Review—1

commQPSKTransmitterReceiver.m

commqpsktxrx_init

runQPSKSystemUnderTest

QPSK→16QAM

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.PhaseFrequencyOffset
dsp.VariableFractionalDelay
comm.AWGNChannel

QPSKReceiver
comm.AGC
dsp.FIRDecimator
comm.PSKCoarseFrequencyEstimator
comm.PhaseFrequencyOffset

comm.CarrierSynchronizer
comm.SymbolSynchronizer
FrameFormation

QPSKDataDecoder

帮助

QPSK Transmitter and Receiver

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QPSK Transmitter and Receiver

This example shows a digital communications system using QPSK modulation. The example uses Communications System objects to simulate the QPSK transceiver. In particular, this example illustrates methods to address real-world wireless communications issues like carrier frequency and phase offset, timing recovery and frame synchronization.

Open This Example

Review—2

QPSK→16QAM →MIMO

Alamouti 2X1

$$s^1 = [s_1, -s_2^*]$$

$$s^2 = [s_2, \quad s_1^*]$$

TX1

TX2

h_1

h_2

Interference and noise

n_1, n_2

Channel estimator

h_1 h_2

Combiner

ML detector

EbNo=5dB

Documentation

CONTENTS

QPSK Transmitter and Receiver

This example shows a digital communications system using QPSK modulation. The example uses Communications System objects to simulate the QPSK transceiver. In particular, this example illustrates methods to address real-world wireless communications issues like carrier frequency and phase offset, timing recovery and frame synchronization.

Open This Example

前沿通信系统设计

1 WiFi通信系统（6周）
- 实验目标：利用USRP实现802.11a/n图像传输
- 软件：MATLAB，硬件：USRP
- 授课内容：MATLAB通信编程、USRP文本传输、MIMO系统、802.11a/n仿真、802.11a/n图像传输

2 5G/4G-LTE系统（5周）
- 实验目标：利用USRP实现LTE图像传输
- 软件：MATLAB，硬件：USRP
- 授课内容：小区搜索过程、MIB/SIB解码过程、LTE图像传输、LDPC编解码过程、srsLTE系统

3 无线网络传输系统（3周）
- 实验目标：利用Telos实现无线多跳网络传输数据
- 软件：TinyOS、NesC
- 授课内容：TinOS编程、MICAZ平台介绍、无线多跳网络数据收集、无线信道建模、无线定位、路由和数据收集

4 雷达感知系统（2周）
- 实验目标：利用KerberosSDR实现测向
- 软件：MATLAB，硬件：KerberosSDR、树莓派
- 授课内容：MUSIC算法、空间谱估计、KerberosSDR原理，无线开源项目，课程Presentation

Communication Systems Design

Lab 5: 802.11a Image Transmission and Reception

Dr. Wu Guang

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Electrical & Electronic Engineering
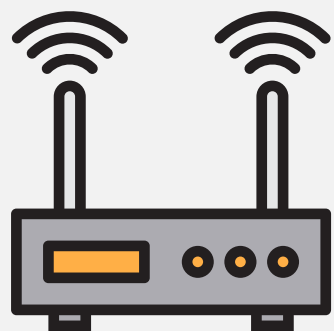**Southern University of Science and Technology**

无线路由器　　　　　　　　　手机

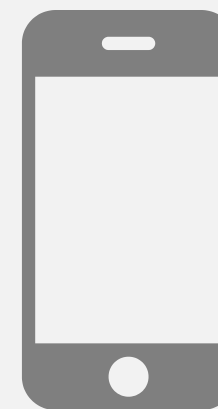Transmitted Image

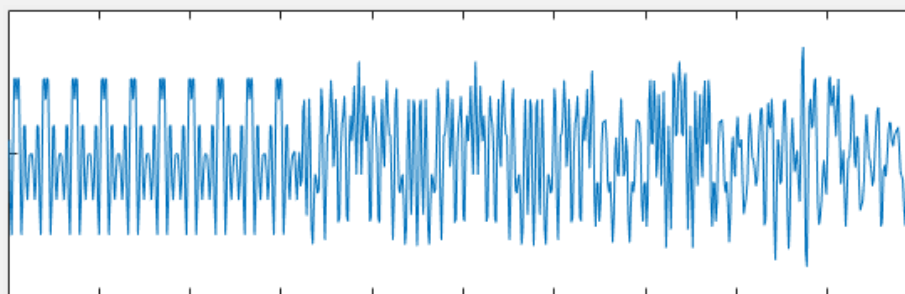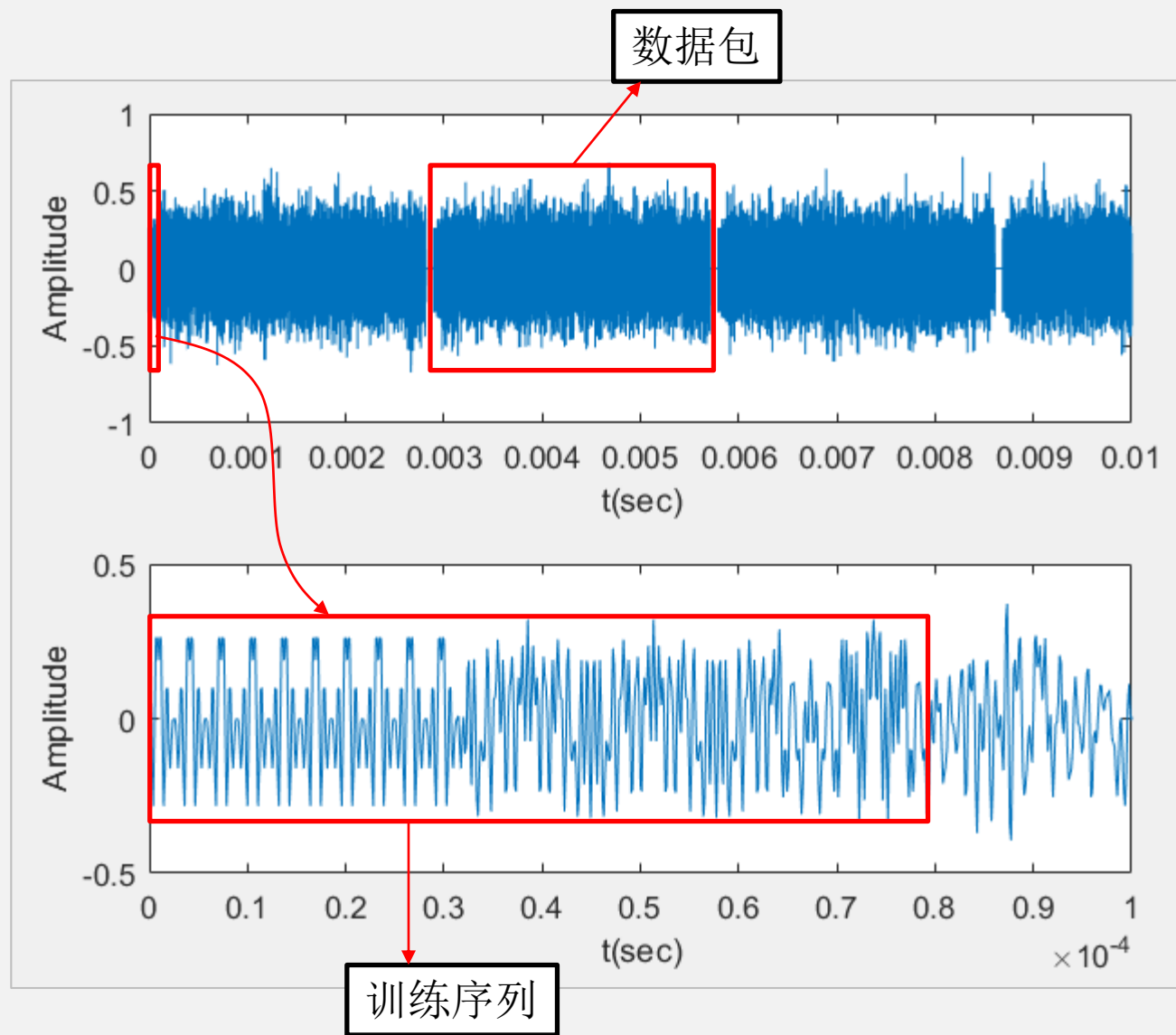无线路由器   手机

