   1000e3,...
        'Position',        figposition([50 30 30 40]));
```




```
radio = findsdru(hSDRu.IPAddress);
if strncmp(radio.Status, 'Success', 7)
e=0;
```

```
% Loop Read
while ( true )
    [data, len]= step(hSDRu);

    if len < FrameLength
       e=e+1;
       disp ( 'Not enough samples returned!' ) ;
       disp(e)
    else
       Ti = [0:20/FrameLength:20-10/FrameLength] ;
       plot (Ti,abs(data));
       drawnow ;
       data = data - mean(data); step(hSpectrum, data);
     end
end
```

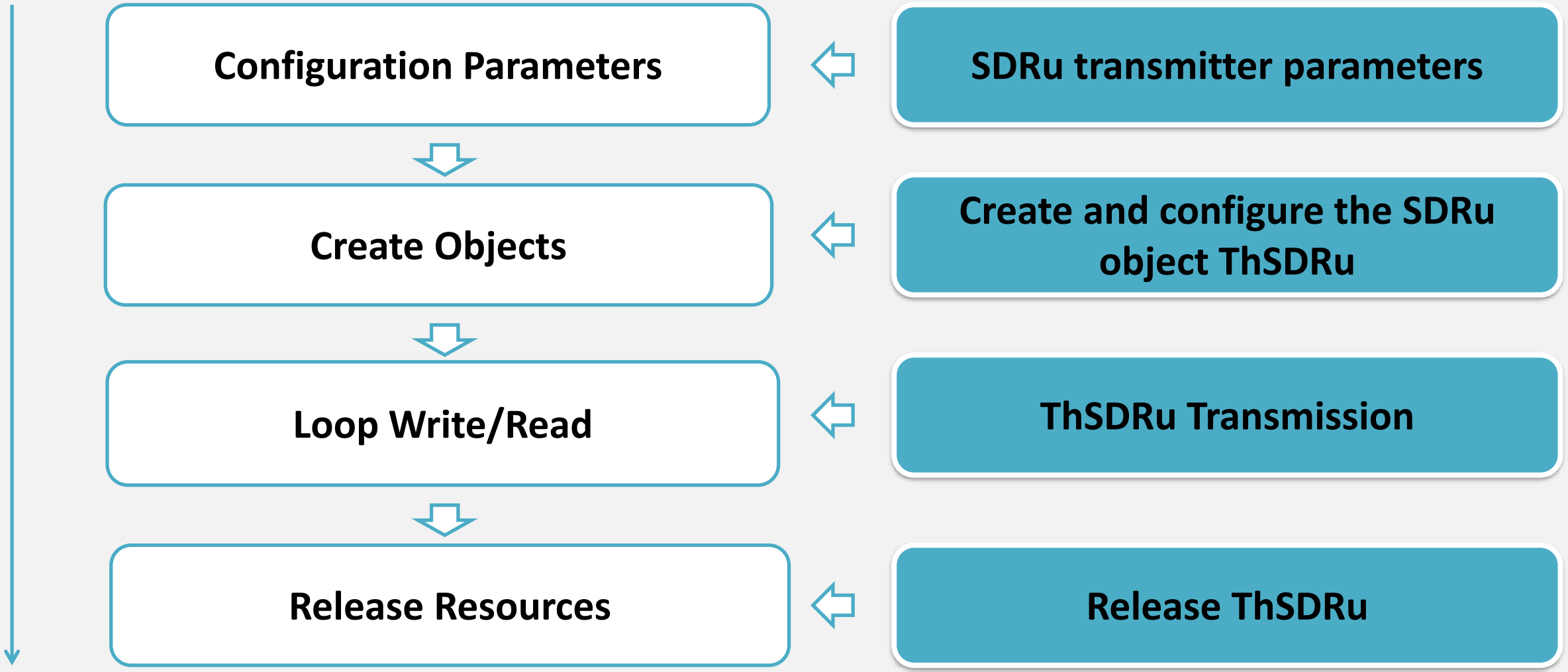
```
end

