BWSIM

For

Academic Purposes

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Prepared By

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1 Introduction

The Broadband Wireless Simulator (BWSIM) is an OFDM technology-based wireless system level simulator. It is capable of performing system level simulations of an OFDM based system in a multi-cellular environment under different deployment scenarios with a variety of radio conditions in the presence of interference of up to two tiers.

BWSIM can be used for doing various research and academic activities. Several projects and experiments can be defined and tried out using BWSIM.

1.1 Purpose

This document gives a sample set of experiments that can be used to bring out key concepts in wireless and cellular systems.

1.2 Related Documents

To know more about the system, the user is referred to the following documents.

- **Functional Description**

  Functional Description document describes the functionalities and features of BWSIM and provides potential users an in depth understanding of its capabilities**.**

- **User Manual**

  The User Manual document guides the users on how to use various features of Broadband Wireless Simulator.

- **Administrator Manual**

  Administrator Manual describes the various administration activities for BWSIM including User management.

1.3 Conventions

The following conventions are followed in this document

`Courier New font` is used to indicate commands to be typed in by the user at command prompt.

1.4 Structure of the Manual

The document is structured in the following way:

Section 2 gives details of the common parameters used in scenarios of various experiments.

Section 3 describers the experiments including the parameters which are to be given for the experiments, expected results and some of the observations that can be derived from the results.

2 Scenarios for experiments

It is very important that the right parameters are chosen while running the scenarios. The parameters which can be used while running the experiments have been provided in this document. Some of them are common across at the experiments and some are specific to an experiment. The common ones are given below and the specific ones are given in individual sections. Please note that this is provided only as a guidance to a basic user. Once a user becomes comfortable with the simulator and knows clearly what each parameter is and how it affects the simulation, there are several ways in which the parameters can be changed and experiments repeated.

The system scenarios Urban Macro, Urban Micro and Rural Macro which are be used for running the experiments listed in the next section are given in the table below (Ref. ITU M.2135).

	Urban Macro (UMa)	***Urban Micro (UMi)***	***Rural Macro (RMa)***
System Terrain	IMT Urban Macro	IMT Urban Micro	IMT Rural Macro
Inter Site Distance of Cell (in meters)	500	200	1732
Common Vertical Tilt (in degrees)	12	12	6
Carrier Frequency (in MHz)	2000	2500	800
Transmission Power of Node (in dBm) (for eNB)	46	41	46
Height of Each Node Type (in meters) (for eNB)	25	10	35
Percentage of Indoor Nodes	0	50	0
User Speed (in m/sec)	8.33	.833	33.33
Minimum distance between eNB and UE (in meters)	25	10	35

Table 1 – Parameters for System Terrains

Below parameters are the common parameters used for simulation along with above parameters.

Parameters for Pico

- Transmission Power of Node (in dBm)- 30
- Height of Each Node Type(in meters)- 10

Parameters for clustered UEs for pico

- Node Drop methods (for Pico UE)- Clustered Pico UE Drop

Parameters for planned dropping of Pico

- Locations of Picos in the Cell- Planned

- Planned Pico Locations in the Cell (here the pico location for a sector is to be provided and correspondingly dropped throughout the layout)

3 Sample set of Experiments

Note: The actual parameters used for generating the results shown below are given in [] brackets, against each of the parameter.

3.1 SINR Distribution for various scenarios

1. Different Terrains
2. Effect of changing cell ISD
3. Effect of changing transmit power
4. Effect of common vertical tilt of antennas
5. Effect of changing percentage of users who are indoor and outdoor
6. Study of relative interference levels in homogeneous networks

For the experiments in this section, following are the common parameters to be configured.

- Simulation Mode as System Level
- Maximum UEs per eNB [200]
- Number of Nodes for UE Node Type [2100] (100 /sector)
- Number of Nodes for eNB Node Type [21]

  (For a single cell configuration, there are 3 sectors/base stations and for a seven cell configuration there are 21 sectors/base stations. The simulation times depends on the number of nodes – base stations as well as the UEs.)

The parameters and the values given below can be used in order to speed the simulation time.

- No of Subframes [1]
- Restricted Reception Status [Enabled]
- eNBs with actual reception -any one id from 0 to (no of sectors-1)[0]

3.1.1 Different Terrains

Objective:
To get and analyze the SINR distribution across various terrains.

Procedure:

a) Set the following parameters

- Load UMa or UMi or RMa scenario.

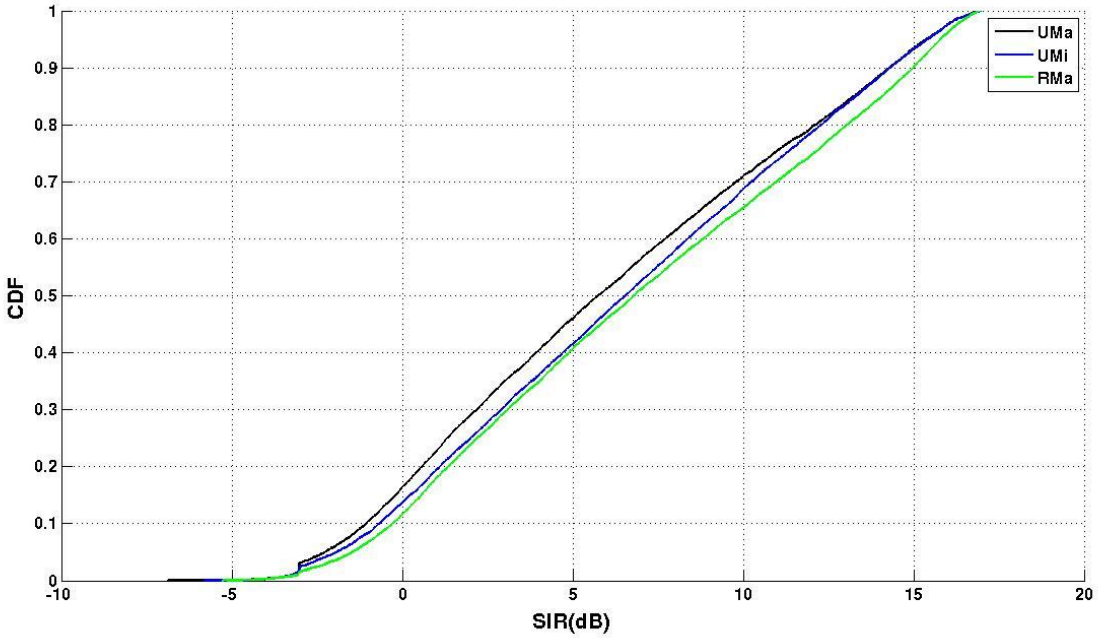
- Set other parameters as specified in Table 1. Parameters for System Terrains

b) Generate the topology and Run the scenario for each of the Terrains – UMa, UMi, RMa

Sample Result:

Files to make the below plot-

- Consider 'SINRindb' in 'SINRDistribution.txt' and plot CDF of SINR for different terrains



3.1.2 Effect of changing cell ISD

Objective:

To get and analyze the SINR distribution with changing Inter-site distance (ISD) for specific antenna tilt values.

Procedure:

a) Set the following parameters

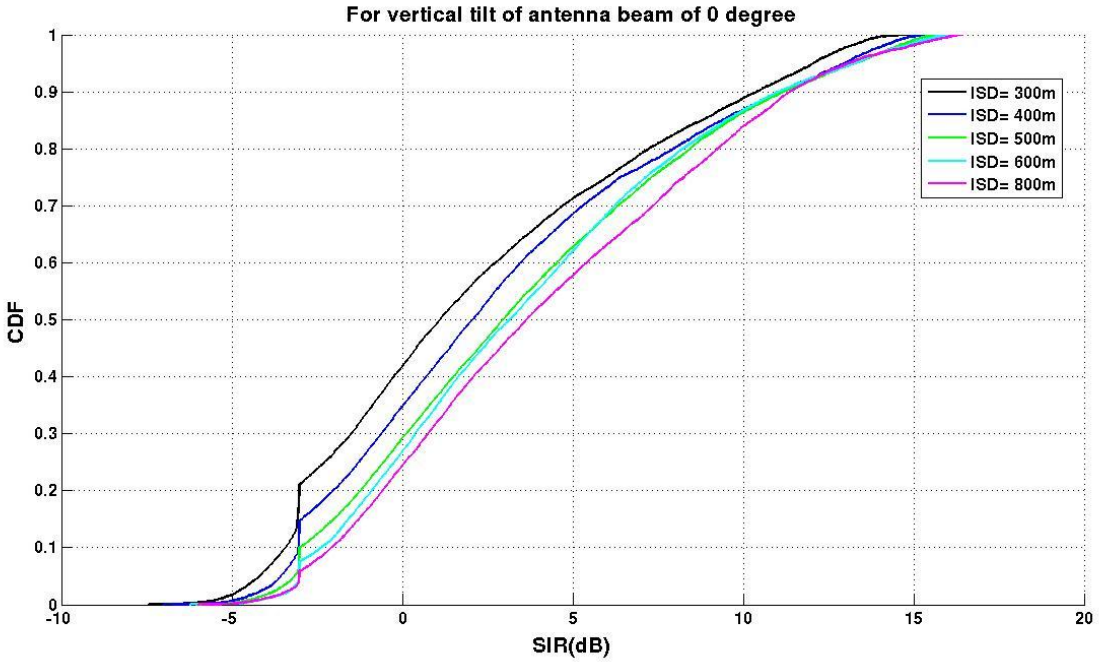
- Load UMa or UMi or RMa scenario. [UMa]
- Common vertical tilt of antenna[12 degrees]
- Inter Site Distance (ISD) of cell [300,400,500,600,800]

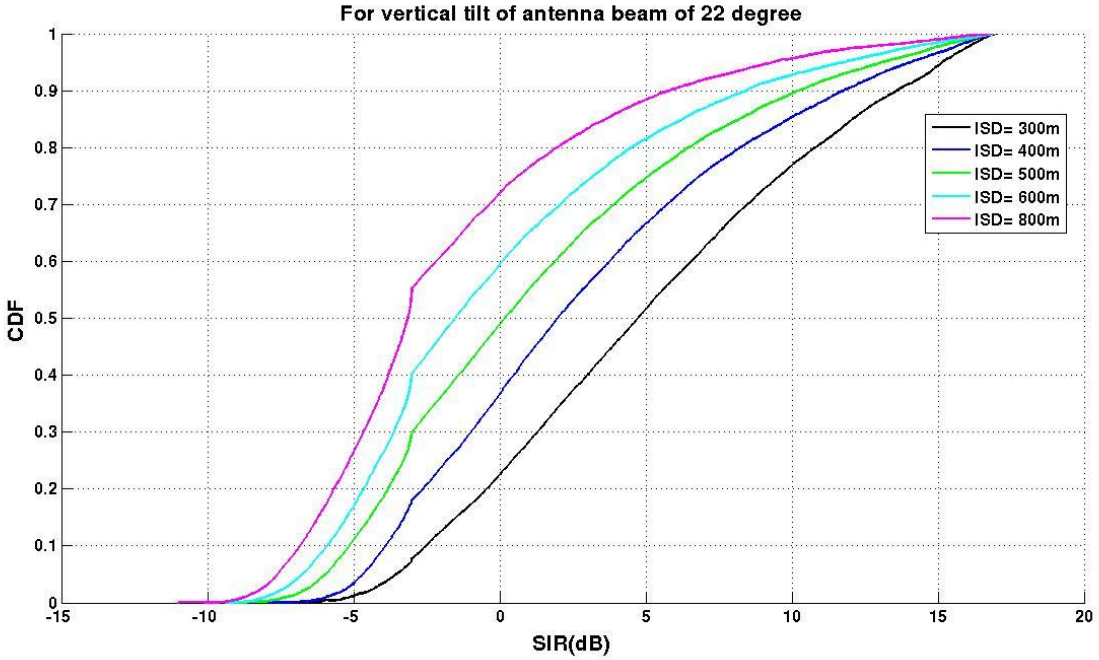
b) Generate the topology and Run the scenario for each of the CellISD values.

Sample Result:

Files to make the below plot:

- Consider 'SINRindb' in 'SINRDistribution.txt' and plot CDF of SINR for different CellISD.


