前沿通信系统设计

主讲人：吴光 博士
Email: wug@sustech.edu.cn

In this course, we will discuss …

Wi-Fi: Wireless Fidelity

LTE: Long Term Evolution

5G: 5th Generation Mobile Communication Technology

¥229.00 包邮 4000+人付款

【顺丰速发】华为路由器千兆端口无线家用wifi穿墙王高速5G双频大功率大户型ax2pro

华为友信猫专卖店 广东 深圳

掌柜热卖

¥139.00 包邮 1000+人付款

【每日发货】腾达AC11全千兆端口无线路由器 家用5G高速wifi穿墙王电信移动光纤大

腾达光恒空专卖店 广东 东莞

掌柜热卖

¥269.00 包邮 6000+人付款

【顺丰当天发】华为WiFi6路由器千兆端口穿墙王家用大户型高速双千兆双频全屋无线

华为友信猫专卖店 广东 深圳

¥1599.00 包邮 500+人付款

【顺丰当天发】华为Q2 Pro子母无线路由器千兆端口Q2S大户型别墅光纤家用企业双频

华为友信猫专卖店 广东 深圳

¥99.90 包邮 1000+人付款

【发顺丰送网线】TP-LINK双频无线路由器全千兆端口家用穿墙王高速网智能百兆大功

八度数码专营店 上海

¥75.00 包邮 1000+人付款

顺丰包邮】TP-LINK信号放大器 无线网络扩展器中继器WIFI6路由扩大增强器 千兆双频

八度数码专营店 上海

¥1299.00 包邮 900+人付款

【星际堡垒】小米路由器AX9000家用千兆端口5G三频无线wifi6增强大户型穿墙王全

小米官方旗舰店 北京

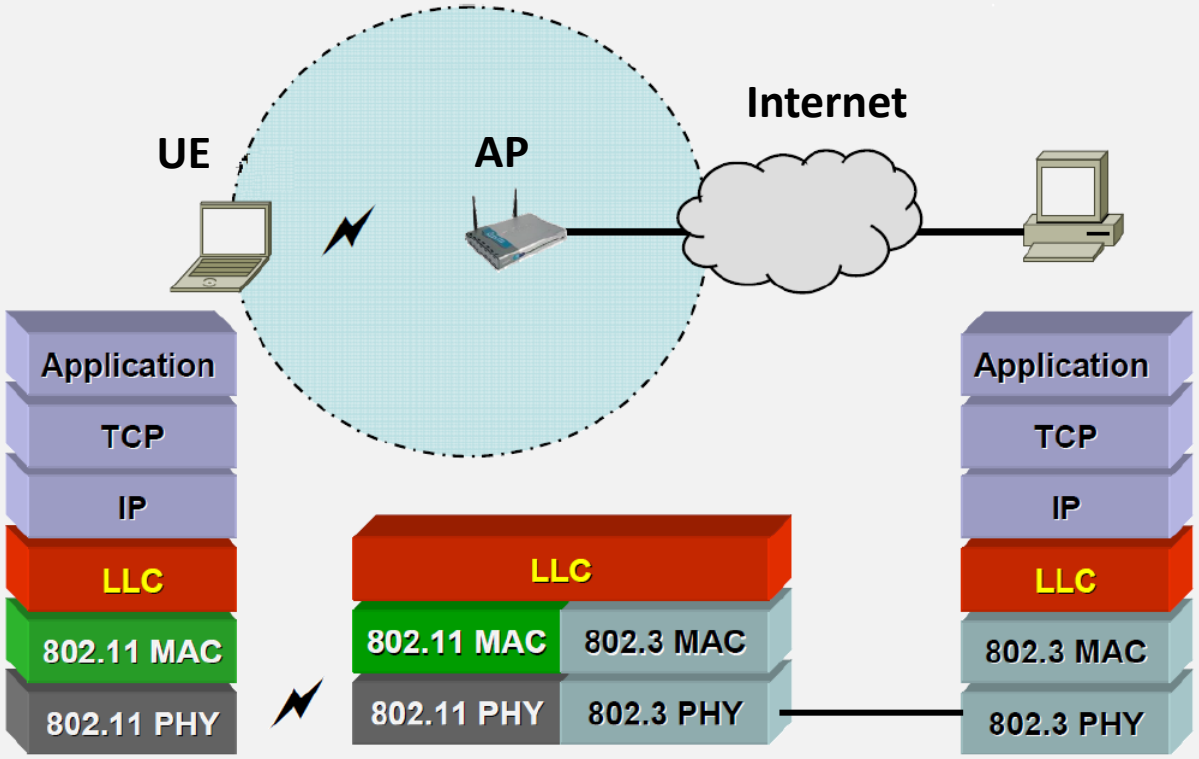
¥299.00 包邮 1万+人付款

【WiFi6新品】小米Redmi路由器AX3000wifi6全千兆端口家用穿墙王5G无线

小米官方旗舰店 北京

UE ⇔ AP ⇔ Internet

WLAN: Wireless Local Area Network



UE: User Equipment

AP: Access Point

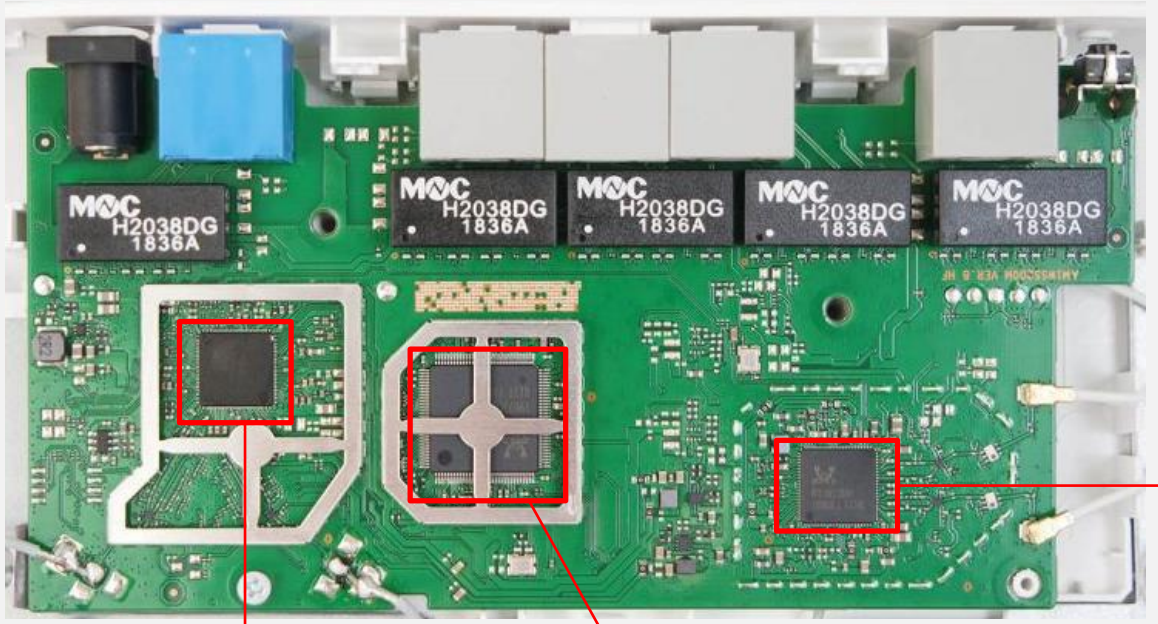
TCP: Transmission Control Protocol

IP: Internet Protocol

LLC: Logical-Link Control

MAC: Media Access Control

PHY: Physical layer



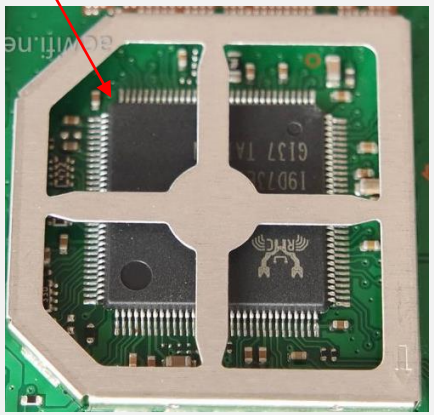
RTL8812BRH

无线信号处理芯片

RTL8197FS

处理器芯片

RTL8367RB



千兆交换机芯片

In this course, we will discuss …

Wi-Fi: Wireless Fidelity

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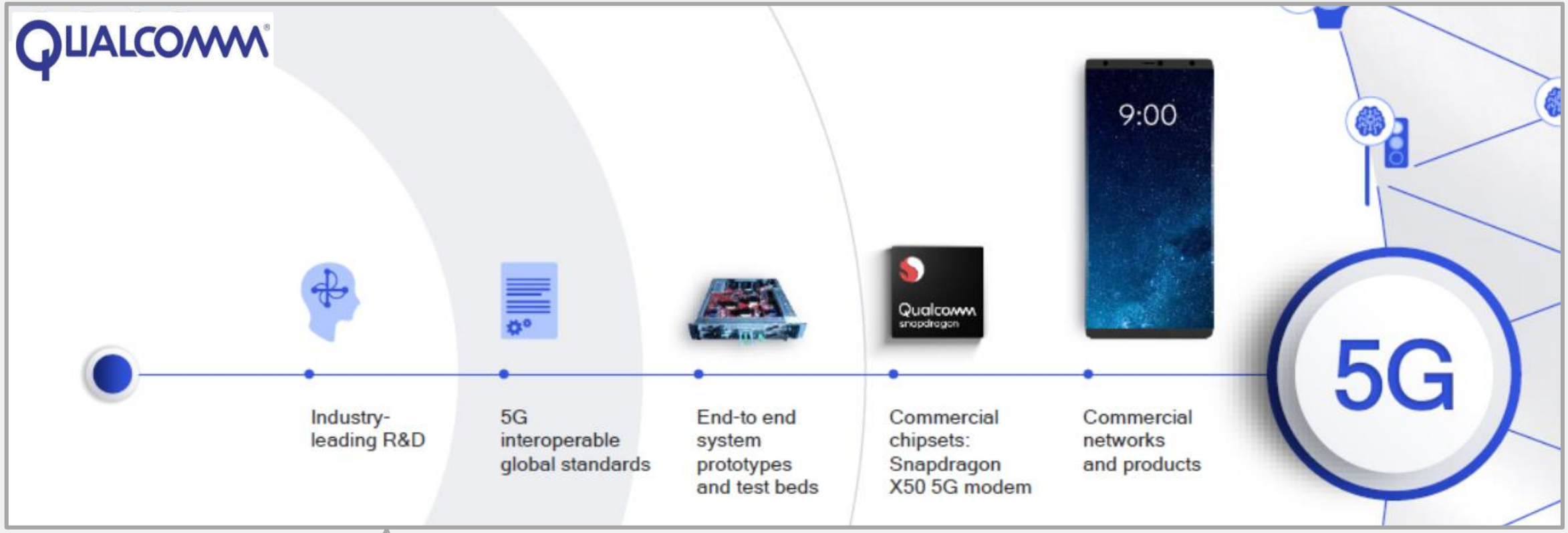
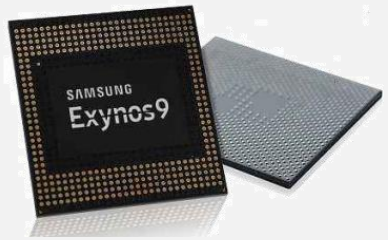
5G: 5th Generation Mobile Communication Technology