% Release all System objects
release(hSDRu);
release(hSpectrum);
```

USRP Implementation

"I never am really satisfied that I understand anything; because, understand it well as I may, my comprehension can only be an infinitesimal fraction of all I want to understand."

- Ada Lovelace

Transmitter Flow Graph



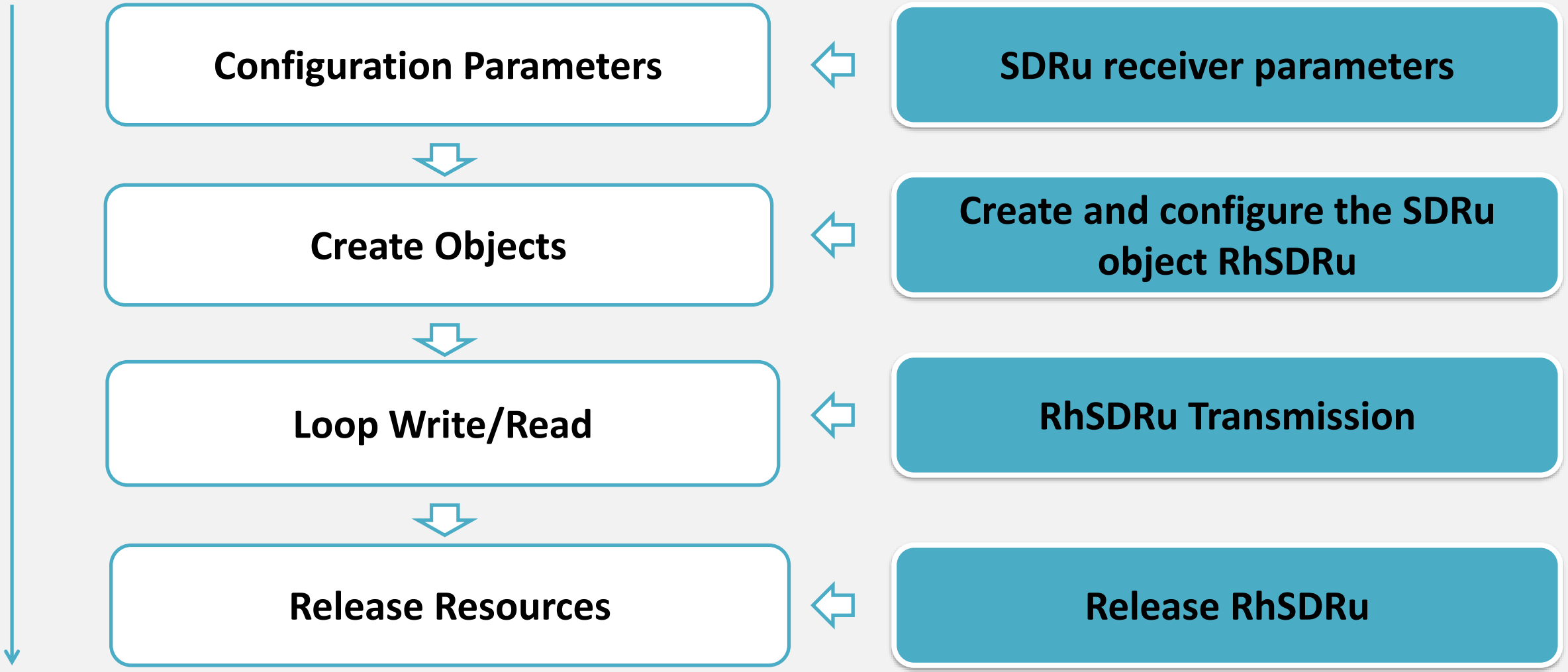
SDRu transmitter parameters

```
%SDRu transmitter parameters

TSimParams.USRPCenterFrequency = 900e6;
TSimParams.USRPGain = 25;
TSimParams.USRPInterpolation = 1e8/TSimParams.Fs;
TSimParams.USRPFrameLength =
TSimParams.Upsampling*TSimParams.FrameSize*TSimParams.RxBufferedFrames;
```

Create and configure the SDRu object ThSDRu