For vertical tilt of antenna beam of 0 degree
CDF
SIR(dB)
ISD= 300m
ISD= 400m
ISD= 500m
ISD= 600m
ISD= 800m


For vertical tilt of antenna beam of 22 degree
CDF
SIR(dB)
ISD= 300m
ISD= 400m
ISD= 500m
ISD= 600m
ISD= 800m

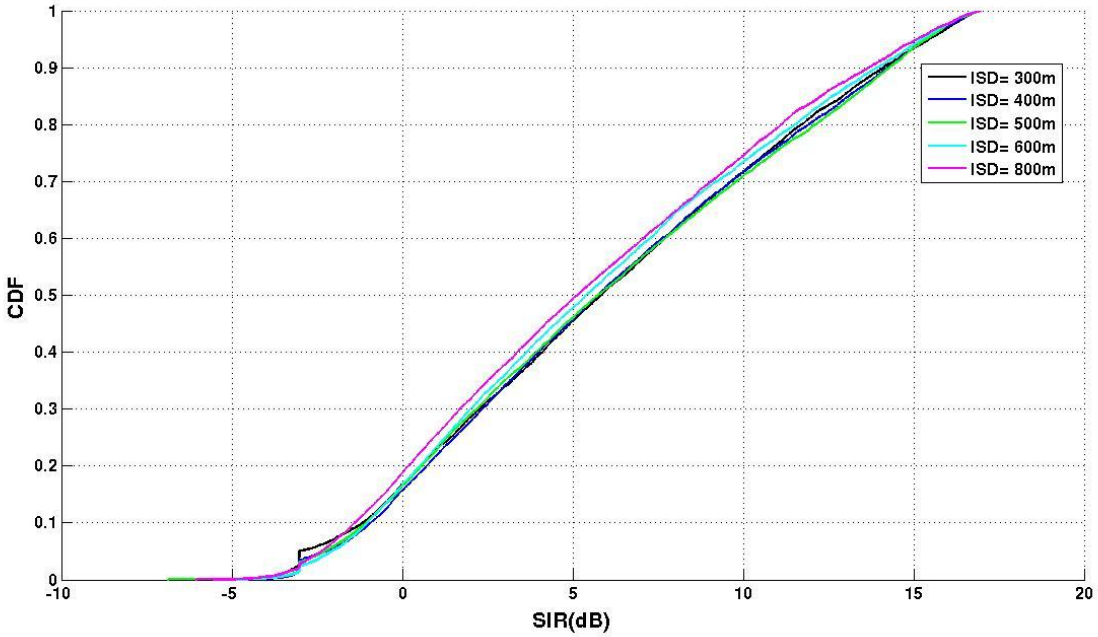


Fig. variation with ISD with vertical tilt of antenna of 12°

Observations:

- As the ISD increases the SIR distribution curve shifts right when the vertical tilt of antenna is 0° i.e. more users have better SIR as the ISD increases.
- As the ISD increases the SIR distribution curve shifts left when the vertical tilt of antenna is 22° i.e. more users have poorer SIR as the ISD increases.
- For vertical antenna tilt of 12° the SIR distribution curve shifts lefts when the ISD deviates from 500m.

3.1.3 Effect of changing transmit power

Objective:

To get and analyze the effect of transmission power on the SINR distribution.

Procedure:

a) Set the following parameters

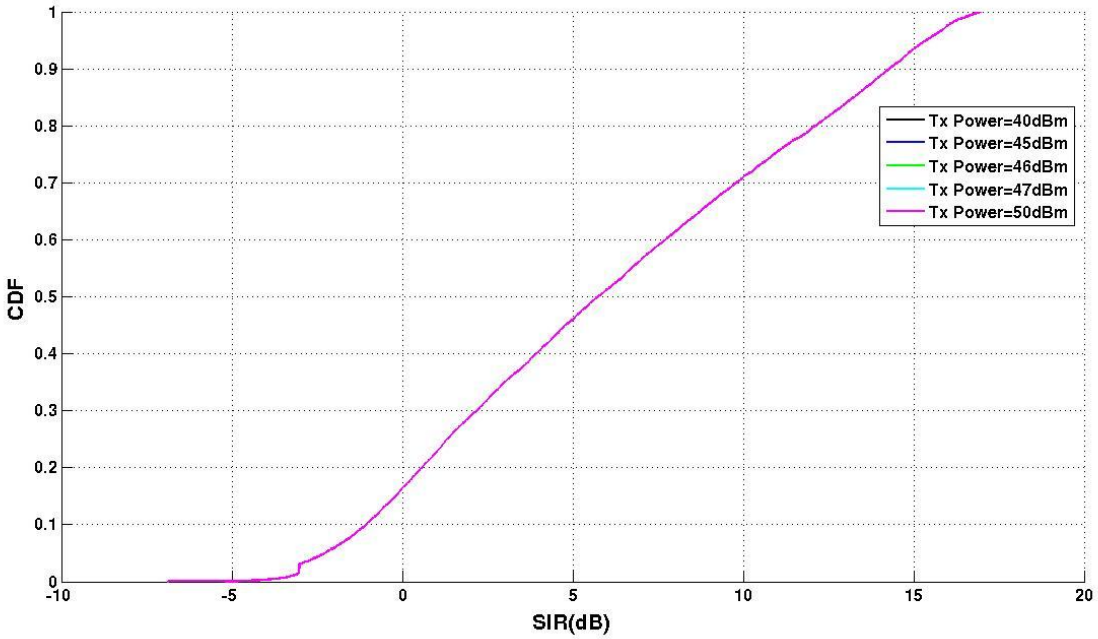
- Load UMa or UMi or RMa scenario. [UMa]
- Transmission power of node (eNB) [40,45,46,47,50]

b) Generate the topology and Run the scenario for each of the Transmitting Power.

Sample Result:

Files to make the below plot-

- Consider 'SINRindb' in 'SINRDistribution.txt' and plot CDF of SINR for Transmitpower



Observation:

- There is no variation in the SIR of the users when the transmit power of the base stations varied.

3.1.4 Effect of common vertical tilt of antennas

Objective:

To get and analyze the effect of vertical tilt of antennas on the SINR distribution.

Procedure:

a) Set the following parameters

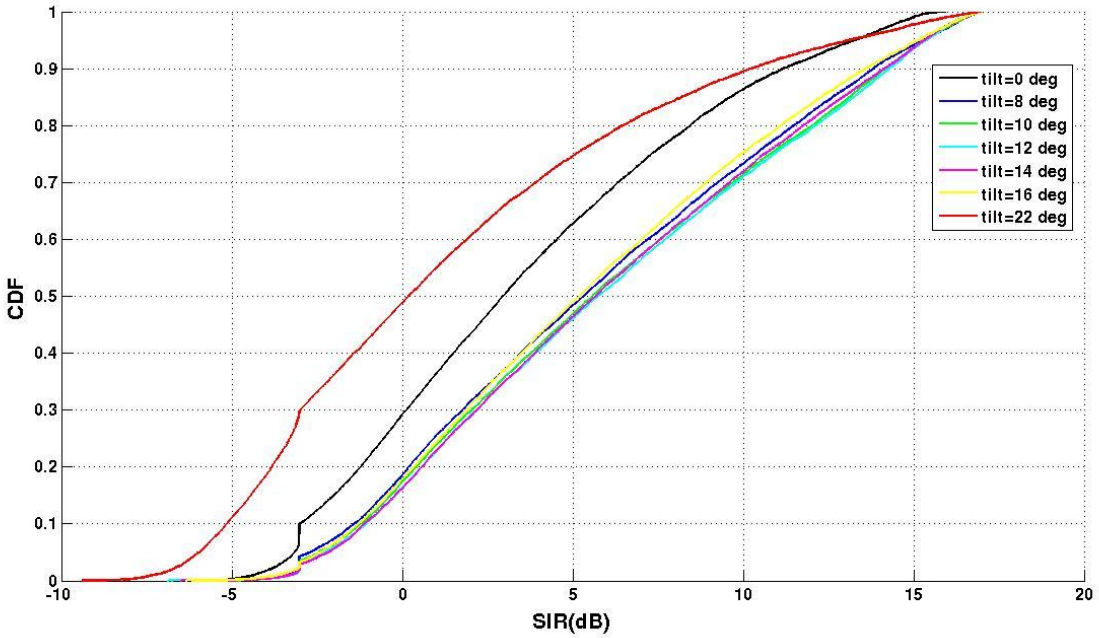
- Load UMa or UMi or RMa scenario. [UMa]
- Common vertical tilt of antenna[0,8,10,12,14,16,22]

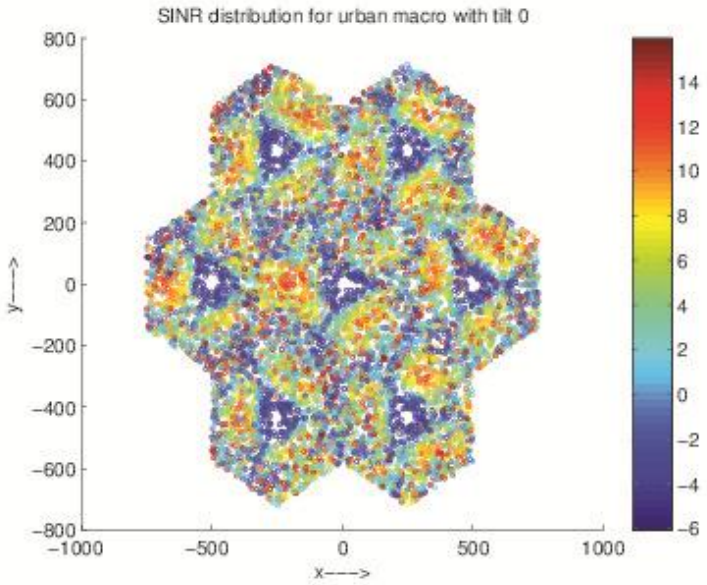
b) Generate the topology and Run the scenario for each of the Antenna Tilt.

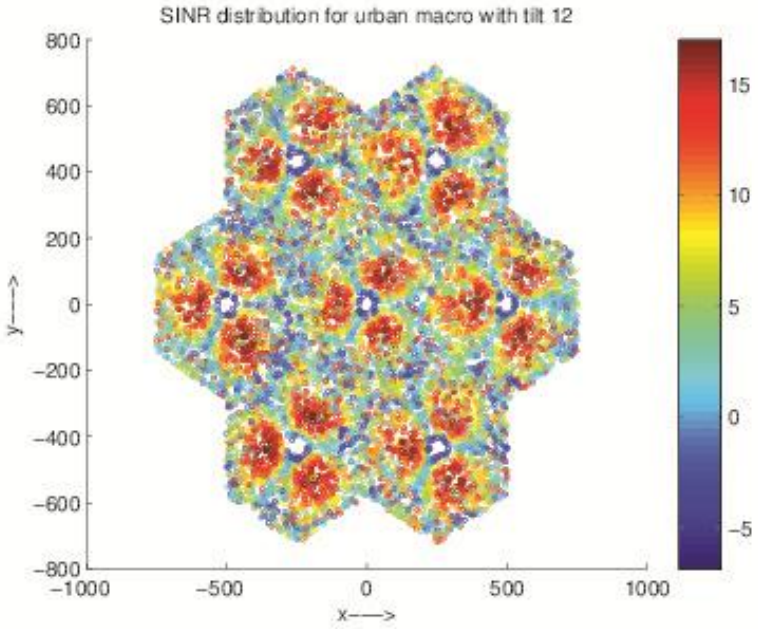
Sample Result:

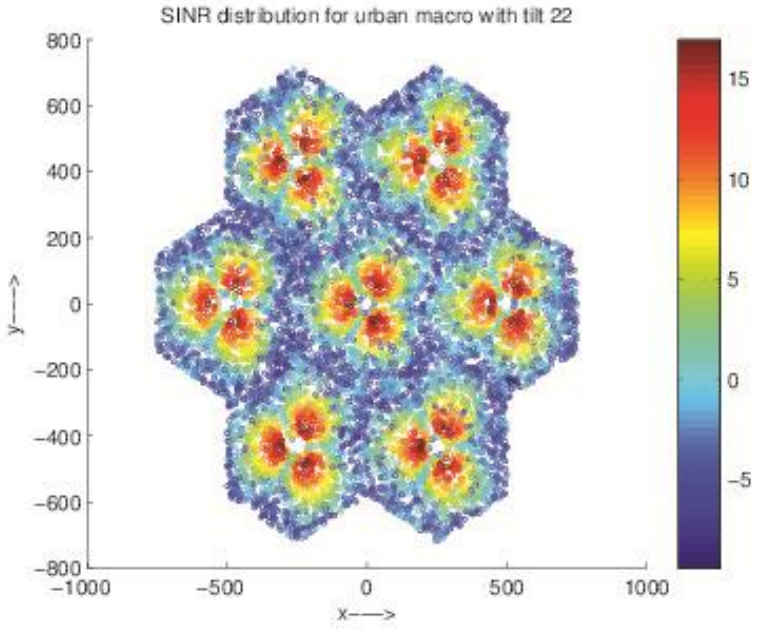
Files to make the below plot -

- Consider 'SINRindb' in 'SINRDistribution.txt' and plot CDF of SINR for different terrains
- Plot 'SINRindb ' with respect to user distance in "detailedLinkInfo.txt"


CDF
SIR(dB)
tilt=0 deg
tilt=8 deg
tilt=10 deg
tilt=12 deg
tilt=14 deg
tilt=16 deg
tilt=22 deg


SINR distribution for urban macro with tilt 0
y---->
x---->





Observations:

- The nearby users to the BS have less SINR for vertical antenna tilt of 0° while the cell edge users have low SINR for vertical antenna tilt of 22°.
- The number of users with low SINR is less for the case where vertical antenna tilt is 12°.

3.1.5 Effect of changing percentage of users who are indoor and outdoor

Objective:

To get and analyze how the distribution of indoor and outdoor users affect the SINR distribution.

