MAJOR PROJECT EXTERNALS

POWER ALLOCATION, ADAPTIVE BEAMFORMING IN LTE THROUGH PILOT-BASED CHANNEL ESTIMATION

INTERNAL GUIDE

PROF. SHUSHRUTHA K S

EXTERNAL GUIDE

DR. SAPTARSHI CHAUDHURI

1.	MOHAMED OMAR SHARIEF K	1RV12EC089
2.	NIKHIL MAHADEVAPPA KALLER	1RV12EC103
3.	PRABHASA K	1RV12EC111

R.V.COLLEGE OF ENGINEERING, 21-5-2016

PRESENTATION FLOW

- INTRODUCTION
- LTE PHY MODULATION AND CODING
- PILOT-BASED CHANNEL ESTIMATION
- POWER ALLOCATION
- ADAPTIVE BEAMFORMING
- FUTURE WORK
- REFERENCES

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INTRODUCTION

- LITERATURE SURVEY
- MOTIVATION
- PROBLEM STATEMENT
- OBJECTIVES
- METHODOLOGY
- SPECIFICATIONS

PROBLEM STATEMENT

- In a wireless, multi-user, mobile environment, Base Station antennas must:

  - ✓ **Dynamically steer the signal (beam) to the User Equipment**
  - ✓ **With a suitable power**
  - ✓ **Based on channel conditions**

- STATEMENT – MATLAB implementation of power allocation and adaptive beamforming through a [UE location, Power required] look-up table based on downlink channel conditions and path loss

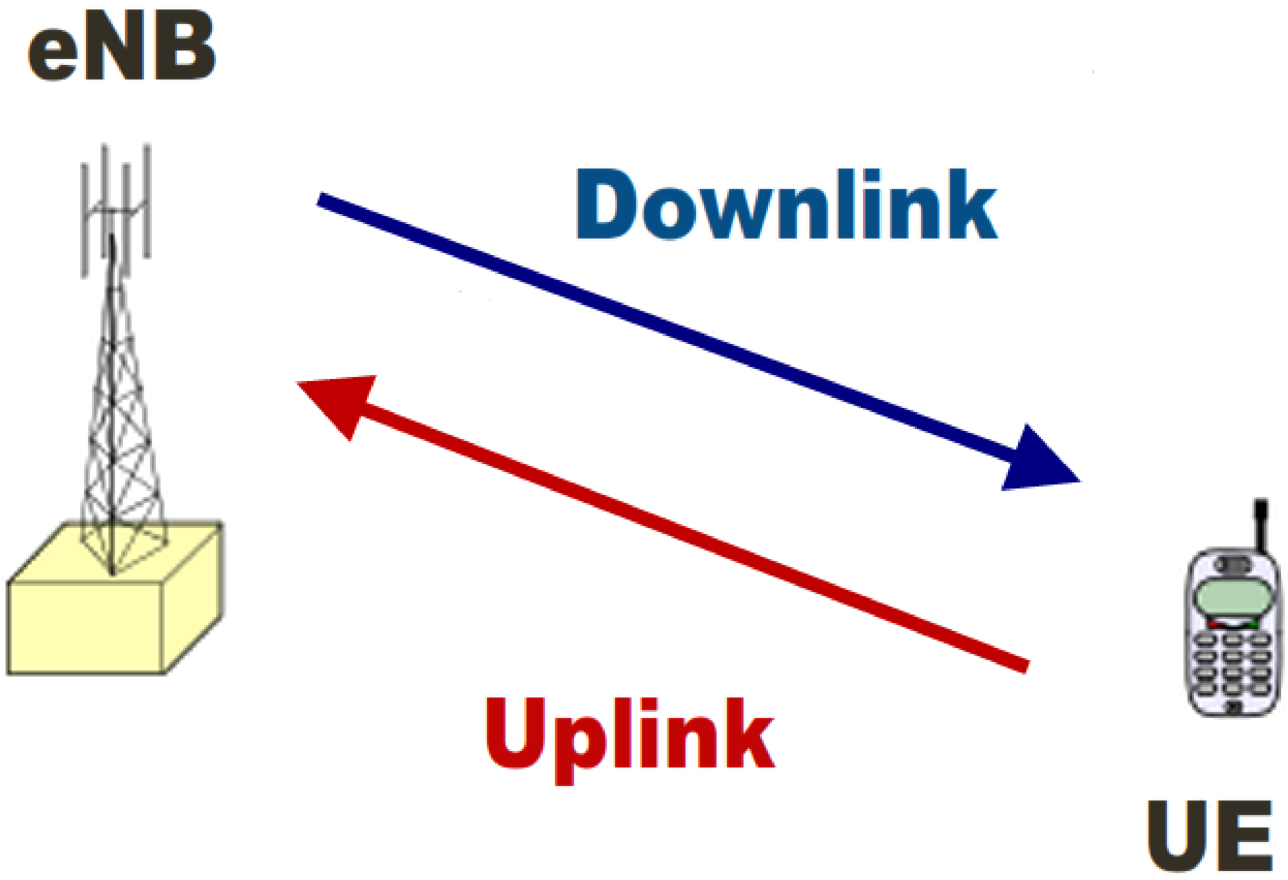
OBJECTIVES

- Understanding of LTE-PHY and enabling technologies
- Recreate modules that implement Modulation and Coding
- Pilot-based OFDM Channel Estimation
- Path Loss calculation
- Distance Based Power allocation
- Adaptive beam-steering through antenna array

METHODOLOGY

- Understanding of LTE-PHY and enabling technologies
- Recreate modules that implement Modulation and Coding
- Pilot-based OFDM Channel Estimation
- Path Loss calculation
- Distance Based Power allocation
- Adaptive beam-steering through antenna array

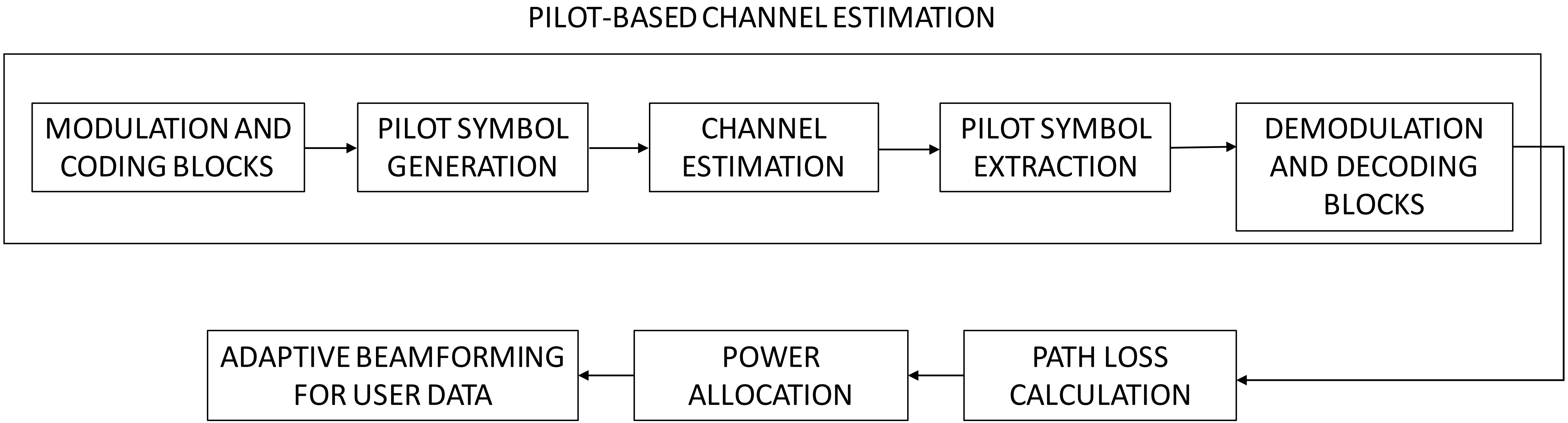
LTE NOMENCLATURE



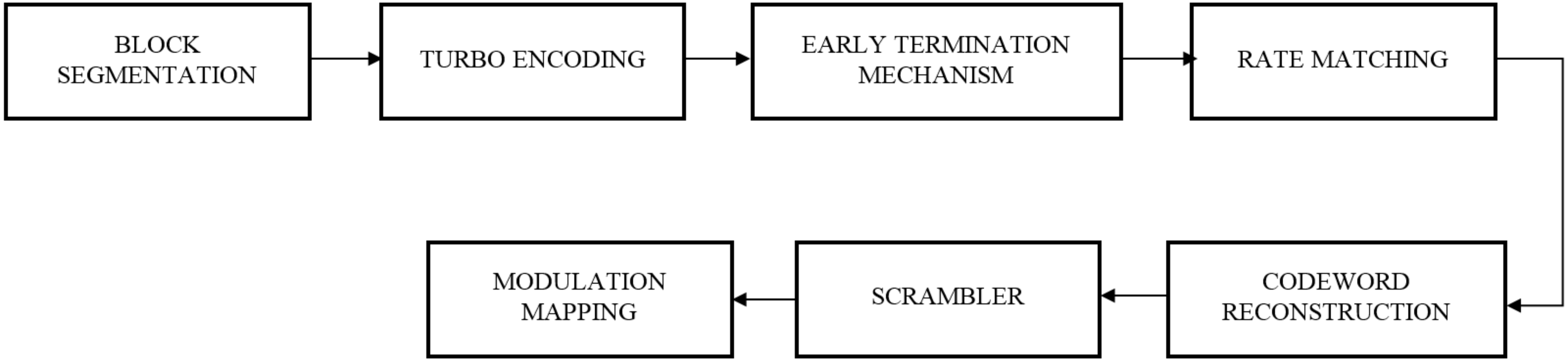
eNB = Enhanced Node Base Station

UE = User Equipment

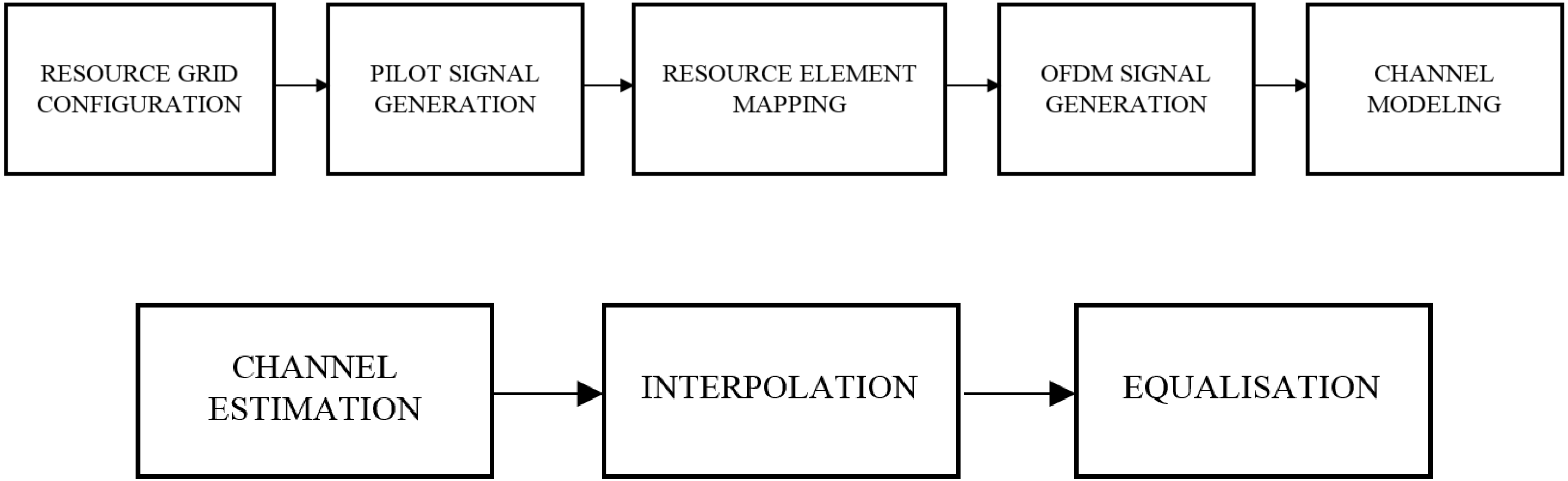
BLOCK DIAGRAM



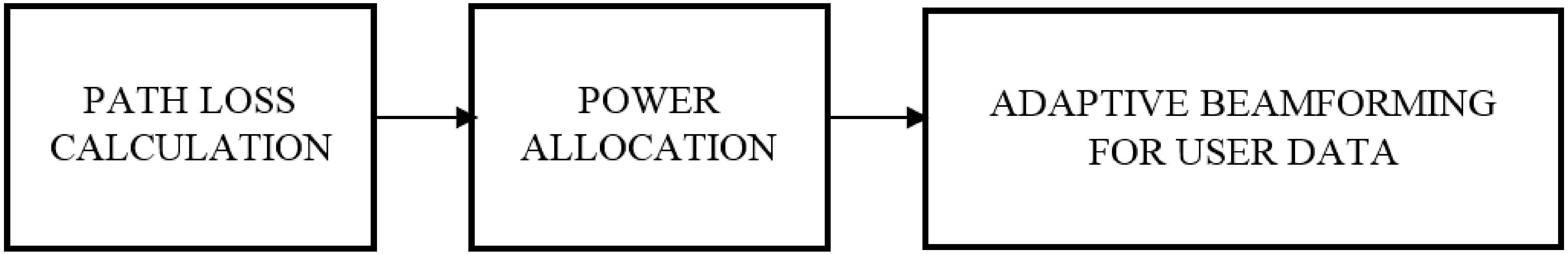
LTE PHY MODULATION AND CODING



PILOT-BASED DOWNLINK OFDM CHANNEL ESTIMATION



POWER ALLOCATION, ADAPTIVE BEAMFORMING



SPECIFICATIONS - LTE PARAMETERS

OFDM parameters for downlink transmission subframe duration (1 ms) subcarrier spacing (15 kHz)						
Bandwidth (MHz)	1.4	3	5	10	15	20
Sampling frequency (MHz)	1.92	3.84	7.68	15.36	23.04	30.72
FFT size	128	256	512	1024	1536	2048
Number of resource blocks	6	15	25	50	75	100
OFDM symbols per slot			14/12		(Normal/extended)	
CP length			4.7/5.6		(Normal/extended)	

Channel bandwidth (MHz)	Number of resource blocks
1.4	6
3	15
5	25
10	50
15	75
20	100

SPECIFICATIONS - LTE PARAMETERS

Specification No.	Description
TS 36.101	User Equipment (UE) radio transmission and reception
TS 36.104	Base Station (eNodeB) radio transmission and reception
TS 36.201	LTE physical layer: General description
TS 36.211	Physical channels and modulation
TS 36.212	Multiplexing and channel coding
TS 36.213	Physical layer procedures
TS 36.214	Physical layer measurements
TS 36.305	Functional specification of User Equipment (UE) positioning
TR 36.824	LTE coverage enhancements
TR 36.863	Study on Cell-specific Reference Signals (CRS)
TR 36.897	Study on Elevation Beamforming for LTE