```
%Create and configure the ThSDRu

ThSDRu = comm.SDRuTransmitter('192.168.10.2', ...
    'CenterFrequency',      prmQPSKTransmitter.US RPCenterFrequency, ...
    'Gain',                 prmQPSKTransmitter.USRPGain, ...
    'InterpolationFactor',  prmQPSKTransmitter.USRPInterpolation);
```

Receiver Flow Graph



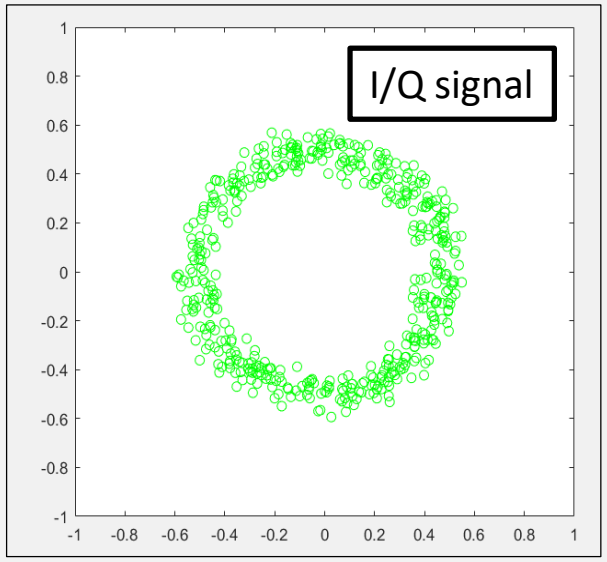
SDRu receiver parameters

```
%SDRu receiver parameters

SimParams.USRPCenterFrequency = 900e6;
SimParams.USRPGain = 31;
SimParams.USRPDecimationFactor = SimParams.MasterClockRate/SimParams.Fs;
SimParams.USRPFrontEndSampleRate = 1/SimParams.Fs;
SimParams.USRPFrameLength =
SimParams.Upsampling*SimParams.FrameSize*SimParams.RxBufferedFrames;