Procedure:

a) Set the following parameters

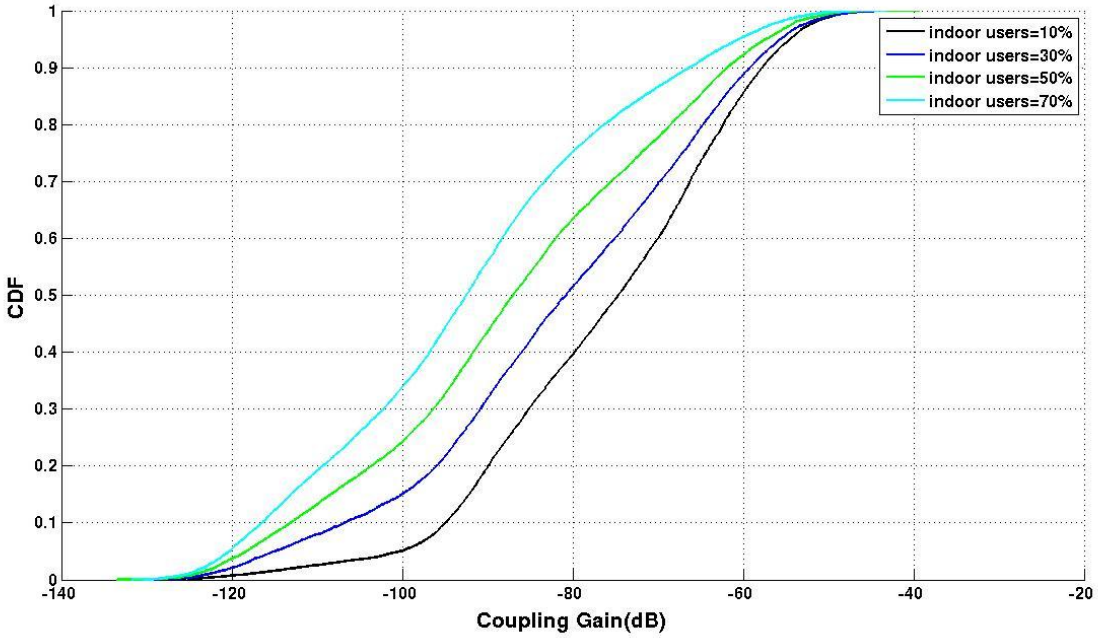
- Load UMi [UMi]
- Set other parameters as specified in Table 1. Parameters for System Terrains
- Percentage of indoor nodes [10,30,50,70,90]

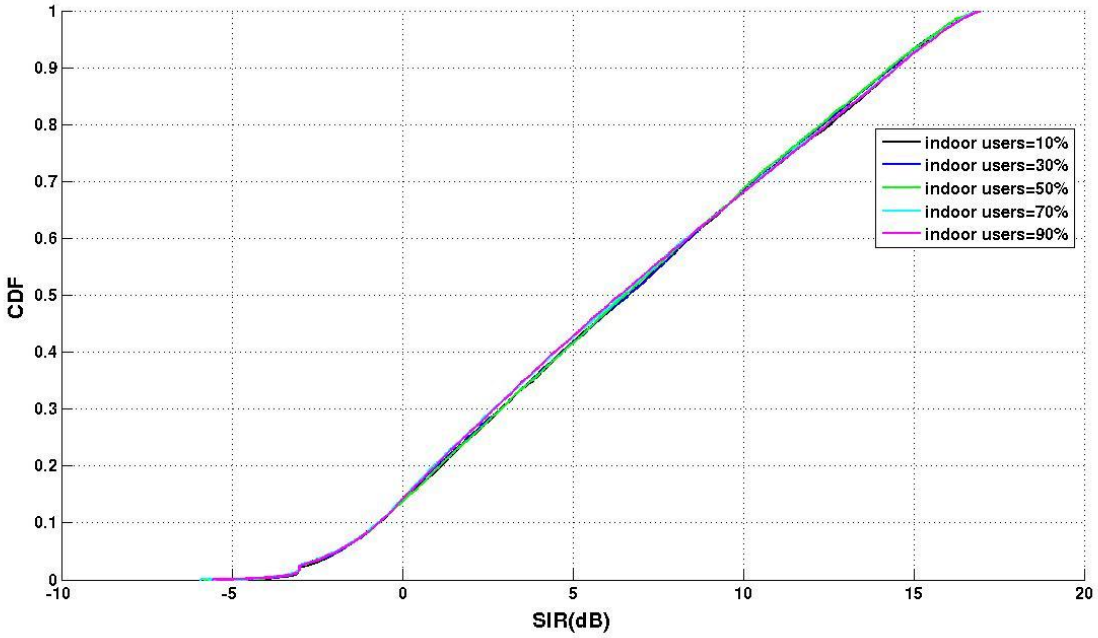
b) Generate the topology and Run the scenario for different percentage of indoor users.

Sample Result:

Files to make the below plot -

- 'Associated –ServiceNode' and 'couplingGain' in 'CouplingGainDownlink.txt' and plot CDF of SINR for different terrains
- 'SINRindb' in 'SINRDistribution.txt' and plot CDF of SINR for different percentage of Indoor users





Observations:

- As the percentage of indoor users increases the coupling gain CDF shifts right i.e. the numbers of users having low coupling gain increases.
- The SIR CDF is not affected much with the variation in the percentage of the indoor users.

3.2 Path Loss

Objective:

To observe the nature of variation of path loss with distance, frequency for non-LOS and LOS users.

Procedure:

a) Set the following parameters (the typical values for the parameters are also listed)

- Simulation Mode as System Level
- Number of Nodes of each type [eNB-21, UE-2100]
- 'Maximum UEs per eNB' [200]
- Load UMa or UMi or RMa scenario.
- Set other parameters for the terrain as specified in Table 1. Parameters for System Terrains

The following parameters can be used in order to speed the simulation time.

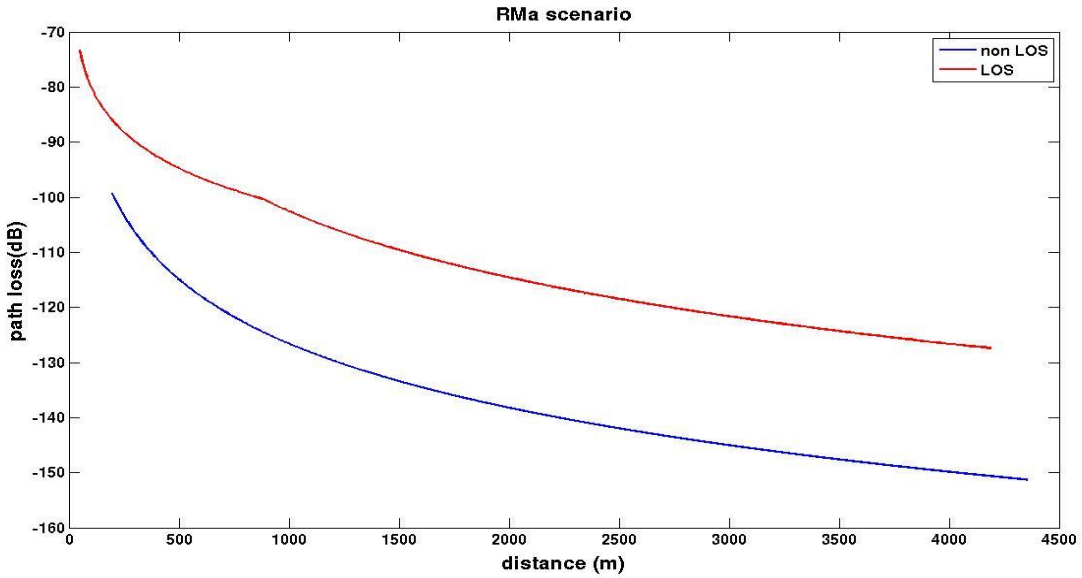
- No of Subframes [1]
- Restricted Reception Status [Enabled]
- eNBs with actual reception [any one id from 0 to (no of sectors-1)]

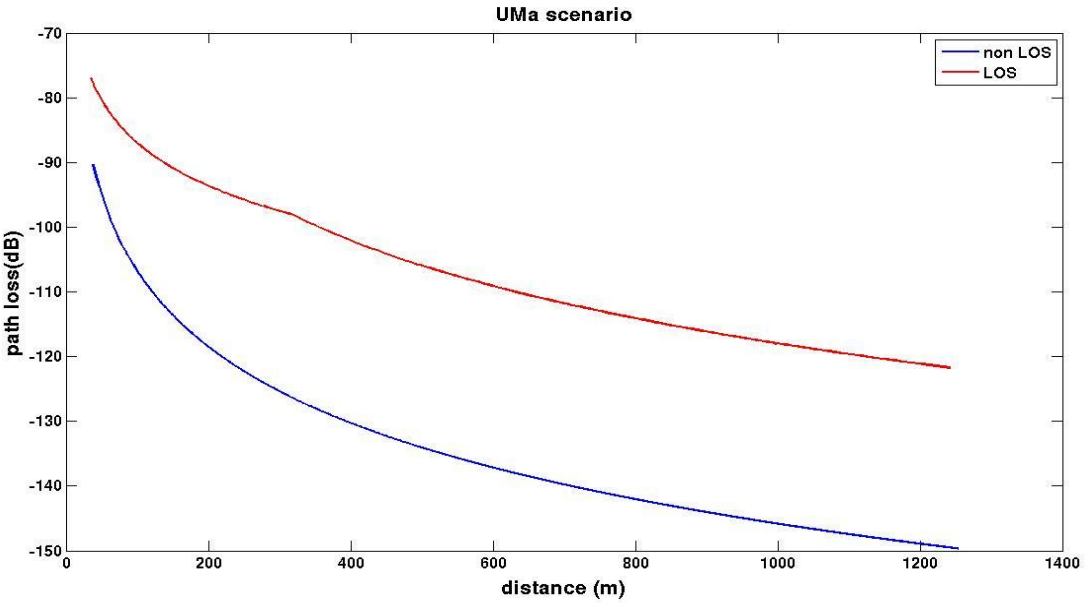
b) Generate the topology and Run the scenario for Different terrains.

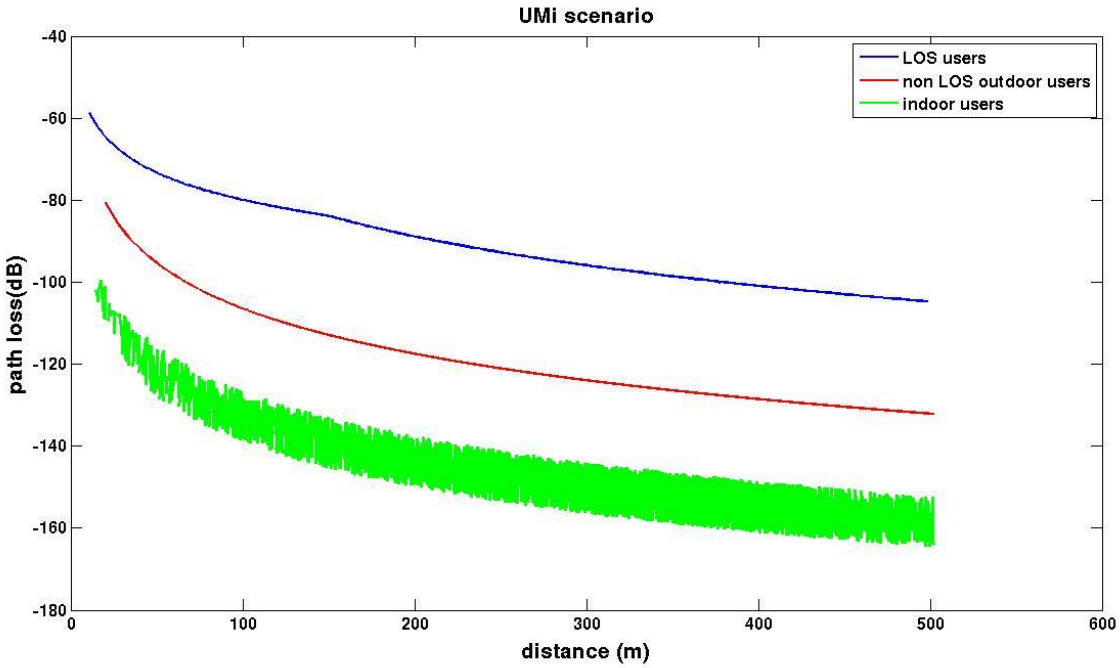
Sample Result:

Files to make the below plot –

- Consider 'PathlossInDB' and 'distance' and 'isLOS' columns in "detailedLinkinfo.txt" of output files. And draw a graph between 'PathlossInDB vs distance'.







Sample Observations:

- Pathloss(dB) increases exponentially with distance
- Pathloss is more for non LOS users than LOS users at a specific distance.
- Pathloss is more for indoor users than outdoor users.
- Pathloss increases with frequency.

3.3 Link level BER Performance

Experiments to observe:

- Link level BER Performance without FEC
- Link level BER Performance with various CQI indices
- Link level BER Performance with various transmission modes

For the experiments in this section, following are the common parameters to be configured.

- Simulation Mode as Link Level
- Method for Generating Channel [Jakes model]

In addition, the following parameters can be used in order to speed the simulation time.

