5G LTE Radio Measurements Logging and Plotting

Software: NetSim Pro v13.2.20 (64-bit), Visual Studio 2022.

Project Download Link:

https://github.com/NetSim-TETCOS/5G_Radio_Measurements_v13_2_20/archive/refs/heads/main.zip

Follow the instructions specified in the following link to download and setup the Project in NetSim:

https://support.tetcos.com/en/support/solutions/articles/14000128666-downloading-and-setting-up-netsim-file-exchange-projects

Introduction

NetSim 5G Radio measurements include pathloss, received power, SINR, MCS, CQI, and Beamforming gain, which useful for an in-depth understanding of network performance. These parameters are recorded in a .csv file which can be opened from the results window post simulation.

Features

1. Users can plot Pathloss, Shadow Fading Loss, Total Loss, Received Power, SNR, Beam Forming Gain, MCS Index, and CQI Index vs. time using NetSim Plot.

2. Users can log Pathloss, Shadow Fading Loss, Total Loss, Rx_ Received Power, SNR, Beam Forming Gain, MCS Index, and CQI Index with time stamps, to a CSV log file.

3. Users need to provide a file-based input (per a certain format) at the start of simulation for the parameters to be plotted or logged.

4. The plots are unique to
   a. Each gNB-UE pair
   b. Carrier ID
   c. DL or UL

5. The log entries are unique to
   a. Each gNB-UE pair
   b. Carrier ID
   c. DL or UL
   d. Each layer

6. The output parameters for different MIMO layers ($Min\ (N_t, N_r)$) are stacked in a single plot

7. Parameters are logged every slot time (1ms) and plotted.

8. There is no restriction in NetSim on the number of gNBs / UE in the network.

Example

Network Scenario:

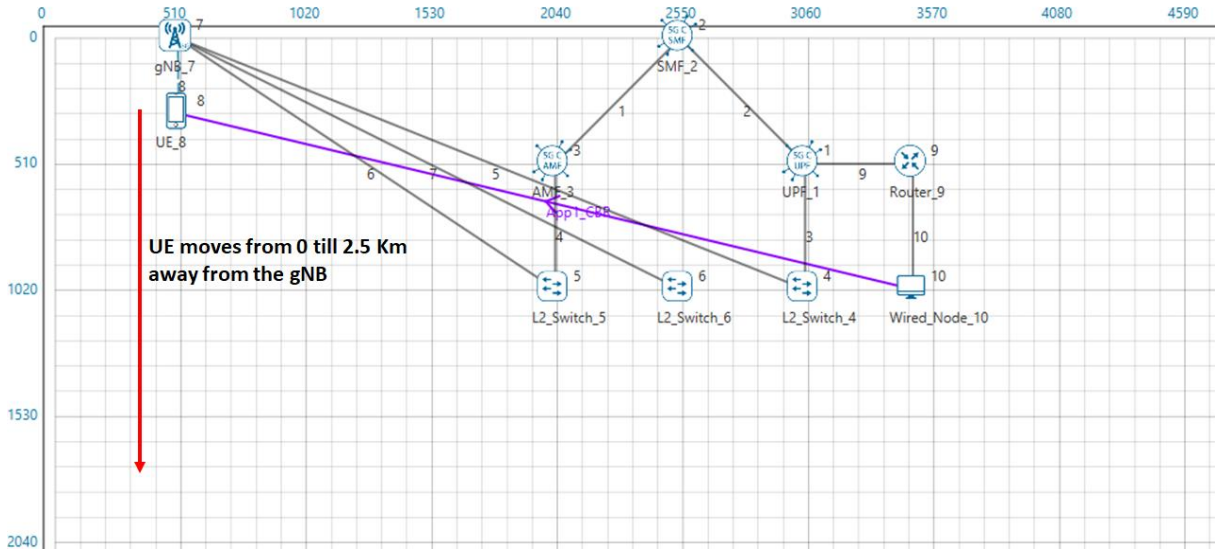
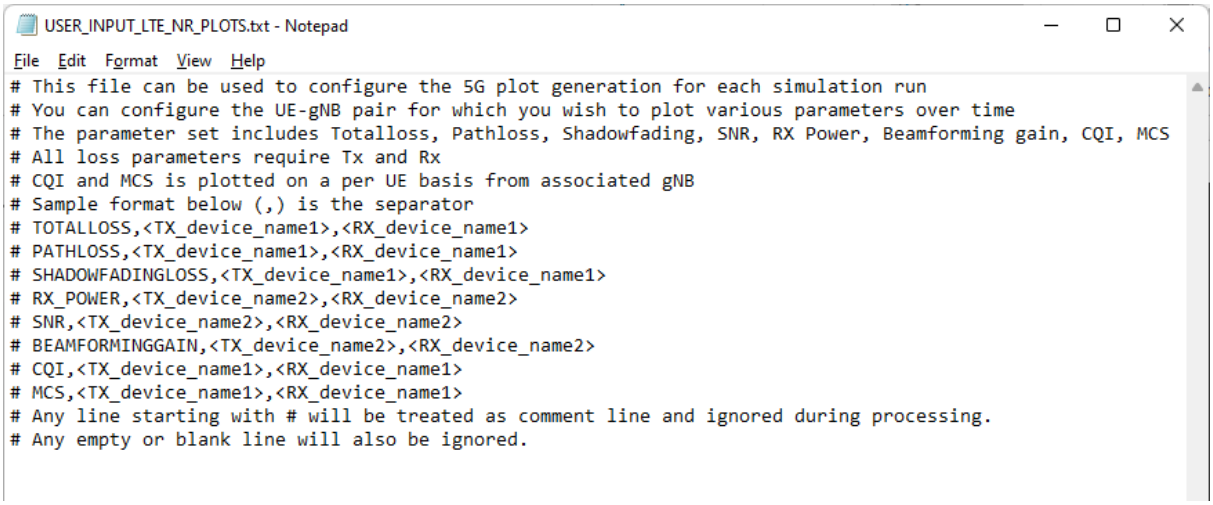