Demo: Image Transmission

数据包

训练序列

Transmitted Image

Received Image

How to build a WiFi packet ?

- How to design the training sequences ?

- How to pack the information bits?

- How to compete for the wireless channels ?
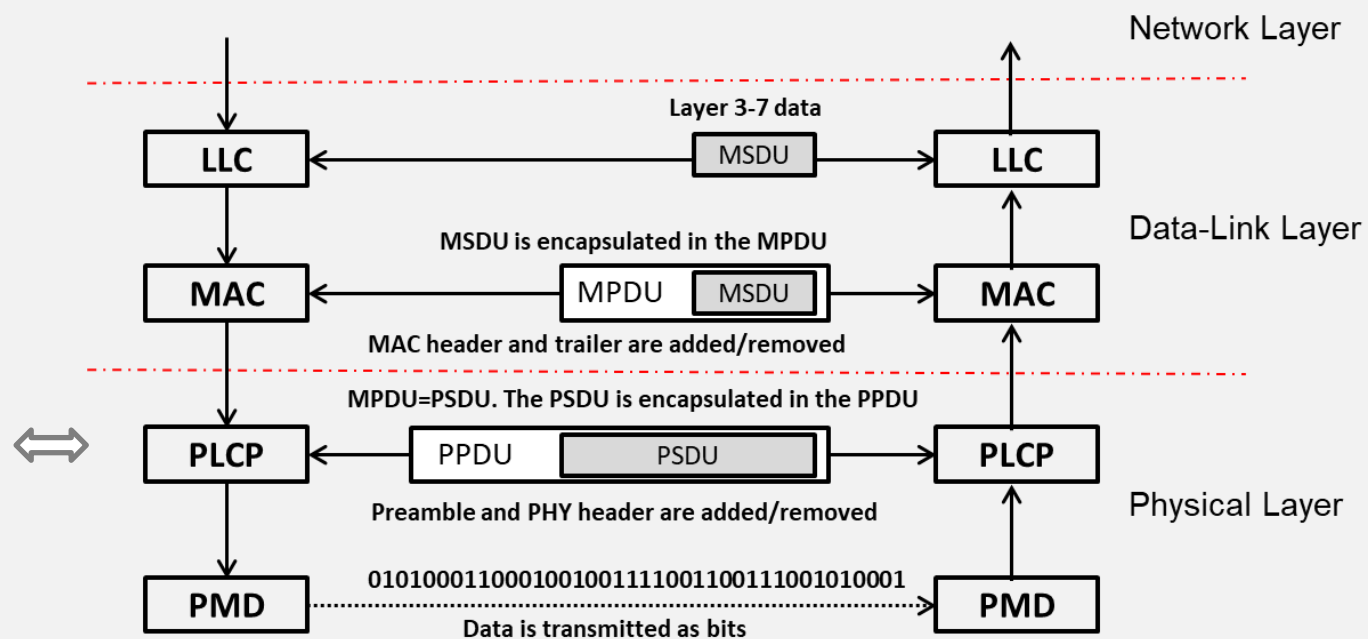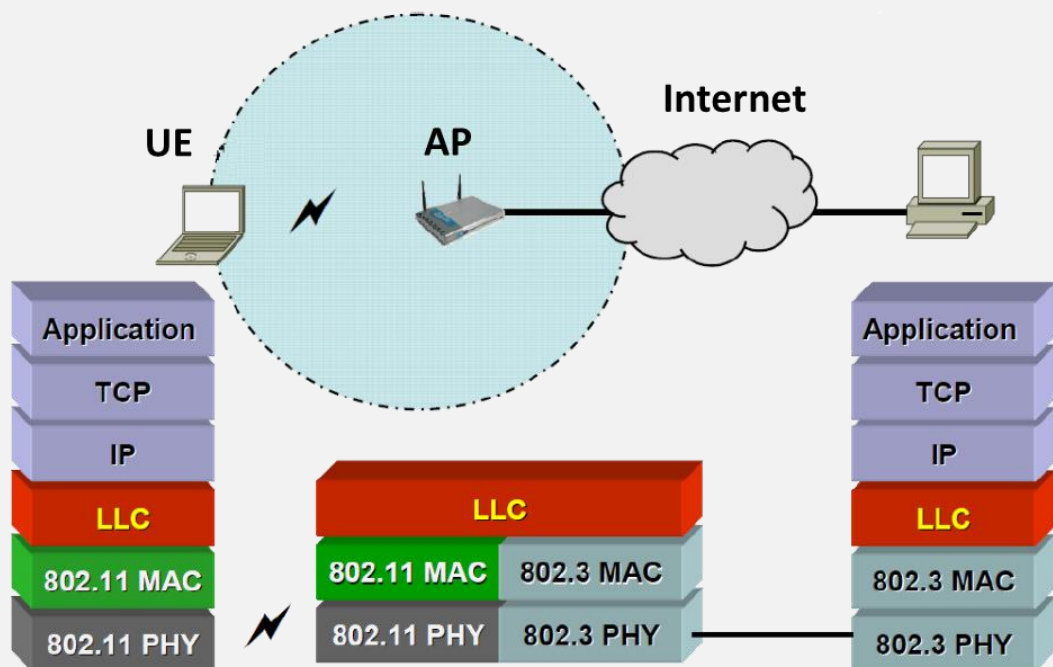