- Bandwidth [1.4 MHz]
- User speed [20 meters/sec]
- Number of subframes [1000]

Note: In order to get a smooth curve especially for higher SNRs, the number of subframes need to chosen higher. However when the number of subframes are more, the simulation times also increase. Suggested numbers are given in the sections below.

3.3.1 Link level BER Performance without FEC

Objective:

To observe the BER (Bit Error Rate)/BLER(Block Error rate) performance of the link without using FEC (Forward Error correcting Code)

Procedure:

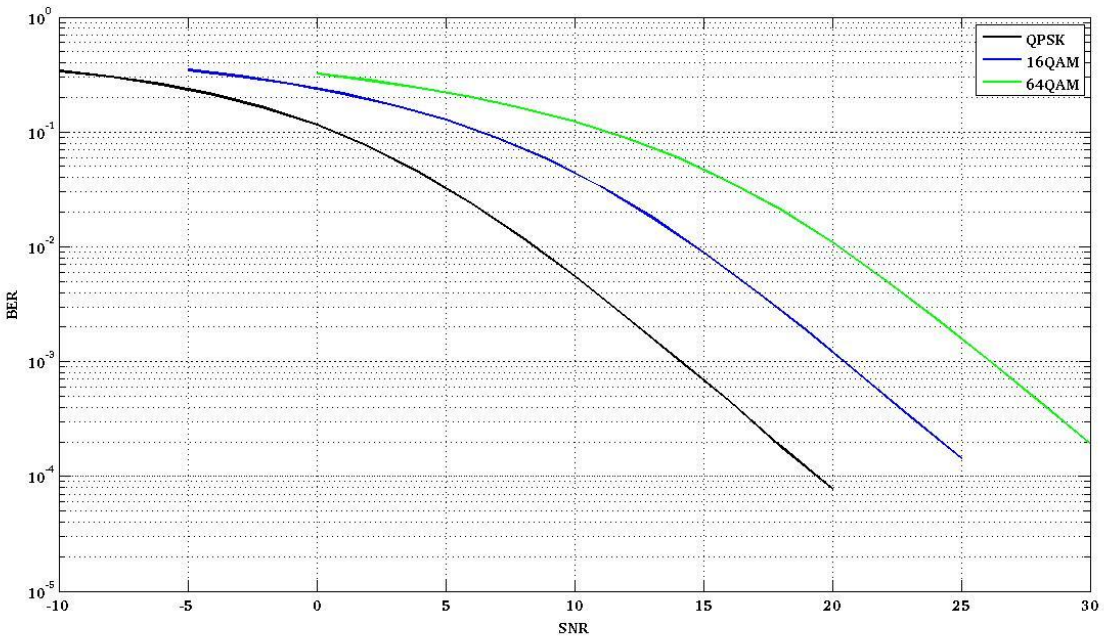
a) Set the following parameters
   - FEC Status: Disabled
   - Modulation Scheme: QPSK/ 16QAM/ 64QAM
   - SNR Range (in dB) – Minimum [say -10]
   - SNR Range (in dB) – Maximum [say 10]
   - SNR Range (in dB) - Step Size [2] (can be higher steps to speed up the time)

b) Generate the topology and Run the scenario for each of the Modulation schemes - QPSK, 16QAM and 64QAM

Sample Result:

Files to make the below plot –

- 'BER' and 'SNR' columns in "dlLinkPerformanceInfo.txt". Plot them in a Semilog scale for different modulation schemes.



Observation:

- As the modulation order increases higher SNR is required to achieve the targeted BER.

3.3.2 Link level BER Performance with various CQI indices

Objective:

To observe the BER (Bit Error Rate)/BLER(Block Error rate) performance of the link for various CQI/MCS indices

Procedure:

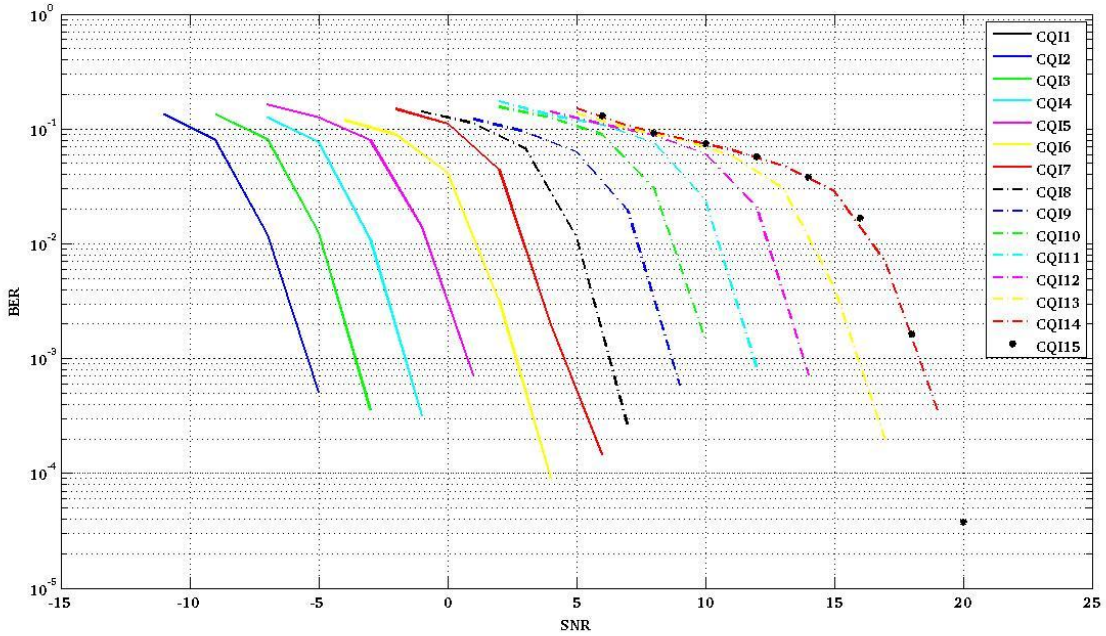
a) Set the following parameters
   - CQI Index[CQI varying from 1 to 15 for each run]
   - SNR Range (in dB) – Minimum[choose appropriate SNR range from the below graphs depends on SNR time of the simulation vary]
   - SNR Range (in dB) – Maximum
   - SNR Range (in dB) - Step Size [1] (can be higher steps to speed up the time)

b) Generate the topology and Run the scenario for each of the CQI indices

Sample Result:

Files to make the below plot –

- 'BER' and 'SNR' columns in "dlLinkPerformanceInfo.txt". Plot them in a Semilog scale for different CQI values.



Observation:

- The BER curve shifts right as the CQI index increases.

3.3.3 Link level BER Performance with various transmission modes

Objective:

To observe the BER (Bit Error Rate)/BLER(Block Error rate) performance of the link for various transmission modes

Procedure:

a) Set the following parameters
   - CQI Index [1]
   - SNR Range (in dB) – Minimum [choose appropriate SNR range from the below graphs depends on SNR time of the simulation vary]
   - SNR Range (in dB) – Maximum
   - SNR Range (in dB) - Step Size [1] (can be higher steps to speed up the time)
   - Number of Antennas in Each Node [as per configuration given below]
   - Downlink Transmission Mode [as per configuration given below]
   - Downlink Number of Layers [as per configuration given below]
   - Downlink Number of Codewords [as per configuration given below]

b) Generate the topology and Run the scenario for each of the Transmission modes

   Configurations:

   Transmission mode 1,Codeword -1,Number of layers -1,tx*Rx antennas -1*2

   Transmission mode 2,Codeword -2,Number of layers -2,tx*Rx antennas -2*2

   Transmission mode 3,Codeword -2,Number of layers -2,tx*Rx antennas -2*2

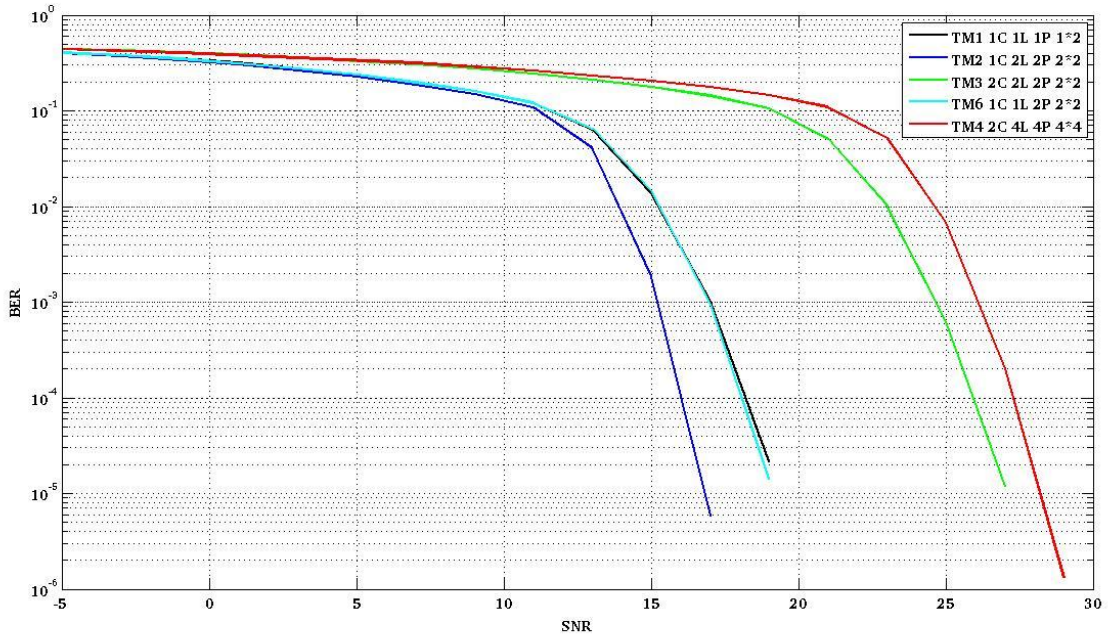
   Transmission mode 6,Codeword -1,Number of layers -1,tx*Rx antennas -2*2

   Transmission mode 4,Codeword -2,Number of layers -4,tx*Rx antennas -4*4

Sample Result:

Files to make the below plot –

- 'BER' and 'SNR' columns in "dlLinkPerformanceInfo.txt". Plot them in a Semilog scale for different Transmission modes.



Observations:

- Performance across transmission Modes are plotted.
- As the spatial multiplexing order increases the BER curve shifts right.

3.4 Study of Channel Characteristics

Following experiments are to study the channel characteristics

- PDF of fading channel
- Channel statistics
    - Autocorrelation of Fading channel
    - Average Fade Duration (AFD)
    - Level Crossing Rate (LCR)
    - Product of LCR and AFD
- Sampled Power delay profile for different BW systems
    - Load the Link Level Scenario

Configuring parameters:

These are the common parameters which are to be configured for PDF of Fading Channel and Channel Statistics.

- Simulation Mode [Link Level]
- Number of Sub frames [1000]
- Enable Channel Logs [Enabled]
- Downlink Link Adaptation Status [Disabled]

For faster simulation time and better curves, the following parameters can be configured.

- SNR Range (in dB) Minimum – 15
- SNR Range (in dB) Maximum – 15
- User Speed (in m/sec) – 20

3.4.1 PDF of fading channel

Objective:

To study the channel characteristics of fading channel

Procedure:

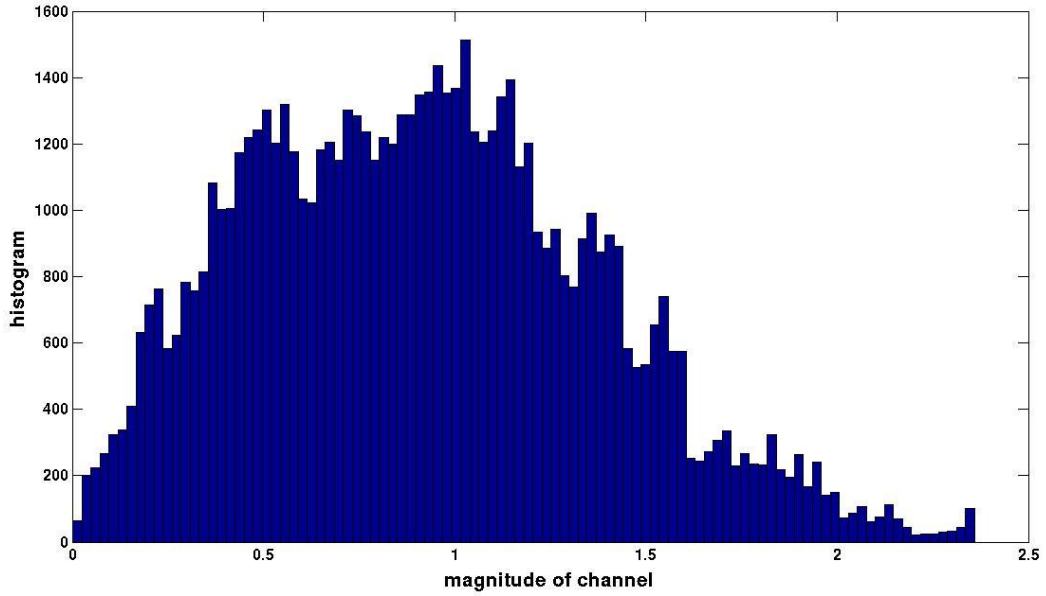
a) Set the following parameters
   - SNR Range (in dB)- Minimum [15]
   - SNR Range (in dB)- Maximum (For simulation only one SNR value can be considered) [15]

b) Generate the topology and Run the scenario.