Figure 1: Network Topology in this experiment

Simulation parameters

Parameter	Value
gNB transmit power	40 dBm
gNB bandwidth	10 MHz
gNB Tx/Rx	2 x 1
DL:UL Ratio	4:1
UE Transmit power	23 dBm
UE Tx/Rx	1 x 2
UE Mobility	File Based Mobility
Beamforming	Enabled
Channel model	3G PP UMa
LOS probability	0
Traffic	DL CBR 10 Mbps
Simulation Time	50 seconds

- Upon running the simulation, a text file will open for the user to provide input for logging and plotting radio measurement parameters.



- For plotting, the input is per the format $< \boldsymbol{parameter} >, < \boldsymbol{device1} >, < \boldsymbol{device2} >$ in the text file. To log gNB – UE (DL) data flow the gNB would be the 1st device while the UE would be the 2nd device. In the reverse direction (UL, UE to gNB) the UE would be the 1st device and the gNB the 2nd devices. In case of multiple gNBs, this input can be given for various gNB-UE pairs.
- For logging, the input is per the format $\boldsymbol{LOG} < \boldsymbol{space} >< \boldsymbol{parameter} >$. This will log the specified parameter for all the gNB-UE pairs in the network.
- Inputs are not case sensitive.
- For the above example, the input in the text file for logging and plotting all the parameters will be:

  TOTALLOSS,gNB_7,UE_8
  PATHLOSS,gNB_7,UE_8
  SHADOWFADINGLOSS,gnb_7,ue_8
  RX_POWER,gNB_7,UE_8
  SNR,gNB_7,UE_8
  BEAMFORMINGGAIN,gNB_7,UE_8
  CQI,gNB_7,UE_8
  MCS,gNB_7,UE_8
  LOG TOTALLOSS
  LOG PATHLOSS
  LOG SHADOWFADINGLOSS
  LOG RX_POWER
  LOG SNR
  LOG BEAMFORMINGGAIN
  LOG CQI
  LOG MCS

- If LOG SNR entry is part of the user input file, Interference power and SINR are also logged along as associated parameters.
- Once the simulation starts, In the command prompt window it will show a message as "**Please update, Save and close the file and press any key to continue**".