Transmitted Image

Received Image

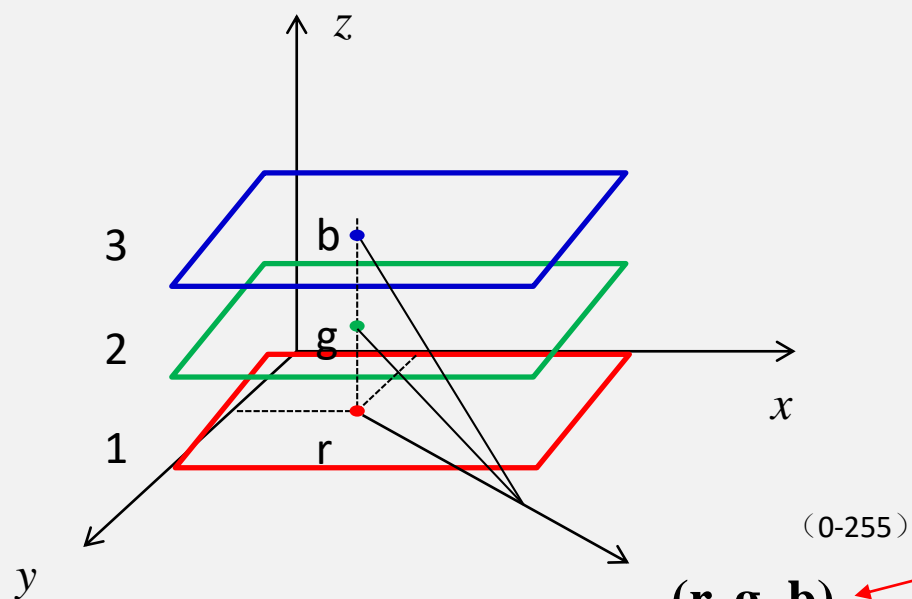# Tx: MSDU---->PPDU, Rx: MSDU---->PPDU

MSDU: MAC Service Data Unit（MAC服务数据单元）

MPDU: MAC Protocol Data Unit（MAC协议数据单元）

PPDU: Presentation Protocol Data Unit（物理层汇聚协议(PLCP)协议数据单元）

Representation of Image: 3D Matrix

（0-255）

(r, g, b)

fData(:,:,1)   fData(:,:,2)   fData(:,:,3)

fData = **imread**()   ← 图像读取

Imshow(fData)   ← 图像显示

```matlab
fileTx = 'sustechLibrary.png';      % ---------------------------------------------> 定义图像文件名


scale = 0.4;        %---------------------------------------------------------------> 缩放因子
[fData_Resize] = ResizeImage(fileTx,scale);   %-------------------------------------> 图像缩放


imsize = size(fData_Resize);      % -------------------------------------------------> 新图像的尺寸


binData = dec2bin(fData_Resize(:),8); %--------------------------------------------> 转换二进制数


txImage = reshape((binData-'0').',1,[]).'; %--------------------------------------> 创建二进制比特流


figure(1);  %----------------------------------------------------------------------> 显示需要传输的图像
subplot(211);
    imshow(fData_Resize);
    title('Transmitted Image');
subplot(212);
    title('Received image will appear here...');
    set(gca,'Visible','off');
    set(findall(gca, 'type', 'text'), 'visible', 'on');
```
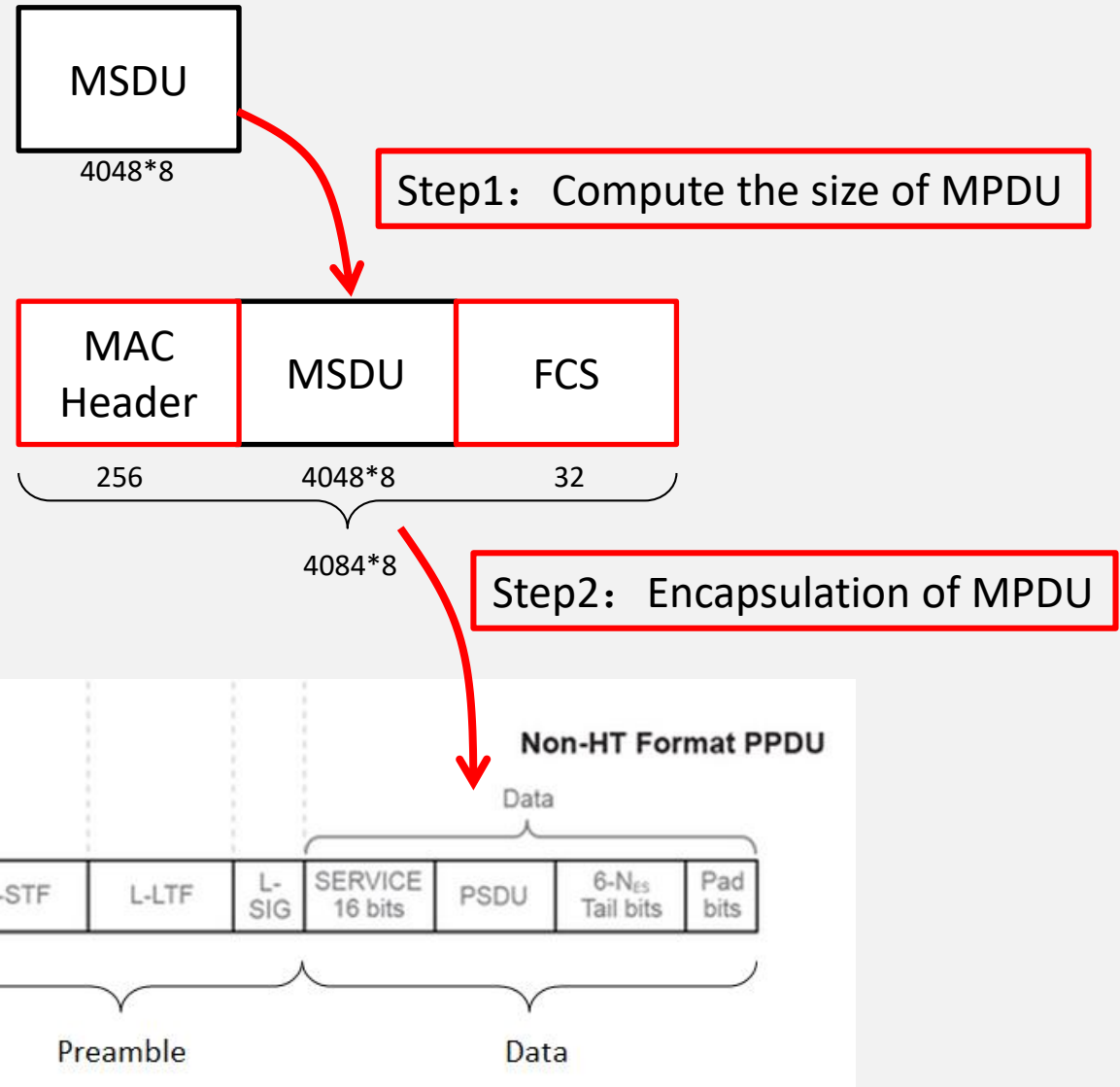