```

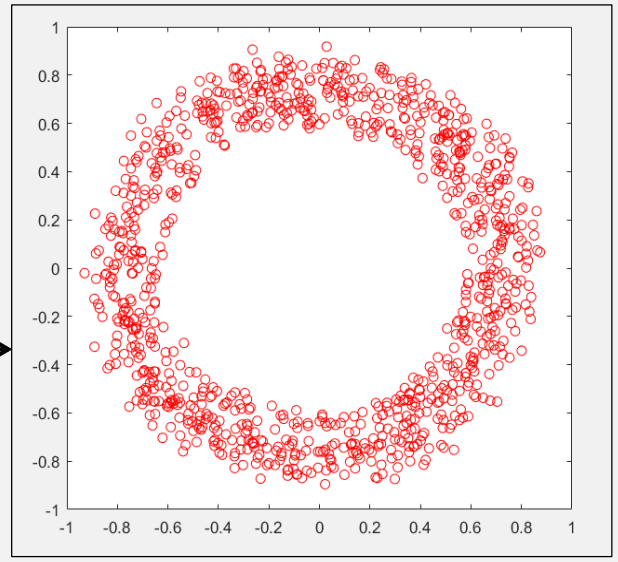
Create and configure the SDRu object RhSDRu

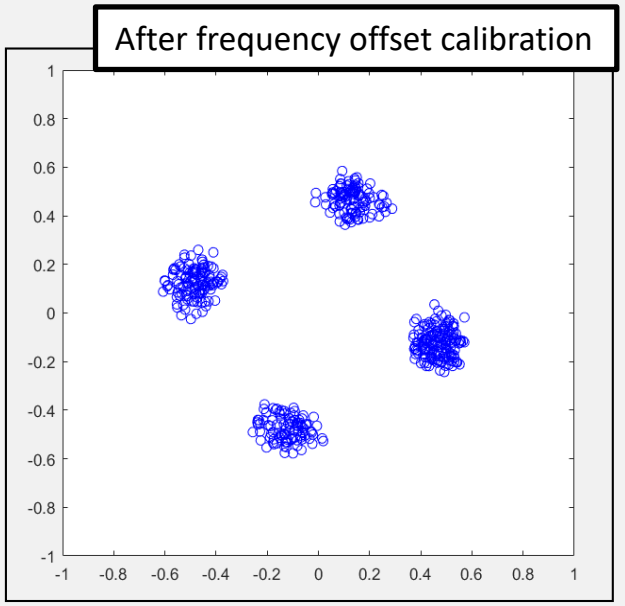
```
RhSDRu = comm.SDRuReceiver(...
        'IPAddress',          prmQPSKReceiver.Address, ...
        'CenterFrequency',    prmQPSKReceiver.USRPCenterFrequency, ...
        'Gain',               prmQPSKReceiver.USRPGain, ...
        'DecimationFactor',   prmQPSKReceiver.USRPDecimationFactor, ...
        'FrameLength',        prmQPSKReceiver.USRPFrameLength, ...
        'OutputDataType',     'double');
```

Hello world Transmission



After AGC and matched filtering →

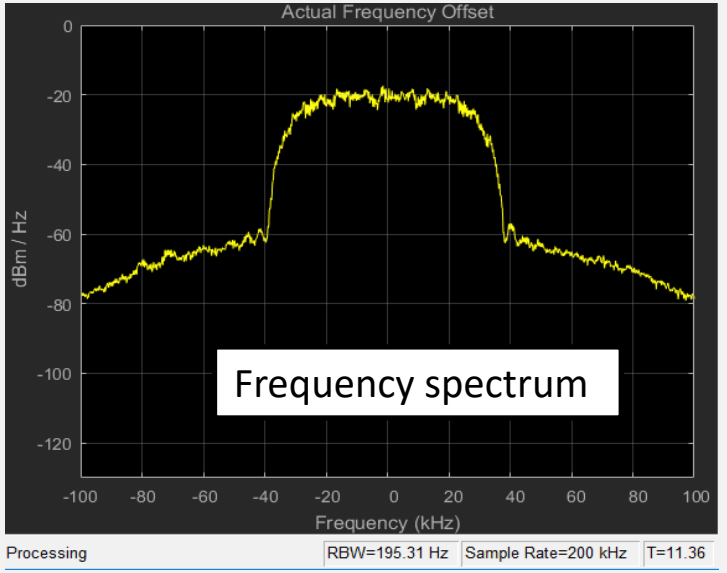




命令行窗口