*USER_INPUT_LTE_NR_PLOTS.txt - Notepad

File Edit Format View Help

```
# This file can be used to configure the 5G plot generation for each simulation run
# You can configure the UE-gNB pair for which you wish to plot various parameters over time
# The parameter set includes Totalloss, Pathloss, Shadowfading, SNR, RX Power, Beamforming gain, CQI, MCS
# All loss parameters require Tx and Rx
# CQI and MCS is plotted on a per UE basis from associated gNB
# Sample format below (,) is the separator
# TOTALLOSS,<TX_device_name1>,<RX_device_name1>
# PATHLOSS,<TX_device_name1>,<RX_device_name1>
# SHADOWFADINGLOSS,<TX_device_name1>,<RX_device_name1>
# RX_POWER,<TX_device_name2>,<RX_device_name2>
# SNR,<TX_device_name2>,<RX_device_name2>
# BEAMFORMINGGAIN,<TX_device_name2>,<RX_device_name2>
# CQI,<TX_device_name1>,<RX_device_name1>
# MCS,<TX_device_name1>,<RX_device_name1>
# Any line starting with # will be treated as comment line and ignored during processing.
# Any empty or blank line will also be ignored.
TOTALLOSS,gNB_7,UE_8
PATHLOSS,gNB_7,UE_8
SHADOWFADINGLOSS,gnb_7,ue_8
RX_POWER,gNB_7,UE_8
SNR,gNB_7,UE_8
BEAMFORMINGGAIN,gNB_7,UE_8
CQI,gNB_7,UE_8
MCS,gNB_7,UE_8
LOG TOTALLOSS
LOG PATHLOSS
LOG SHADOWFADINGLOSS
LOG RX_POWER
LOG SNR
LOG BEAMFORMINGGAIN
LOG CQI
LOG MCS
```

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- Add the parameters to be logged, close the input text file and press any key.
- Simulation starts running.

Results and discussion

Upon completion of simulation in the result window users can view the various plots.

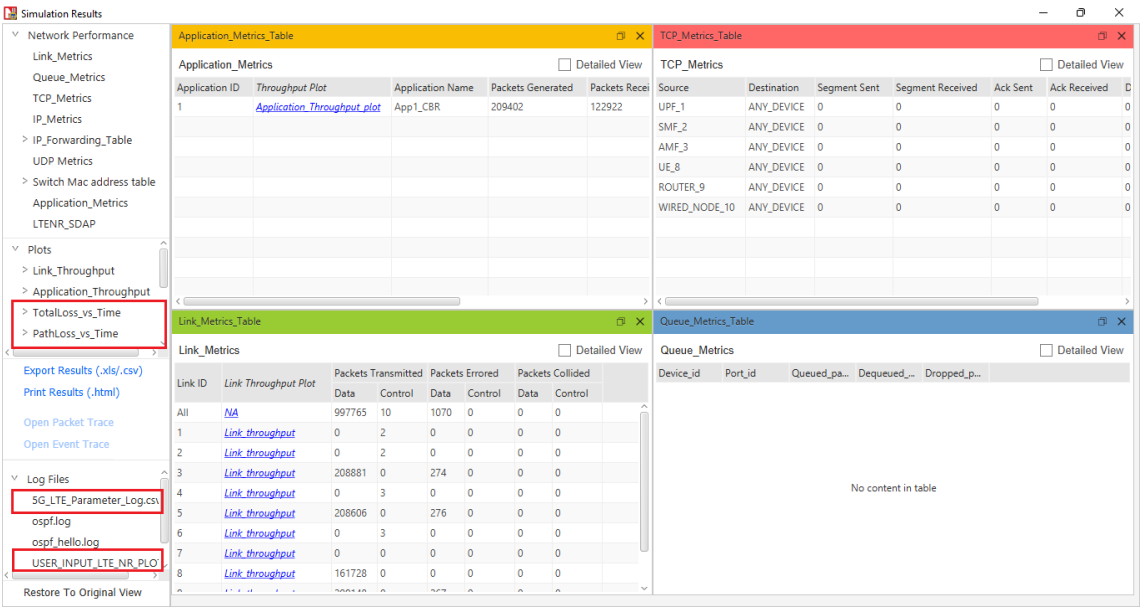


Figure 2: NetSim results dashboard with throughput highlighted

For each carrier, a separate plot is plotted with all the MIMO layers stacked in a single plot. The pathloss, shadow fading loss, and total loss remains same across the layers. Hence, for these parameters there is a single plot for all layers.