Transmitted Image

Transmission process

Step 1: Generate MAC frame

Step 2: Generate Physical baseband waveform

Step 3: Transmit waveform by using USRP
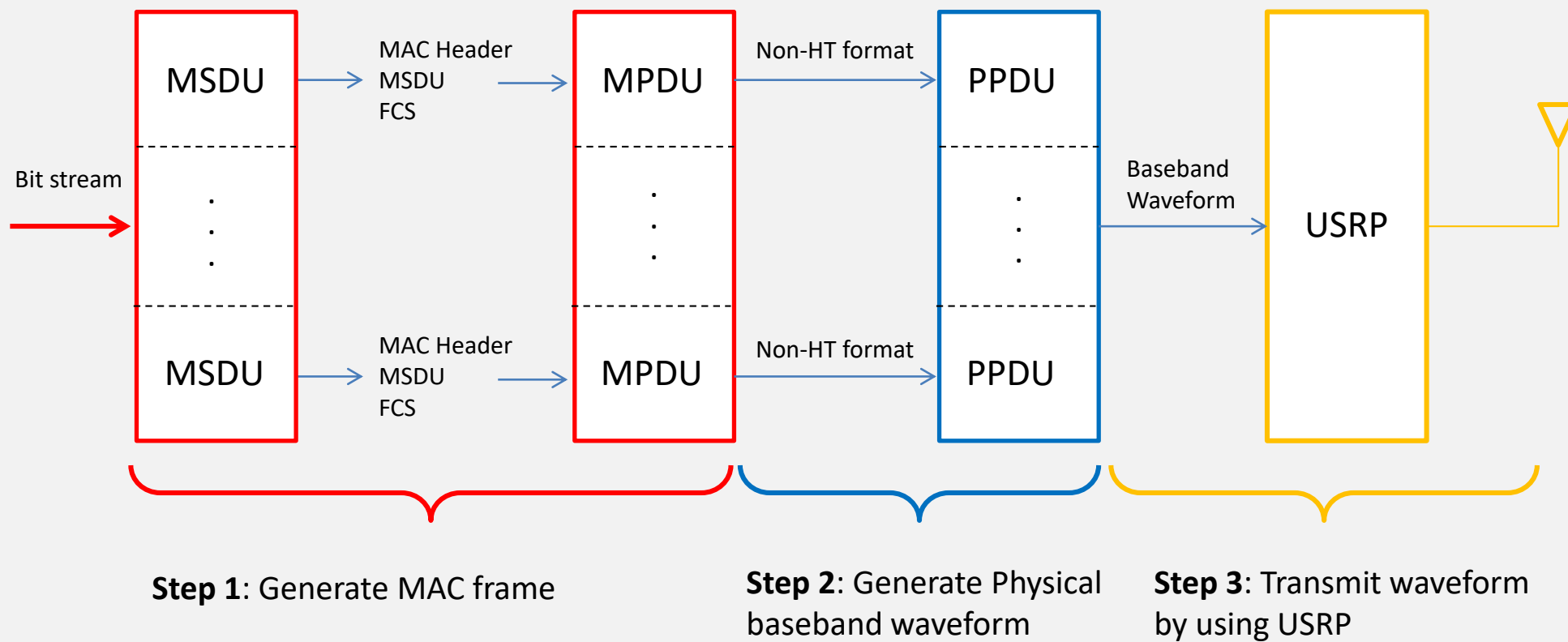
MSDU：MAC Service Data Unit