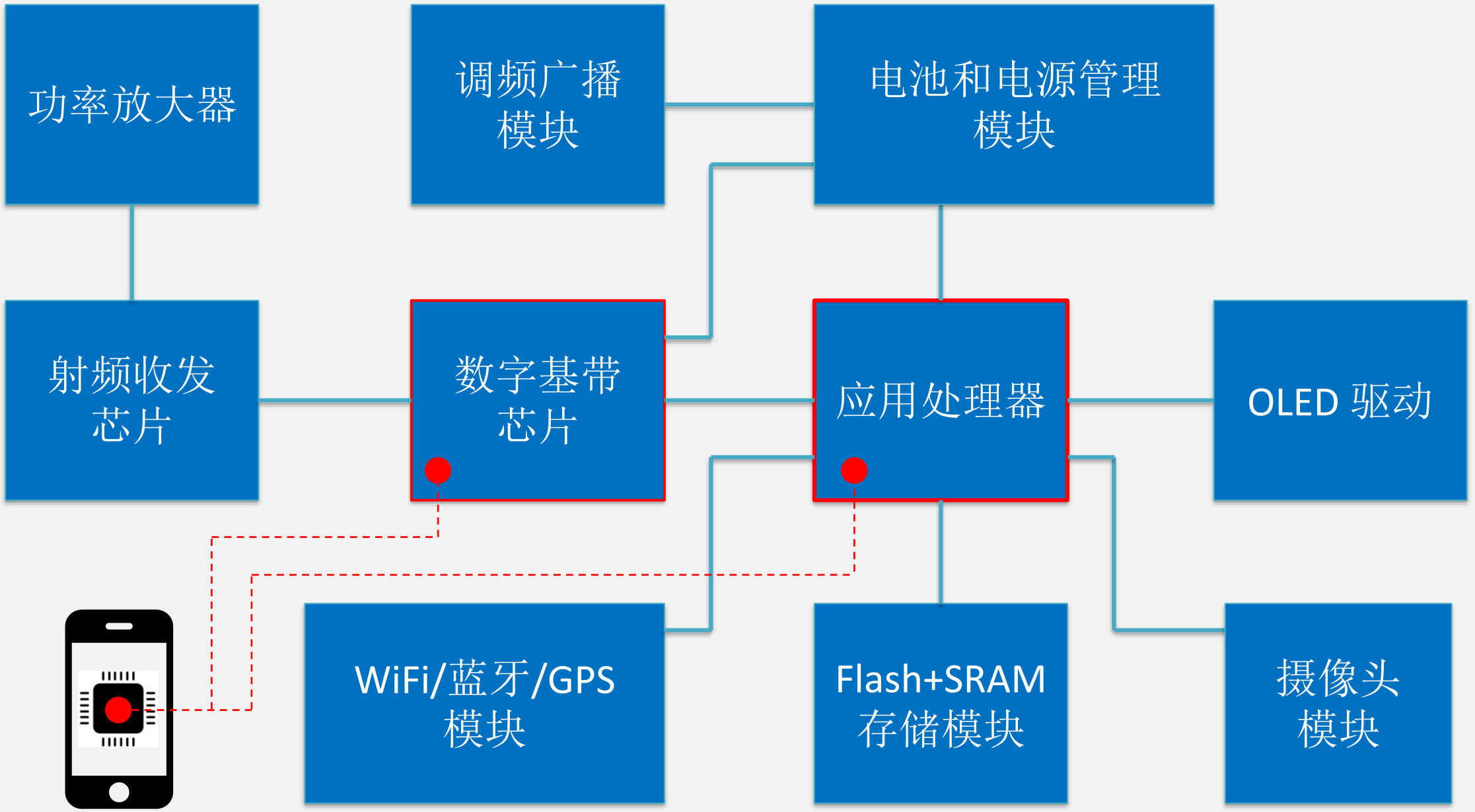


QUALCOMM

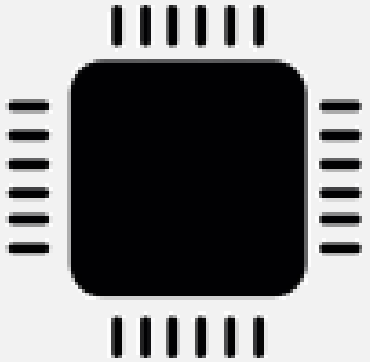
HUAWEI

SAMSUNG

MEDIATEK
聯發科技


功率放大器
调频广播模块
电池和电源管理模块
射频收发芯片
数字基带芯片
应用处理器
OLED 驱动
WiFi/蓝牙/GPS模块
Flash+SRAM存储模块
摄像头模块

Key & Core Technology（卡脖子技术）：Microchip



Microchip

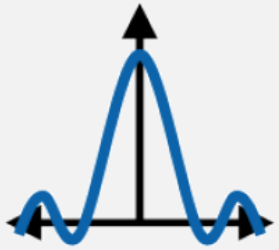
Wi-Fi: Wireless Fidelity

LTE: Long Term Evolution

5G: 5th Generation Mobile Communication Technology

More than 1400+ Steps

The Course will focus on …



From Theory to Practice

Design Verification

Product Verification

Research/ Modeling

Design/ Simulation

Verification/ Validation

Manufacturing

For Example, we can use Software Defined Radio,

ANALOG DEVICES
AHEAD OF WHAT'S POSSIBLE™

Research
- Behavioral Simulation
- Streaming data to MATLAB and IIO-Scope

Algorithm Development
- MATLAB reference implementation
- Hardware streaming

Design Elaboration
- MATLAB
- Simulink modeling
- Hardware streaming
- Data type conversion

Prototype
- Deployment to development board
- Design optimization
- HDL Integration
- Driver Integration

Production
- Deployment to custom hardware
- Validation with complete hardware solution

PlutoSDR

RFSoM+FMC Carrier or Eval FMC + FPGA Carrier

PackRF or RFSoM + Custom Carrier

Custom

南方科技大学
SOUTHERN UNIVERSITY OF SCIENCE AND TECHNOLOGY

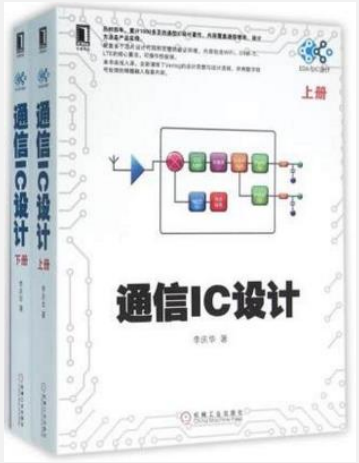
Communication Systems Design

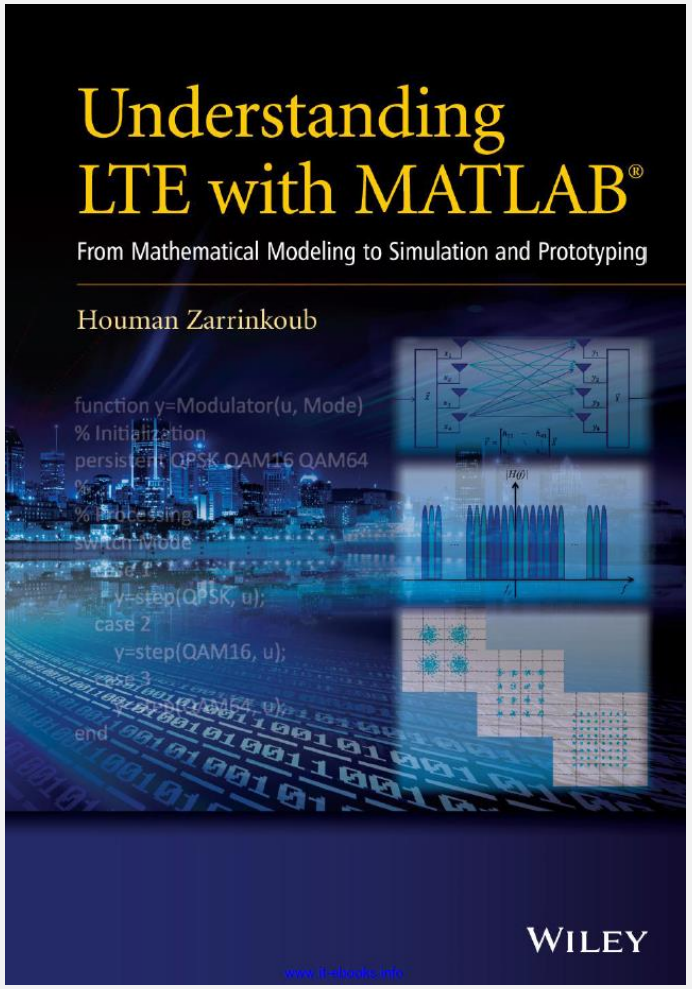
Lab 1: MATLAB Programming for Communication Systems

Dr. Wu Guang
wug@sustech.edu.cn
Electrical & Electronic Engineering
Southern University of Science and Technology

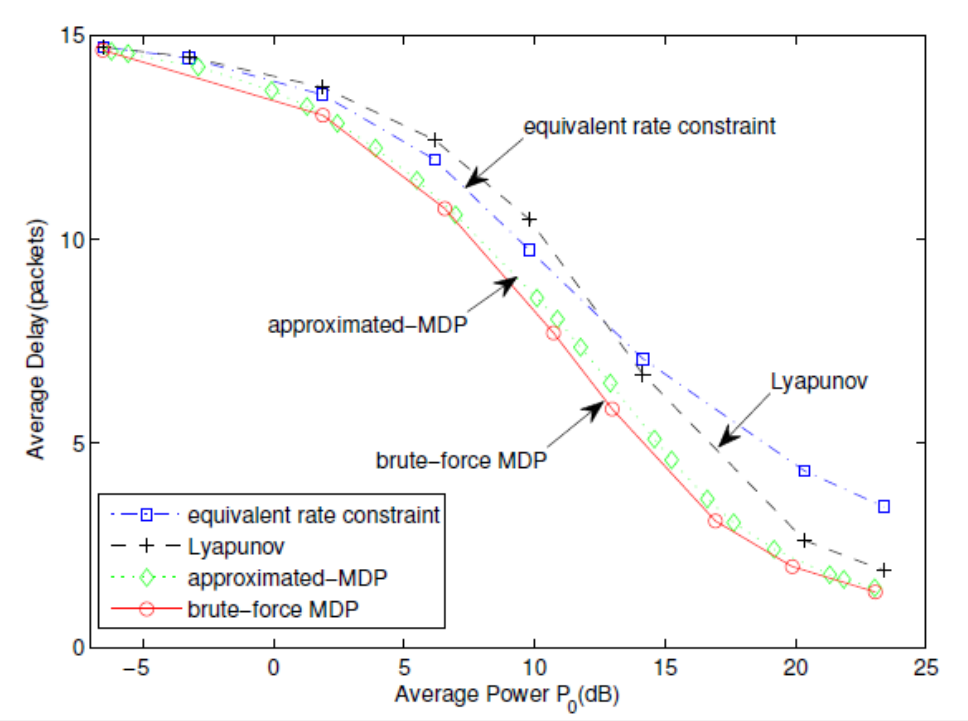

前沿通信系统设计
1 WiFi通信系统（6周）
实验目标：利用USRP实现802.11a/n图像传输
软件：MATLAB, 硬件：USRP
授课内容：MATLAB通信编程、USRP文本传输、MIMO系统、802.11a/n仿真、802.11a/n图像传输
2 5G/4G-LTE系统（5周）
实验目标：利用USRP实现LTE图像传输
软件：MATLAB，硬件：USRP
授课内容：小区搜索过程、MIB/SIB解码过程、LTE图像传输、LDPC编解码过程、srsLTE系统
3 无线网络传输系统（3周）
实验目标：利用Telos实现无线多跳网络传输数据
软件：TinyOS、NesC
授课内容：TinOS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