Sample Result:

Files to make the below plot-

- "CannelLog.txt" for generating these results.



Observations:

- The PDF of the magnitude of the fading channel follow Rayleigh distribution.
- The probability that the magnitude of the fading channel is less is high.

3.4.2 Channel statistics

Objective:

To generate various channel statistics

Procedure:

a) Set the following parameters

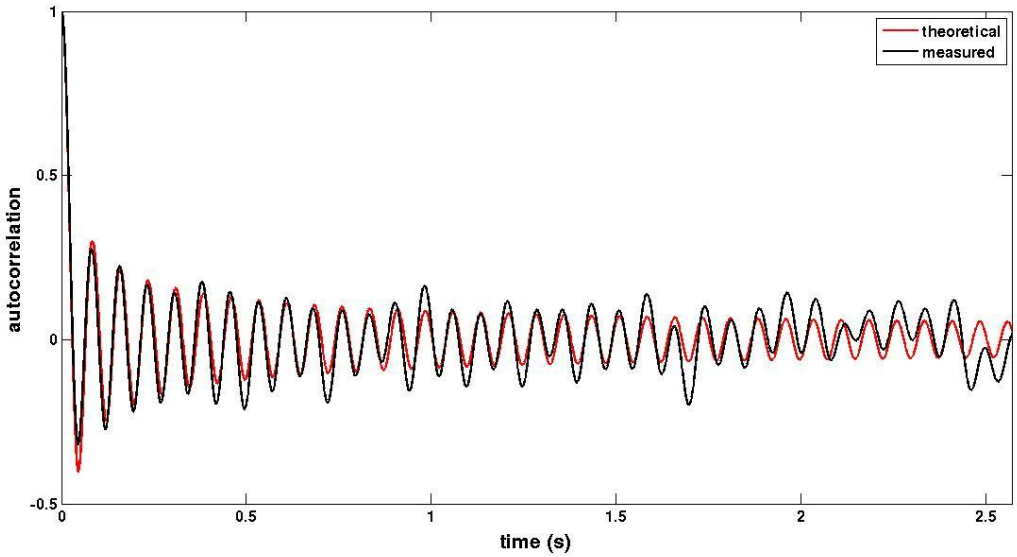
- SNR Range (in dB)- Minimum[15]
- SNR Range (in dB)- Maximum (For simulation only one SNR value can be considered)[15]

b) Generate the topology and Run the scenario for each of the CQI indices

Channel coefficients from the channelLogs.txt can be exported to any of the tools like Matlab to obtain the curves given below.

3.4.2.1 Autocorrelation of Fading Channel

Sample Result:

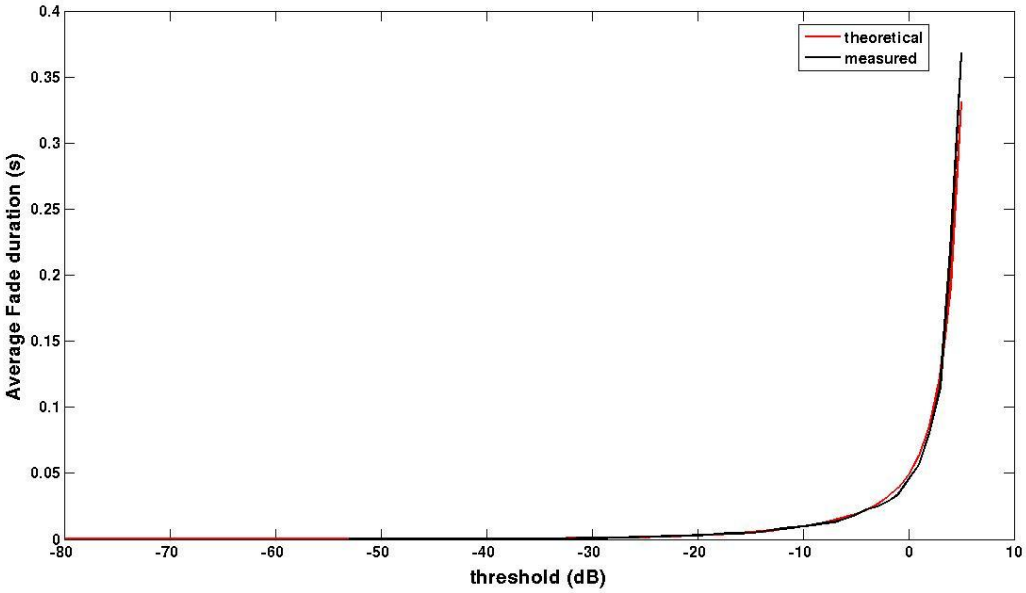


Observations:

- The first few cycles of the autocorrelation function of the fading channel match with the theoretical autocorrelation function $J_0(2\pi f_d \tau)$
- The frequency of the variation of the autocorrelation function depends on the doppler frequency.

3.4.2.2 Average Fade Duration (AFD)

Sample Result:

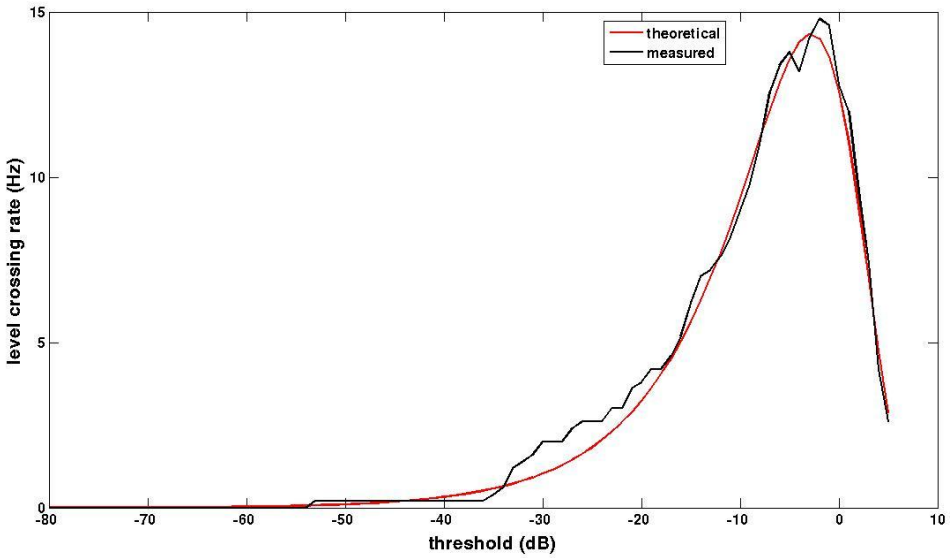


Observations:

- The average duration for which the channel magnitude level is below a threshold increases sharply for a threshold above and around 0dB.

3.4.2.3 Level Crossing Rate (LCR)

Result:

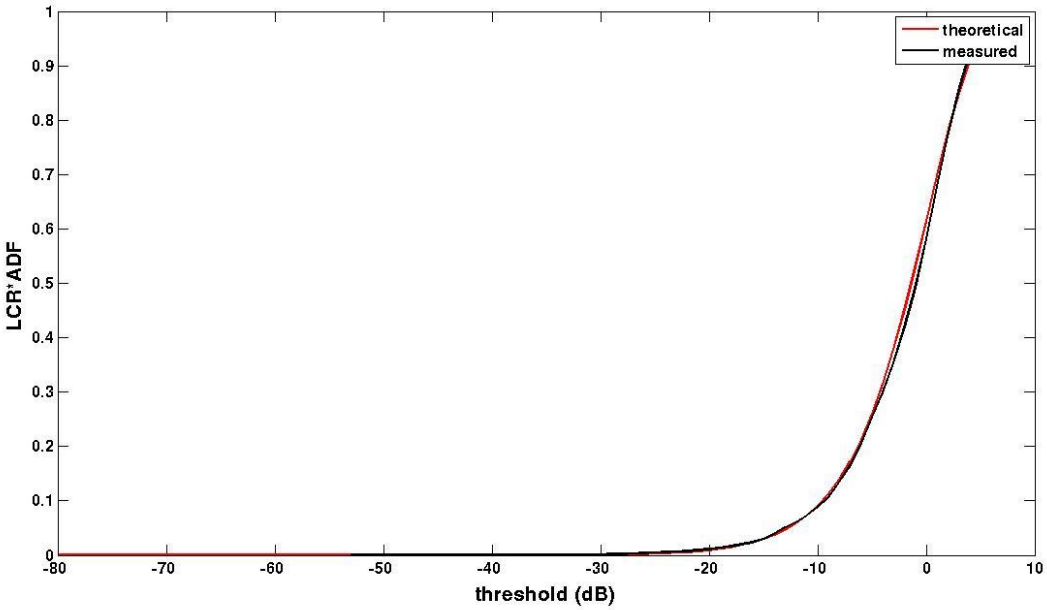


Observations:

- The peak value of the LCR indicates the doppler velocity.
  The LCR decreases for high threshold.

3.4.2.4 Product of LCR and AFD

Sample Result:

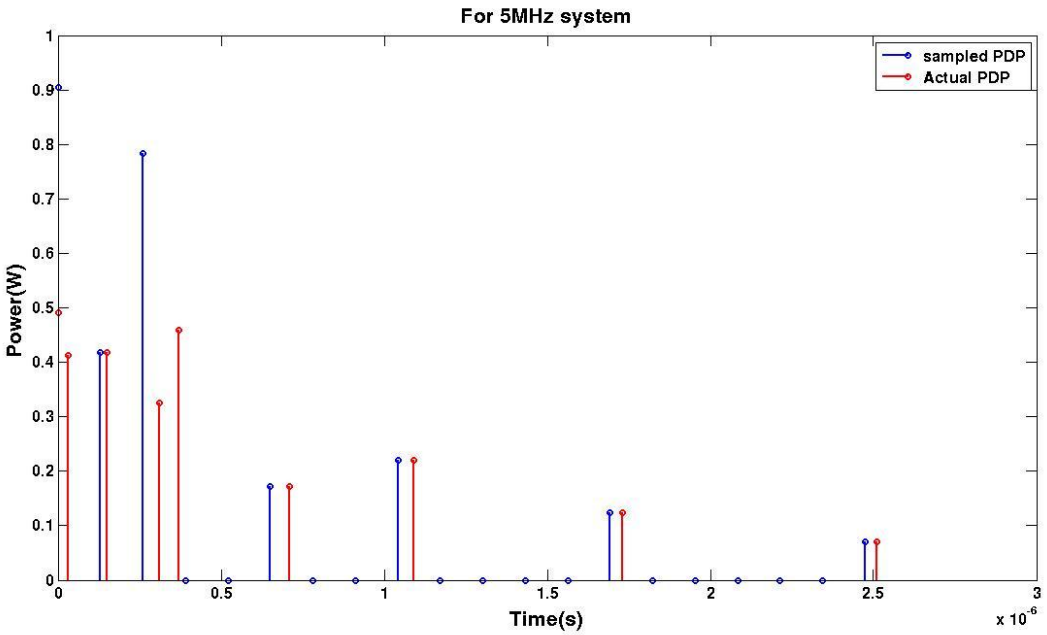


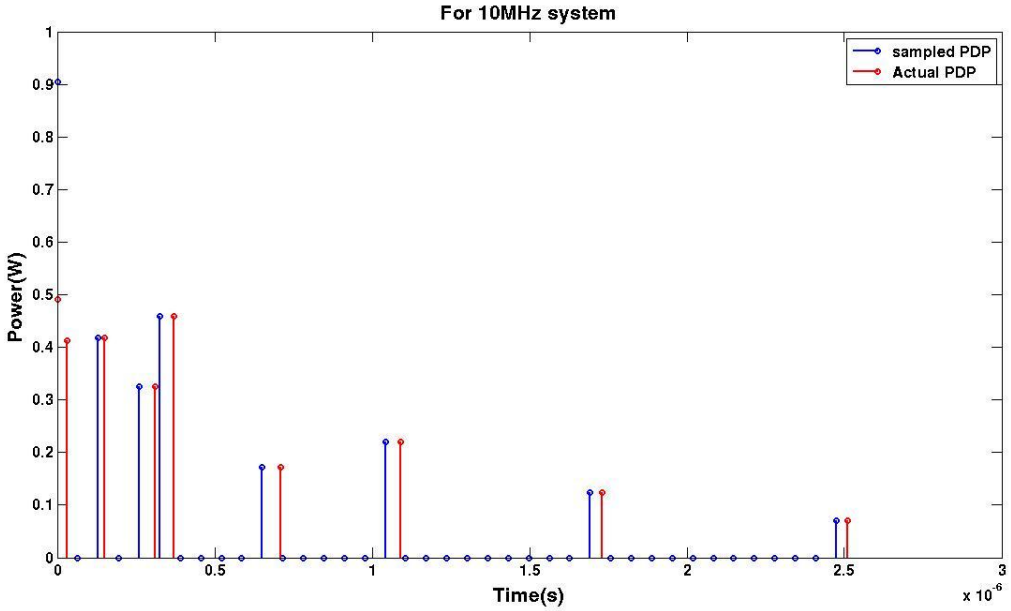
Observations:

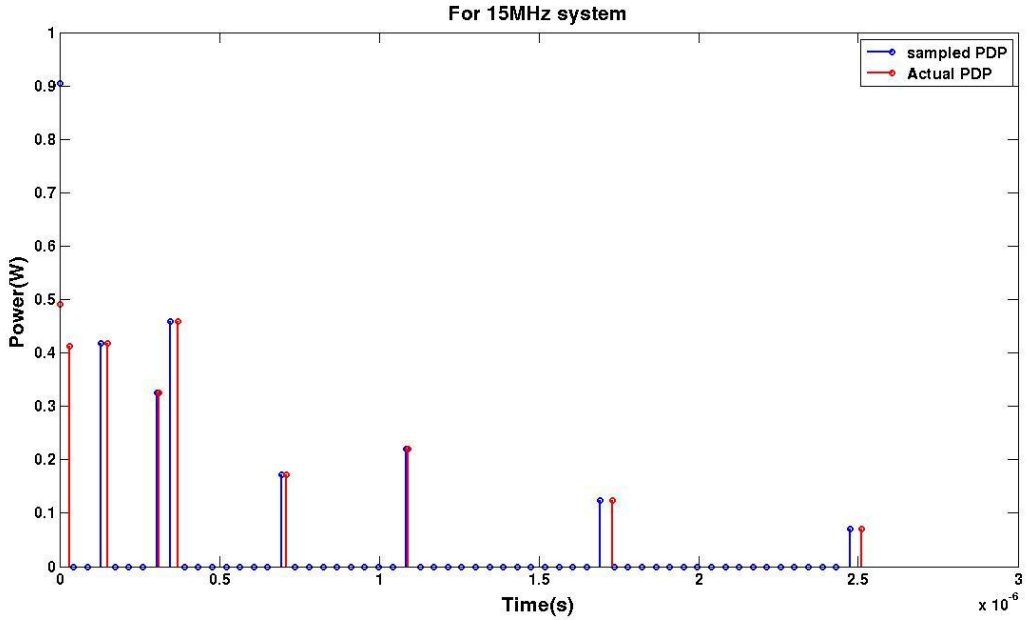
- The product of LCR and AFD increases with the threshold.
  The increase is sharp for a threshold above -10dB

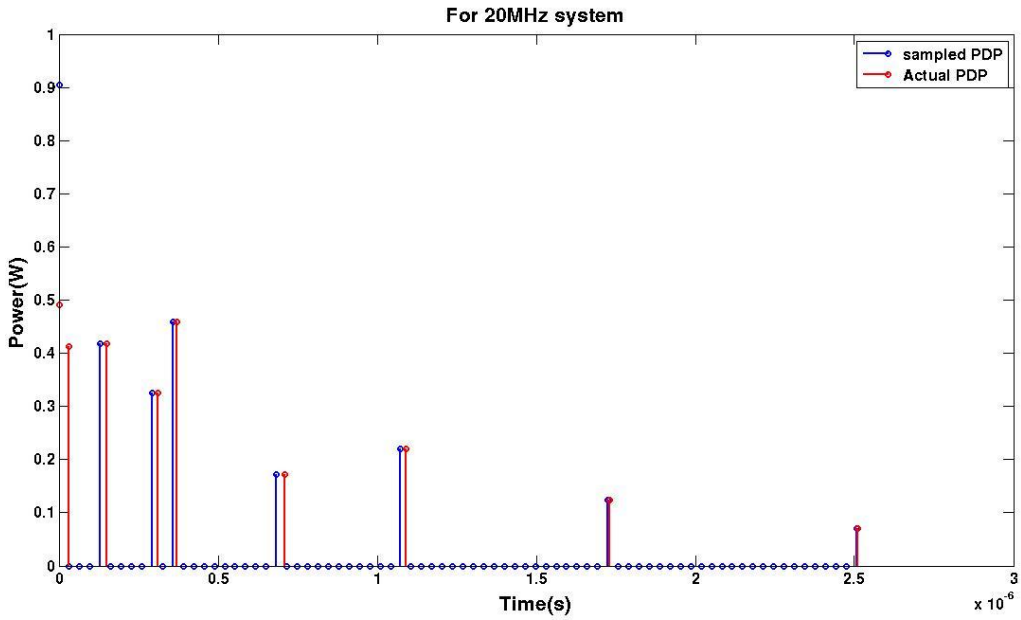
3.4.2.5 Sampled Power Delay profile for different BW systems

Result:




For 10MHz system
sampled PDP
Actual PDP
Power(W)
Time(s)
x 10^-6


For 15MHz system
sampled PDP
Actual PDP
Power(W)
Time(s)
x 10^-6



Observations:

- As the BW of the system increases the sampling frequency increases and thus can resolve the multipaths better.
- If the multipaths are not resolved while sampling then the power of the multipaths within the sampling duration are added to represent single path within that duration.

3.5 Study of relative interference levels in homogeneous networks

Objective:

To study the relative interference levels in networks where there are only Macro base stations ie. No overlay with Picos, femtos etc.

Procedure:

a) Set the following parameters

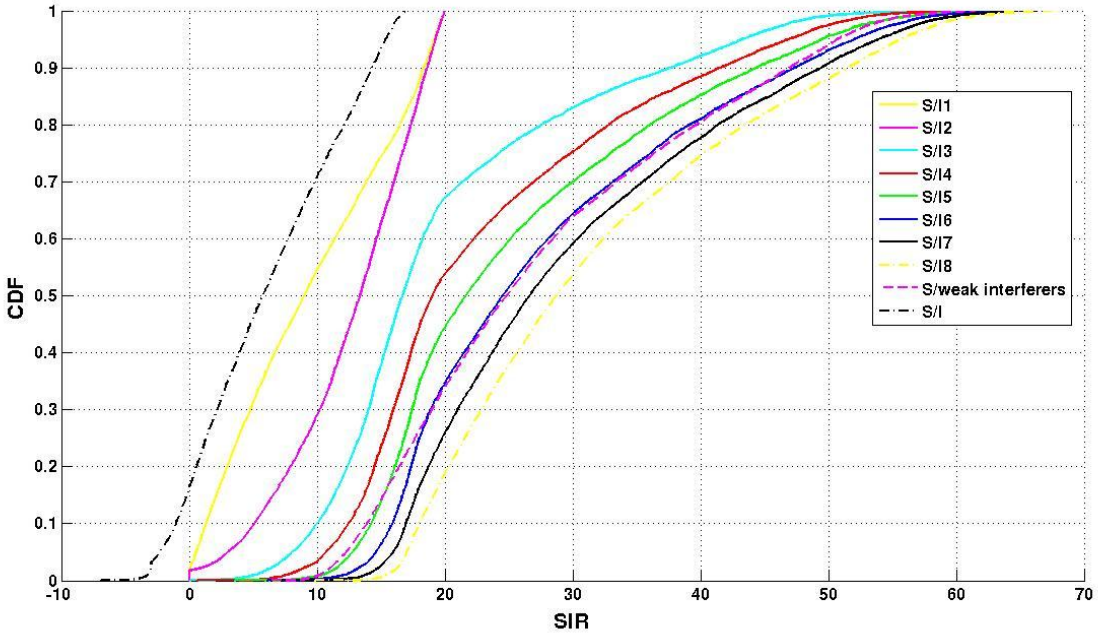
- Simulation Mode [System Level]
- Load UMa [UMa]
- Number of Nodes of Each Type [eNB-21,UE-2100]
- 'Maximum UEs per eNB' [200]

b) Generate the topology and Run the scenario for each of the Transmission modes

Sample Result:

Files to make the below plot –

- From the "downlinkPowerMatrix.txt" generated from the output file consider the signal strengths individually and manually calculate the signal to interference ratio and plot the CDF of calculated results.



Observations:

- The CDF of the ratio of signal power to weak interferers power (interferers excluding the strong eight) is following the signal power to 6th strong interferer power ratio CDF plot.
- The strong Interferers contribute more to the overall SIR CDF plot.

3.6 SINR Distribution for heterogeneous scenarios with Picos

Experiments to study SINR distribution in following scenarios:

- Effect of Pico locations and number of Picos
- Effect of power levels of Picos
- Effect of Pico bias

For the experiments in this section, following are the common parameters to be configured.

- Simulation Mode as System Level

The following parameters can be used in order to speed the simulation time.

- No of Subframes [1]
- Restricted Reception Status [Enabled]
- eNBs with actual reception [any one id from 0 to (no of sectors-1)]

3.6.1 Effect of Pico locations and number of Picos

Objective:

To study the effect of Pico locations and number of Picos on the SINR distribution

Procedure:

a) Set the following parameters

- Number of nodes of each type [see below]
- Node drop methods[eNB-Hexagonal, UE-Random, Pico-Random or Planned, PicoUE- Clustered Pico UE Drop]
- Locations of Picos in the Cell [see below]
- Planned Pico Locations in the Cell [see below]

For Random Pico configuration, following parameters can be chosen:

1)eNB-21 ,UE-2100,pico -0, picoUE-0

2) eNB-21 ,UE-1176,pico -21, picoUE-42

3) eNB-21 ,UE-1092,pico -42, picoUE-168

4) eNB-21 ,UE-924,pico -84, picoUE-336

For Planned Pico Configuration following parameters can be chosen:

1)eNB-21 ,UE-2100,pico -0, picoUE-0, pico location-[00000]

2) eNB-21 ,UE-1176,pico -21, picoUE-42,pico location-[125 0]

3) eNB-21 ,UE-1092,pico -42, picoUE-168,pico location-[193.19 51.76 -51.76 193.19]

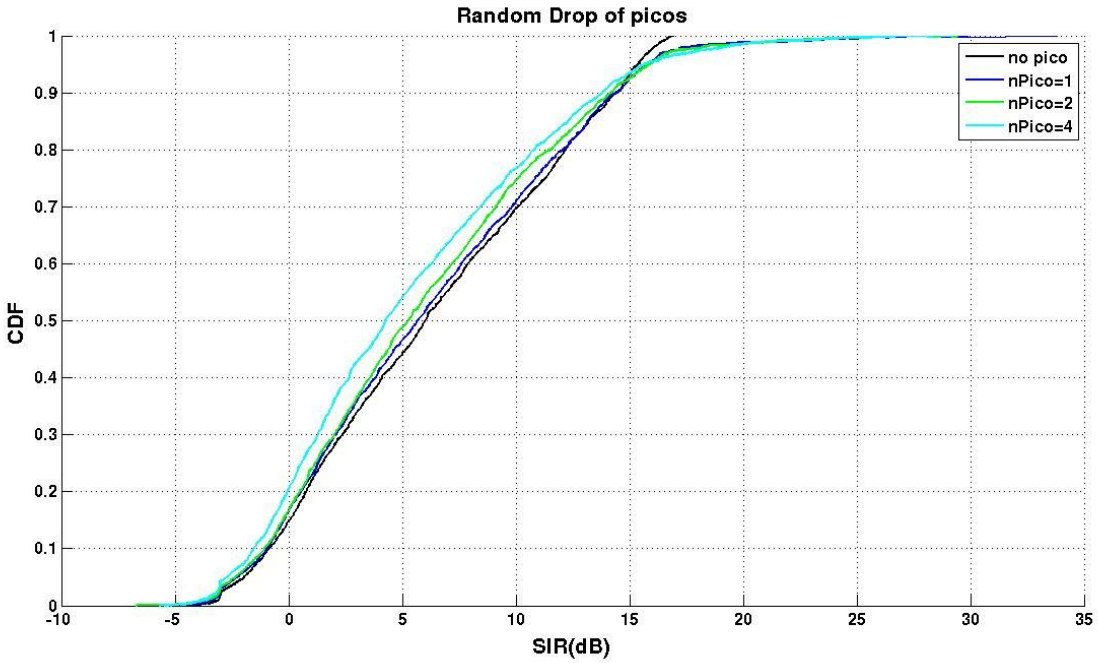
4) eNB-21 ,UE-924,pico -84, picoUE-336,picolocation-[196.96 34.73 185.43 74.92 -68.40 187.93 -27.83 198.043]

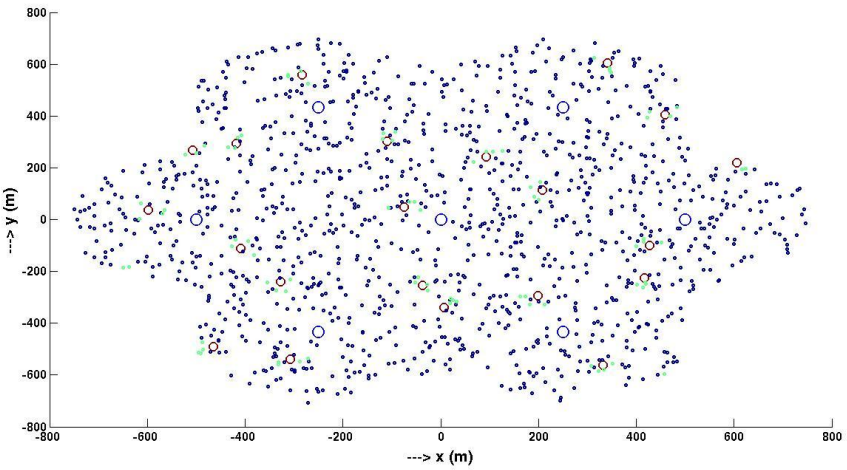
b) Generate the topology and Run the scenario different number of picos.