MPDU：MAC Protocol Data Unit

PPDU：Presentation Protocol Data Unit

MSDU

4048*8

Step1：Compute the size of MPDU

MAC Header	MSDU	FCS
256	4048*8	32

4084*8

Step2：Encapsulation of MPDU

Non-HT Format PPDU

Data

L-STF	L-LTF	L-SIG	SERVICE 16 bits	PSDU	6-N_{ES} Tail bits	Pad bits

Preamble

Data

MSDU---->MPDU
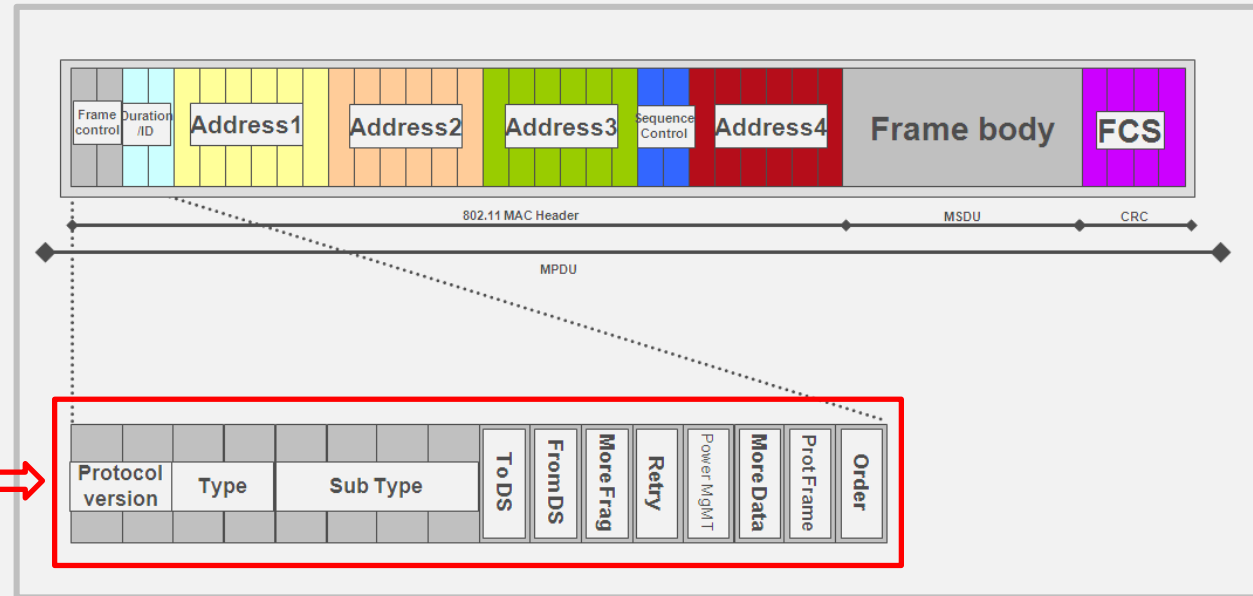
fields =

    'ProtocolVersion'
    'Type'
    'Subtype'
    'ToDS'
    'FromDS'
    'MoreFragments'
    'Retry'
    'PowerManagement'
    'MoreData'
   'ProtectedFrame'
    'Order'

In this Lab,

MAC Header	Frame body	FCS
32*8	4048*8	4*8

```matlab
46      % 3.2 将二进制码流封装成PSDU数据包
47      MPDU_Param.lengthMACheader = 256;  %--------------------------------------------> MPDU头部所需的比特数
48      MPDU_Param.lengthFCS = 32;         %--------------------------------------------> FCS所需的比特数
49      MPDU_Param.generatorPolynomial = [32 26 23 22 16 12 11 10 8 7 5 4 2 1 0];  %-----------> CRC-32校验多项式（除数）
50
51      % MPDU：| MAC头部（256 bits）|+|MSDU比特（4048*8 bits）|+|校验位（32 bits）|
52      [txData, psduData, numMSDUs, lengthMPDU] = createPSDU(txImage, MPDU_Param);  %-------------> 创建psdu数据包
53
54      % 3.3 将PSDU数据包封装成为Non-HT格式的波形
55      [txWaveform, nonHTcfg, chanBW, overSampleFactor] = createTxWaveform(psduData, numMSDUs, lengthMPDU);
56      fs = helperSampleRate(chanBW);  %--------------------------------------------> 计算信号（5M）采样率
57
58      figure(2)
59      subplot(2,1,1)
60      plot((1:length(txWaveform))/(fs*overSampleFactor),real(txWaveform))
61      xlabel('t(sec)')
62      ylabel('Amplitude')
63      axis([0 0.01 -1 1])
64      hold on
65      subplot(2,1,2)
66      plot((1:length(txWaveform))/(fs*overSampleFactor),real(txWaveform))
67      xlabel('t(sec)')
68      ylabel('Amplitude')
69      axis([0 0.0001 -0.5 0.5])
```
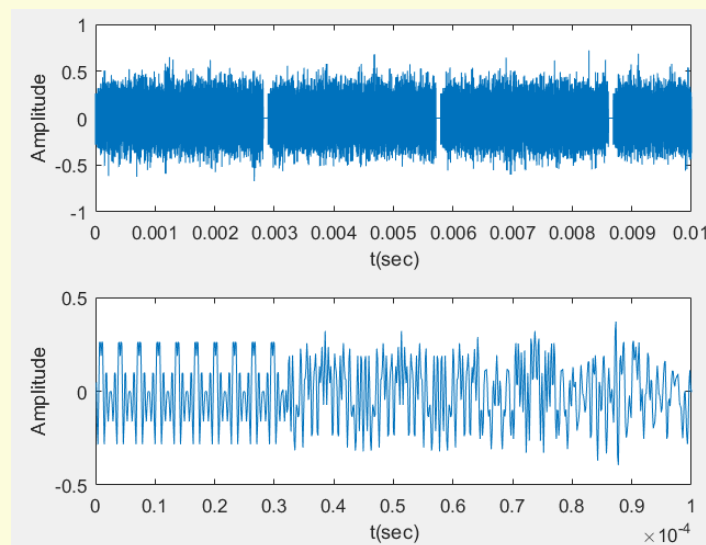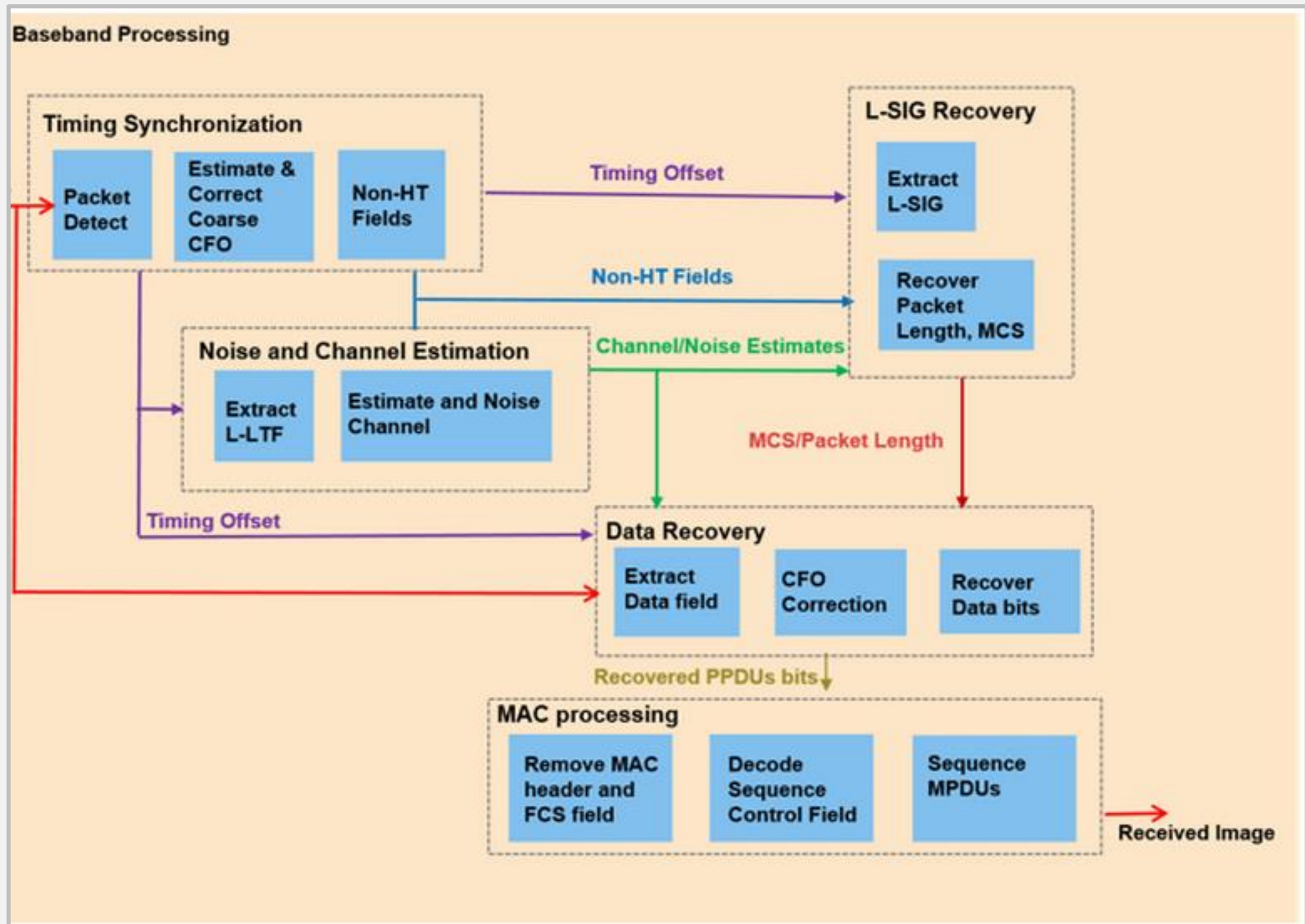
```matlab
73 -    SNR_i=30;     %----------------------------------------------------------------> 设置信噪比
74 -    [txWaveformAWGN] = createAWGNChannel(nonHTcfg, txWaveform, SNR_i);   %-------------------> 添加加性高斯白噪声
```

```matlab
1      %% AWGN Channel
2
3      function [txWaveformAWGN]=createAWGNChannel(nonHTcfg, txWaveform, SNR_i)
4
5  -    [datax,pilotsx] = helperSubcarrierIndices(nonHTcfg, 'Legacy');
6  -    Nst = numel(datax)+numel(pilotsx); % Number of occupied subcarriers
7  -    Nfft = helperFFTLength(nonHTcfg);    % FFT length
8
9  -    AWGN = comm.AWGNChannel;
10 -    AWGN.NoiseMethod = 'Signal to noise ratio (SNR)';
11 -    AWGN.SignalPower = 1;                % Unit power
12 -    AWGN.SNR = SNR_i-10*log10(Nfft/Nst); % Account for energy in nulls
13
14 -    txWaveformAWGN=step(AWGN, txWaveform);
```