Sl No	Parameter	Specifications
1	LTE Version	Release 8
2	Layer involved	LTE PHY – Layer 1
3	Mode and Duplexing	Downlink, FDD
4	Frequency Bands	25 for FDD, 11 for TDD
5	Frequency range	1.9 GHz to 3.8 GHz
6	Subcarrier spacing	15kHz
7	Channel Bandwidth (LTE specified)	1.4-20 MHz
8	Number of Resource Blocks (Depends on BW)	6-100
9	Subcarrier per Resource Block	12
10	OFDM symbols per Resource Block	7
11	Types of Channel Information	6

Sl No	Block	Specifications
1	Modulator/Demodulator (Adaptive)	QPSK, 16-QAM, 64-QAM
2	Scrambler/Descrambler	Number of shift registers:31
3	Turbo Encoder/Decoder	Rate: 1/3, Block Size: 40-6144
4	CRC Generator/Detector	Length: 24 bits
5	FFT (Block size depends on Bandwidth used)	Size: 128-2048

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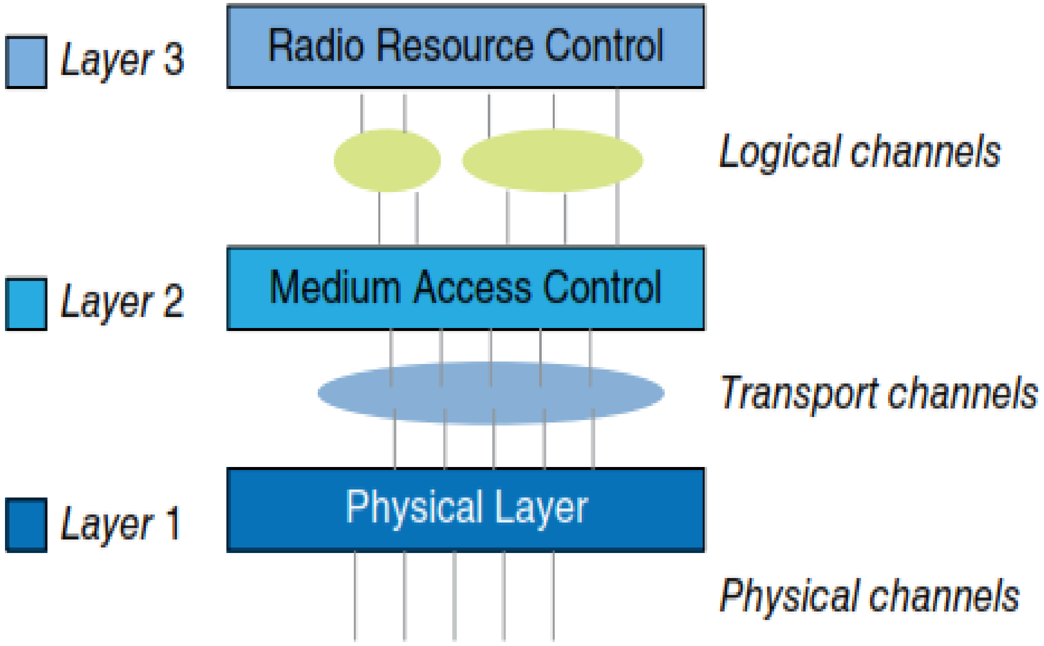
METHODOLOGY

Understanding of LTE-PHY

- Downlink – eNodeB to UE
- Air Interface – OFDM
- Enabling Technologies
    - ➢ MIMO – MU-MIMO
    - ➢ TX, RX DIVERSITY
    - ➢ LINK ADAPTATION



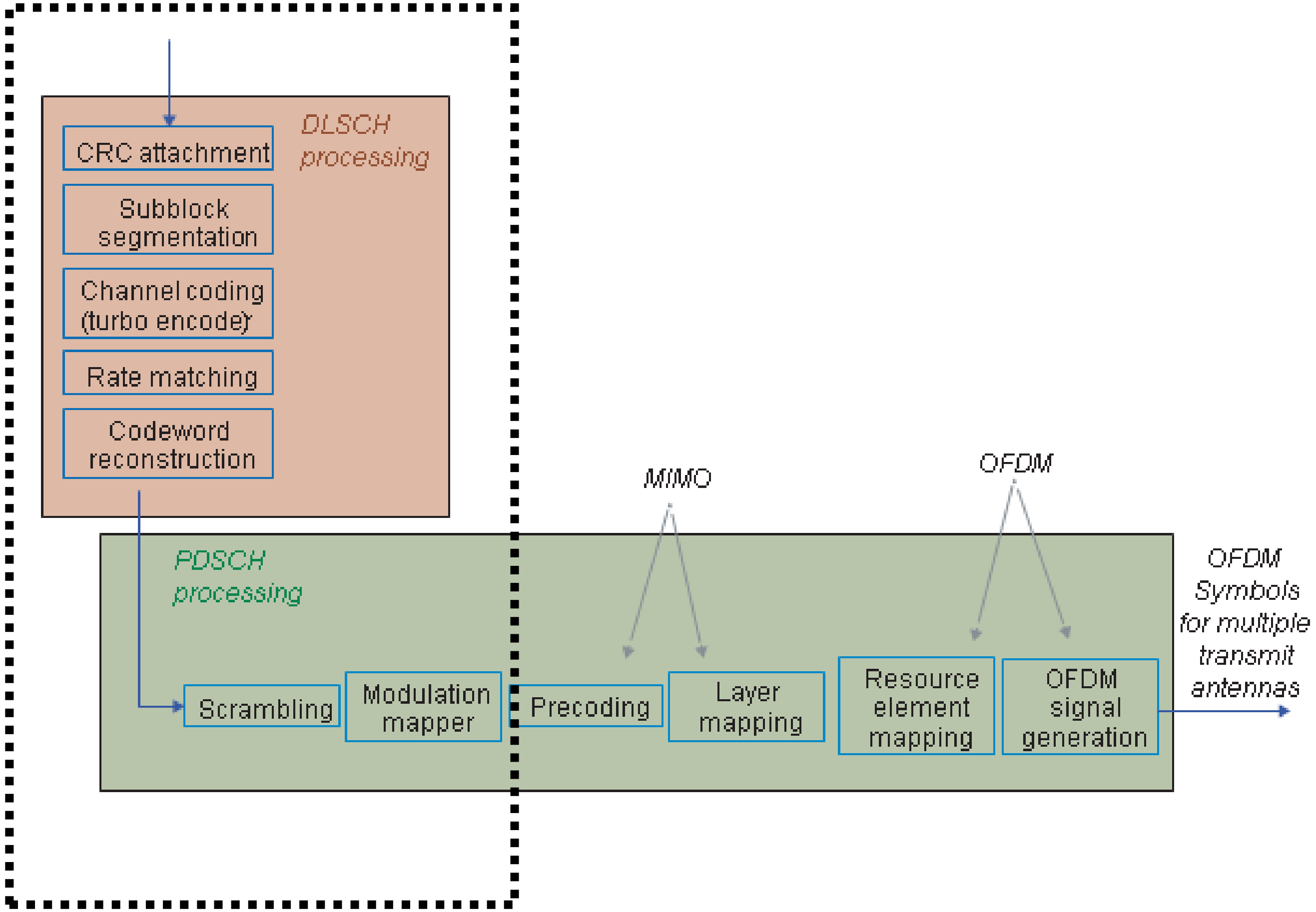
LTE MODEL

METHODOLOGY

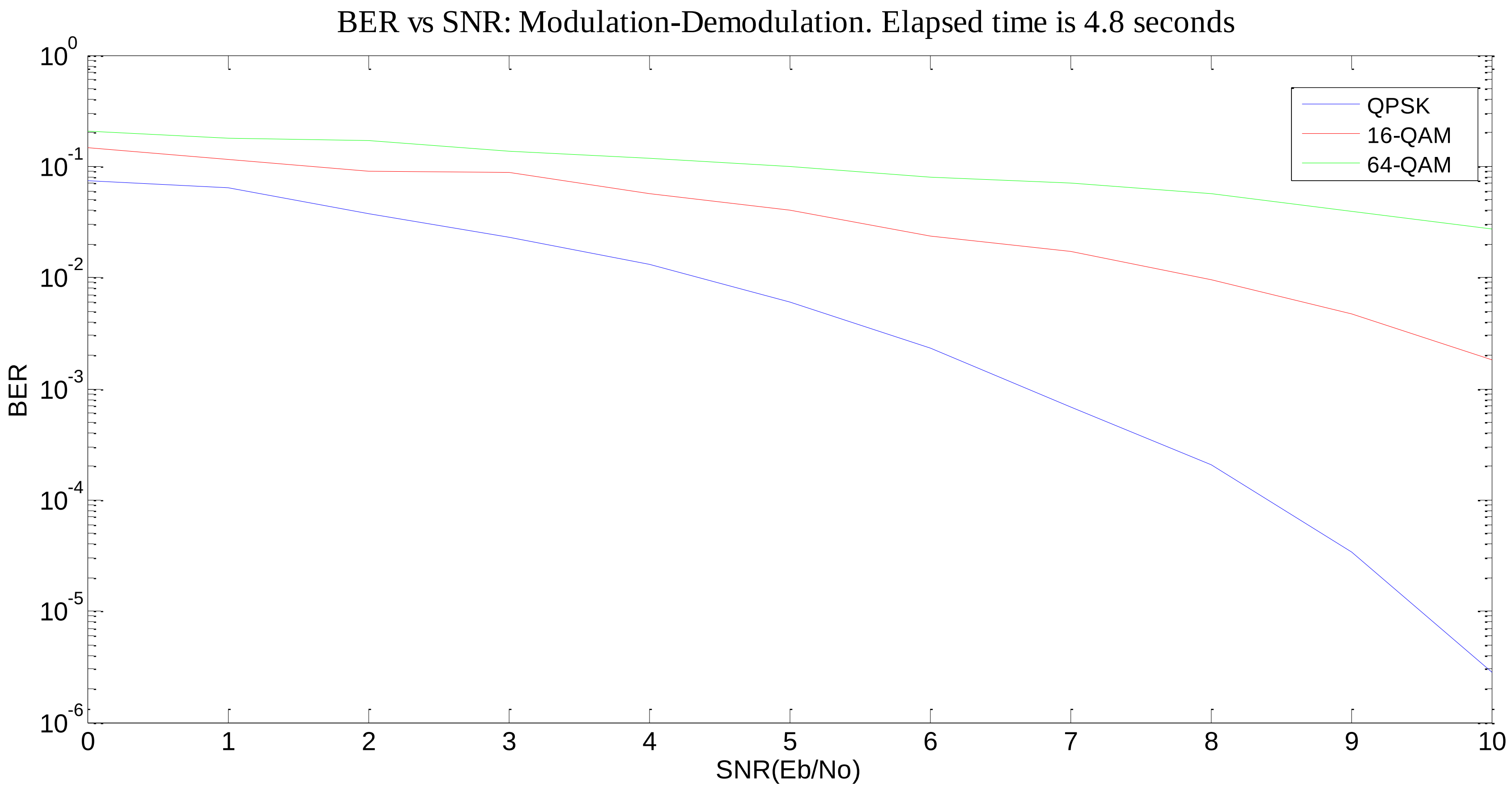
Modulation and Coding

- Adaptive Modulation – QPSK/16-QAM/64-QAM
- Scrambling – Gold sequence (31 bits)
- Turbo Coding (Rate 1/3)
- Open source codes
  - ➢ Rate Matching
  - ➢ Codeblock Segmentation
- Channel Processing