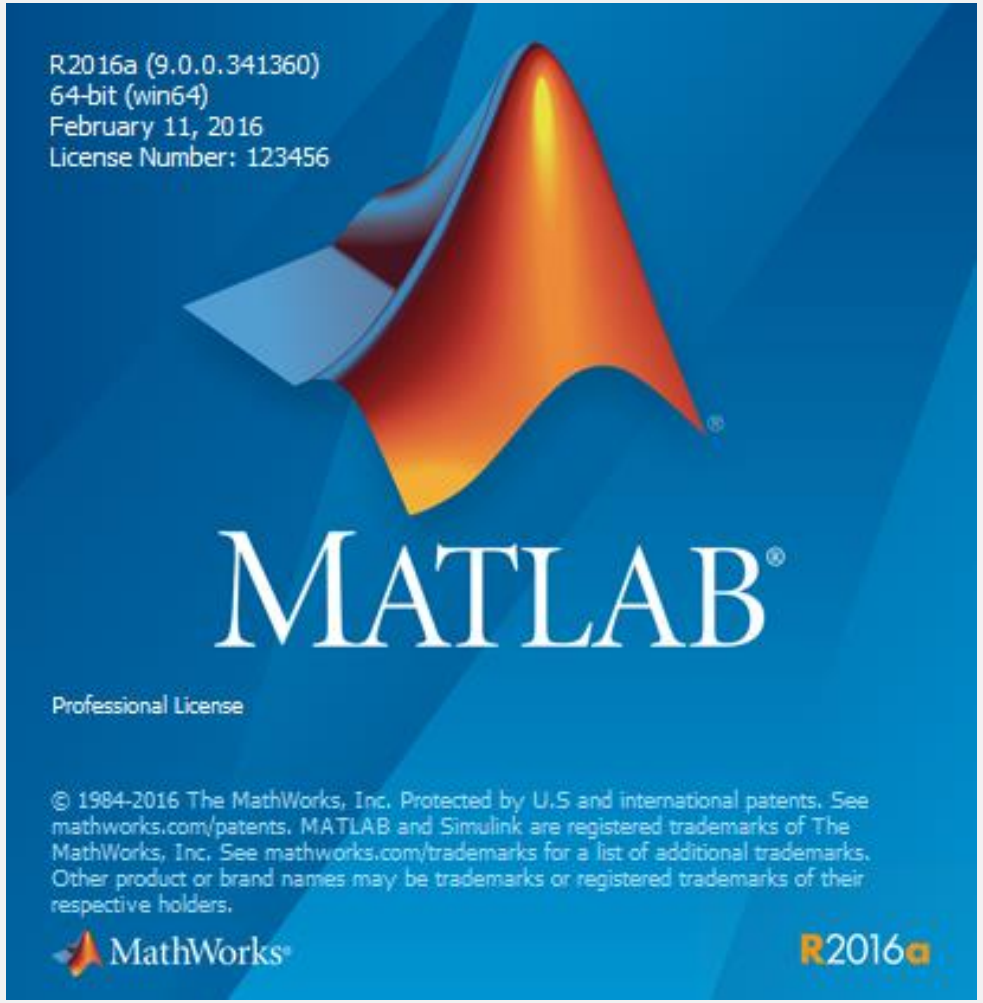
Reference books





MATLAB Programming (Required)





Course Workload

- **Lab Section**: Basic Lab Assignments (**60%**)
  - In-class Demonstration and Explanation
  - Lab Report
- **Project** (**40%**)
  - Project Presentation
  - Final Report
  - Best Report and Best Presentation Awards
- **Special Gifts** (**+20%**)
  - In-class Feedback
  - Research-based Report: Development of a novel method, Analysis and interpretation of the proposed algorithm.

About the Special Gifts

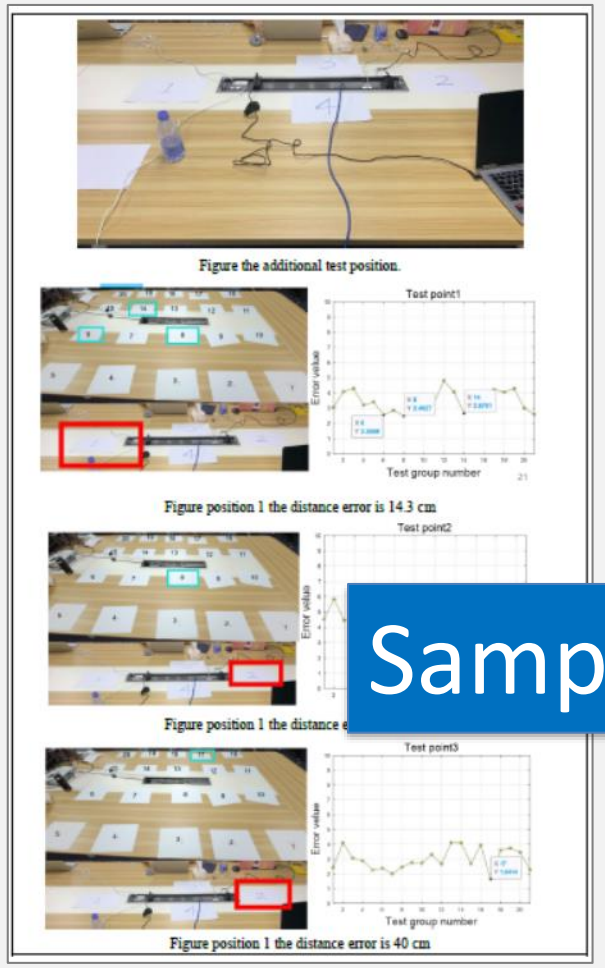


Figure the additional test position.

Test point1

Error value

Test group number

Figure position 1 the distance error is 14.3 cm

Test point2

Figure position 1 the distance e

Test point3

Figure position 1 the distance error is 40 cm

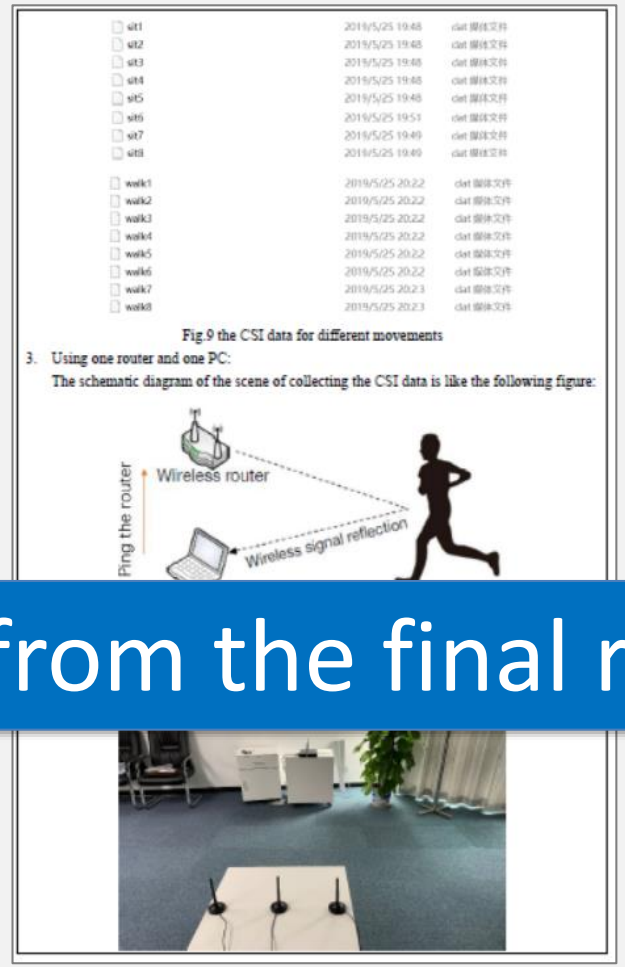


Fig.9 the CSI data for different movements

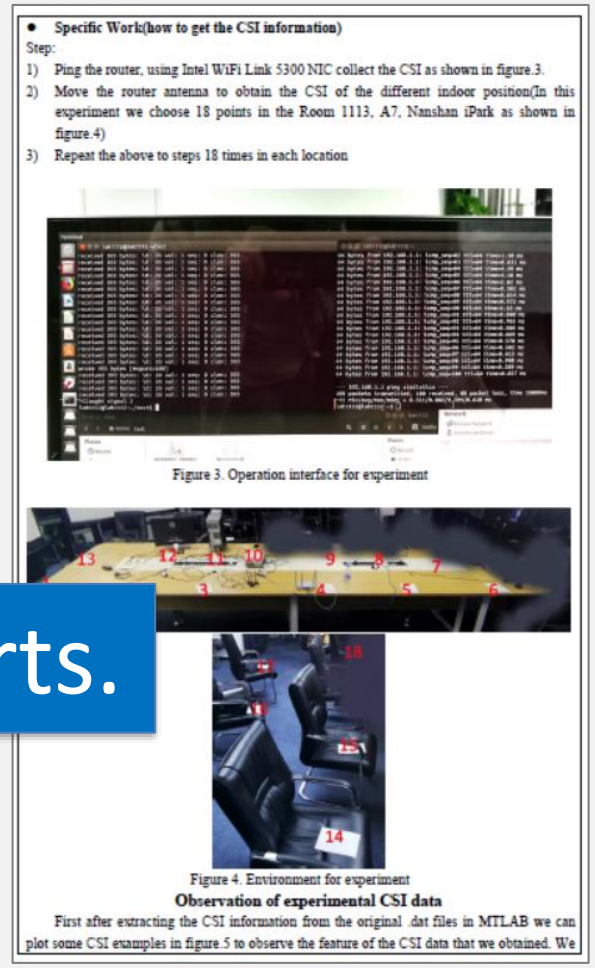
3. Using one router and one PC:

The schematic diagram of the scene of collecting the CSI data is like the following figure:

Wireless router

Ping the router

Wireless signal reflection



- **Specific Work(how to get the CSI information)**

Step:

1) Ping the router, using Intel WiFi Link 5300 NIC collect the CSI as shown in figure.3.
2) Move the router antenna to obtain the CSI of the different indoor position(In this experiment we choose 18 points in the Room 1113, A7, Nanshan iPark as shown in figure.4)
3) Repeat the above to steps 18 times in each location

Figure 3. Operation interface for experiment

Figure 4. Environment for experiment

Observation of experimental CSI data

First after extracting the CSI information from the original .dat files in MTLAB we can plot some CSI examples in figure.5 to observe the feature of the CSI data that we obtained. We

Samples from the final reports.

About the Washington Accord Graduate Attribute Profile (5/12)

Problem analysis	WA2: Identify, formulate, research literature and analyse complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences and engineering sciences (WK1 to WK4).
Design/ development of solutions	WA3: Design solutions for complex engineering problems and design systems, components or processes that meet specified needs with appropriate consideration for public health, and safety, cultural, societal and environmental considerations (WK5).
Investigation	WA4: Conduct investigations of complex problems using research-based knowledge (WK8) and research methods including design of experiments, analysis and interpretation of data, and synthesis of information to provide valid conclusions.
Modern tool usage	WA5: Create, select and apply appropriate techniques, resources and modern engineering and IT tools, including prediction and modelling, to complex engineering problems, with an understanding of the limi-tations (WK6).