设置信噪比

```matlab
%% 5. 接收机信号处理过程
%5.1. 捕获WLAN数据包
burstCaptures = [txWaveformAWGN;txWaveformAWGN];   %---------------------------------------> 波形复制，为信号解码准备
step(hsa,burstCaptures);      %---------------------------------------> 显示信号的频谱

%5.2. 接收参数设置
samplesPerFrame = length(txWaveform);  %---------------------------------------> 单帧采样点数
rxSamplesPerFrame = samplesPerFrame*2; %---------------------------------------> 波形复制后，单帧采样点数

%5.3. 数据包处理
[rxBit,offsetLLTF,pktOffset,packetSeq]=ReceiverProc(MPDU_Param,nonHTcfg,hcd,chanBW,overSampleFactor,burstCaptures);

%5.4. 图像重构和误码率计算
lengthTxImage = length(txImage);       %---------------------------------------> 计算图像的尺寸
reBuildImage(rxBit,offsetLLTF,pktOffset,packetSeq,numMSDUs,MPDU_Param,txData,lengthTxImage,imsize)
```
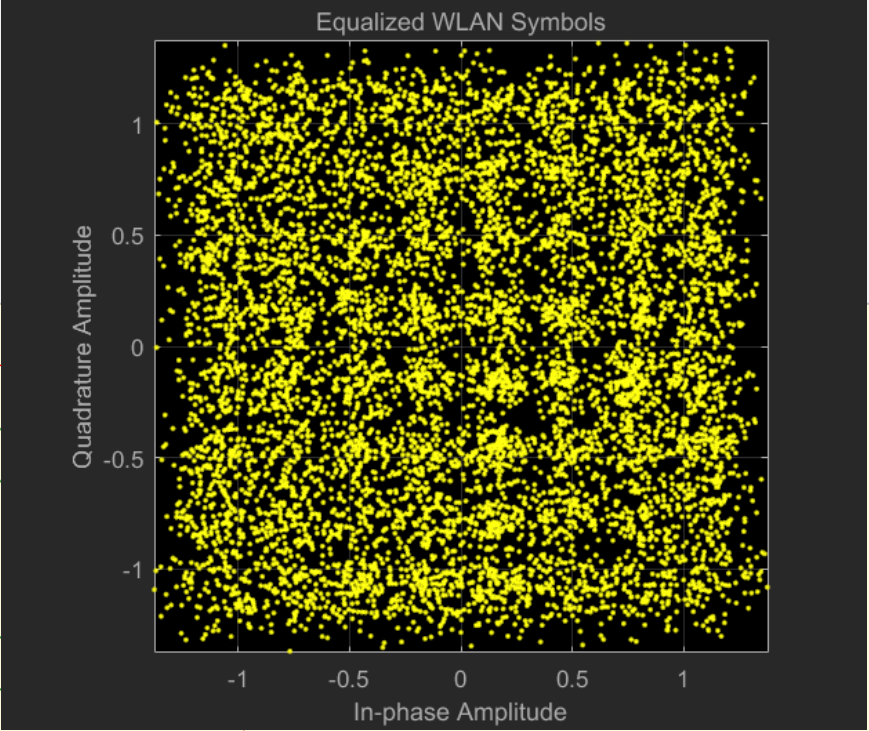
```
77    %% 5. 接收机信号处理过程
78    %5.1. 捕获WLAN数据包
79 —  burstCaptures = [txWaveformAWGN;txWaveformAWGN];   %----------------------------------> 波形复制，为信号解码准备
80 —  step(hsa,burstCaptures);         %------------------------------------------------------> 显示信号的频谱
81
82    %5.2. 接收参数设置
83 —  samplesPerFrame = length(txWaveform);   %-------------------------
84 —  rxSamplesPerFrame = samplesPerFrame*2;  %-------------------------
85
86    %5.3. 数据包处理
87 —  [rxBit,offsetLLTF,pktOffset,packetSeq]=ReceiverProc(MPDU_Pa
88
89    %5.4. 图像重构和误码率计算
90 —  lengthTxImage = length(txImage);        %-------------------------
91 —  reBuildImage(rxBit,offsetLLTF,pktOffset,packetSeq,numMSDUs,
92
93
```
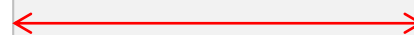