- **Reverse sequence at receiver**



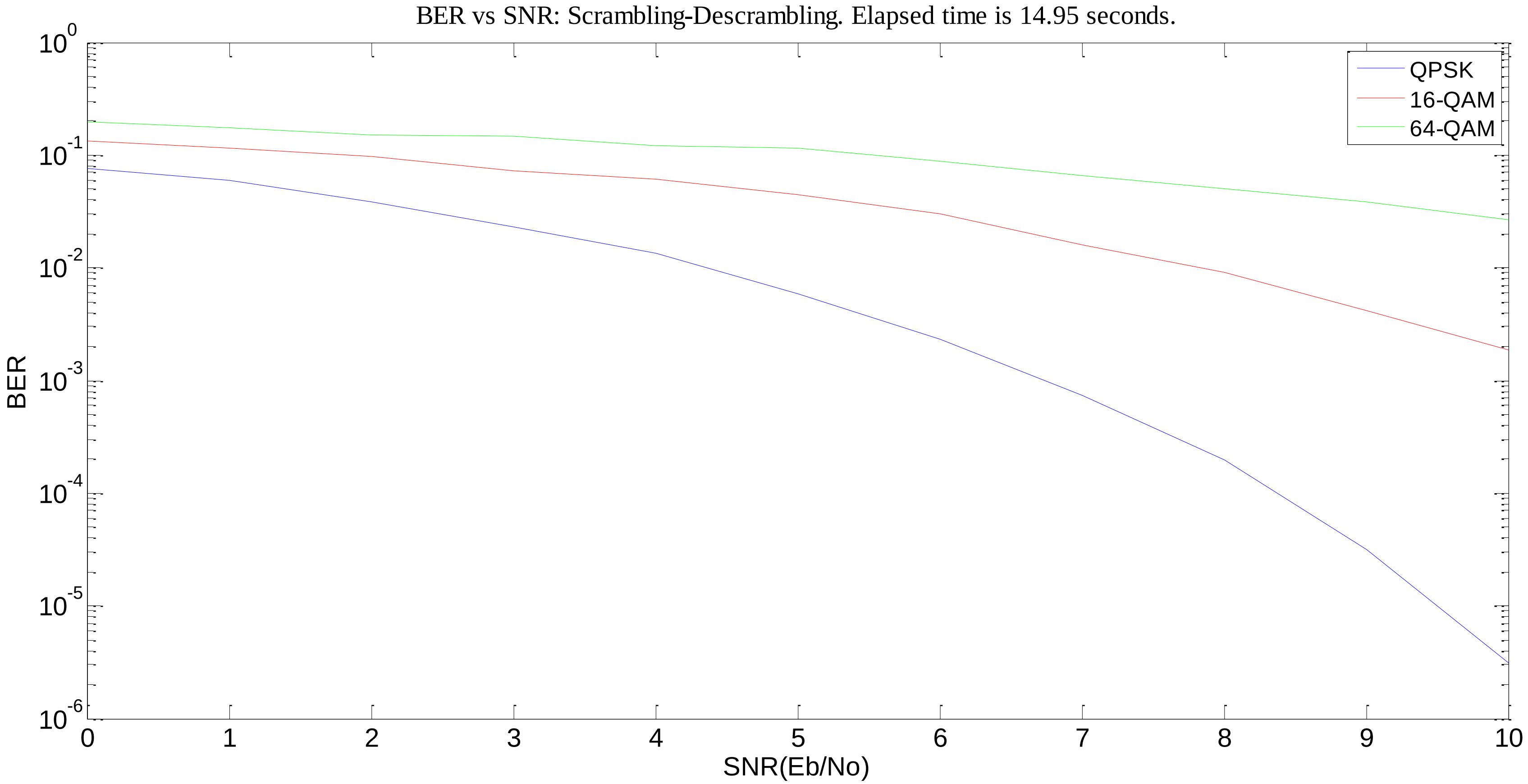
RESULTS – ADAPTIVE MODULATION



INPUT PARAMETERS

ModulationMode
EbNo (SNR)
maxNumErrors = 200
maxNumBits = 10^7

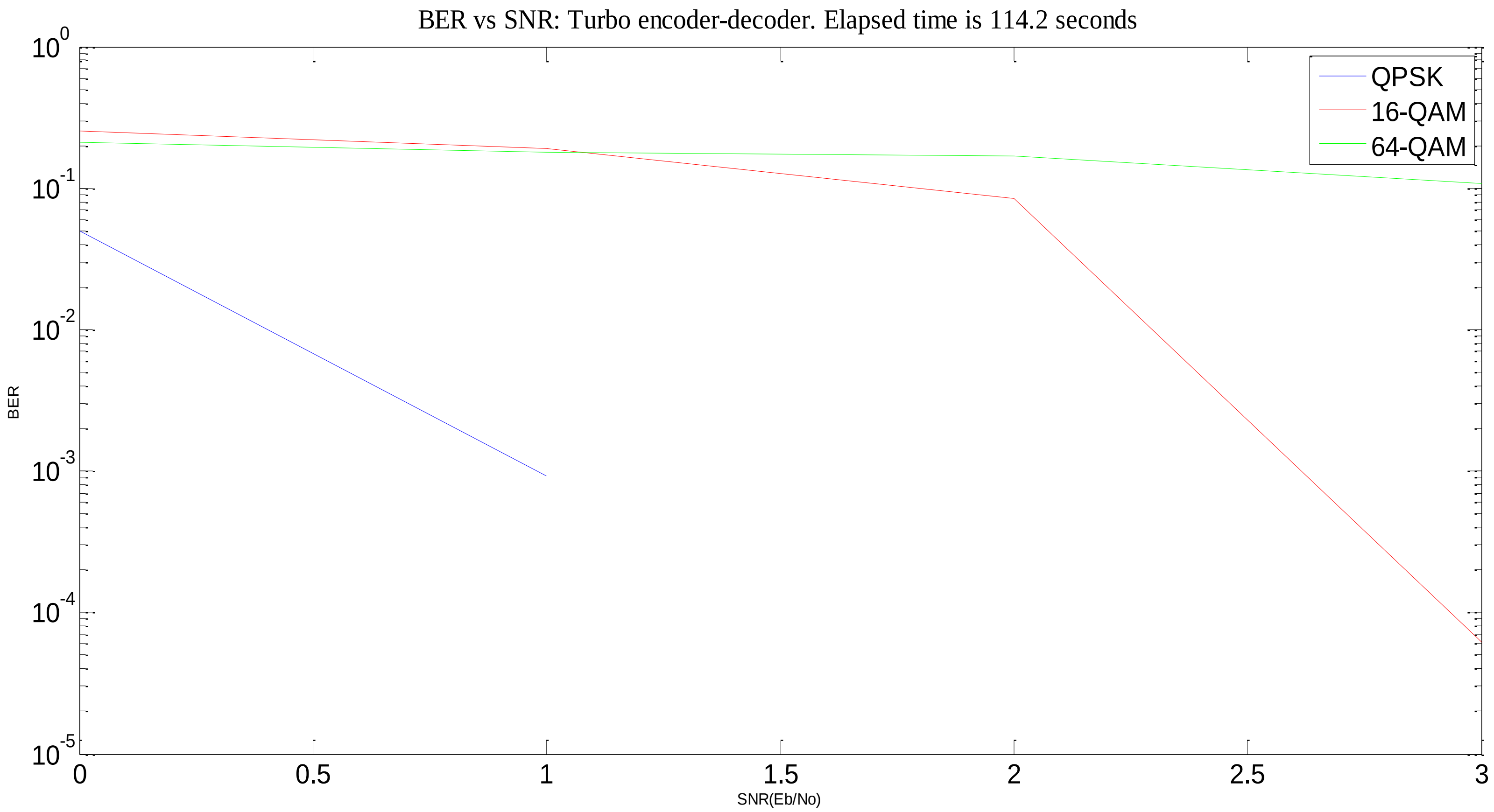
RESULTS - SCRAMBLING



INPUT PARAMETERS

ModulationMode
EbNo (SNR)
maxNumErrors = 200
maxNumBits = 10^7

RESULTS – TURBO CODING




```
count =

    550


numErrs =

    203


numBits =

     1439744
```

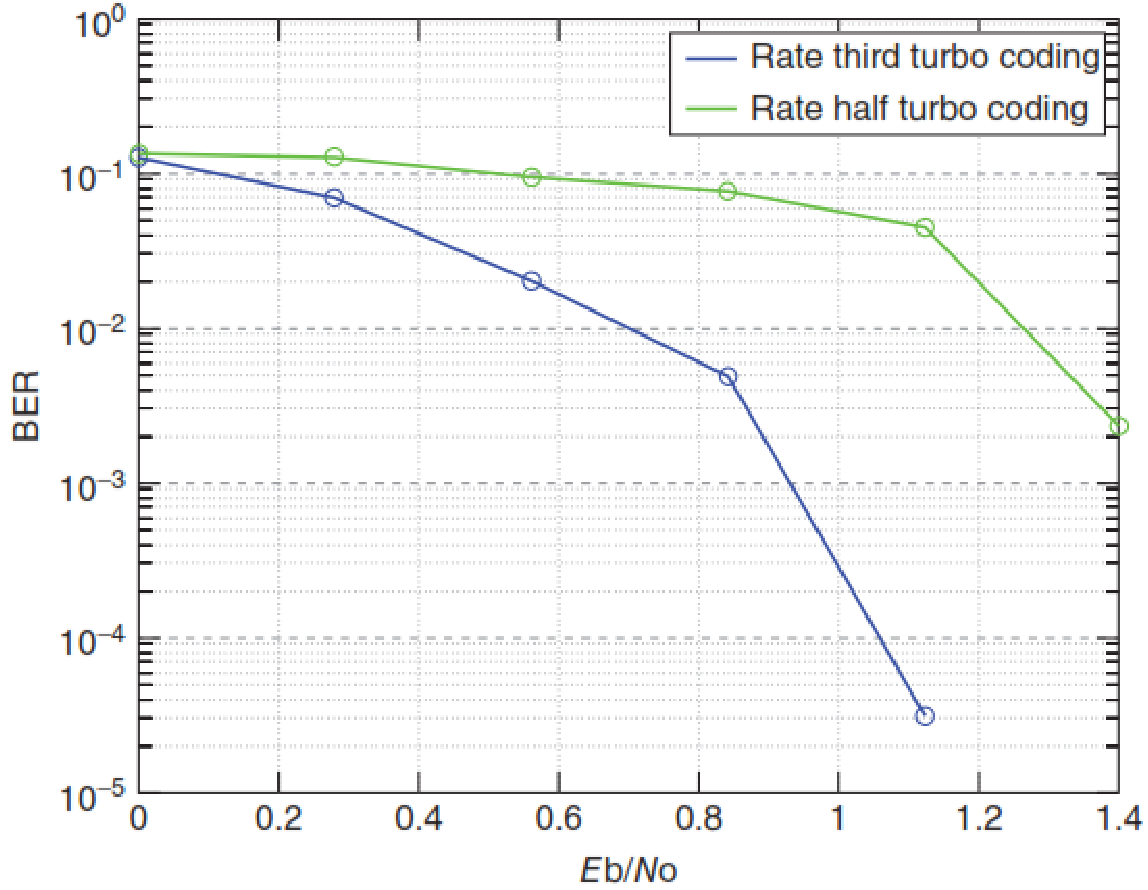
RESULTS – EARLY TERMINATION

- Turbo Coding consumes almost 90% of runtime so far
- This can be reduced by generating CRC bits
- Only last 24 CRC bits checked, thereby reducing runtime

Command Window

```
>> EbNo=1; maxNumErrs=1e7; maxNumBits=1e7;
tic; [a,b]=Turbo(EbNo,maxNumErrs, maxNumBits); toc;
tic; [a,b]=Early_Termination(EbNo,maxNumErrs, maxNumBits); toc;
Elapsed time is 197.800292 seconds.
Elapsed time is 116.198952 seconds.
```

RESULTS – RATE MATCHING




```
numErrs =

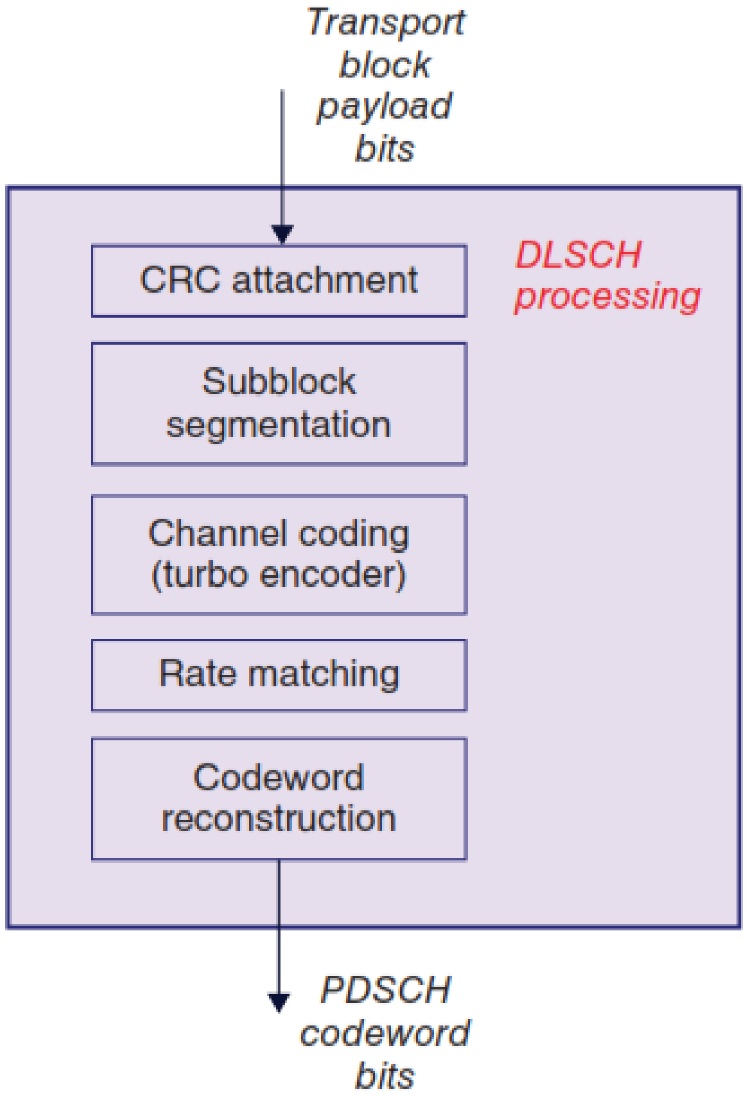
    24


numBits =

     5001416

Elapsed time is 66.892972 seconds.
```

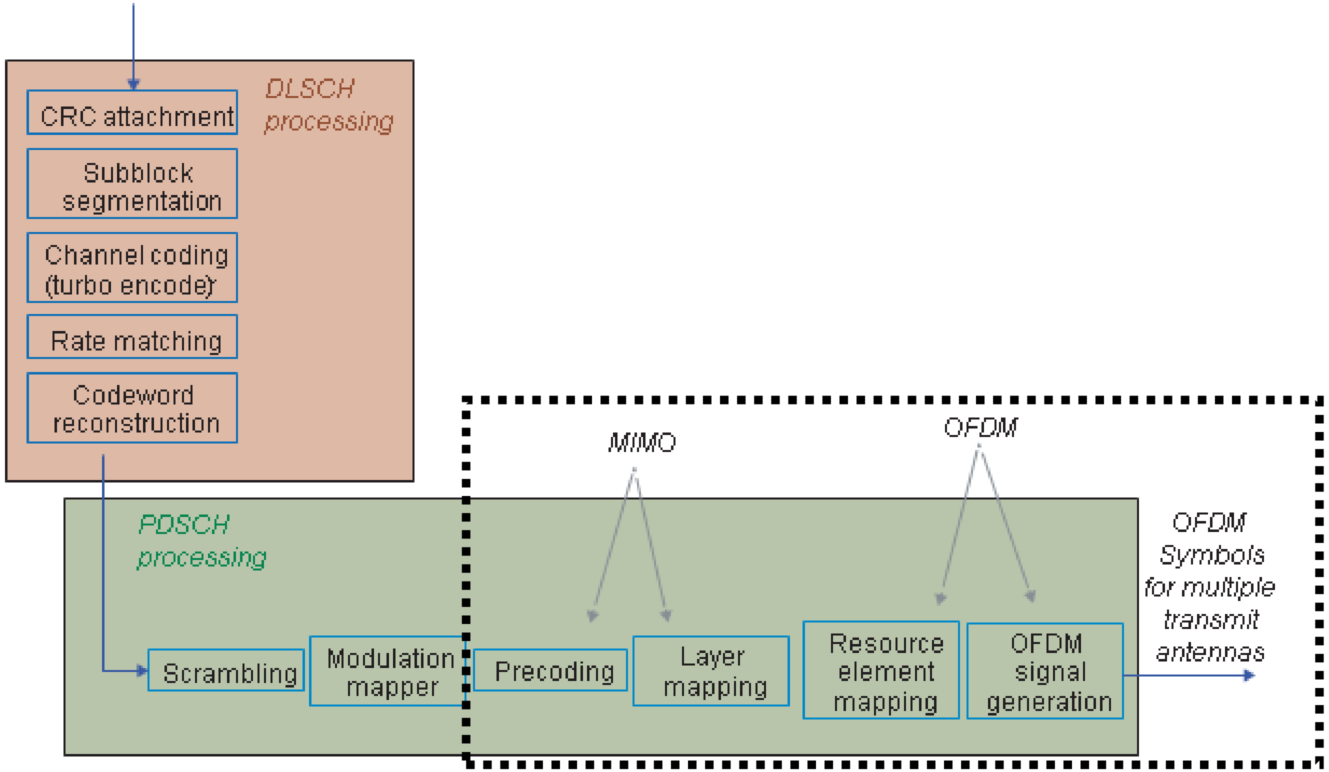
OVERALL BLOCK 1



METHODOLOGY

Pilot-based OFDM Channel Estimation

- Multipath Fading – Frequency Selective
- Mobility – Doppler Effect
- Resource Grid Configuration
    - ➢ Six types of signals
    - ➢ CSR – Pilot Signals
    - ➢ Reference Generation – Open Source
- Resource Element Mapping
- OFDM Signal Generation
- Channel Modeling and Estimation