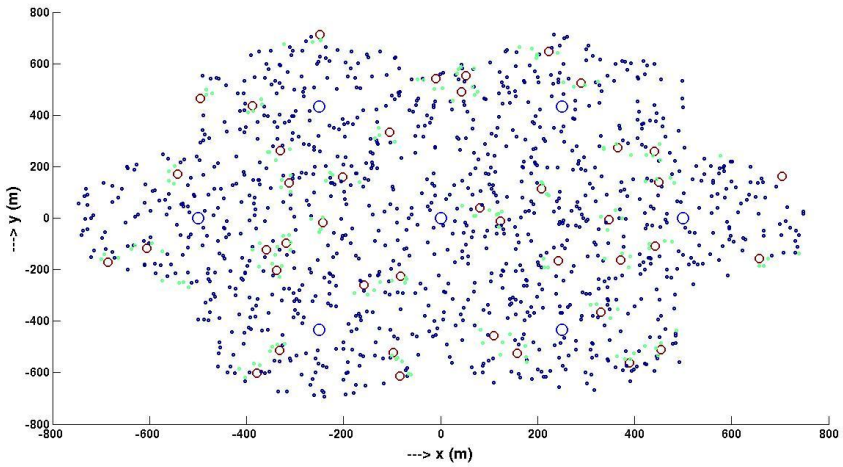
Sample Result:

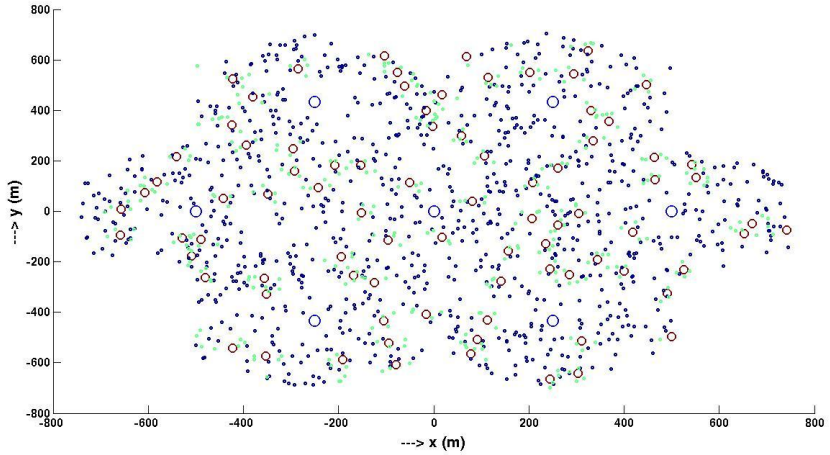
Files to make the below plot –

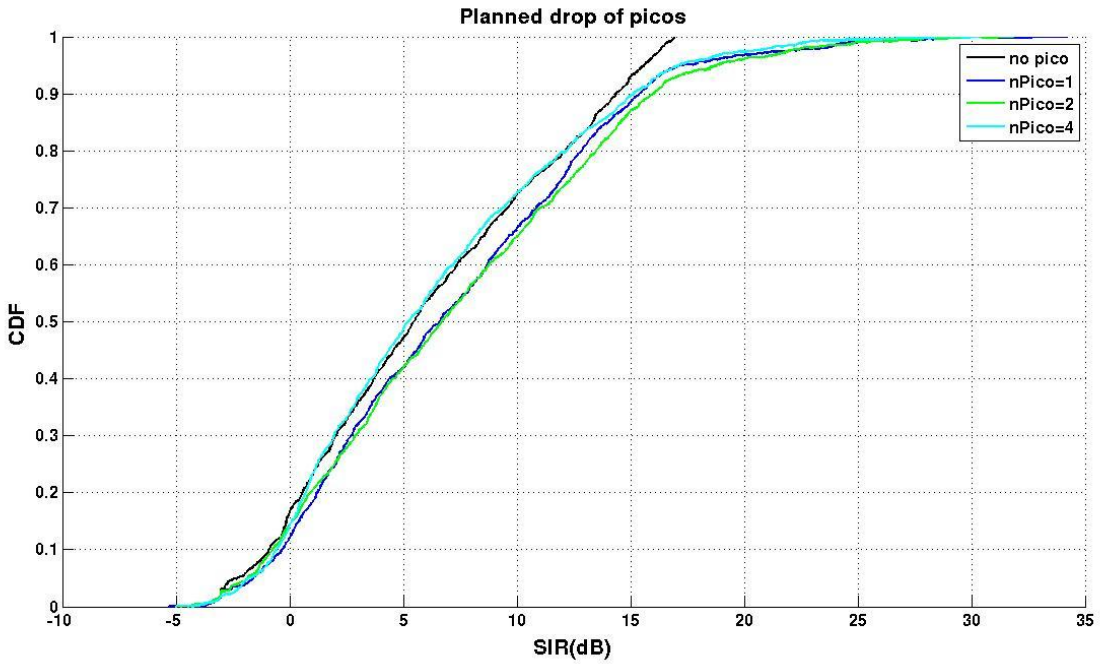
- Calculate the SIR[divide the strongest value to the sum of all other values of user] values for each users by considering the signal strength values from “downlinkPowerMatrix.txt” and plot the CDF and plot for different number of picos.

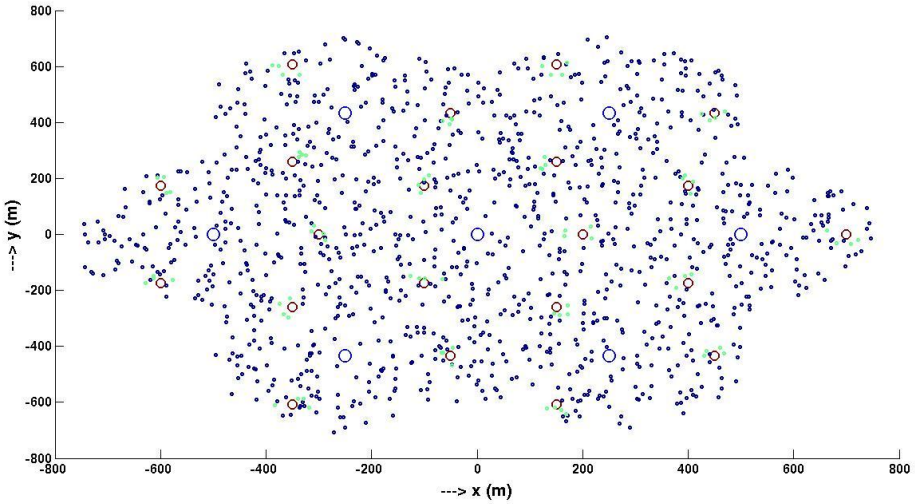

Random Drop of picos
CDF
SIR(dB)
no pico
nPico=1
nPico=2
nPico=4

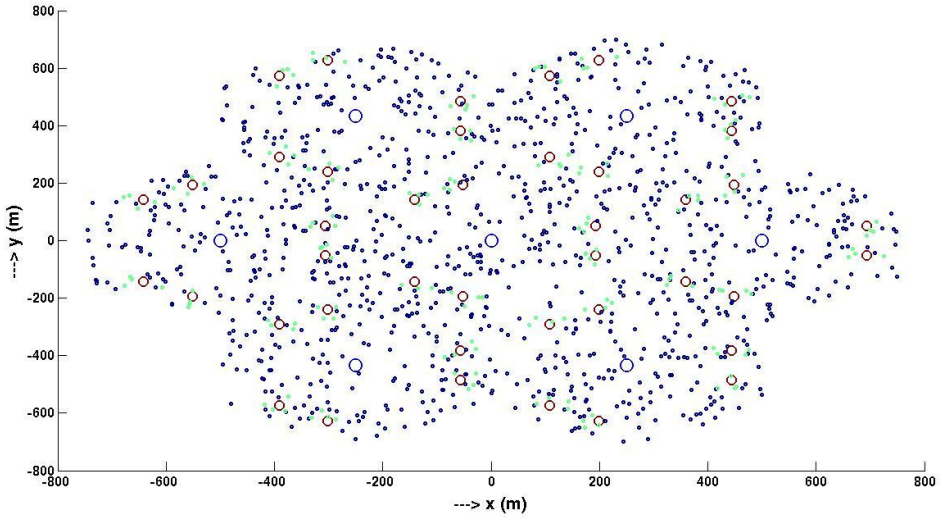

---> y (m)
---> x (m)

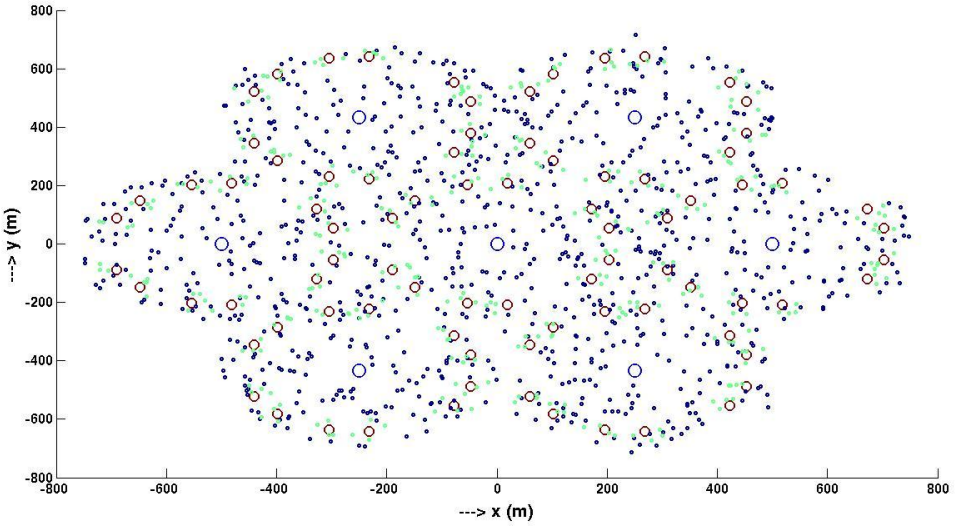

---> y (m)
---> x (m)


800
600
400
200
0
-200
-400
-600
-800
---> y (m)
-800
-600
-400
-200
0
200
400
600
800
---> x (m)


Planned drop of picos
no pico
nPico=1
nPico=2
nPico=4
CDF
SIR(dB)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
-10
-5
0
5
10
15
20
25
30
35


800
600
400
200
0
-200
-400
-600
-800
<--- y (m)
-800
-600
-400
-200
0
200
400
600
800
---> x (m)


800
600
400
200
0
-200
-400
-600
-800
<--- y (m)
-800
-600
-400
-200
0
200
400
600
800
---> x (m)



Observations:

- Compared to random drop planned drop leads to better SIR distribution.
- As the number of Picos increases in the system the performance gain till some extent (for the planned dropping case the SIR distribution improves till no. of Picos=2) and later no gain or it detoriates due to more interference.

3.6.2 Effect of power levels of Picos

Objective:

To study the effect of power levels of Picos on the SINR distribution

Procedure:

a) Set the following parameters

- Number of nodes of each type [see below]
- Node drop methods [see below]
- Locations of Picos in the Cell [see below]
- Planned Pico Locations in the Cell [see below]
- Transmission Power of Node (in dBm) (Pico Transmit Power 30dbm,25dbm,35dbm)

For Planned Pico Configuration:

1)eNB-21 ,UE-2100,pico -0, picoUE-0, pico location-[00000]

2) eNB-21 ,UE-1176,pico -21, picoUE-42,pico location-[125 0]

3) eNB-21 ,UE-1092,pico -42, picoUE-168,pico location-[193.19 51.76 -51.76 193.19]

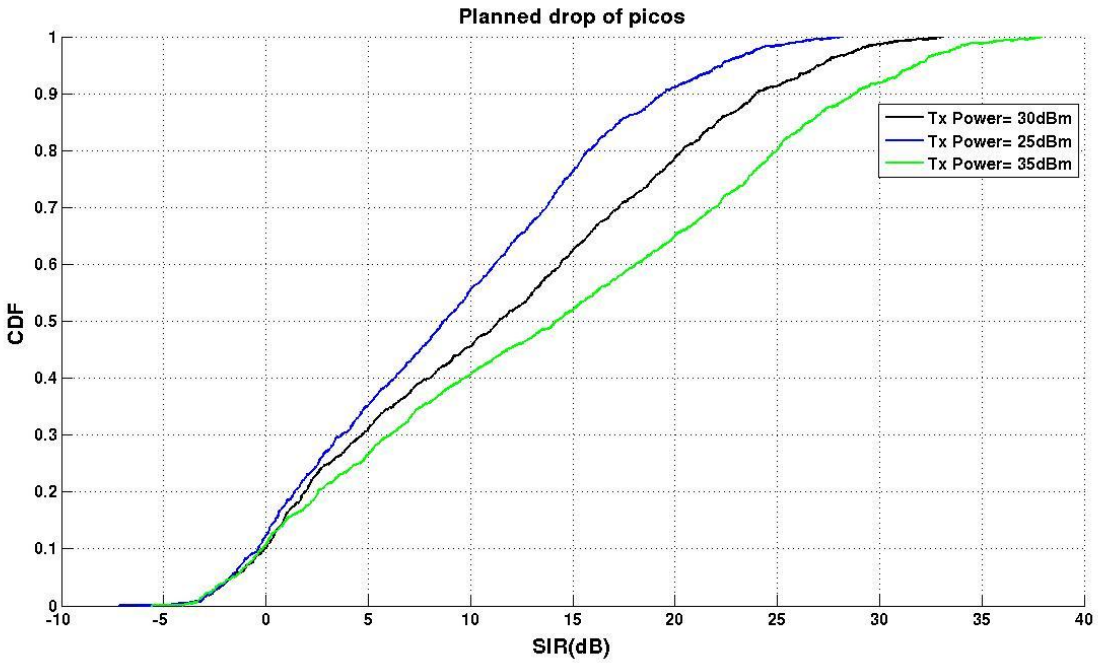
4) eNB-21 ,UE-924,pico -84, picoUE-336,picolocation-[196.96 34.73 185.43 74.92 -68.40 187.93 -27.83 198.043]

b) Generate the topology and Run the scenario for different transmitted power of picos.