Received Baseband WLAN Signal Spectrum
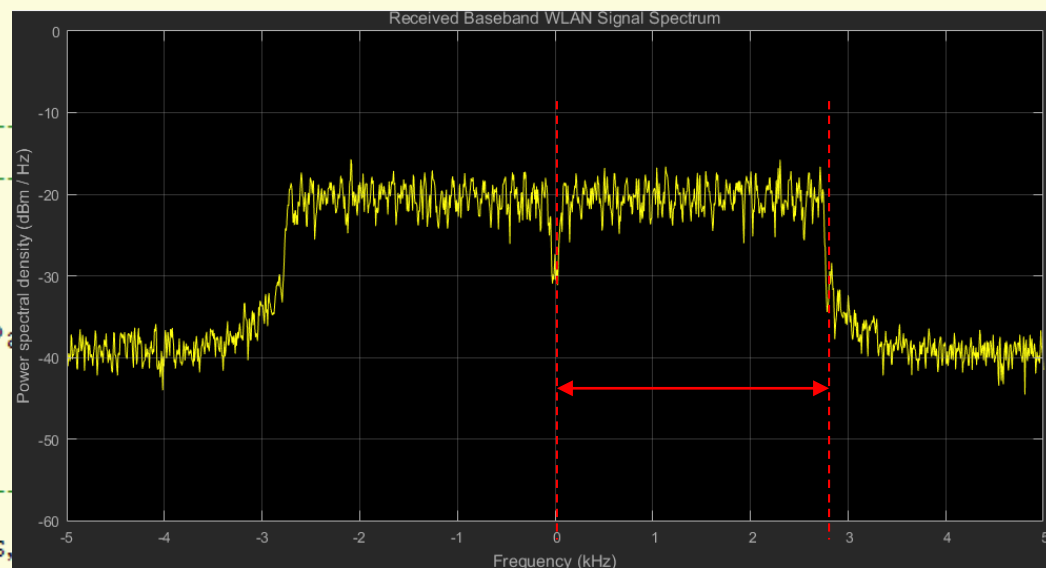
MCS: Modulation and Coding Scheme

MCS索引	空间流数量	调制方式	速率(Mb/s)	
			800ns GI	400ns GI
0	1	BPSK 1/2	6.5	7.2
1	1	QPSK 1/2	13.0	14.4
2	1	QPSK 3/4	19.5	21.7
3	1	16-QAM 1/2	26.0	28.9
4	1	16-QAM 3/4	39.0	43.3
5	1	64-QAM 2/3	52.0	57.8
6	1	64-QAM 3/4	58.5	65.0

Equalized WLAN Symbols

```
85
86          %5.3. 数据包处理
87 —        [rxBit, offsetLLTF, pktOffset, packetSeq]=ReceiverProc(MPDU_Param, nonHTcfg, hcd, chanBW, overSampleFactor, burstCaptures);
88
89          %5.4. 图像重构和误码率计算
90 —        lengthTxImage = length(txImage);        %----------------------------------------------------> 计算图像的尺寸
91 —        reBuildImage(rxBit, offsetLLTF, pktOffset, packetSeq, numMSDUs, MPDU_Param, txData, lengthTxImage, imsize)
92
93
```

Bit Error Rate (BER):
        Bit Error Rate (BER) = 0.00015.
        Number of bit errors = 164.
    Number of transmitted bits = 1066464.

Transmitted Image

Received Image

```matlab
77     %% 5.接收机信号处理过程
78     %5.1.  捕获WLAN数据包
79 —   burstCaptures = [txWaveformAWGN;txWaveformAWGN];    %------------------------------
80 —   step(hsa,burstCaptures);      %------------------------------
81
82     %5.2.  接收参数设置
83 —   samplesPerFrame = length(txWaveform);   %------------------------------
84 —   rxSamplesPerFrame = samplesPerFrame*2;  %------------------------------
85
86     %5.3.  数据包处理
87 —   [rxBit,offsetLLTF,pktOffset,packetSeq]=ReceiverProc(MPDU_Param,nonHTcfg,hcd,ch
88
89     %5.4.  图像重构和误码率计算
90 —   lengthTxImage = length(txImage);        %------------------------------------> 计算图像的尺寸
91 —   reBuildImage(rxBit,offsetLLTF,pktOffset,packetSeq,numMSDUs,MPDU_Param,txData,lengthTxImage,imsize)
92
93
```

Assignments

➢ Read the example '**802.11a Transmission and Reception Using Analog Devices AD9361/AD9364**' in WLAN System Toolbox.

➢ Explain the functions of the following six subcomponents respectively,

    (1) ResizeImage.m

    (2) createPSDU.m

    (3) createTxWaveform.m

    (4) createAWGNChannel.m

    (5) ReceiverProc.m

    (6) reBuildImage.m

Implement '**16/64-QAM** 802.11a Transmission and Reception' according to the example.