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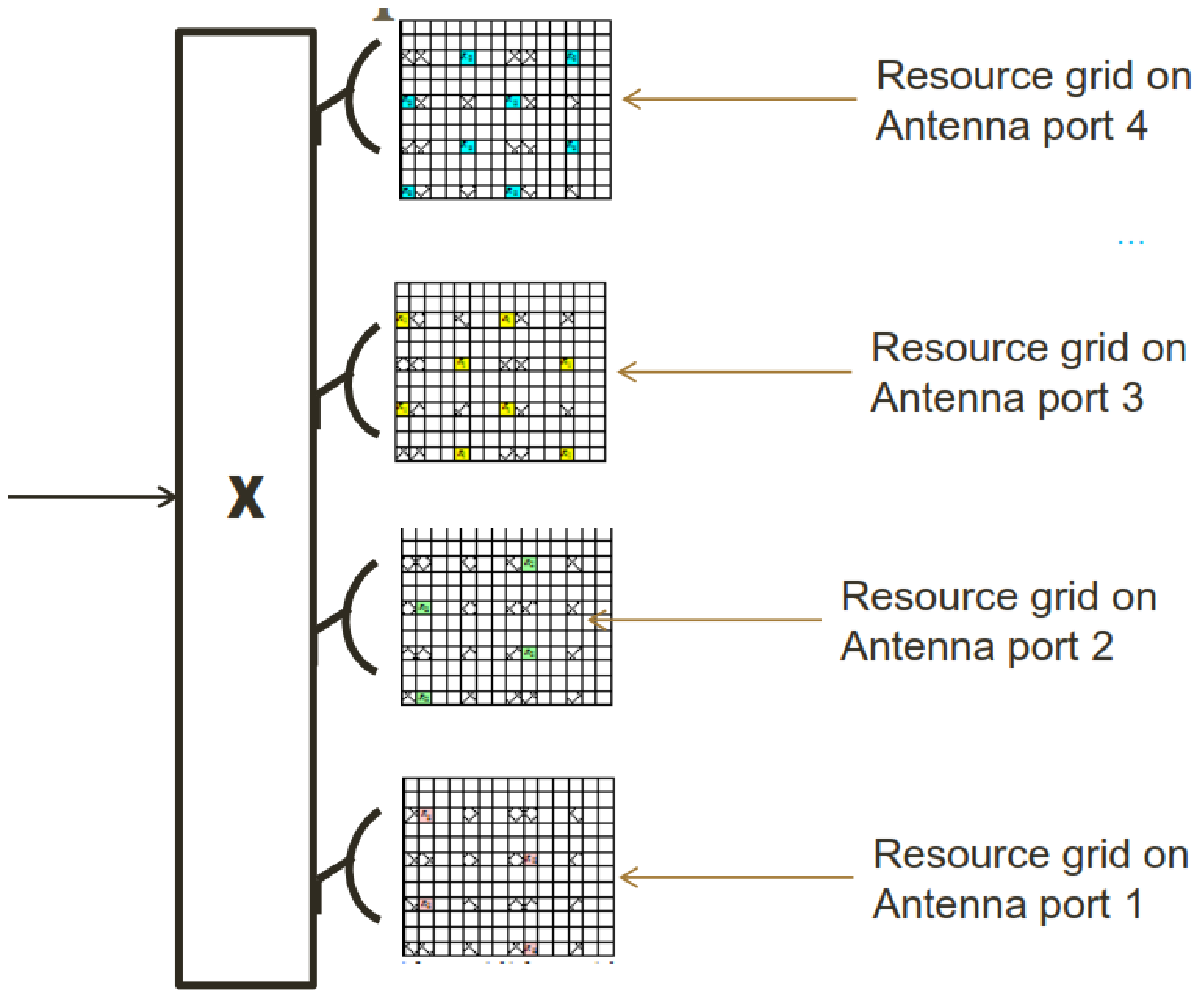
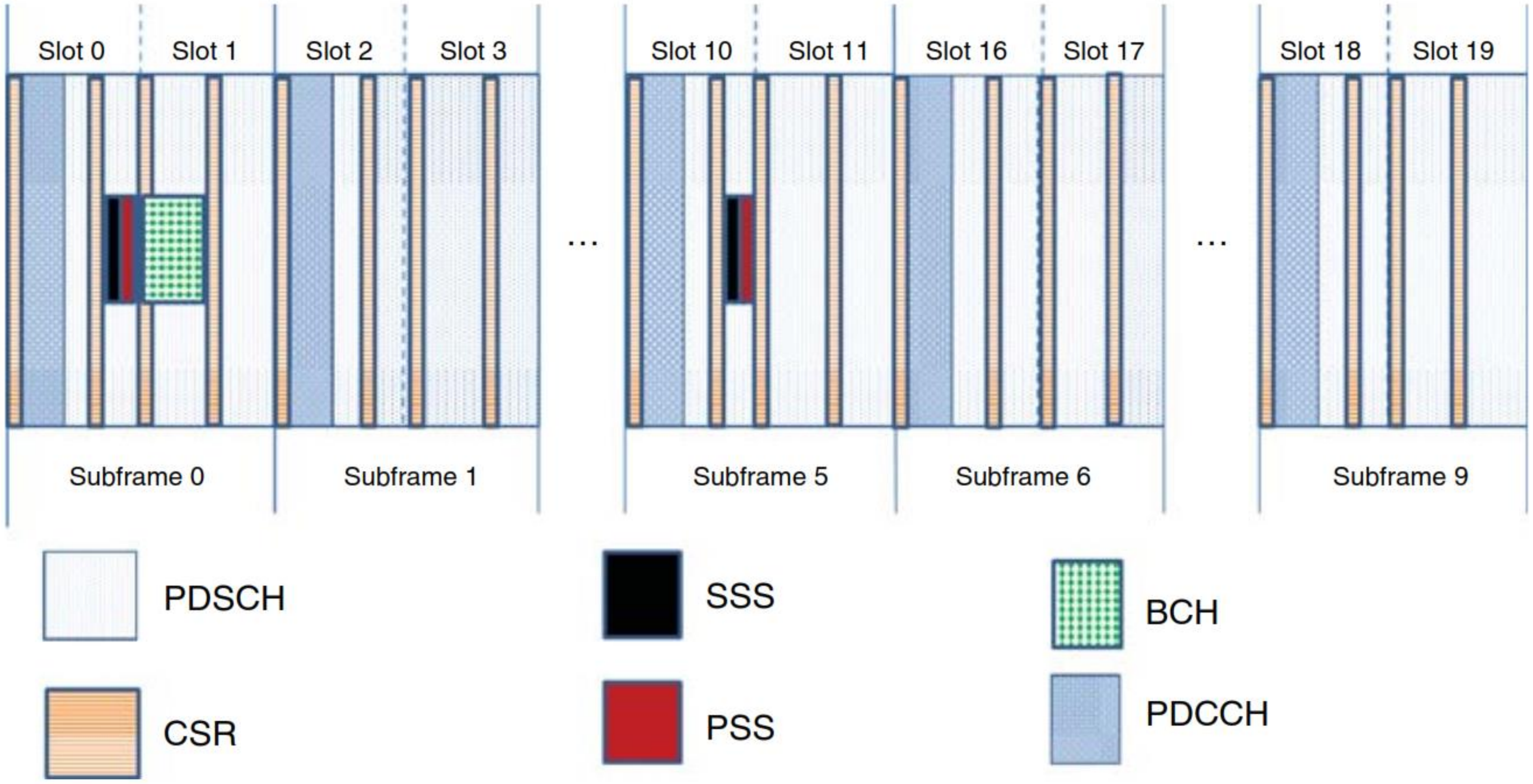
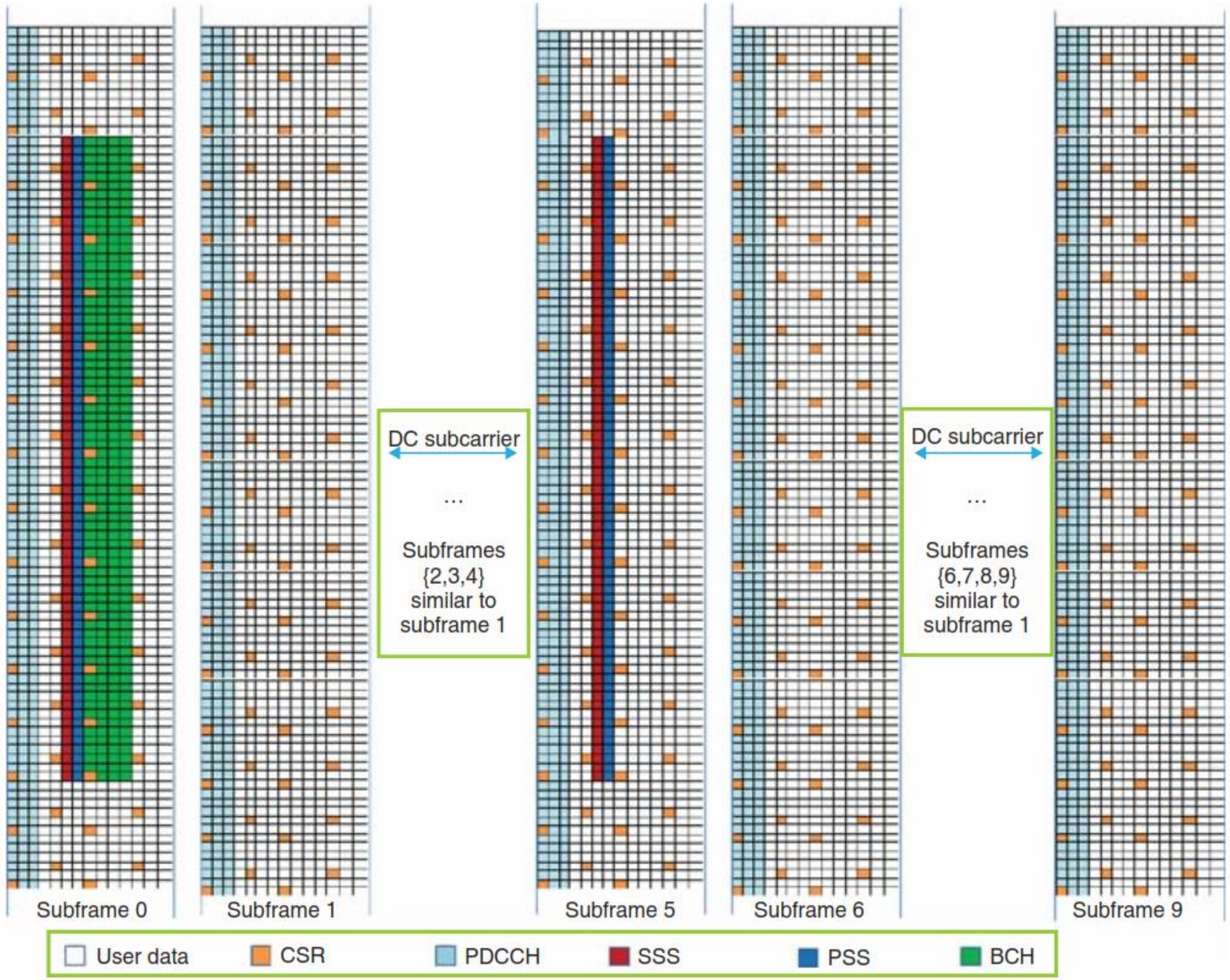
RESOURCE GRID ON ANTENNA PORTS



LTE RESOURCE GRID





DC subcarrier
...
Subframes {2,3,4} similar to subframe 1
DC subcarrier
...
Subframes {6,7,8,9} similar to subframe 1
Subframe 0
Subframe 1
Subframe 5
Subframe 6
Subframe 9
User data
CSR
PDCCH
SSS
PSS
BCH

RESOURCE GRID CONFIGURATION

```
function p= prmsPDSCH(chanBW, contReg, modType, varargin)
% Returns parameter structures for LTE PDSCH simulation.
%
% Assumes a FDD, normal cyclic prefix, full-bandwidth, single-user
% SISO or SIMO downlink transmission.
%% PDSCH parameters
switch chanBW
case 1 % 1.4 MHz
BW = 1.4e6; N = 128; cpLen0 = 10; cpLenR = 9;
Nrb = 6; chanSRate = 1.92e6;
case 2 % 3 MHz
BW = 3e6; N = 256; cpLen0 = 20; cpLenR = 18;
Nrb = 15; chanSRate = 3.84e6;
case 3 % 5 MHz
BW = 5e6; N = 512; cpLen0 = 40; cpLenR = 36;
Nrb = 25; chanSRate = 7.68e6;
case 4 % 10 MHz
BW = 10e6; N = 1024; cpLen0 = 80; cpLenR = 72;
Nrb = 50; chanSRate = 15.36e6;
case 5 % 15 MHz
BW = 15e6; N = 1536; cpLen0 = 120; cpLenR = 108;
Nrb = 75; chanSRate = 23.04e6;
case 6 % 20 MHz
BW = 20e6; N = 2048; cpLen0 = 160; cpLenR = 144;
Nrb = 100; chanSRate = 30.72e6;
end
```

Channel bandwidth (MHz)	Number of resource blocks
1.4	6
3	15
5	25
10	50
15	75
20	100

RESULTS – Fixed BW, Varying Modulation Scheme (QPSK, 16-QAM)

```
>> prmsPDSCH(1,7,1)

ans =

                 BW: 1400000
                  N: 128
             cpLen0: 10
             cpLenR: 9
                Nrb: 6
          chanSRate: 1920000
            contReg: 7
              numTx: 1
              numRx: 1
          numLayers: 1
       numCodeWords: 1
             deltaF: 15000
             Nrb_sc: 12
           Ndl_symb: 7
       numResources: 1008
    numCSRResources: 48
          numContRE: 492
           numBCHRE: 276
           numSSSRE: 72
           numPSSRE: 72
          numDataRE: [3x1 double]
   numDataResources: 960
                 Qm: 2
        numLayPerCW: 1
        numDataBits: 1920
       numPDSCHBits: [3x1 double]
               maxG: 936
```

```
>> prmsPDSCH(1,7,2)

ans =

                 BW: 1400000
                  N: 128
             cpLen0: 10
             cpLenR: 9
                Nrb: 6
          chanSRate: 1920000
            contReg: 7
              numTx: 1
              numRx: 1
          numLayers: 1
       numCodeWords: 1
             deltaF: 15000
             Nrb_sc: 12
           Ndl_symb: 7
       numResources: 1008
    numCSRResources: 48
          numContRE: 492
           numBCHRE: 276
           numSSSRE: 72
           numPSSRE: 72
          numDataRE: [3x1 double]
   numDataResources: 960
                 Qm: 4
        numLayPerCW: 1
        numDataBits: 3840
       numPDSCHBits: [3x1 double]
               maxG: 1872
```

RESULTS – Varying BW (1.4, 3, 5 MHz) Fixed Modulation Scheme

```
>> prmsPDSCH(1,7,1)

ans =

                  BW: 1400000
                   N: 128
              cpLen0: 10
              cpLenR: 9
                 Nrb: 6
           chanSRate: 1920000
             contReg: 7
               numTx: 1
               numRx: 1
           numLayers: 1
        numCodeWords: 1
              deltaF: 15000
              Nrb_sc: 12
            Ndl_symb: 7
        numResources: 1008
     numCSRResources: 48
           numContRE: 492
           numBCHRE: 276
           numSSSRE: 72
           numPSSRE: 72
           numDataRE: [3x1 double]
    numDataResources: 960
                  Qm: 2
         numLayPerCW: 1
         numDataBits: 1920
        numPDSCHBits: [3x1 double]
                maxG: 936
```

```
>> prmsPDSCH(2,7,1)

ans =

                  BW: 3000000
                   N: 256
              cpLen0: 20
              cpLenR: 18
                 Nrb: 15
           chanSRate: 3840000
             contReg: 7
               numTx: 1
               numRx: 1
           numLayers: 1
        numCodeWords: 1
              deltaF: 15000
              Nrb_sc: 12
            Ndl_symb: 7
        numResources: 2520
     numCSRResources: 120
           numContRE: 1230
            numBCHRE: 276
            numSSSRE: 72
            numPSSRE: 72
           numDataRE: [3x1 double]
    numDataResources: 2400
                  Qm: 2
         numLayPerCW: 1
         numDataBits: 4800
        numPDSCHBits: [3x1 double]
                maxG: 2340
```

```
>> prmsPDSCH(3,7,1)

ans =

                  BW: 5000000
                   N: 512
              cpLen0: 40
              cpLenR: 36
                 Nrb: 25
           chanSRate: 7680000
             contReg: 7
               numTx: 1
               numRx: 1
           numLayers: 1
        numCodeWords: 1
              deltaF: 15000
              Nrb_sc: 12
            Ndl_symb: 7
        numResources: 4200
     numCSRResources: 200
           numContRE: 2050
            numBCHRE: 276
            numSSSRE: 72
            numPSSRE: 72
           numDataRE: [3x1 double]
    numDataResources: 4000
                  Qm: 2
         numLayPerCW: 1
         numDataBits: 8000
        numPDSCHBits: [3x1 double]
                maxG: 3900
```