Result Plots

1. **Pathloss Plot**

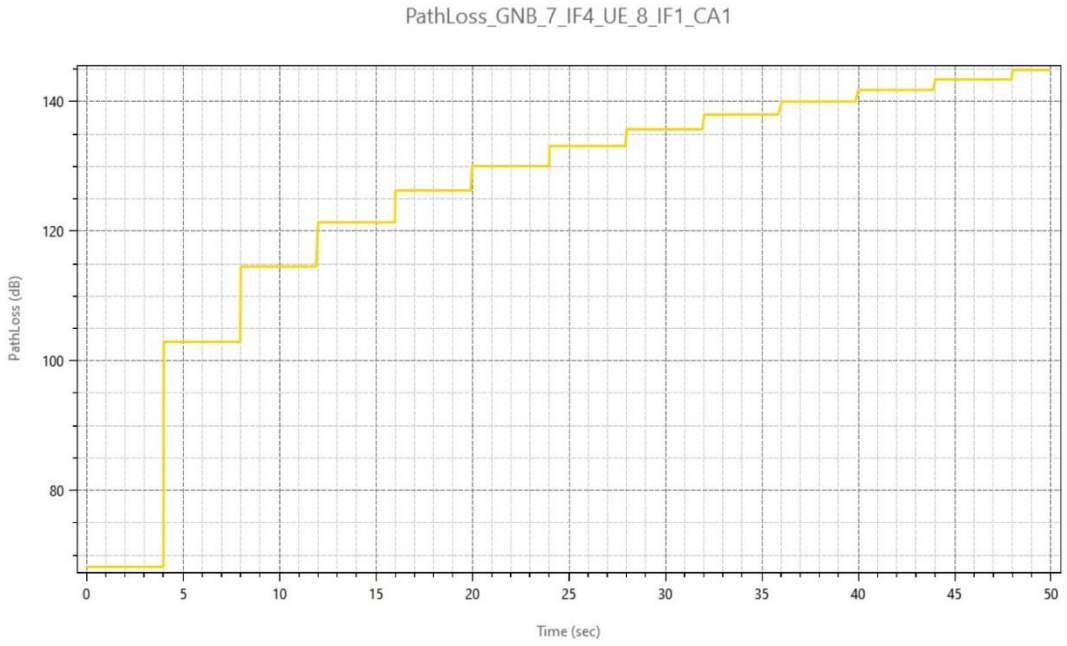


Figure 3: Pathloss Plot in NetSim

2. **Total Loss (Shadow Fading loss plus Path loss)**

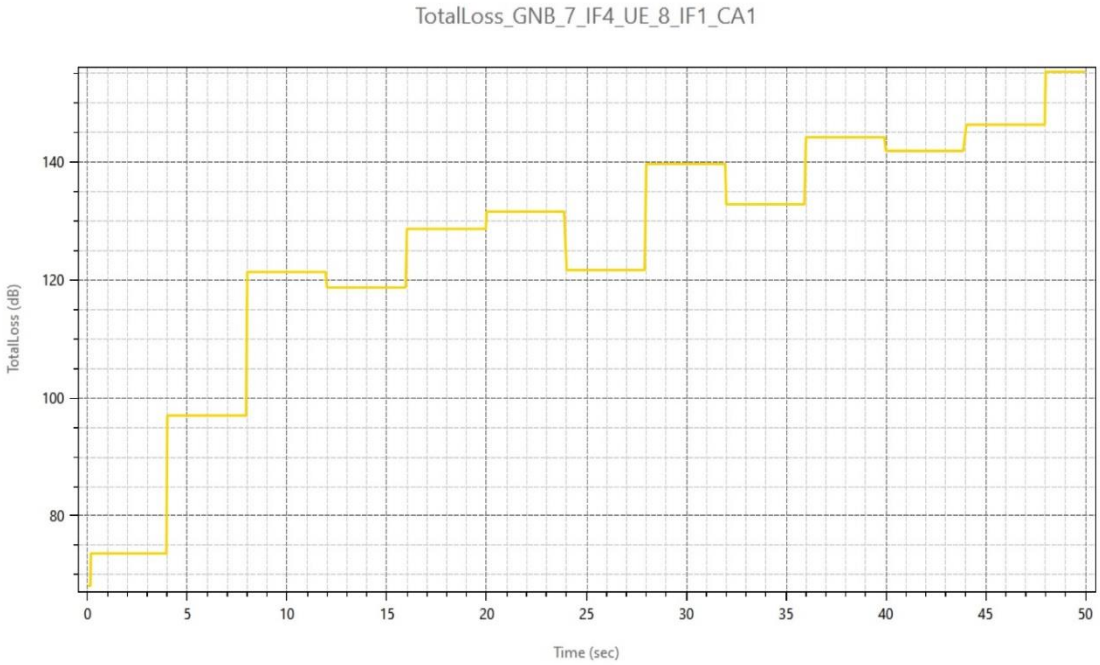


Figure 4: Total Loss (Shadow Fading loss plus Path loss) in NetSim