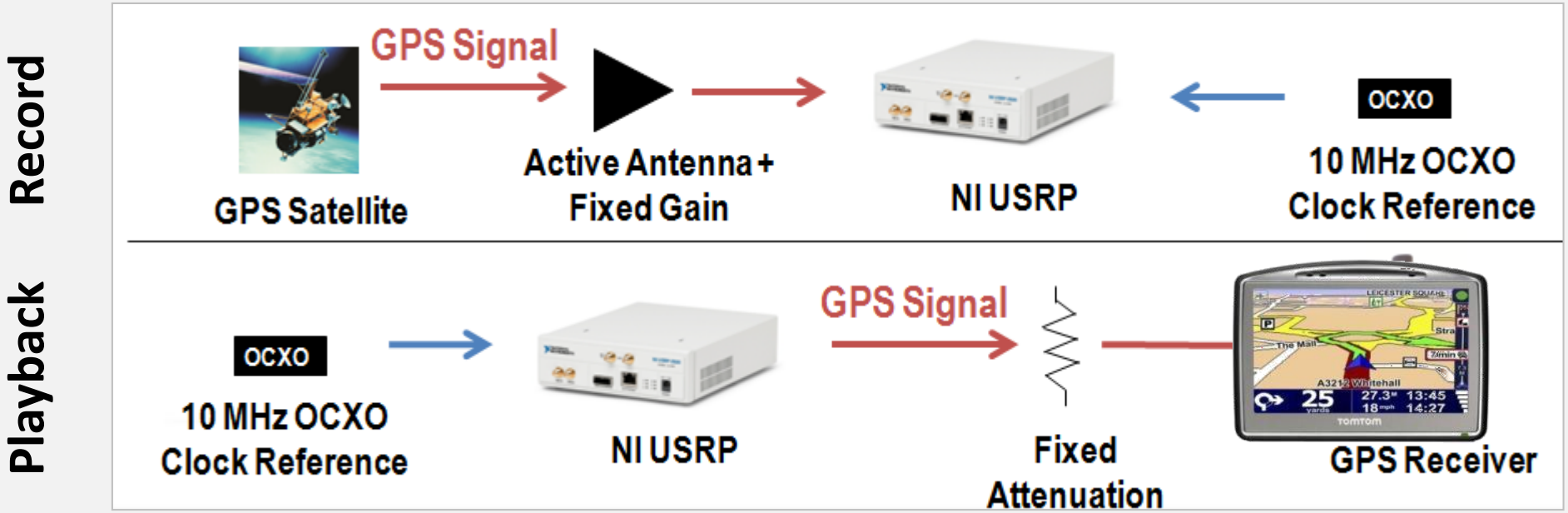
- Question ?

More Research Projects based on USRP

For Communication Systems Design

RF Record & Playback

- Record and play back up to 20 MHz of bandwidth
- Repeatable testing of algorithms / devices on realistic dataset
- Supplement a PXI lab with low-cost playback at your desk

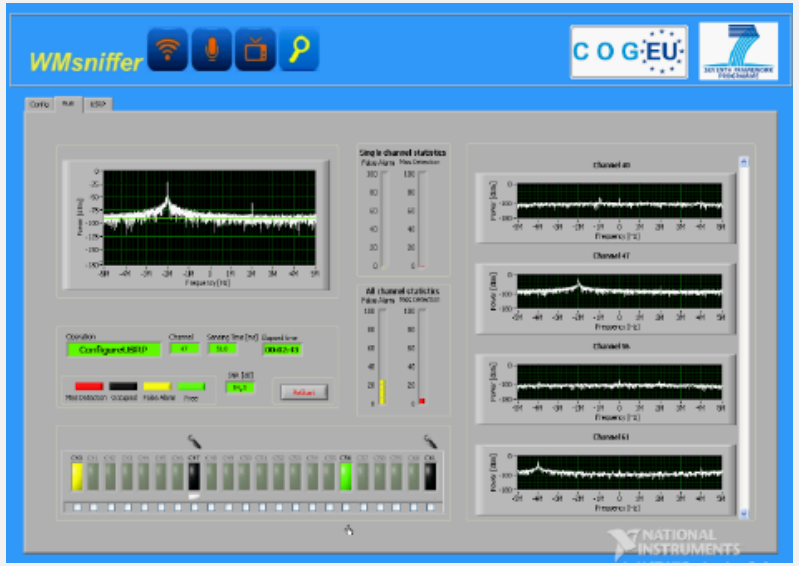


NI USRP Research Case Study:

Cognitive Radio & Whitespace

Large Scale Cognitive Radio Testbed

- Prototyping cognitive radio in LabVIEW
- Spectral sensing with blind detection
- Database driven geo-location with GPS
- Deployed in Munich, Germany



"LabVIEW software and the NI USRP hardware are key components of this research project, allowing the team to rapidly prototype and successfully deploy the first cognitive radio test bed of this kind." ***Dr. Paulo Marques, COGEU***

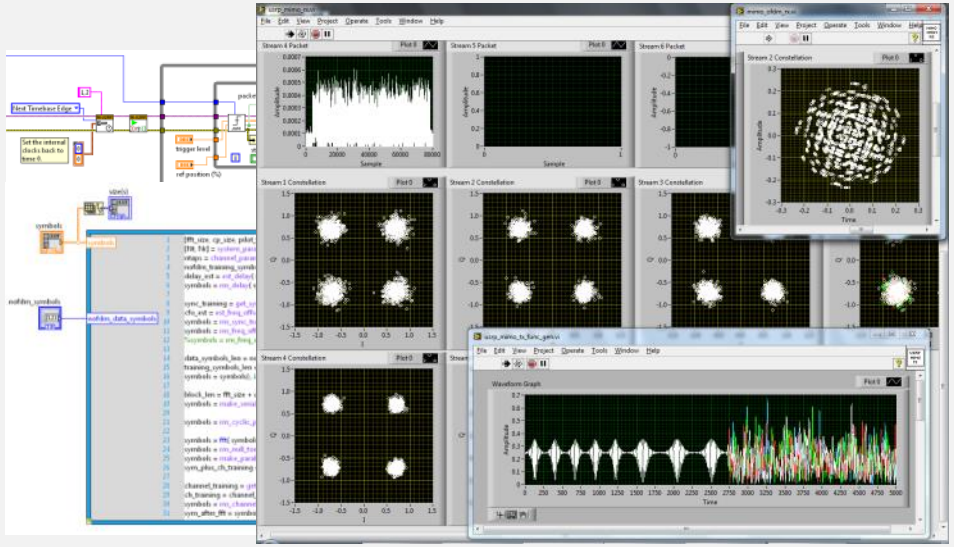
Aveiro, Portugal

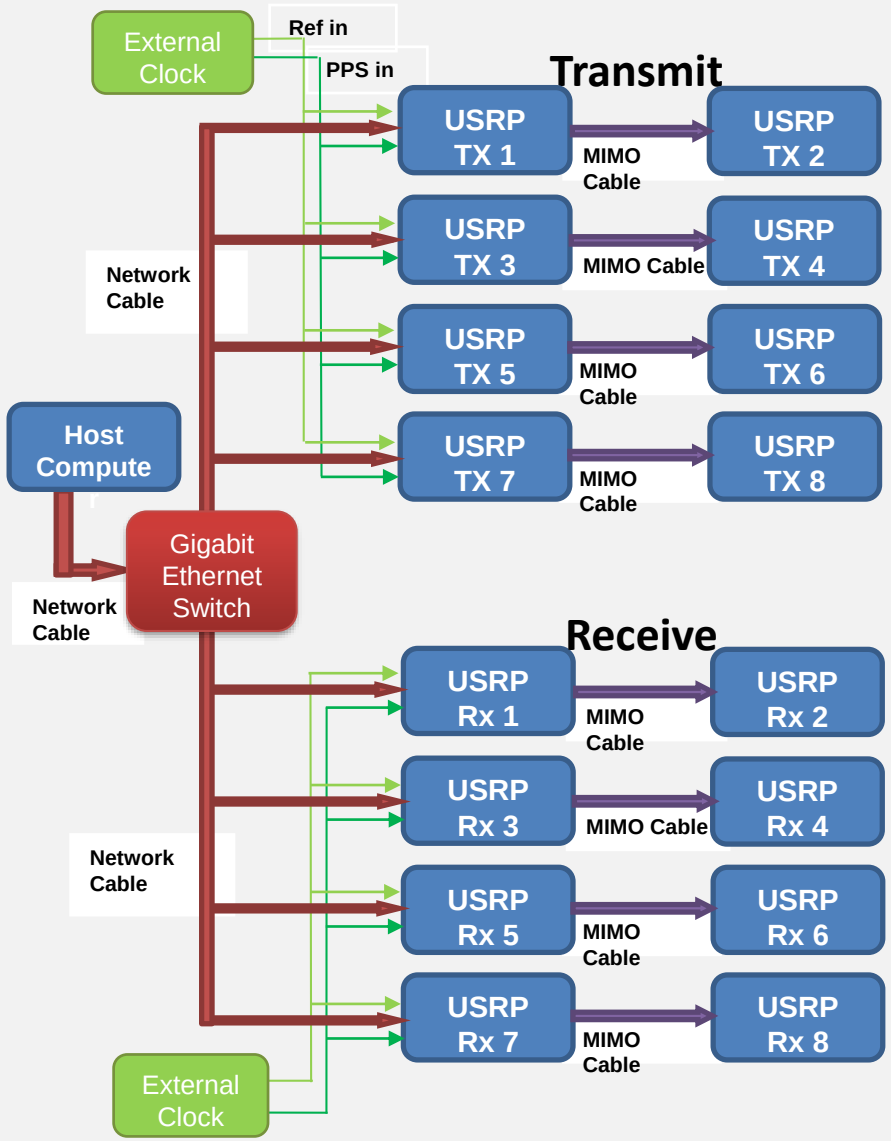
NI USRP Research Case Study:

NI USRP 8x8 MIMO Testbed

Dr. Robert Heath
Director WNCG
University of Texas at Austin

- Adaptable from 2x2 to 8x8
- Algorithm design in MathScript RT
- 128 subcarrier OFDM, 4 QAM, spatial diversity
- Independently clocked, phase coherent Tx & Rx



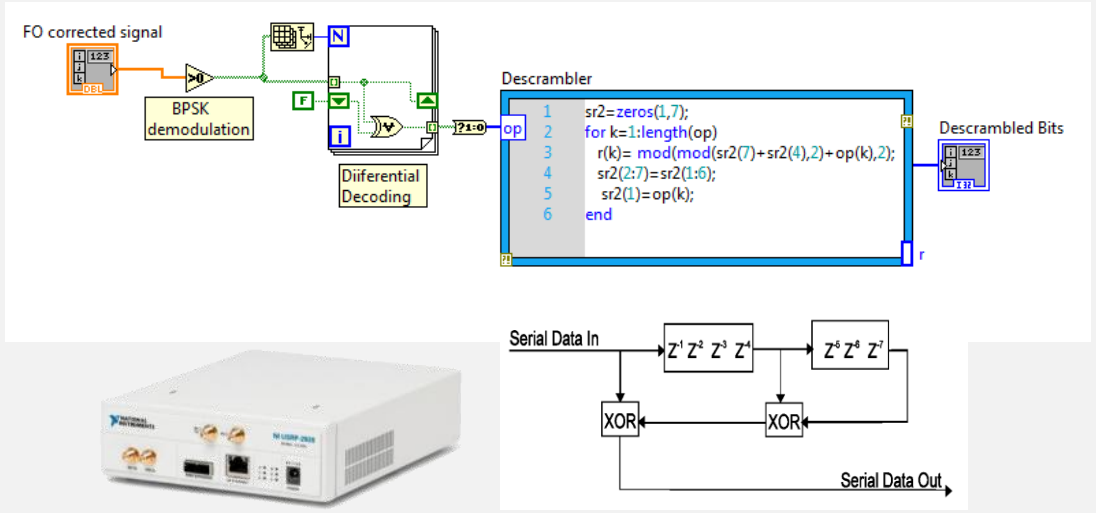


NI USRP Research Case Study:
Physical Layer Prototyping

Dr. Murat Torlak

- Continuously monitoring multiple wifi channels
- Demodulation and descrambling of 802.11b beacon signals
- Identification of hotspots, tracking relative power levels

Demodulate | Descramble



802.11b SSID Decoding

Carrier Detection → Frequency Offset Estimation & Correction → Demodulation & Descrambling → Interpret the frame for SSID