RESULTS – PILOT SIGNAL GENERATION

Command Window

New to MATLAB? Watch this Video, see Examples, or read

```
>> CSRgenerator(0,1)

ans(:,:,1) =

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

Command Window

New to MATLAB? Watch this Video, see Examples, or rea

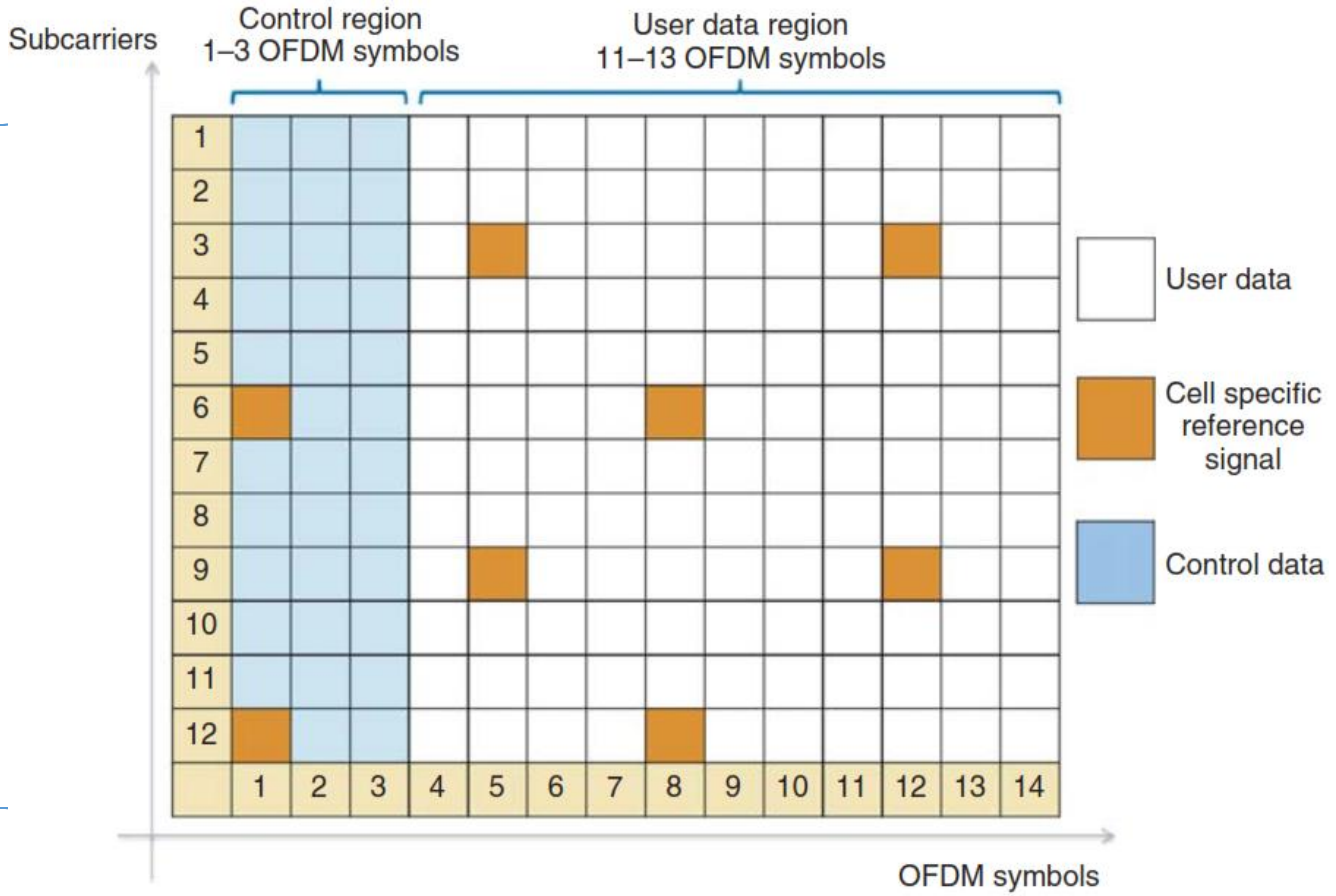
```
  -0.7071 - 0.7071i   0.7071 + 0.7071i
  -0.7071 - 0.7071i   0.7071 + 0.7071i
  -0.7071 + 0.7071i   0.7071 - 0.7071i
   0.7071 + 0.7071i   0.7071 + 0.7071i
   0.7071 + 0.7071i   0.7071 + 0.7071i
  -0.7071 - 0.7071i  -0.7071 - 0.7071i
   0.7071 + 0.7071i  -0.7071 + 0.7071i
  -0.7071 - 0.7071i   0.7071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


ans(:,:,2) =

  -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
  -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
  -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
   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
```

RESULTS – RESOURCE ELEMENT MAPPING

One Resource Block has 12 subcarriers of 15kHz each. For BW = 1.4MHz, there will be 6 Resource Blocks



One Subframe has 14 OFDM symbols. A frame is made up of 10 subframes

RESULTS – RESOURCE ELEMENT MAPPING

Command Window

Columns 1 through 5

0.7071 - 0.7071i	0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	1.0000 + 0.0000i
0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i
0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i
0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	0.7071 - 0.7071i
0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i
0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	1.0000 + 0.0000i
0.7071 + 0.7071i	0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	1.0000 + 0.0000i
0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	1.0000 + 0.0000i
0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i
0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	0.7071 + 0.7071i
0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	1.0000 + 0.0000i
0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i
0.7071 - 0.7071i	0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i
0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i
0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	1.0000 + 0.0000i
0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	-0.7071 + 0.7071i
0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	1.0000 + 0.0000i
0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	1.0000 + 0.0000i
-0.7071 + 0.7071i	0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	1.0000 + 0.0000i
0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	1.0000 + 0.0000i
0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i
0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	-0.7071 - 0.7071i
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0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i
-0.7071 + 0.7071i	0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i
0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	1.0000 + 0.0000i
0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i
0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	-0.7071 - 0.7071i
0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i
0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i
-0.7071 - 0.7071i	0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	1.0000 + 0.0000i
0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i
0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i
0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	0.0000 + 0.0000i	0.7071 - 0.7071i

fx

RESULTS – RESOURCE ELEMENT MAPPING

Command Window

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  Columns 6 through 10

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   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i
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   0.0000 + 0.0000i   0.0000 + 0.0000i  -0.7071 - 0.7071i   0.0000 + 0.0000i   0.0000 + 0.0000i
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fx 0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i
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RESULTS – RESOURCE ELEMENT MAPPING

Command Window

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  Columns 11 through 14

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   0.0000 + 0.0000i   1.0000 + 0.0000i   1.0000 + 0.0000i   1.0000 + 0.0000i
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   0.0000 + 0.0000i   0.0000 + 0.0000i   1.0000 + 0.0000i   0.0000 + 0.0000i
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   0.0000 + 0.0000i   1.0000 + 0.0000i   1.0000 + 0.0000i   1.0000 + 0.0000i
   0.0000 + 0.0000i   0.7071 + 0.7071i   0.0000 + 0.0000i   0.0000 + 0.0000i
   0.0000 + 0.0000i   0.0000 + 0.0000i   1.0000 + 0.0000i   0.0000 + 0.0000i
   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   1.0000 + 0.0000i
   0.0000 + 0.0000i   1.0000 + 0.0000i   0.0000 + 0.0000i   1.0000 + 0.0000i
   0.0000 + 0.0000i   1.0000 + 0.0000i   0.0000 + 0.0000i   1.0000 + 0.0000i
   0.0000 + 0.0000i   1.0000 + 0.0000i   0.0000 + 0.0000i   1.0000 + 0.0000i
   0.0000 + 0.0000i  -0.7071 - 0.7071i   1.0000 + 0.0000i   0.0000 + 0.0000i
   0.0000 + 0.0000i   0.0000 + 0.0000i   1.0000 + 0.0000i   1.0000 + 0.0000i
   0.0000 + 0.0000i   1.0000 + 0.0000i   0.0000 + 0.0000i   1.0000 + 0.0000i
   0.0000 + 0.0000i   1.0000 + 0.0000i   1.0000 + 0.0000i   1.0000 + 0.0000i
   0.0000 + 0.0000i   1.0000 + 0.0000i   0.0000 + 0.0000i   1.0000 + 0.0000i
   0.0000 + 0.0000i   1.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i
   0.0000 + 0.0000i  -0.7071 - 0.7071i   0.0000 + 0.0000i   1.0000 + 0.0000i
   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i
   0.0000 + 0.0000i   1.0000 + 0.0000i   1.0000 + 0.0000i   0.0000 + 0.0000i
   0.0000 + 0.0000i   0.0000 + 0.0000i   1.0000 + 0.0000i   1.0000 + 0.0000i
   0.0000 + 0.0000i   0.0000 + 0.0000i   1.0000 + 0.0000i   0.0000 + 0.0000i
   0.0000 + 0.0000i   1.0000 + 0.0000i   1.0000 + 0.0000i   0.0000 + 0.0000i
   0.0000 + 0.0000i   0.7071 - 0.7071i   0.0000 + 0.0000i   0.0000 + 0.0000i
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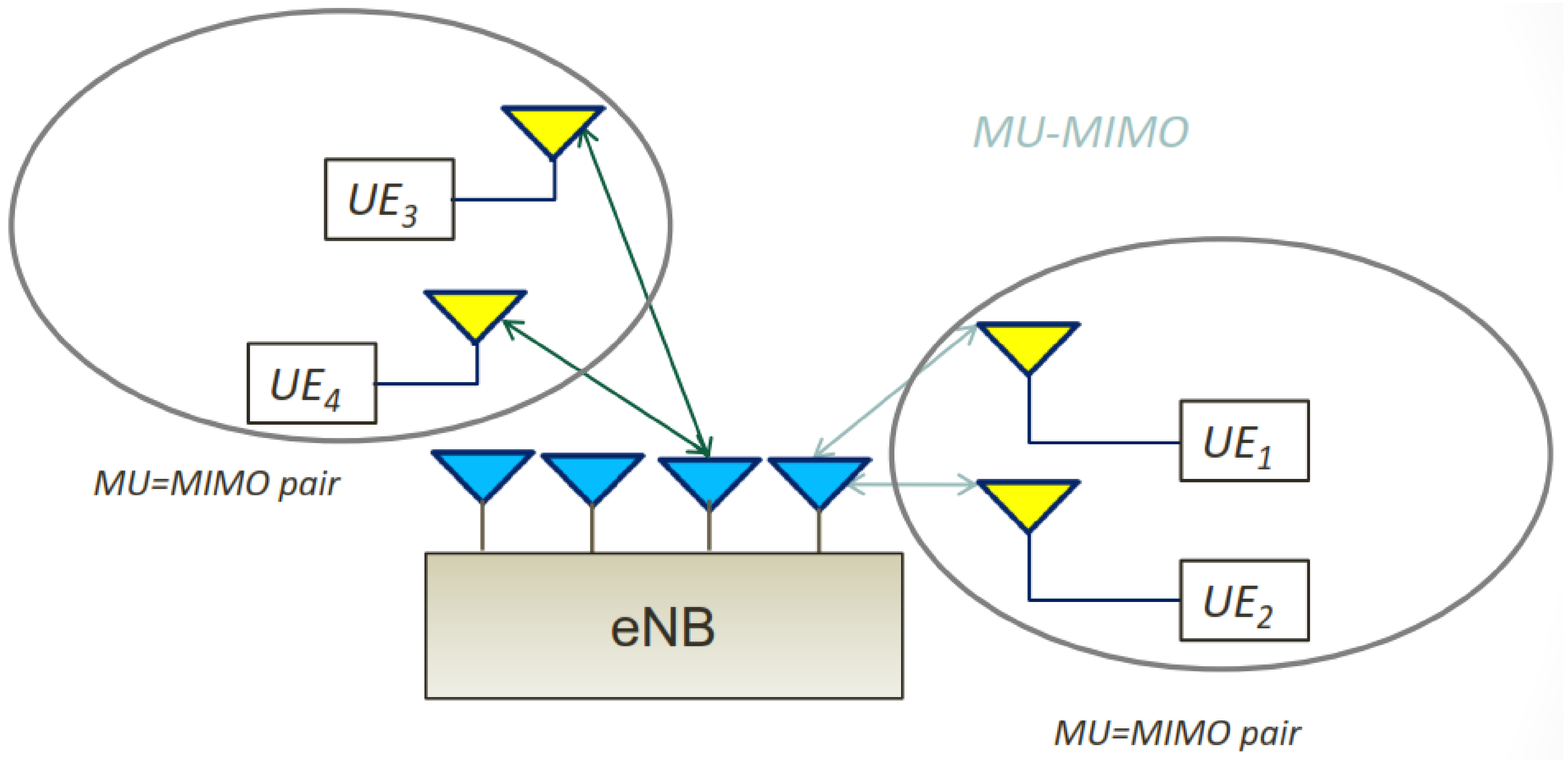
   0.0000 + 0.0000i   1.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i
fx 0.0000 + 0.0000i  -0.7071 - 0.7071i   0.0000 + 0.0000i   0.0000 + 0.0000i
```