3. **Shadow Fading Loss**

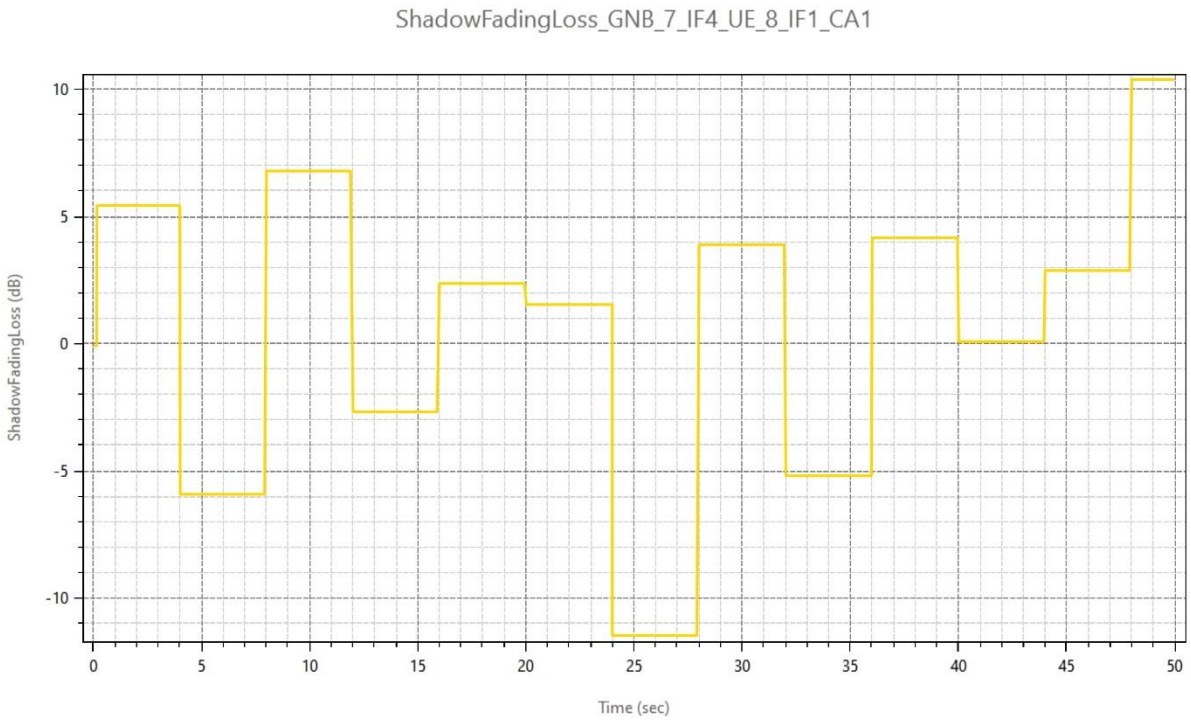


Figure 5: Shadow Fading Loss in NetSim

The plot title is ShadowFadingLoss_GNB_7_IF4_UE_10_IF1_CA1. And the naming convention is <ParameterType>_GNB_<ID>_IF<InterfaceID>_UE_<ID>_IF<InterfaceID>_CA<Carrier_ID>