```
Hello world 004
Hello world 005
Hello world 006
Hello world 007
Hello world 008
Hello world 009
Hello world 010
Hello world 011
Hello world 012
Hello world 013
Error rate is = 0.000368.
Hello world 014
Hello world 015
Hello world 016
Hello world 017
```

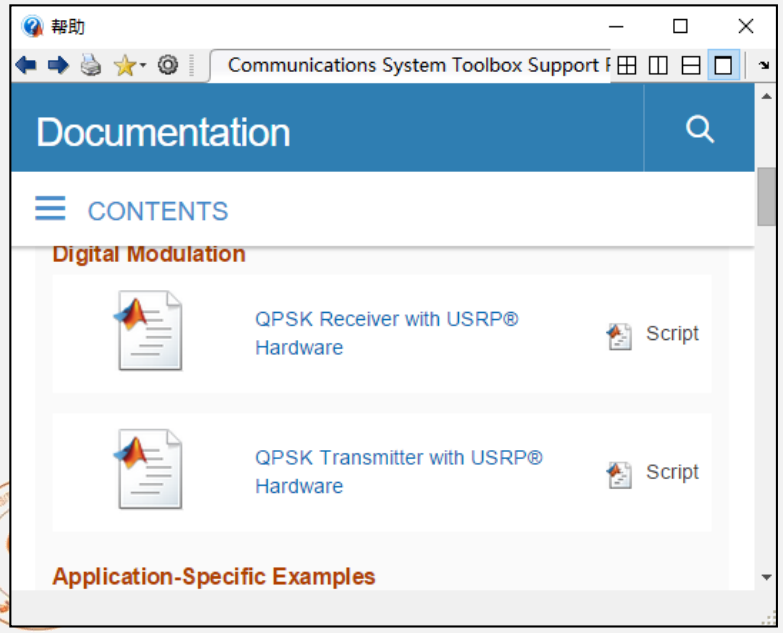
Received message

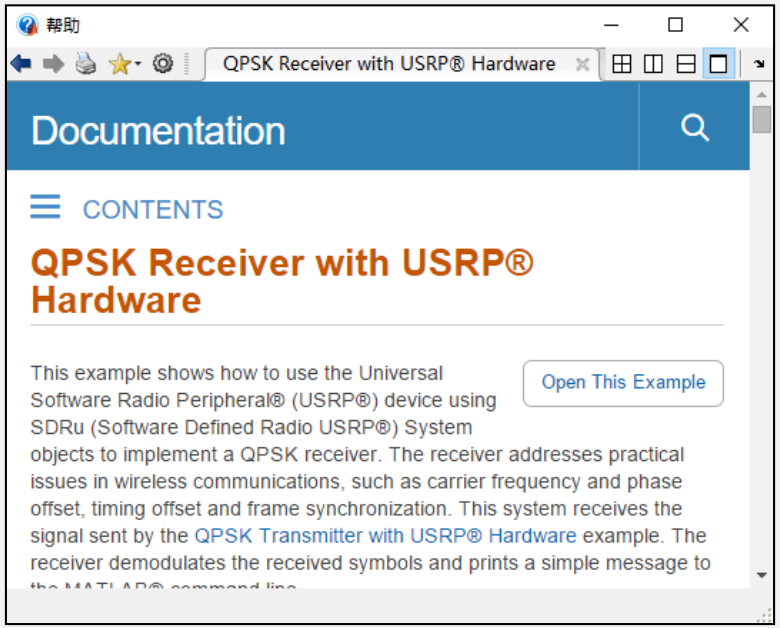


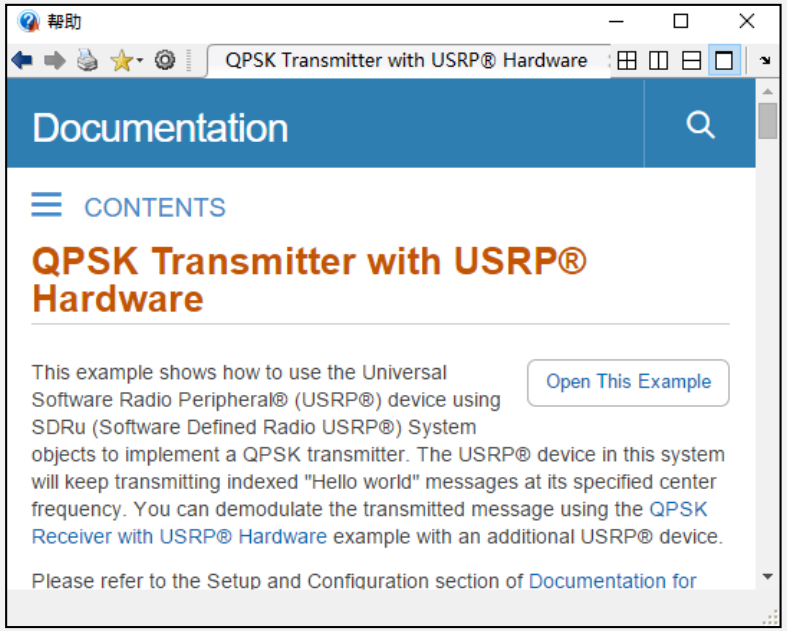
南方科技大学
SOUTHERN UNIVERSITY OF SCIENCE AND TECHNOLOGY

Assignments

- 4/16/64-QAM simulation (Lab2)
- Text recover with Pre-Recorded data.







subfunction

sdruqpskreceiver_init.m

runSDRuQPSKReceiver.m

QPSKCoarseFrequencyCompensator.m

Revision

```
hRx = sdruQPSKRxR( ...
        'DesiredAmplitude',                1, ...
        'ModulationOrder',                 prmQPSKReceiver.M, ...
        'DownsamplingFactor',              prmQPSKReceiver.Downsampling, ...
```

```
% Rx parameters
SimParams.BarkerLength = 13; % Number of Barker code symbols
SimParams.DataLength = (SimParams.FrameSize - SimParams.BarkerLength)*4;
SimParams.MessageLength = 112; % Number of message bits per frame, 7 ASCI
SimParams.FrameCount = 100;
```

```
obj.pCoarseFreqEst = comm.QAMCoarseFrequencyEstimator( ...
    'FrequencyResolution', obj.CoarseCompFrequencyResolution, ...
    'SampleRate', currentSampleRate);
```

- Question ?