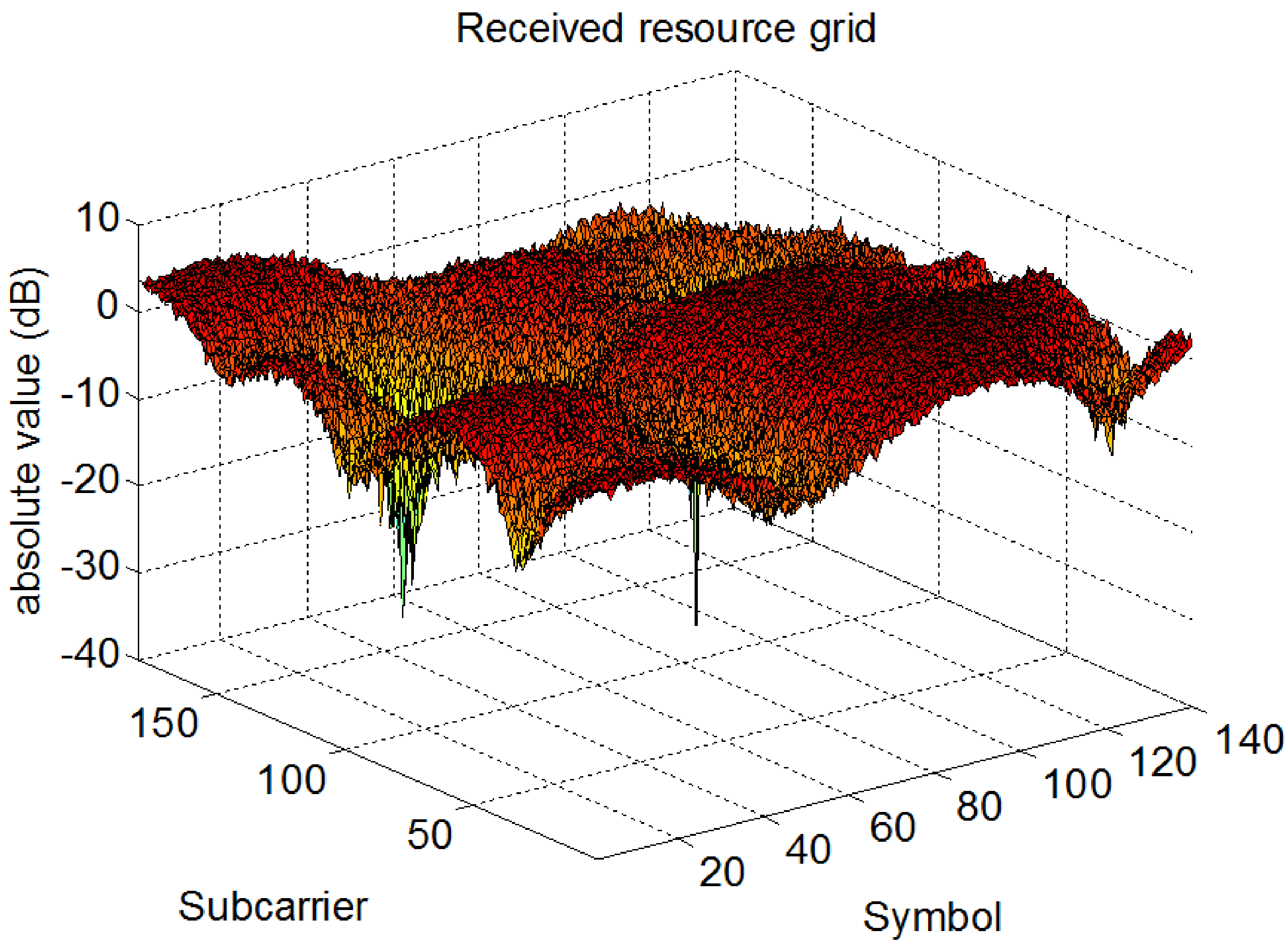
MIMO TRANSMISSION MODES

LTE transmission modes	Description
Mode 1	Single-antenna transmission
Mode 2	Transmit diversity
Mode 3	Open-loop codebook-based precoding
Mode 4	Closed-loop codebook-based precoding
Mode 5	Multi-user-MIMO version of transmission mode 4
Mode 6	Single-layer special case of closed-loop codebook-based precoding
Mode 7	Release-8 non-codebook-based precoding supporting only single-layer based on beamforming
Mode 8	Release-9 non-codebook-based precoding supporting up to two layers.
Mode 9	Release-10 non-codebook-based precoding supporting up to eight layers

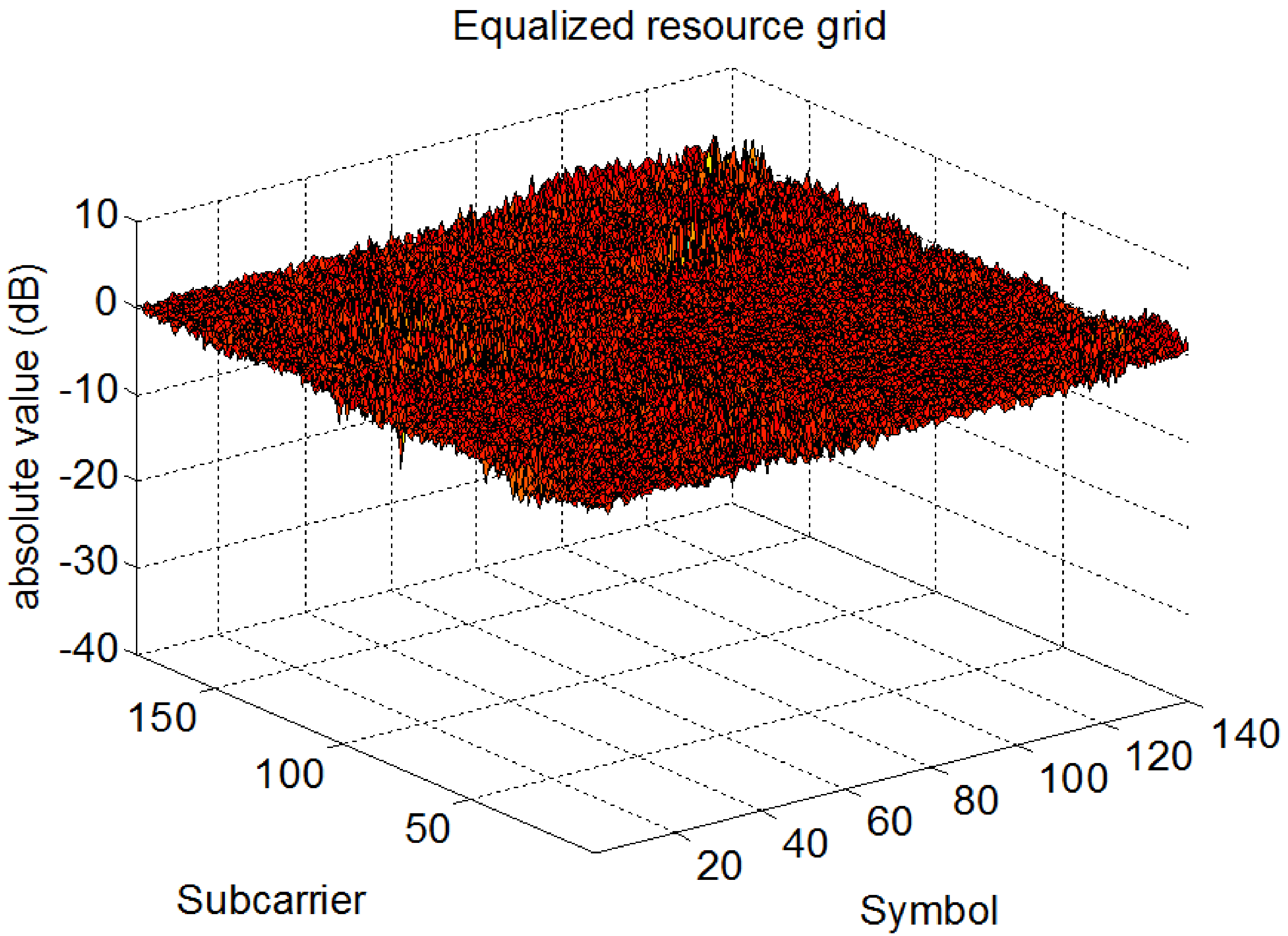
TRANSMISSION MODE 5 – MULTIUSER MIMO



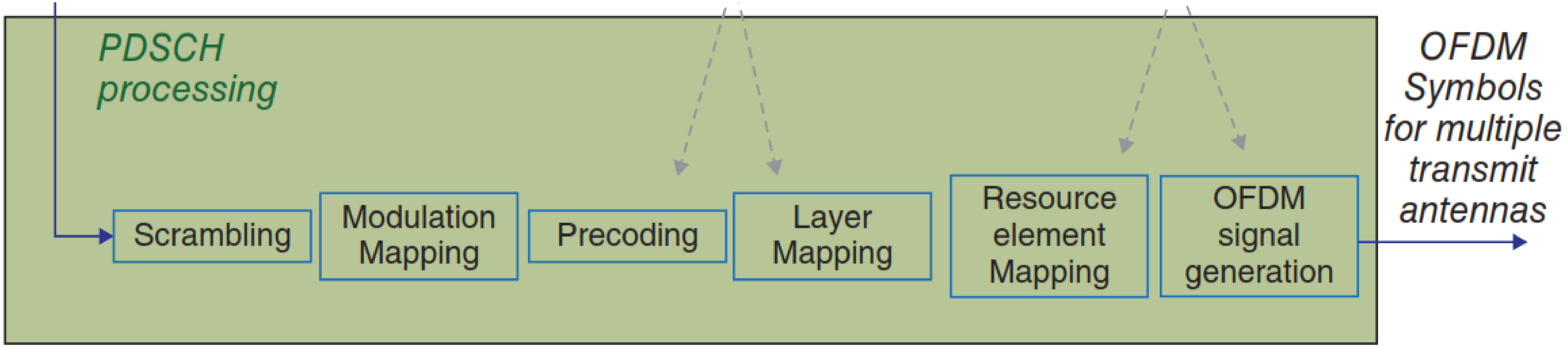
EQUALIZER EFFECT



EQUALIZER EFFECT



OVERALL BLOCK 2 AND 3



- INTRODUCTION
- LTE PHY MODULATION AND CODING
- PILOT-BASED CHANNEL ESTIMATION
- POWER ALLOCATION
- ADAPTIVE BEAMFORMING
- FUTURE WORK
- REFERENCES

METHODOLOGY

Path Loss calculation

- P_t – Transmitted Power (Notified to UE)
- P_r – Received Power (Measured by UE)
- $10*\log(P_t / P_r)$ – Path Loss

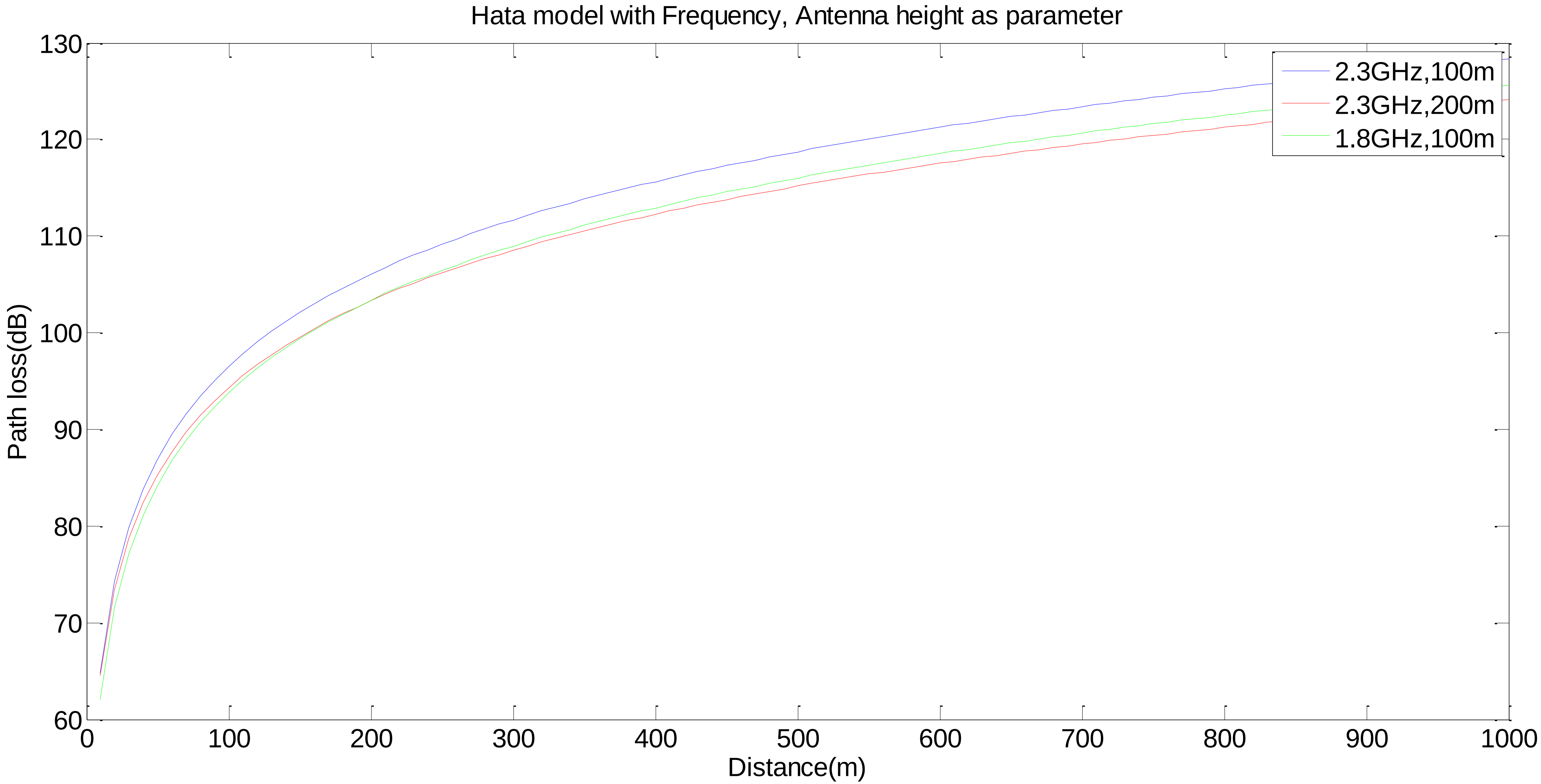
- **Okumura Hata Model**

  P_{loss} = 69.55 + 26.16*log10(frequency) - 13.82*log10(h_{te}) + (44.9 - 6.55*log10(h_{te}))*log10(distance);