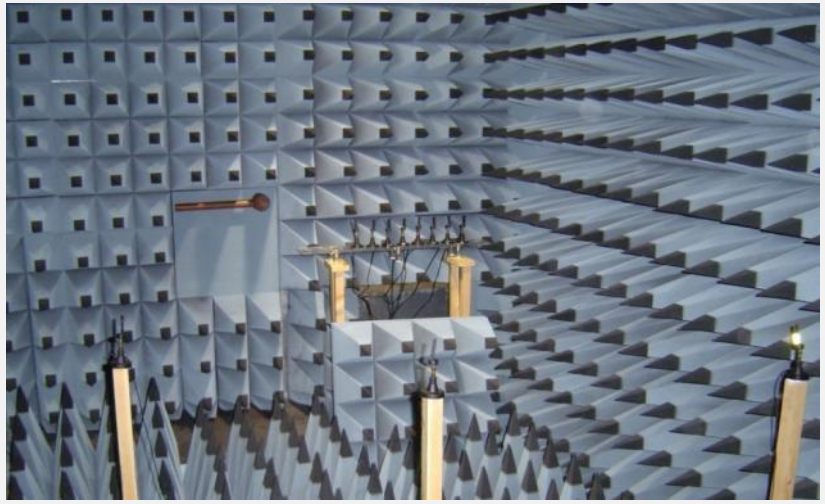
NI USRP Research Case Study:

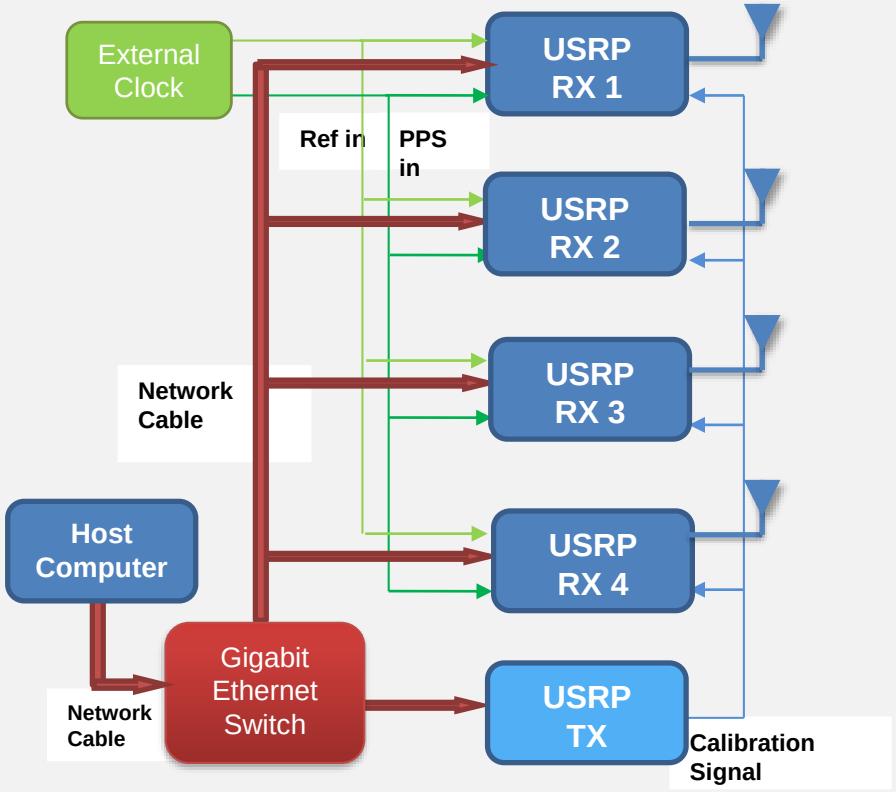
Position Detection & Localization

Prof. Athanassios Manikas
Comm & Array Processing Chair
Imperial College, London

- Testing MUSIC direction finding algorithm
- Rapid prototyping in LabVIEW with MathScript RT
- Synchronized up to12 USRP devices
- Reference provides continuous phase alignment compensation

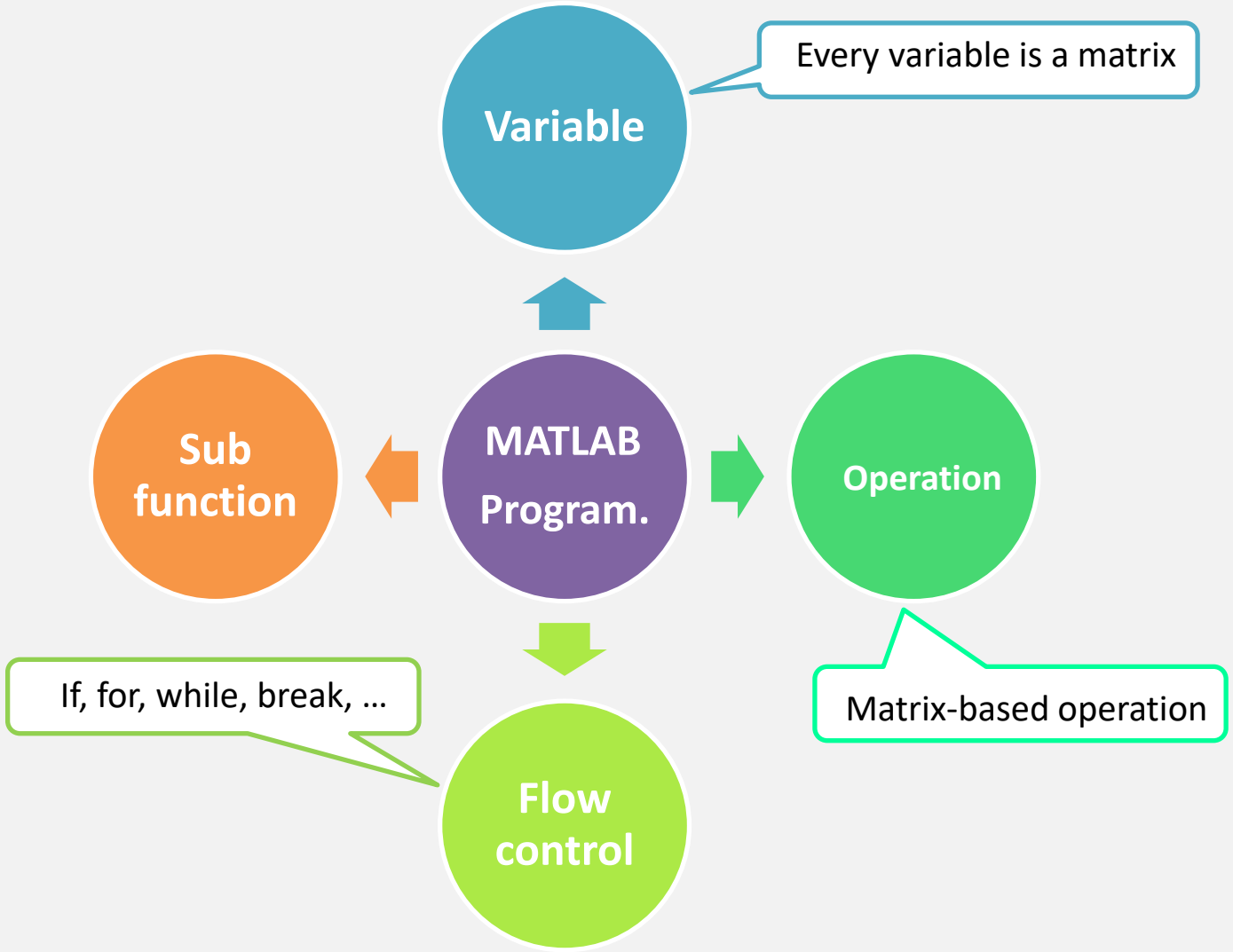
Direction Finding (uniform linear array)

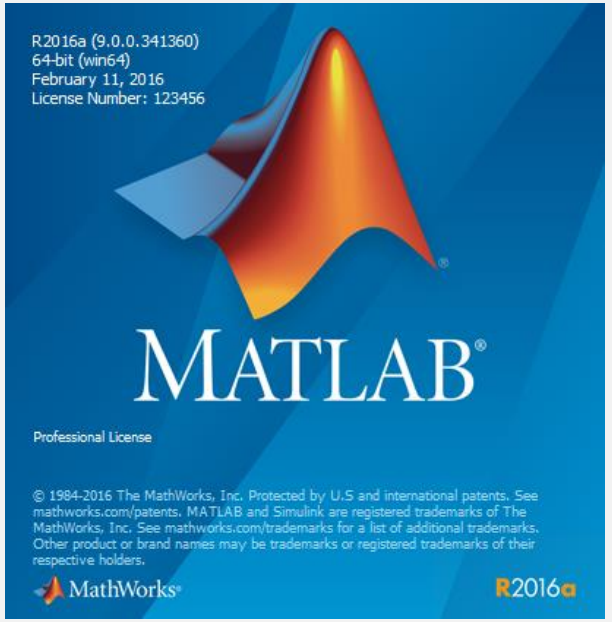




Advanced Programming

For Communication Systems Design


Variable
Every variable is a matrix
Sub function
MATLAB Program.
Operation
If, for, while, break, …
Flow control
Matrix-based operation


R2016a (9.0.0.341360)
64-bit (win64)
February 11, 2016
License Number: 123456
MATLAB®
Professional License
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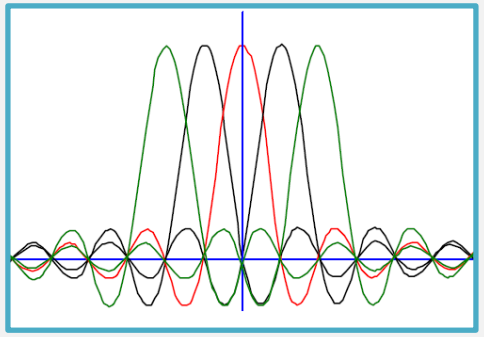
MathWorks
R2016a

Everything in MATLAB is matrix

```
A1 = [1 2 3]
    A1 =
          1    2    3
```

```
A2 = [1 2 3; 5 1 4; 3 4 -1]
    A2 =
          1    2    3
          5    1    4
          3    4   -1
```

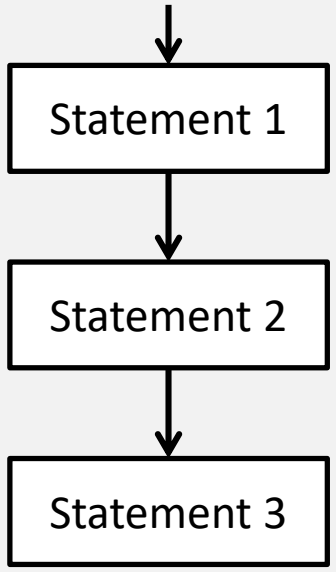
```
A3(:,:,1) = A2;
A3(:,:,2) = 2*A2;
A3(:,:,3) = 3*A2;
    A3(:,:,1) =
          1    2    3
          5    1    4
          3    4   -1
    A3(:,:,2) =
          2    4    6
         10    2    8
          6    8   -2
    A3(:,:,3) =
          3    6    9
         15    3   12
          9   12   -3
```



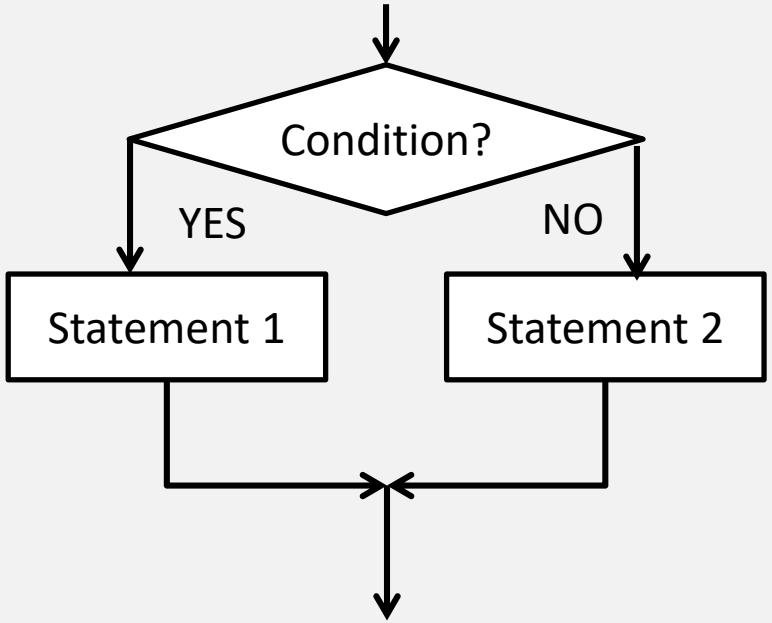
Flow Control

Similar to almost all programming language, MATLAB program has three basic structures:

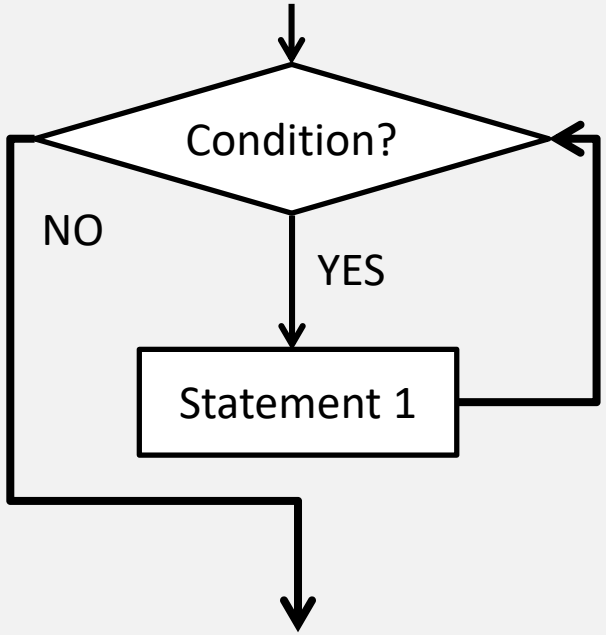
- Sequence, Selection and Repetition



Sequence

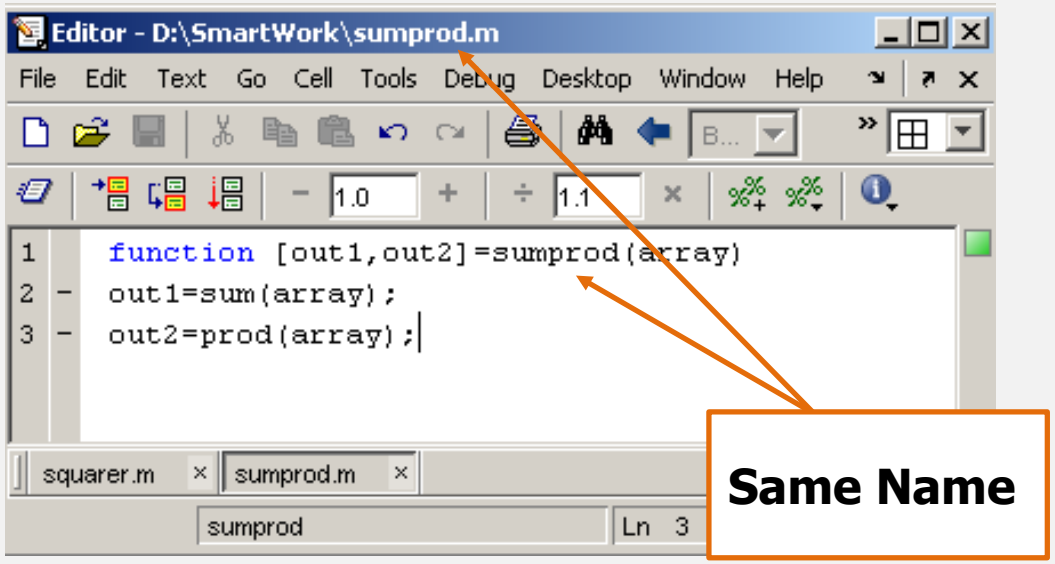


Selection: if

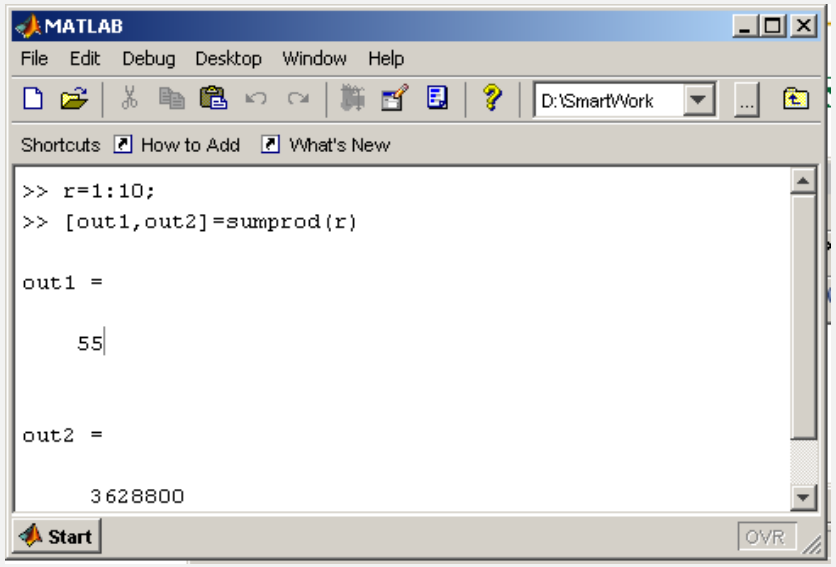


Repetition: for & while

Sub function



Step 1

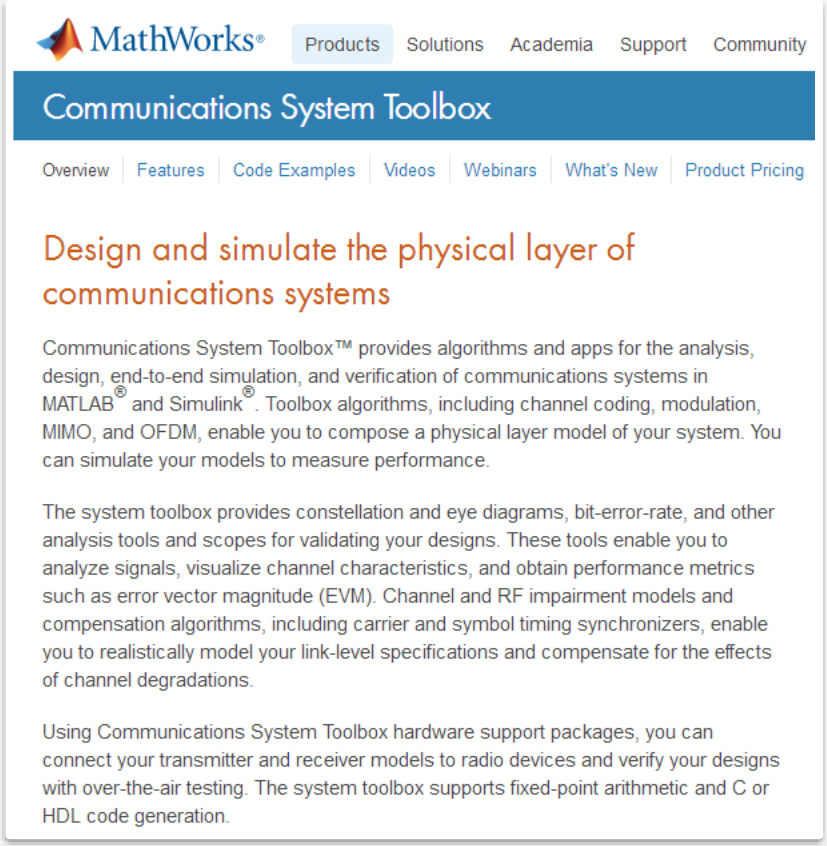


Step 2

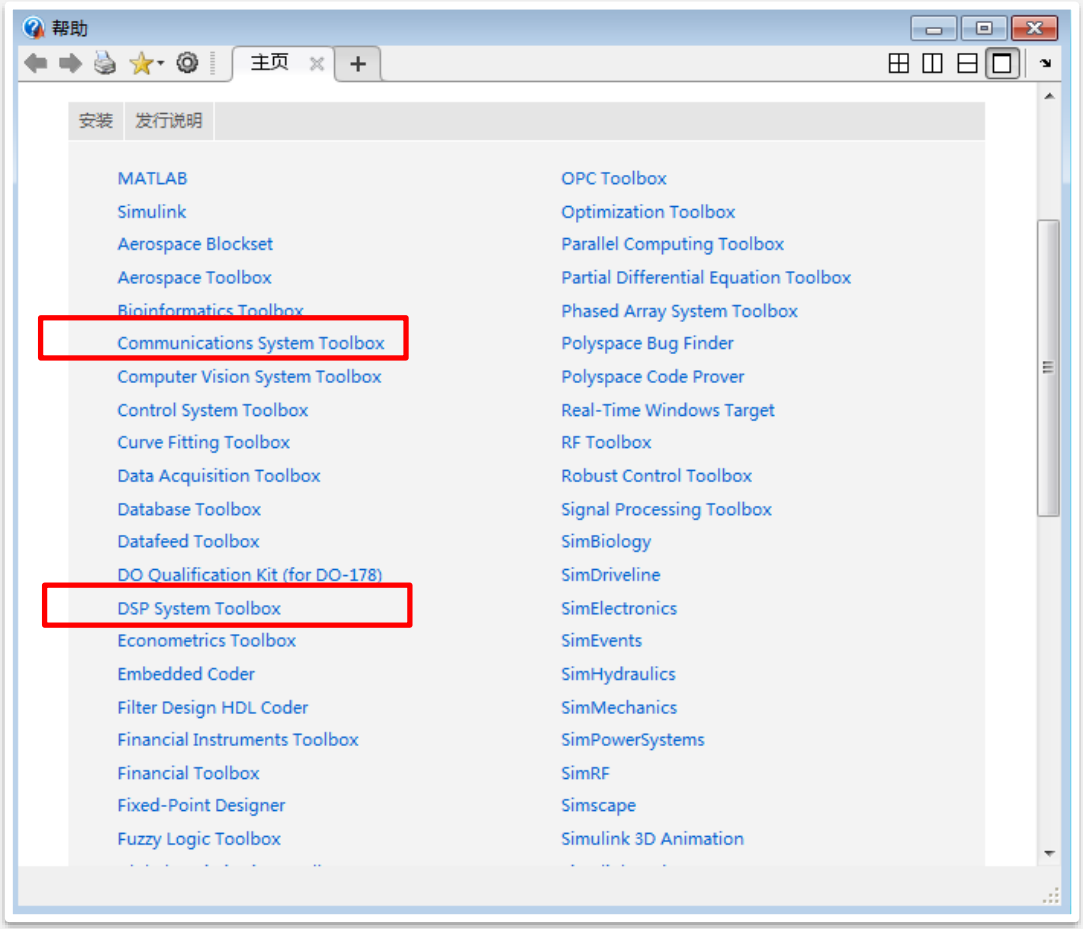
MATLAB System Toolboxes

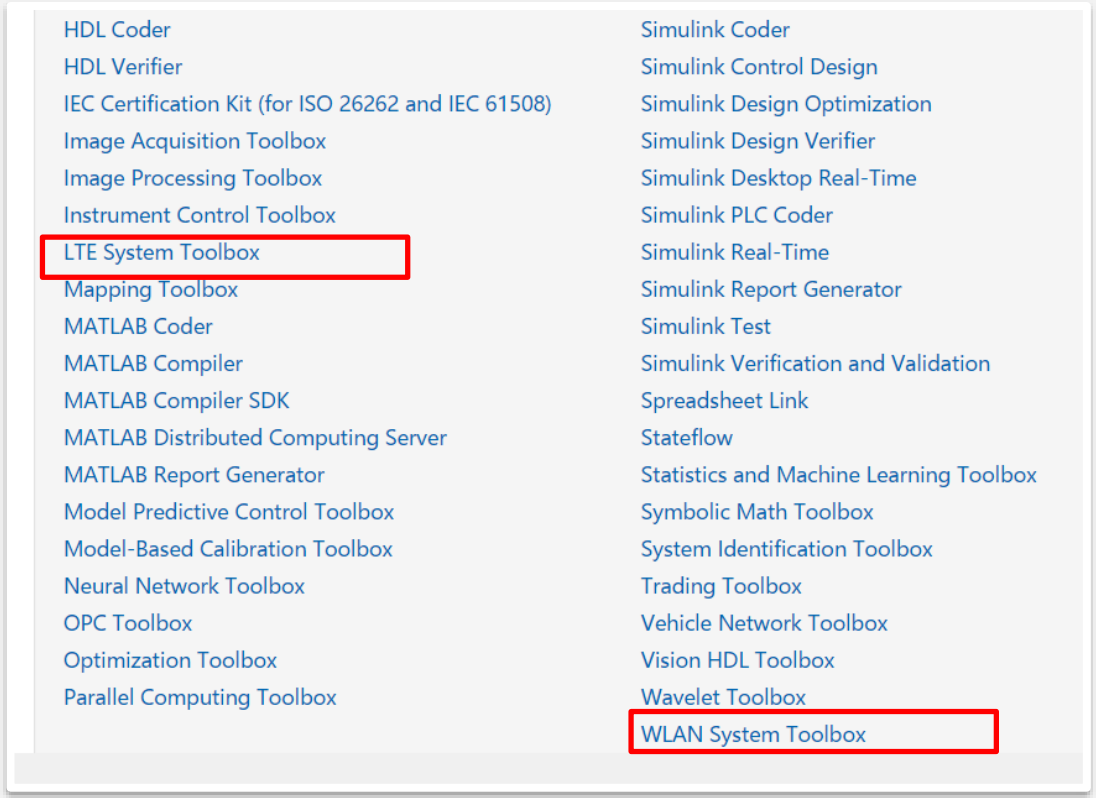
- MATLAB's toolboxes provide specialized mathematical functionalities in areas including signal processing and communications.

- **Four system toolboxes**
  - **DSP System Toolbox,**
  - **Communications System Toolbox**
  - **WLAN System Toolbox**
  - **LTE System Toolbox**



MATLAB System Toolboxes



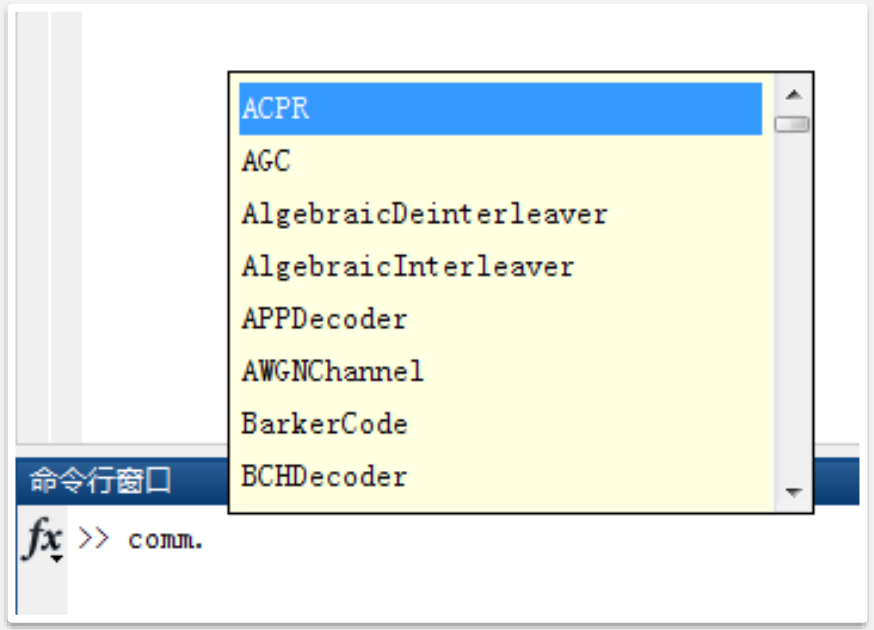


Example: Comm.<Tab>

- System objects of the Communications System Toolbox belong to the communications (comm) package and their names start with the common prefix “comm.”

- Type “comm.” followed by a Tab key at the MATLAB command prompt:

```
>> comm.<Tab>
```



Example：Comm.QPSKModulator

- Create a instance of comm.QPSKModulator:

```
>> Modulator=comm.QPSKModulator
```

- Change the phase-offset property of the QPSK modulator property using dot notation:

```
>> Modulator.PhaseOffset = pi/2
```

命令行窗口

```
>> Modulator=comm.QPSKModulator

Modulator =

  System: comm.QPSKModulator

  Properties:
       PhaseOffset: 0.785398163397448
         BitInput: false
     SymbolMapping: 'Gray'
    OutputDataType: 'double'

>> Modulator.PhaseOffset=pi/2

Modulator =

  System: comm.QPSKModulator

  Properties:
       PhaseOffset: 1.5707963267949
         BitInput: false
     SymbolMapping: 'Gray'
    OutputDataType: 'double'
```

Run system object

- There are two syntaxes available by which to execute the step method of a System object:

- Use dot notation to call the System object:

  >> u=randi([0 1],10,1)

  >> **y=Modulator.step (u)**

- Use the step method as a function and make the System object the first function argument:

  >> **y=step (Modulator, u)**

命令行窗口

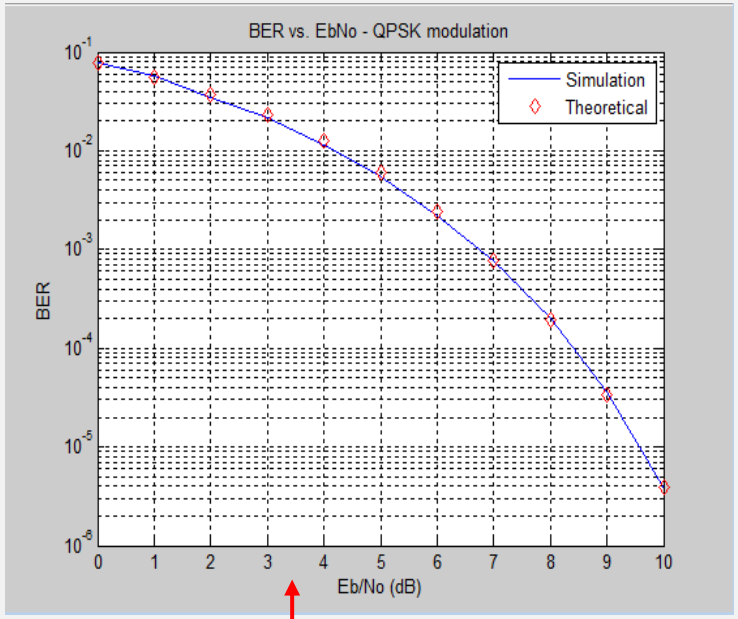
```
>> y=step(Modulator,u)

y =

   0.7071 + 0.7071i
   0.7071 + 0.7071i
  -0.7071 + 0.7071i
  -0.7071 + 0.7071i
  -0.7071 + 0.7071i
  -0.7071 + 0.7071i
   0.7071 + 0.7071i