4. Rx_Power Plot

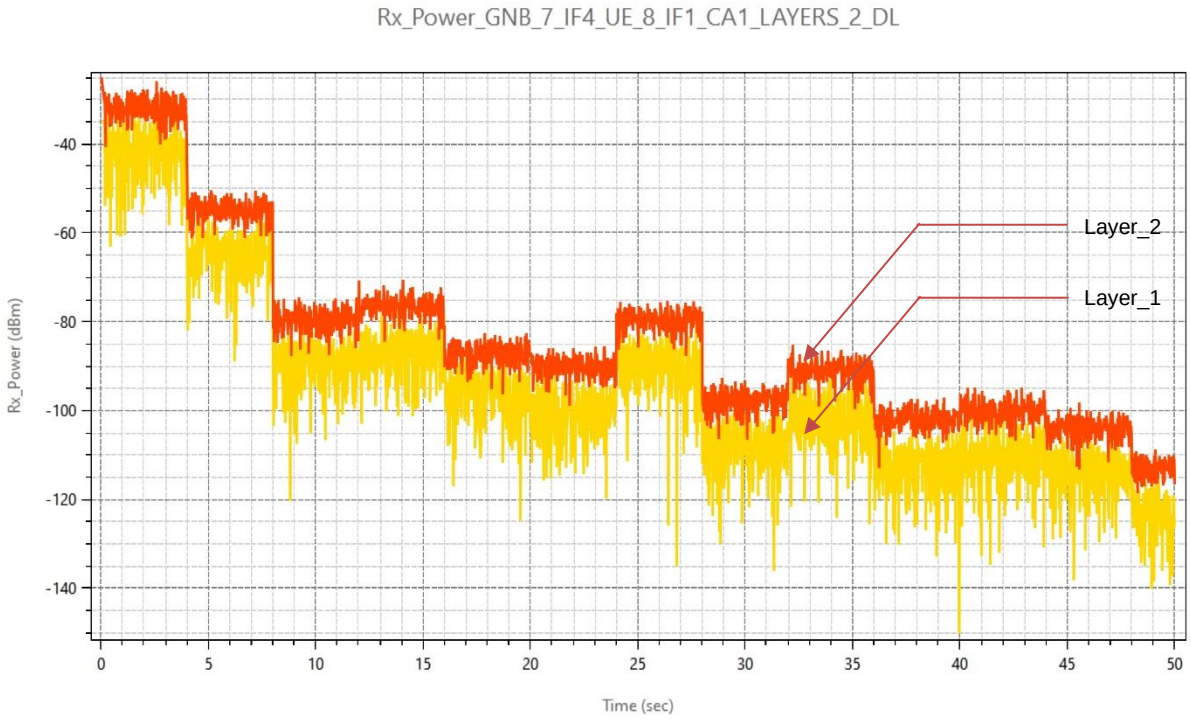


Figure 6: Rx_Power Plot in NetSim

5. SNR Plot

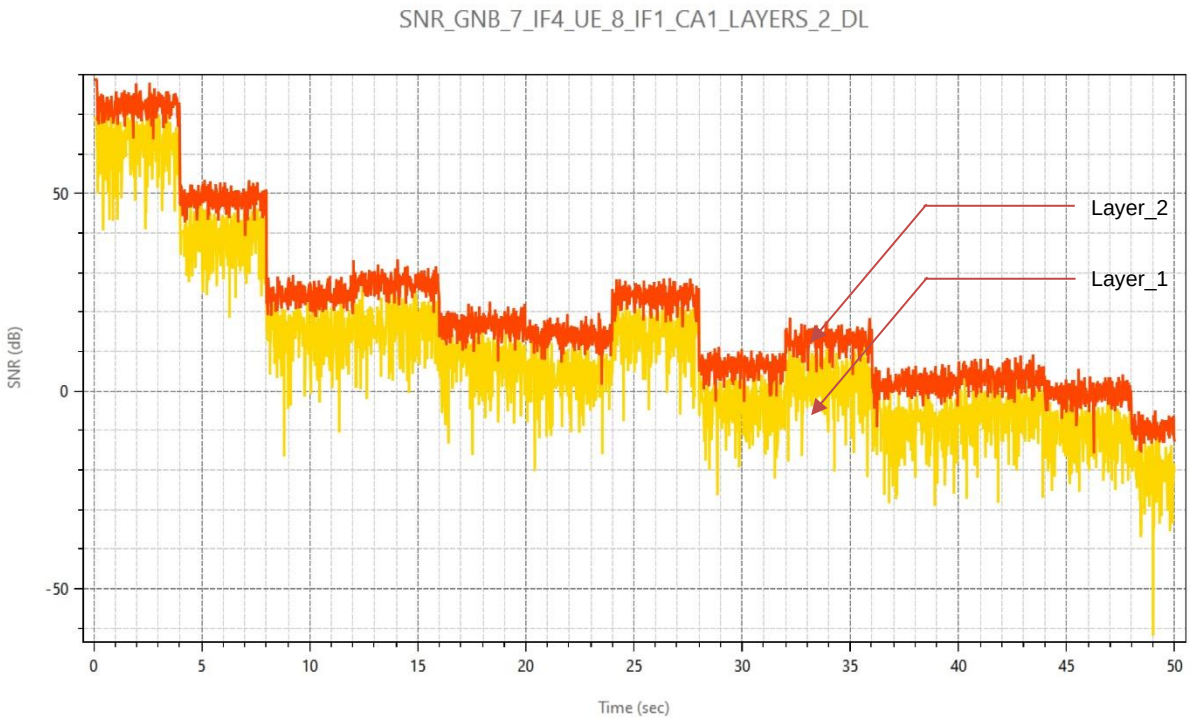


Figure 7: SNR Plot in NetSim

6. **Beam Forming Gain** (if, the Fast-Fading Model is set to Rayleigh with Eigen Beamforming)