- **Rearranged Okumura Hata Model**

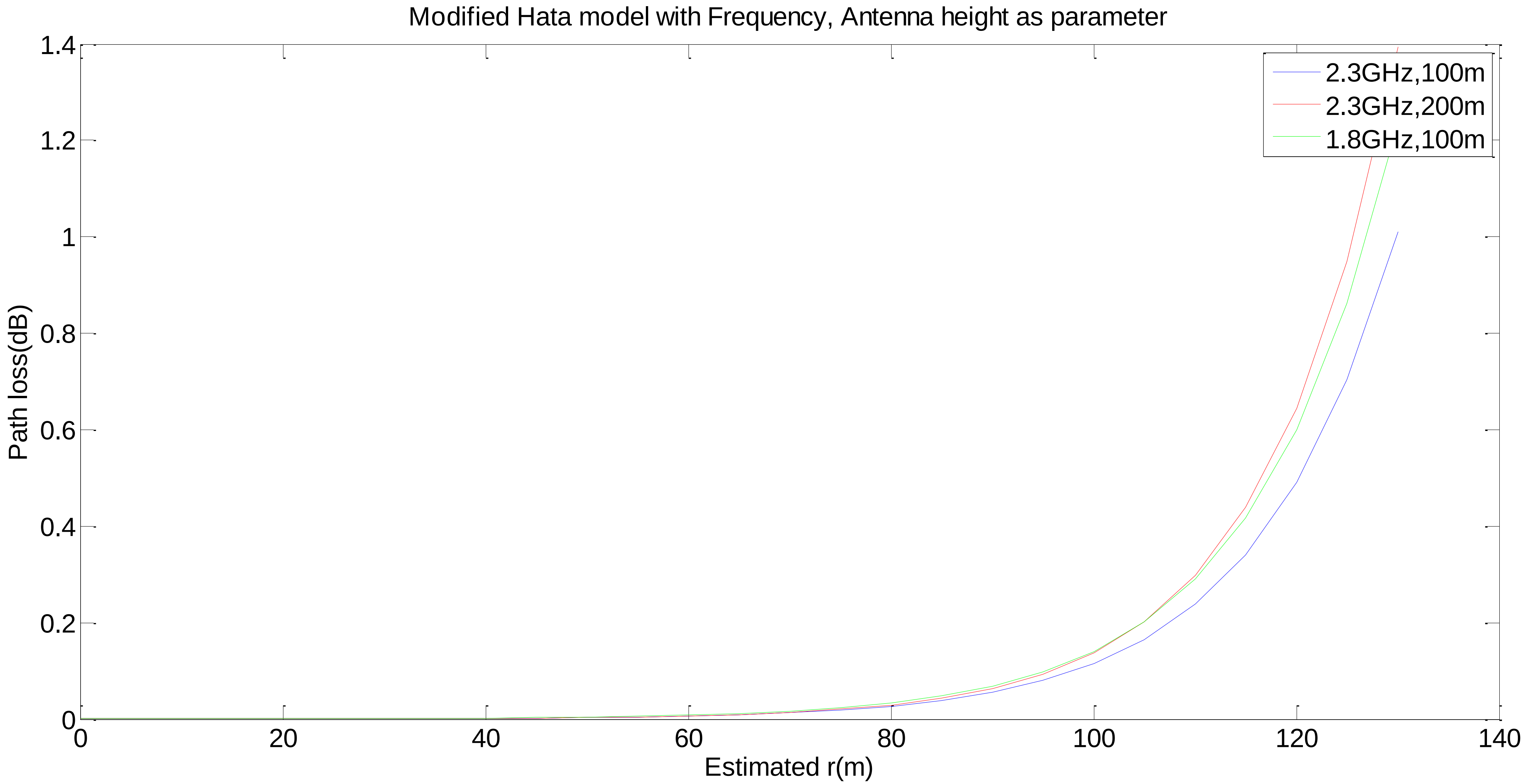
  Distance = 10.^((P_{loss} - 69.55 - 26.16*log10(frequency) + 13.82*log10(h_{te}))/(44.9 - 6.55*log10(h_{te})));

RESULTS



Hata model with Frequency, Antenna height as parameter
2.3GHz,100m
2.3GHz,200m
1.8GHz,100m
Path loss(dB)
Distance(m)
130
120
110
100
90
80
70
60
0
100
200
300
400
500
600
700
800
900
1000

RESULTS



Modified Hata model with Frequency, Antenna height as parameter
2.3GHz,100m
2.3GHz,200m
1.8GHz,100m
Path loss(dB)
Estimated r(m)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
0
20
40
60
80
100
120
140

METHODOLOGY

<u>Determination of (r,θ) of user</u> – DoA Estimation – MUSIC Algorithm

<u>Power allocation</u> – Power Control through Open-loop Feedback Techniques

<u>(r,P) Look-up table for entire cell</u> – Obtaining relation between the two variables

Repeating entire process for multi-user MIMO

Downlink Power Control

- Power control refers to the strategies or techniques required in order to adjust, correct and manage the power from the base station and the mobile station in an efficient manner.
- It minimises the necessary transmission power level to achieve good quality of service. This reduces the co-channel interference in other cells, which increases the system capacity.
- Open-loop power control

Distance Based Power Allocation

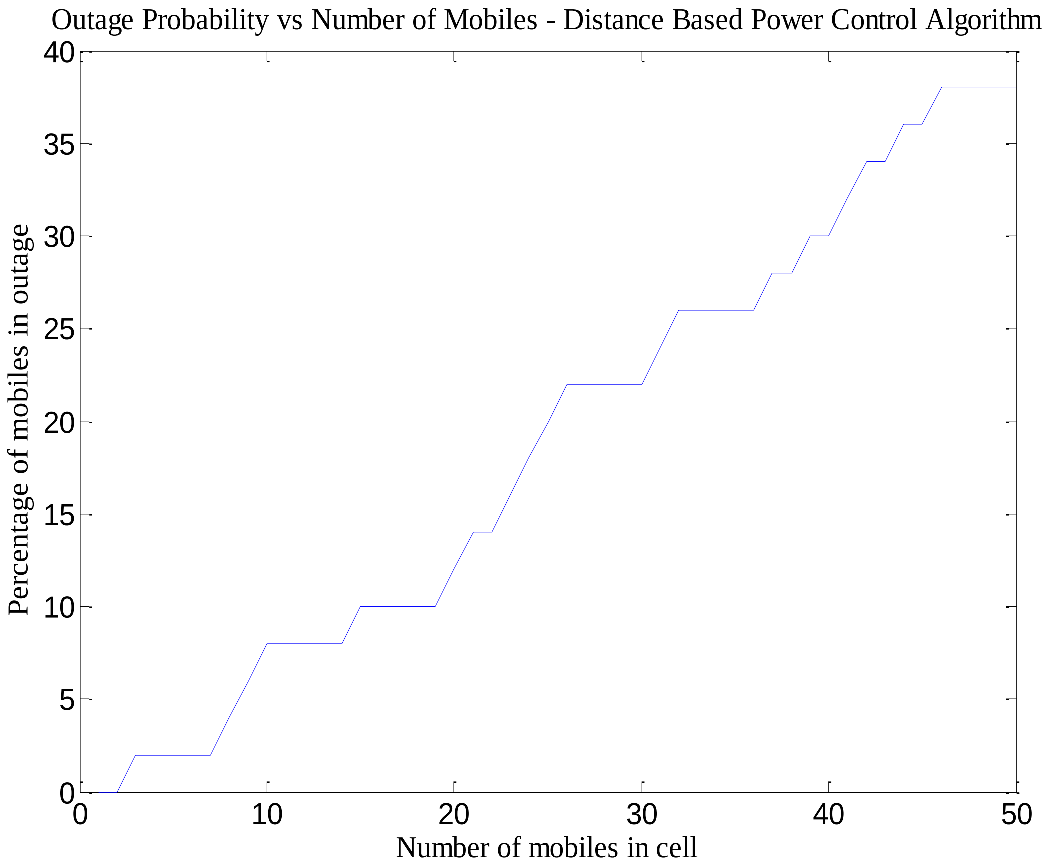
- The distance-based power allocation algorithm (DBPA) uses the distance between base station and each mobile station to allocate transmitted power to each each of its served mobile.
- The DBPA algorithm computes the transmitted power of mobile m according to the following equation:

$$p_m = k x_{a_m m}^n$$

$$\text{where, } x_{a_m m} = \begin{cases} \frac{d_{a_m m}}{R}, & \text{if } d_{a_m m} > d_{min} \\ \frac{d_{min}}{R}, & \text{if } d_{a_m m} \leq d_{min} \end{cases}$$

- k=positive constant, R=maximum range, n= real positive value,d= distance between MS and BS.

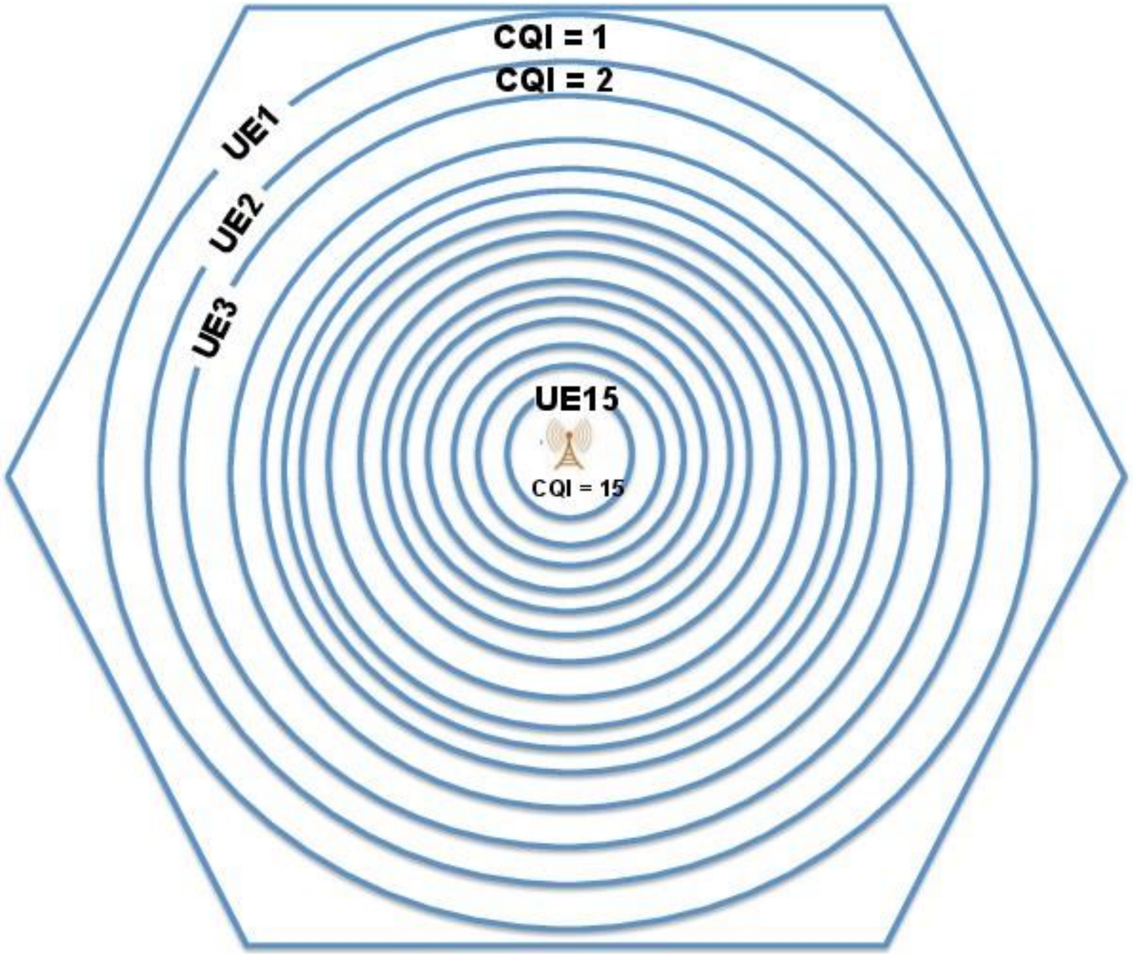
RESULTS-DBPA



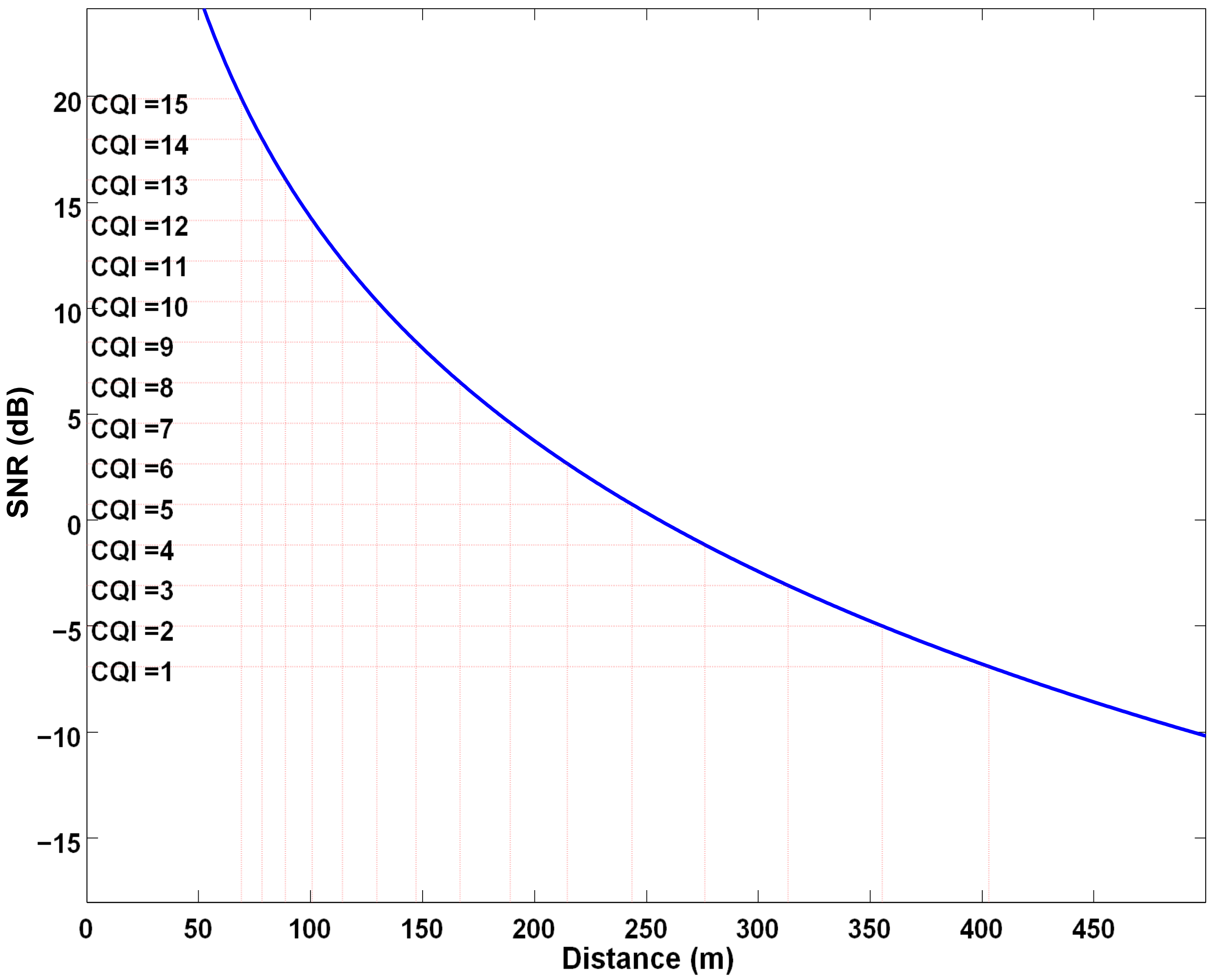
RESULTS-DBPA

CQI Index	Modulation	Code Rate X 1024	Efficiency
0	No transmission		
1	QPSK	78	0.1523
2	QPSK	120	0.2344
3	QPSK	193	0.3880
4	QPSK	308	0.6016
5	QPSK	449	0.8770
6	QPSK	602	1.1758
7	16QAM	378	1.4766
8	16QAM	490	1.9141
9	16QAM	616	2.4063
10	64QAM	466	2.7305
11	64QAM	567	3.3223
12	64QAM	666	3.9023
13	64QAM	722	4.5234
14	64QAM	873	5.1152
15	64QAM	948	5.5547