Sample Result:

Files to make the below plot –

- Calculate the SIR[divide the strongest value to the sum of all other values of user] values for each users by considering the signal strength values from "downlinkPowerMatrix.txt" and plot the CDF and plot for different transmitter power of picos.



Observations:

- As the Transmit power of the Pico is increased the SIR CDF plot shifts right i.e. users have better SIR. (scenario with more clustered users considered here)

3.6.3 Effect of pico bias

Objective:

To study the effect of power levels of Picos on the SINR distribution

Procedure:

a) Set the following parameters

- Number of nodes of each type [eNB -21,UE-2100]
- Node drop methods [Choose as given in the earlier experiment]
- Locations of Picos in the Cell [Choose as given in the earlier experiment]

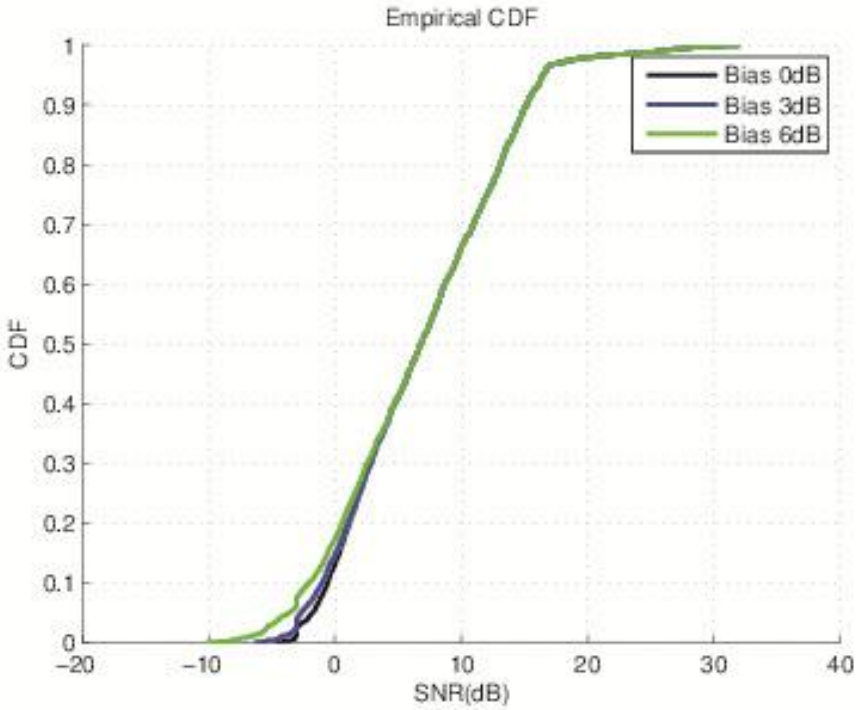
- Planned Pico Locations in the Cell [Choose as given in the earlier experiment]
- Pico Bias (in dB)[Bias – 0,3,6 db]

b) Generate the topology and Run the scenario for different picoBisa's.

Sample Result:

Files to make the below plot –

- Calculate the SIR[divide the strongest value to the sum of all other values of user] values for each users by considering the signal strength values from "downlinkPowerMatrix.txt" and plot the CDF and plot for different pico Bias.



Observations:

- As the pico bias increases few users experience more interference resulting in a shift in starting point of SIR CDF.

3.7 Study of CQI variation

Experiments to study:

- CQI variations for different users
- CQI variations in different sub bands

For the experiments in this section, following are the common parameters to be configured.

- Simulation Mode as System Level

3.7.1 CQI variations for different users

Objective:

To study the CQI variation for different users

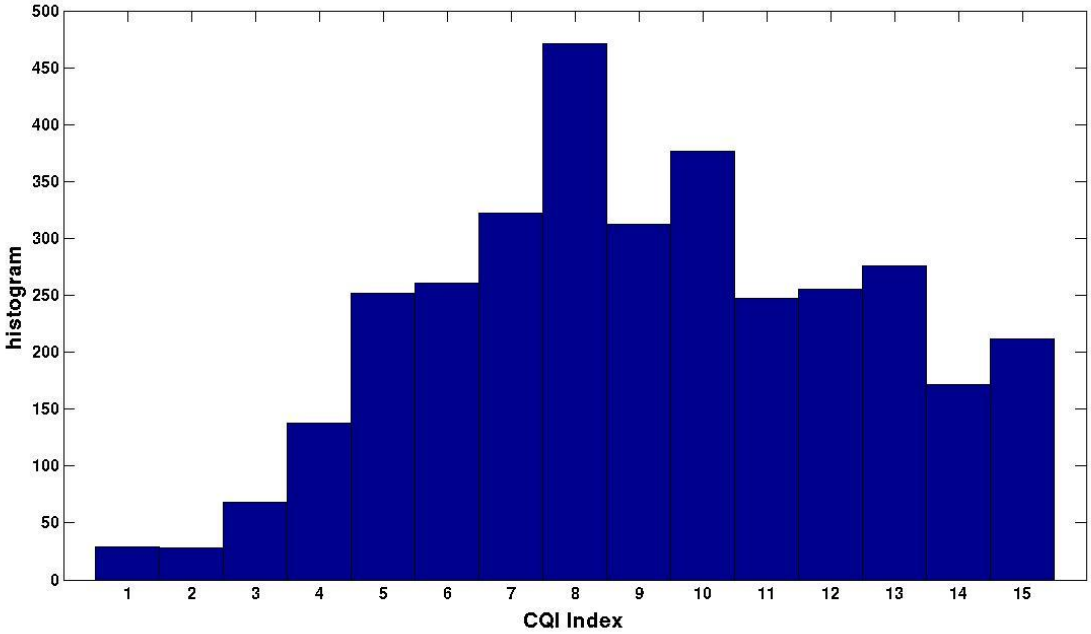
Procedure:

a) Set the following parameters
   - Number of Sub frames- 26
   - Bandwidth (in MHz) [5]
   - Number of Downlink Resource Blocks [25]
   - Number of Nodes (eNB) [21]
   - Number of Nodes (UE) [210 (10 users/sector)]
   - Type of Scheduler- Round Robin
   - Method of Resource Allocation- Distributed
   - Periodic Mode-Mode [1 0]; wideband CQI no PMI
   - Restricted Reception Status- Disabled
   - Maximum UEs per eNB- 20
b) Generate the topology and Run the scenario for each of the CQI indices

Sample Result:

Files to make the below plot

- plot the Histogram of "CQI_Indices" from "WideBandCQIlogs.txt".



Observation:

- The CQI index distribution across users is similar to gaussian distribution.

3.7.2 CQI variations in different sub bands

Objective:

To study the CQI variation for different sub-bands

Procedure:

a) Set the following parameters

- Number of Sub frames- 115
- Bandwidth (in MHz)- 5MHz
- Number of Downlink Resource Blocks-25
- Number of Nodes (eNB)- 21
- Number of Nodes (UE) – 210 (10 users/sector)
- Type of Scheduler- Round Robin
- Method of Resource Allocation- Localized
- Periodic Mode- Mode [2 0]; subband CQI no PMI
- Restricted Reception Status- Enabled
- eNBs with actual reception [any one id from 0 to (no of sectors-1)]
- Maximum UEs per eNB- 20

b) Generate the topology and Run the scenario for each of the CQI indices

Sample Result:

Files to make the below plot:

- wideBandCqi.txt and plot CQI index for different subframe and subbands.

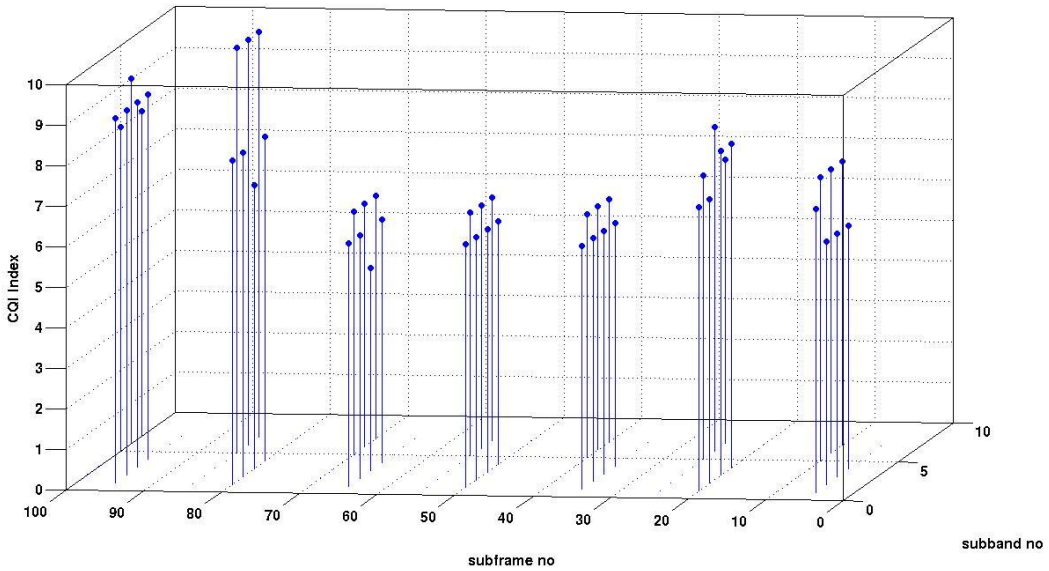


Fig. For Medium SNR user with low doppler

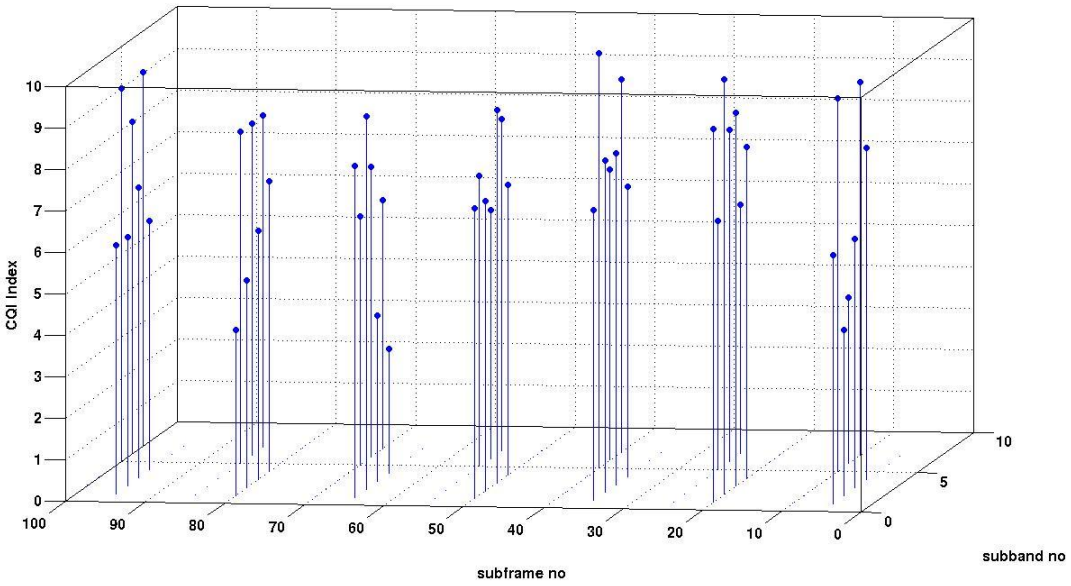


Fig. For medium SNR user with high doppler

Observations:

- As the doppler increases the CQI index variation with time increases.
- Variation of the CQI index across the band of frequencies can be observed.