  -0.7071 + 0.7071i
  -0.7071 + 0.7071i
   0.7071 + 0.7071i
```

In-Class Exercise

Algorithm

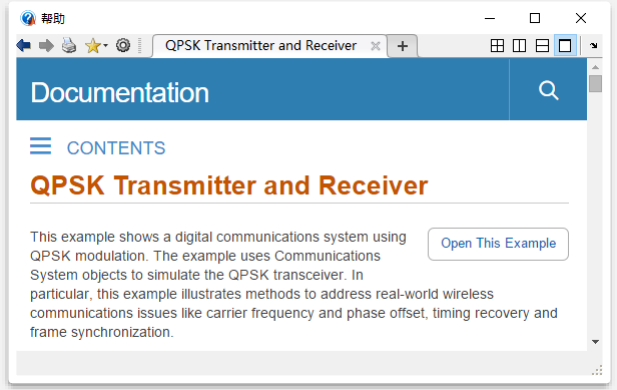
MATLAB script

```
%% Constants
FRM=2048;
MaxNumErrs=200;MaxNumBits=1e7;
EbNo_vector=0:10;BER_vector=zeros(size(EbNo_vector));
%% Initializations
Modulator      = comm.QPSKModulator('BitInput',true);
AWGN           = comm.AWGNChannel;
DeModulator =  comm.QPSKDemodulator('BitOutput',true);
BitError       = comm.ErrorRate;
%% Outer Loop computing Bit-error rate as a function of EbNo
for EbNo = EbNo_vector
   snr = EbNo + 10*log10(2);
   AWGN.EbNo=snr;
   numErrs = 0; numBits = 0;results=zeros(3,1);
   %% Inner loop modeling transmitter, channel model and receiver for each EbNo
   while ((numErrs < MaxNumErrs) && (numBits < MaxNumBits))
      % Transmitter
      u          = randi([0 1], FRM,1);          % Generate random bits
      mod_sig = step(Modulator,   u);          % QPSK Modulator
      % Channel
      rx_sig  = step(AWGN,       mod_sig);      % AWGN channel
      % Receiver
      y =      step(DeModulator, rx_sig);       % QPSK Demodulator
      results = step(BitError,    u, y);        % Update BER
      numErrs = results(2);
      numBits = results(3);
   end
   % Compute BER
   ber = results(1); bits= results(3);
   %% Clean up & collect results
   reset(BitError);
   BER_vector(EbNo+1)=ber;
end
%% Visualize results
EbNoLin = 10.^(EbNo_vector/10);
theoretical_results = 0.5*erfc(sqrt(EbNoLin));
semilogy(EbNo_vector, BER_vector)
grid;title('BER vs. EbNo - QPSK modulation');
xlabel('Eb/No (dB)');ylabel('BER');hold;
semilogy(EbNo_vector,theoretical_results,'dr');hold;
legend('Simulation','Theoretical');
```

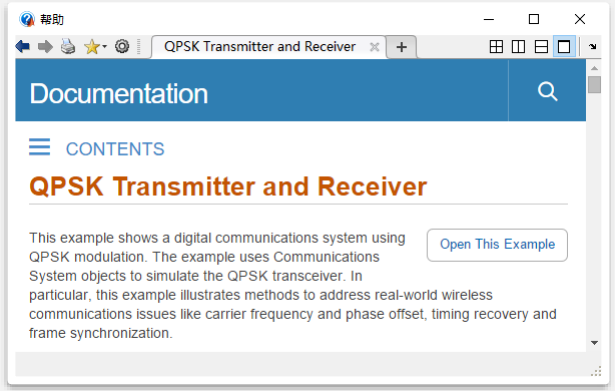


Assignments

- Read the example '**QPSK Transmitter and Receiver**' in Communications System Toolbox.
- Explain the functions of the following six subcomponents respectively,
  - (1) Automatic Gain Control
  - (2) Coarse frequency compensation
  - (3) Fine frequency compensation
  - (4) Timing recovery
  - (5) Frame Synchronization
  - (6) Data decoder



- Implement '**16-QAM** Transmitter and Receiver' according to the example.
- Compare the BER between QPSK and 16-QAM under different EbN0 condition.