RESULTS-DBPA



RESULTS-DBPA



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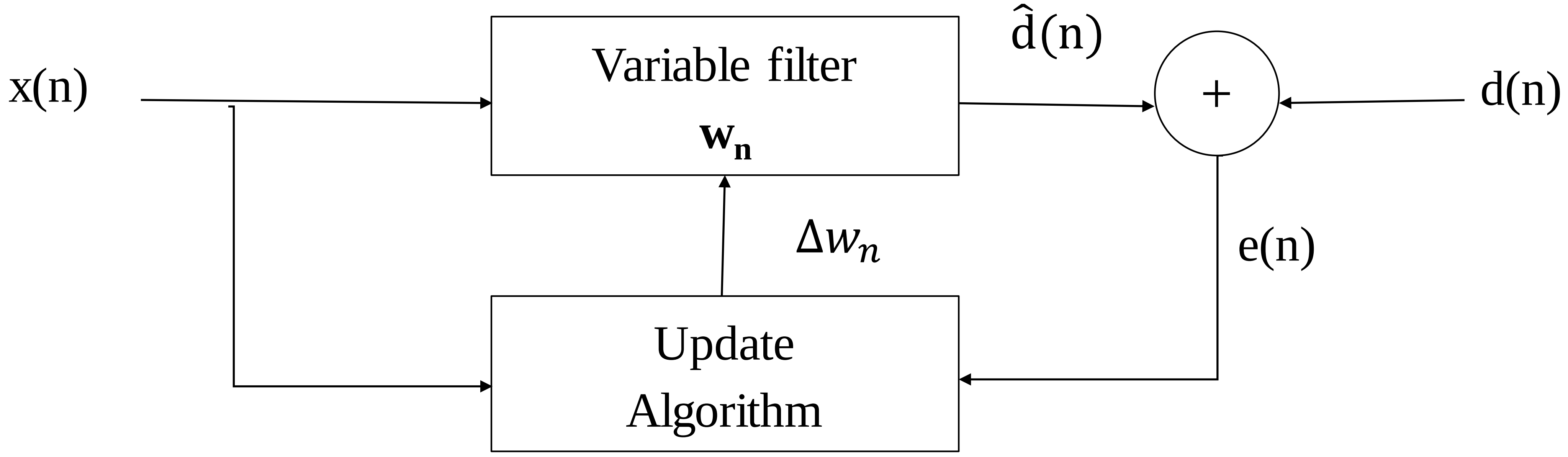
METHODOLOGY

Adaptive beam-steering from antenna – LMS Algorithm



BLOCK DIAGRAM

METHODOLOGY

- **MATHEMATICAL MODELING**

- ANTENNA ARRAY PATTERN – For n arrays, separated by a uniform distance d, oriented at angle θ, having weights w_n, Array Factor (AF) is given as:

$$AF(\theta) = \sum_{i=0}^{N-1} w_n e^{jknd \sin(\theta)}$$

- BEAMFORMING ALGORITHM – The weights for LMS algorithm is given as:

$$w_{l,k+1} = w_{lk} + 2\mu \; \epsilon_k \; x_{lk}$$

METHODOLOGY

- **MATHEMATICAL MODELING**

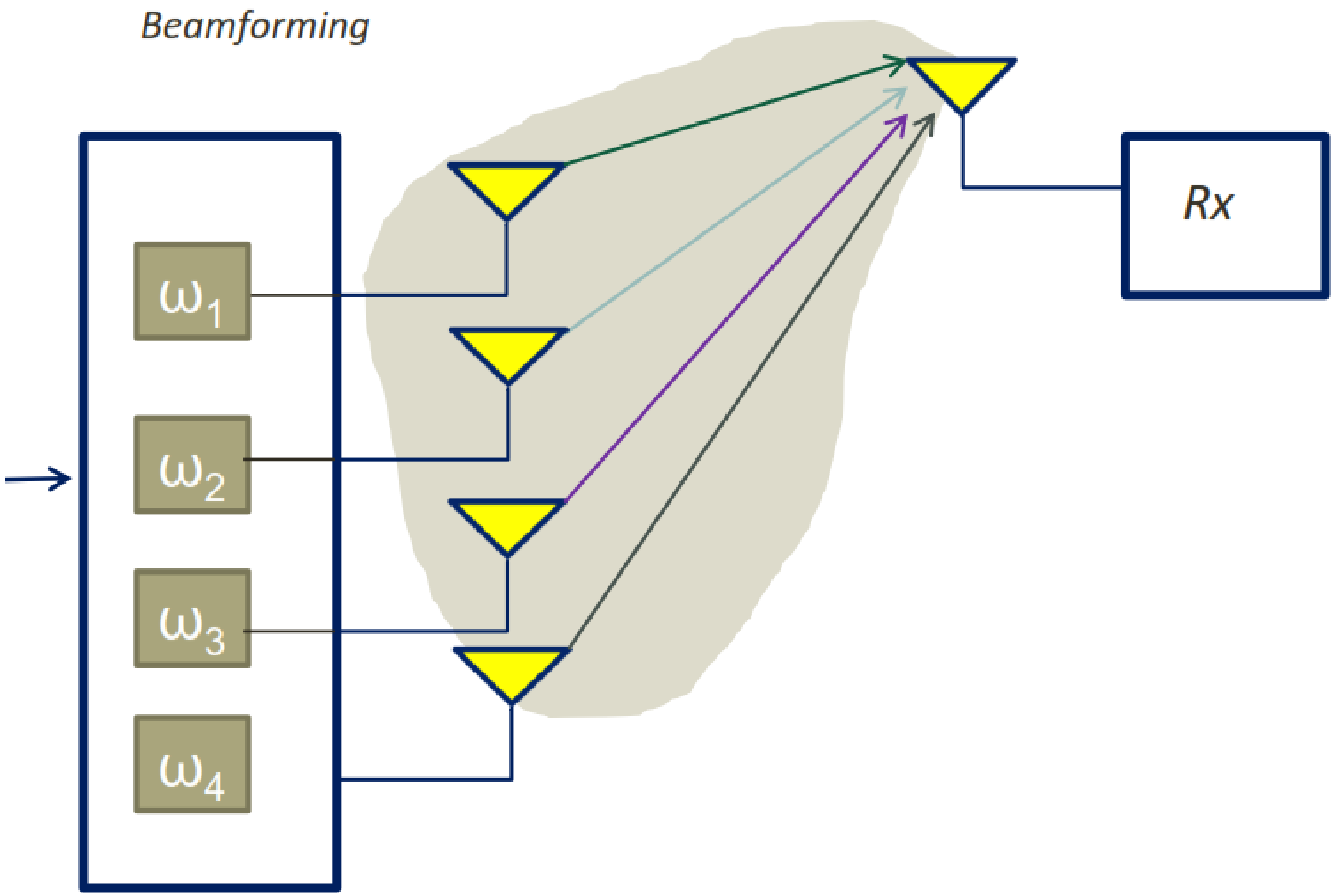
- ANTENNA ARRAY PATTERN – For n arrays, separated by a uniform distance d, oriented at angle θ, having weights w_n, Array Factor (AF) is given as:

$$AF(\theta) = \sum_{i=0}^{N-1} w_n e^{jknd \sin(\theta)}$$

- BEAMFORMING ALGORITHM – The weights for LMS algorithm is given as:

$$w_{l,k+1} = w_{lk} + 2\mu \ \epsilon_k \ x_{lk}$$

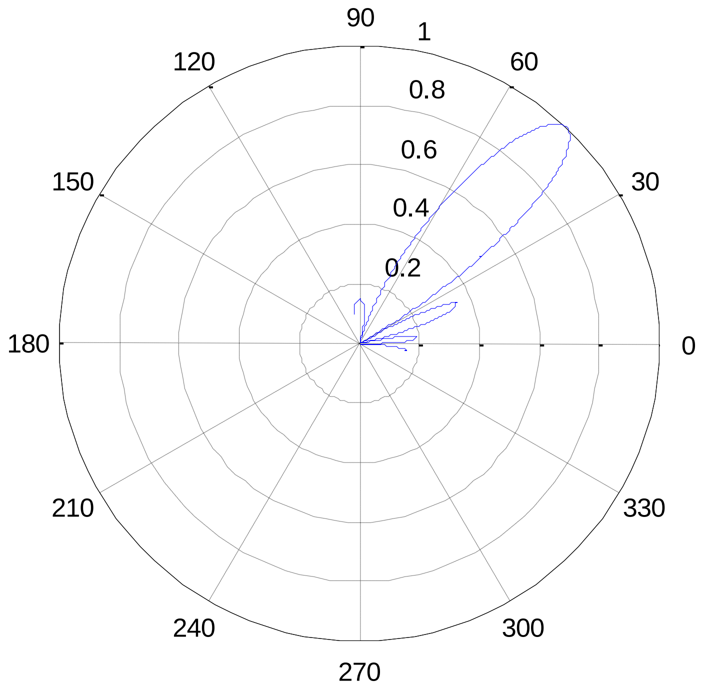
TRANSMISSION MODE 7 – UE BEAMFORMING

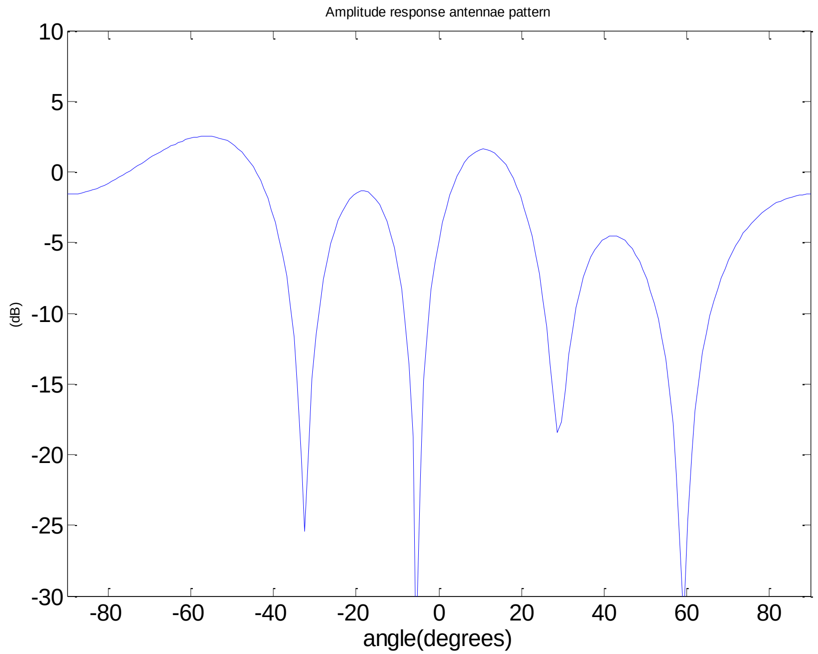


RESULTS

Desired signal arrives at an angle of 45 degrees – MAXIMISE POWER

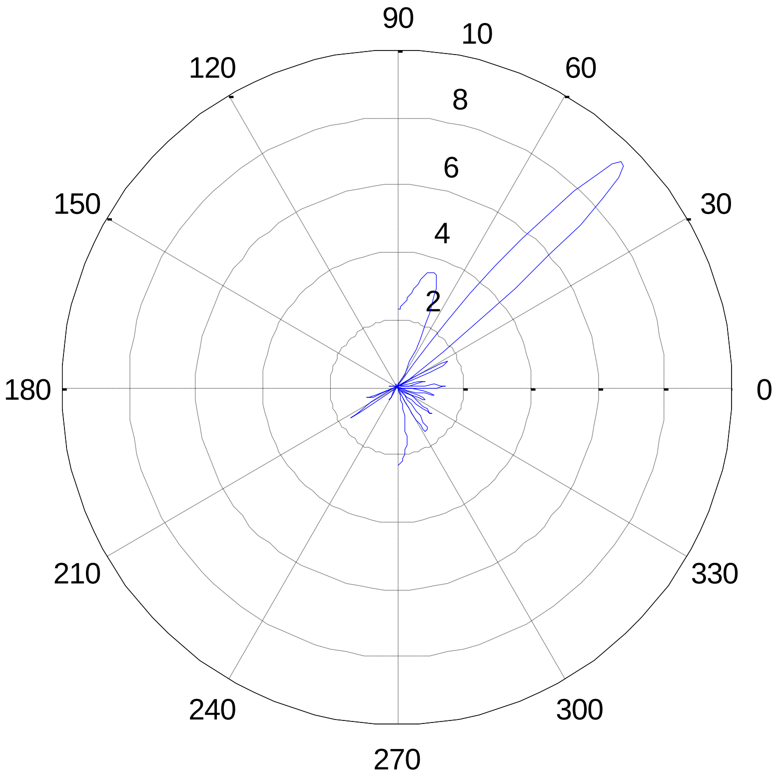
Interferer signals arrive at 30, 60 degrees – STEER NULLS

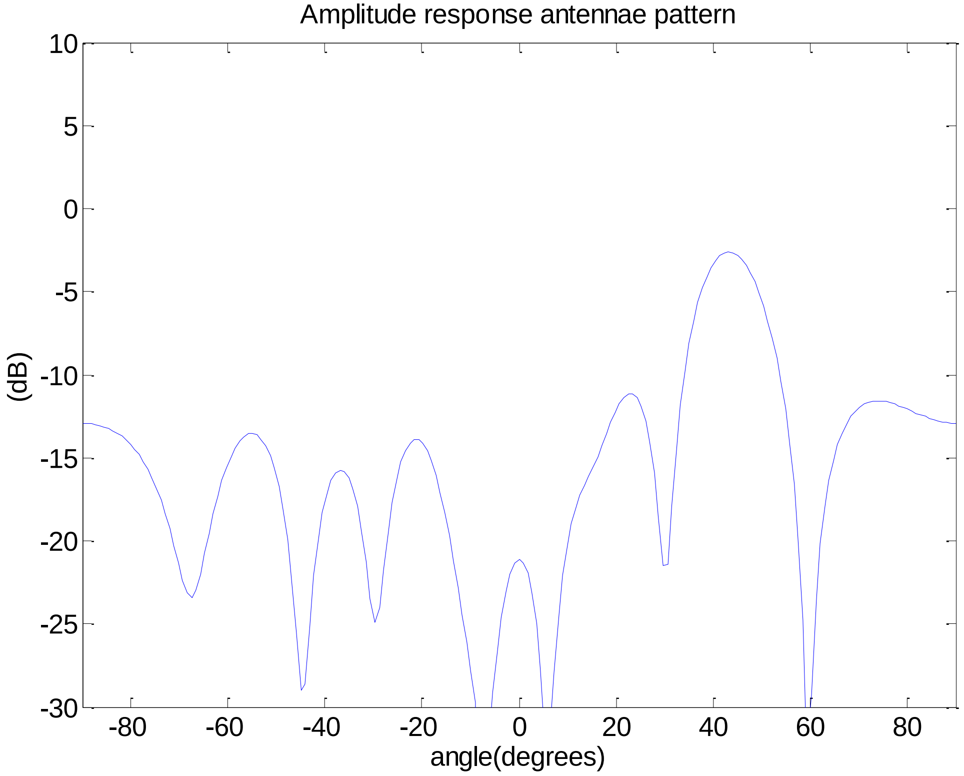




POLAR, AMPLITUDE PATTERN OF RECEIVED BEAM – MAXIMA AT 45 DEGREES, NULLS AT 30, 60 DEGREES

RESULTS





SAME DIRECTIONAL VALUES WITH NUMBER OF ANTENNAS INCREASED FROM 5 TO 10

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FUTURE SCOPE – AT WIPRO

- IMPLEMENTATION OF MIMO, LINK ADAPTATION ALGORITHMS
- CHANNEL-DEPENDENT SCHEDULING
- CONVERSION OF MATLAB CODE TO C
- IMPLEMENTATION ON TI DSP BOARD
- DEVELOP RELATION MATRIX BETWEEN PHYSICAL, LOGICAL ANTENNA

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