➢ Compare the BER between QPSK and 16/64-QAM under different EbN0 condition.
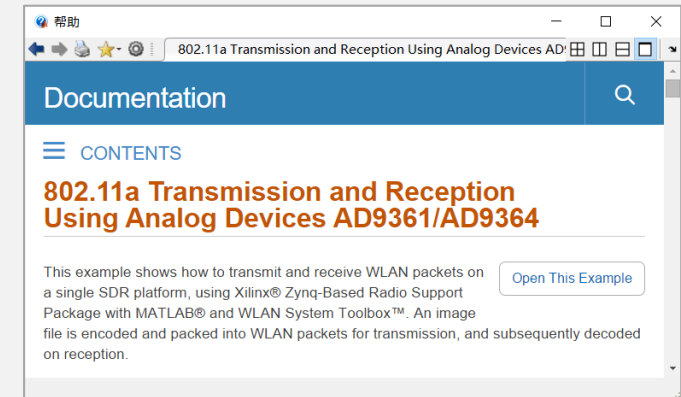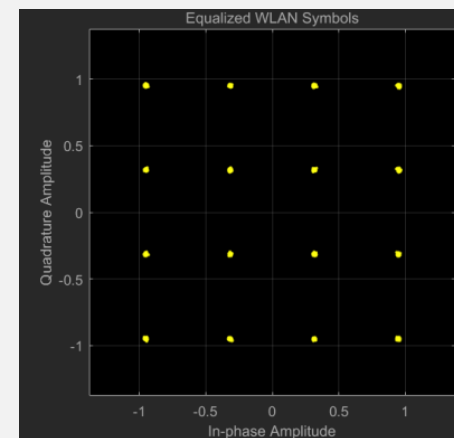
MCS=Inf
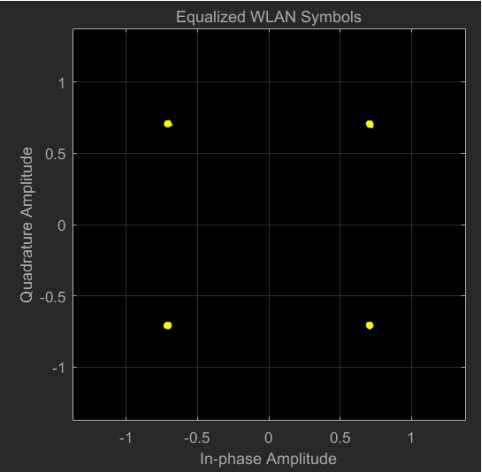
MCS=2
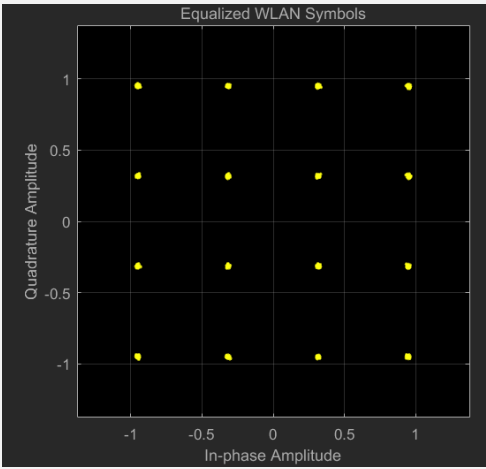
MCS=4
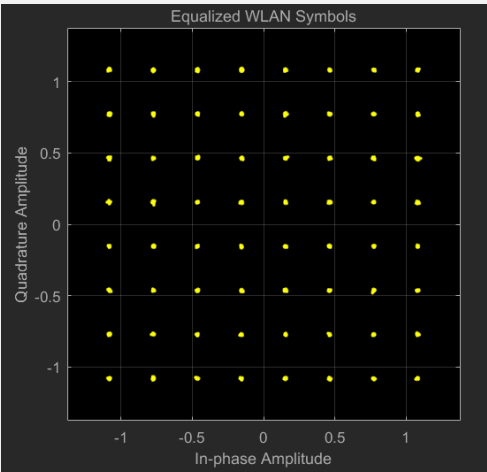
MCS=6

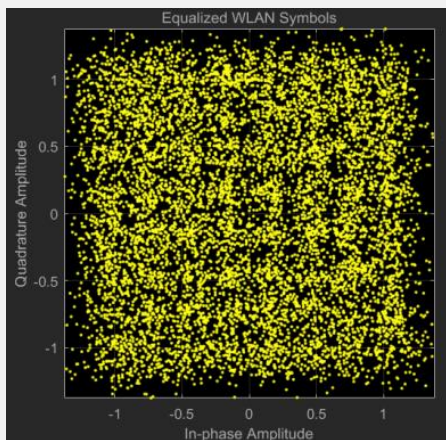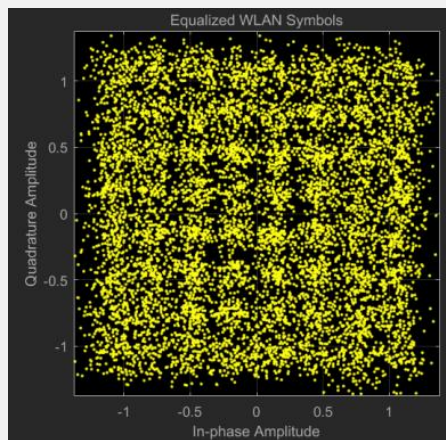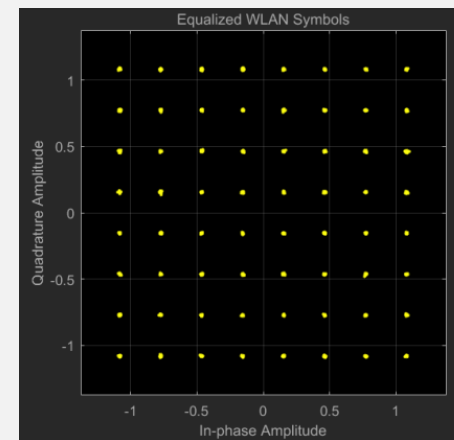MCS=4
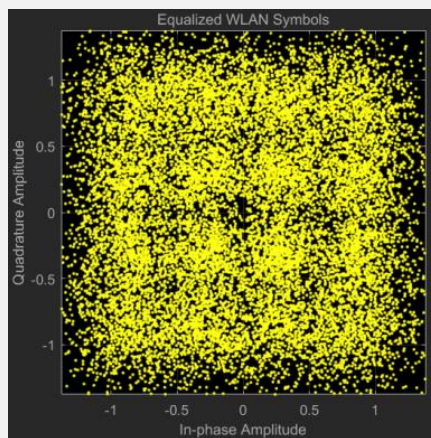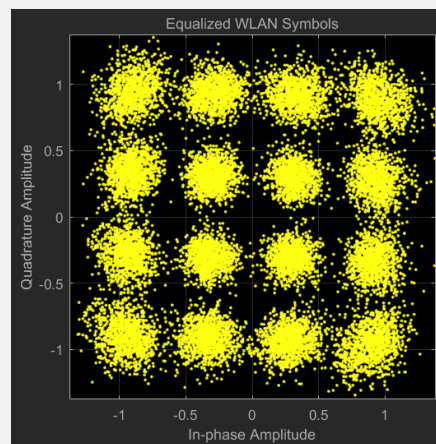
SNR=23   SNR=29   SNR=Inf

MCS=6

SNR=29

SNR=30

SNR=Inf

- **Question ?**