commQPSKTransmitterReceiver.m

commqpsktxrx_init

runQPSKSystemUnderTest

General simulation parameters
Tx parameters
Channel parameters
Rx parameters

QPSKTransmitter

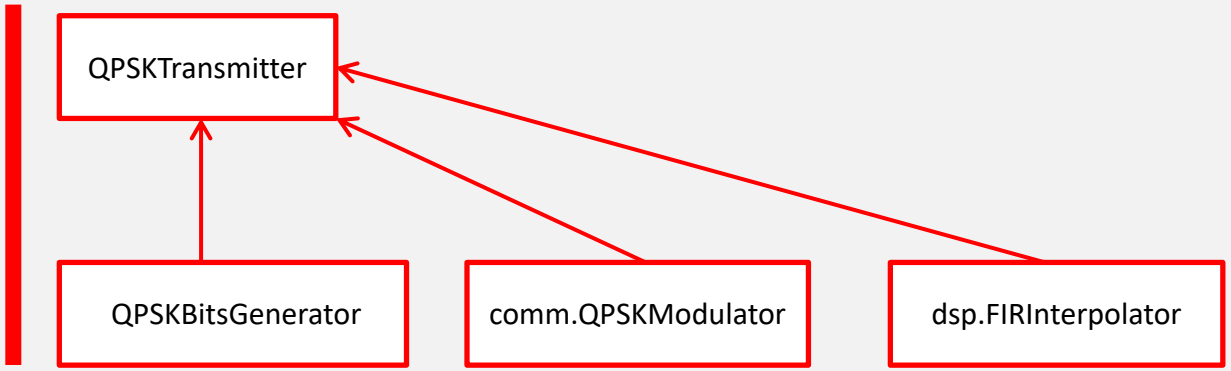
QPSKReceiver

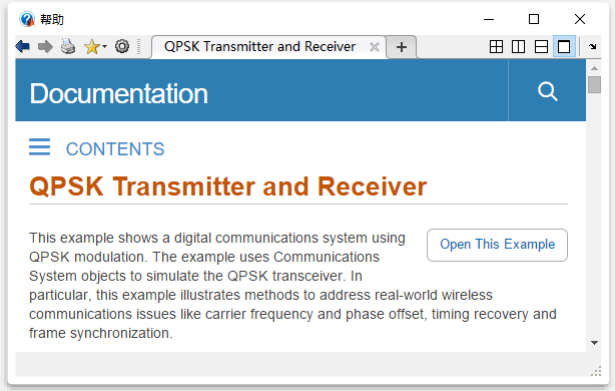
QPSKChannel

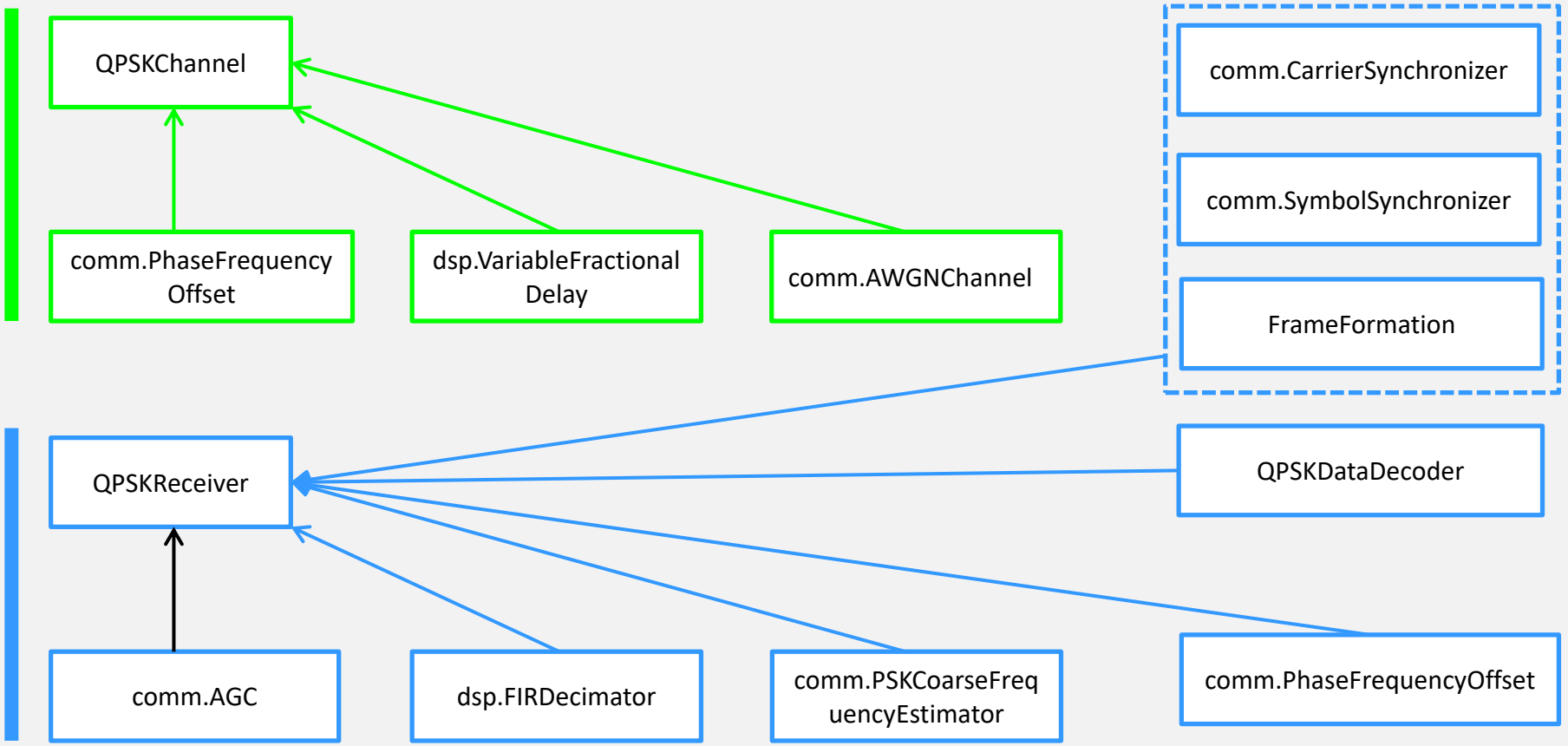
createQPSKScopes

hTx
hRx
hChan
hScopes

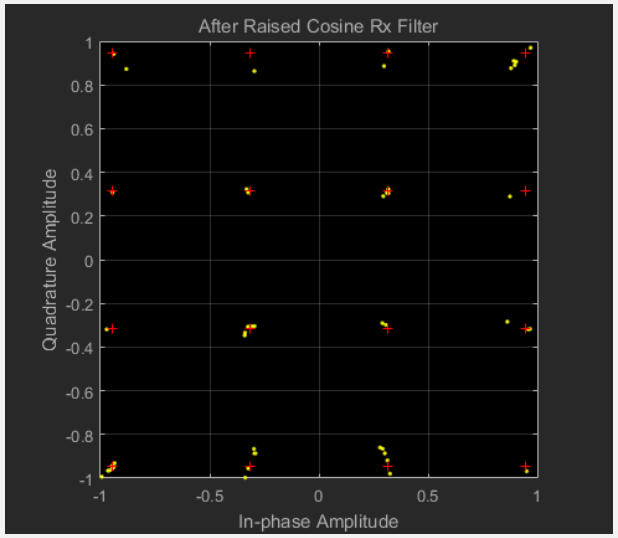
for
step(hTx,...)
step(hRx,...)
step(hChan,...)
step(hScopes,...)
end

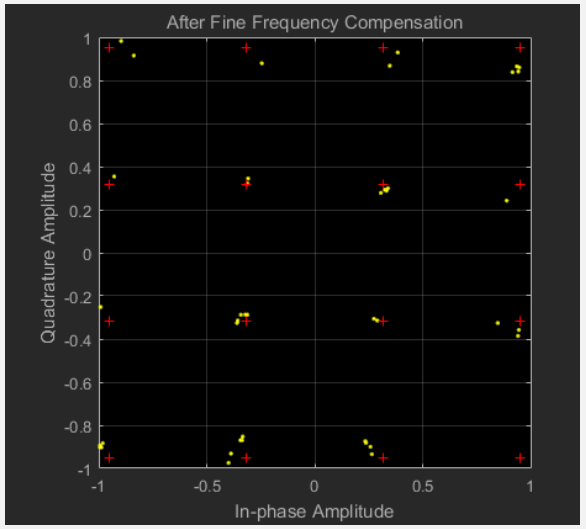

QPSKTransmitter
QPSKBitsGenerator
comm.QPSKModulator
dsp.FIRInterpolator


帮助
QPSK Transmitter and Receiver
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


QPSKChannel
comm.PhaseFrequency Offset
dsp.VariableFractional Delay
comm.AWGNChannel
comm.CarrierSynchronizer
comm.SymbolSynchronizer
FrameFormation
QPSKReceiver
QPSKDataDecoder
comm.AGC
dsp.FIRDecimator
comm.PSKCoarseFrequencyEstimator
comm.PhaseFrequencyOffset

PhaseOffset = 0,
EbNo = 40,
FrequencyOffset = 0;

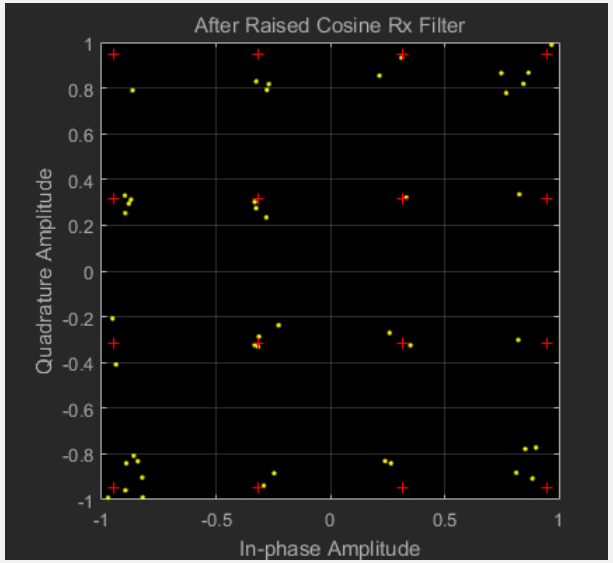


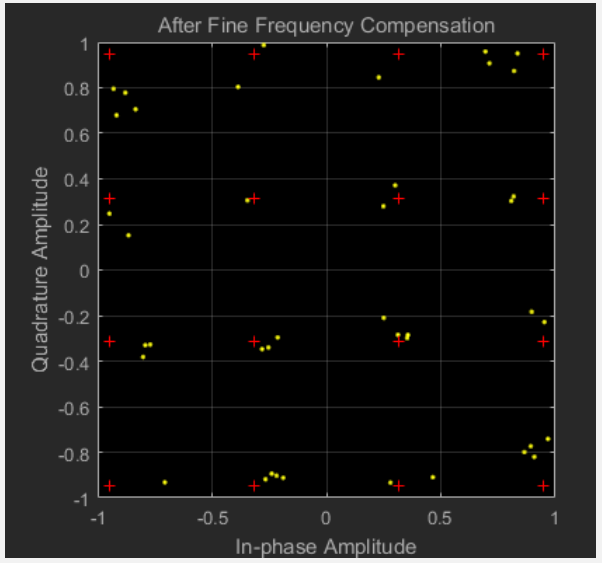


命令行窗口

```
  c  f`<Do^qu:  %1%
    r   R      W&J#m"q
Z% T`z:"i   L]KJ2
He  nJW'o}Dd=1003
Hello world 1004
Hello world 1005
Hello world 1006
Hello world 1007
Hello world 1008
Hello world 1009
Hello world 1010
Hello world 1011
```

PhaseOffset = 0,
EbNo = 20,
FrequencyOffset = 0;





命令行窗口

```
T  /    G\L].0Wd&  5
 ello world 1077
F8U r"$<-?O      _J
mello world 1079
h    8b7pIm:C     %
t7llo world 1081
Hello world 1082
Hello world 1083
Hello world 1084
Hello world 1085
Hello world 1086
Hello world 1087
Hello world 1088
```

- Question ?