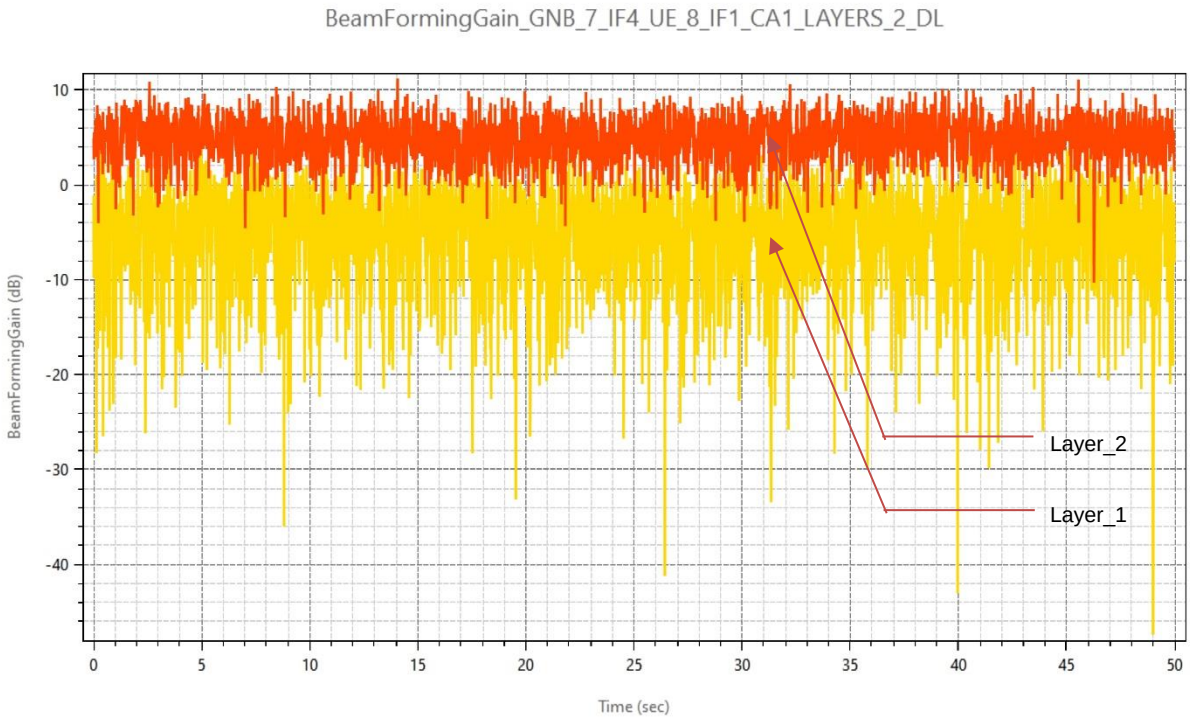


Figure 8: Beam Forming Gain in NetSim

7. **CQI Index Plot**

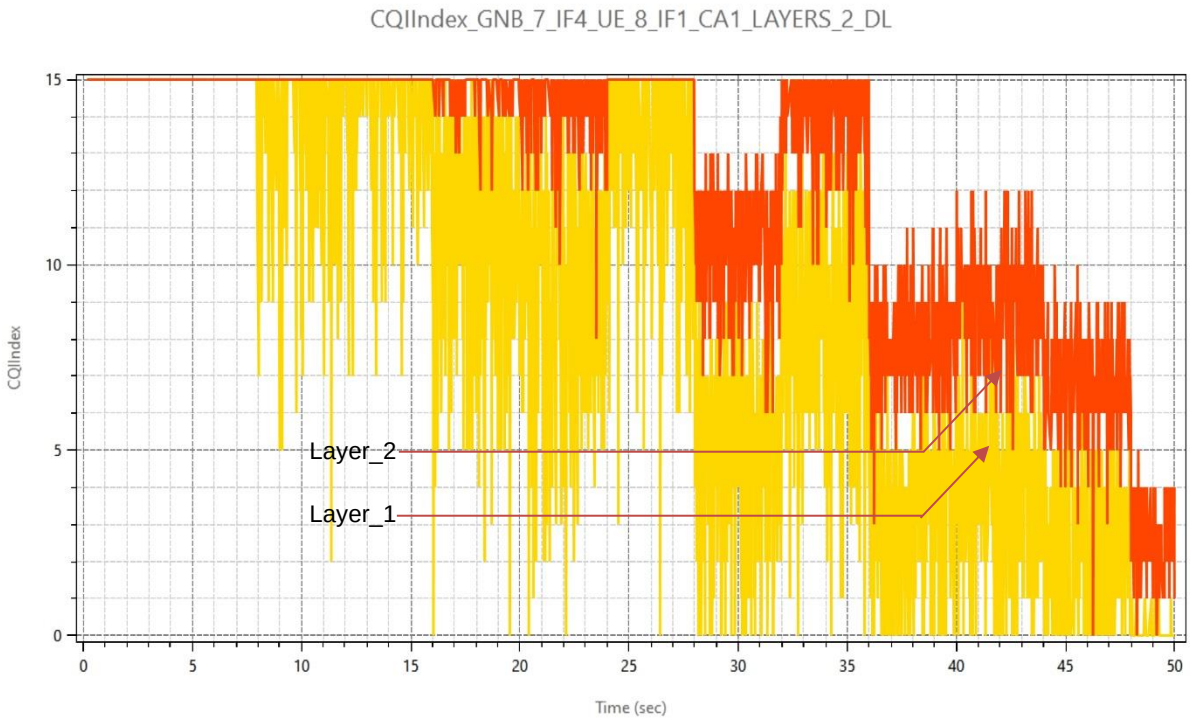


Figure 9: CQI Index Plot in NetSim

8. MCS Index Plot

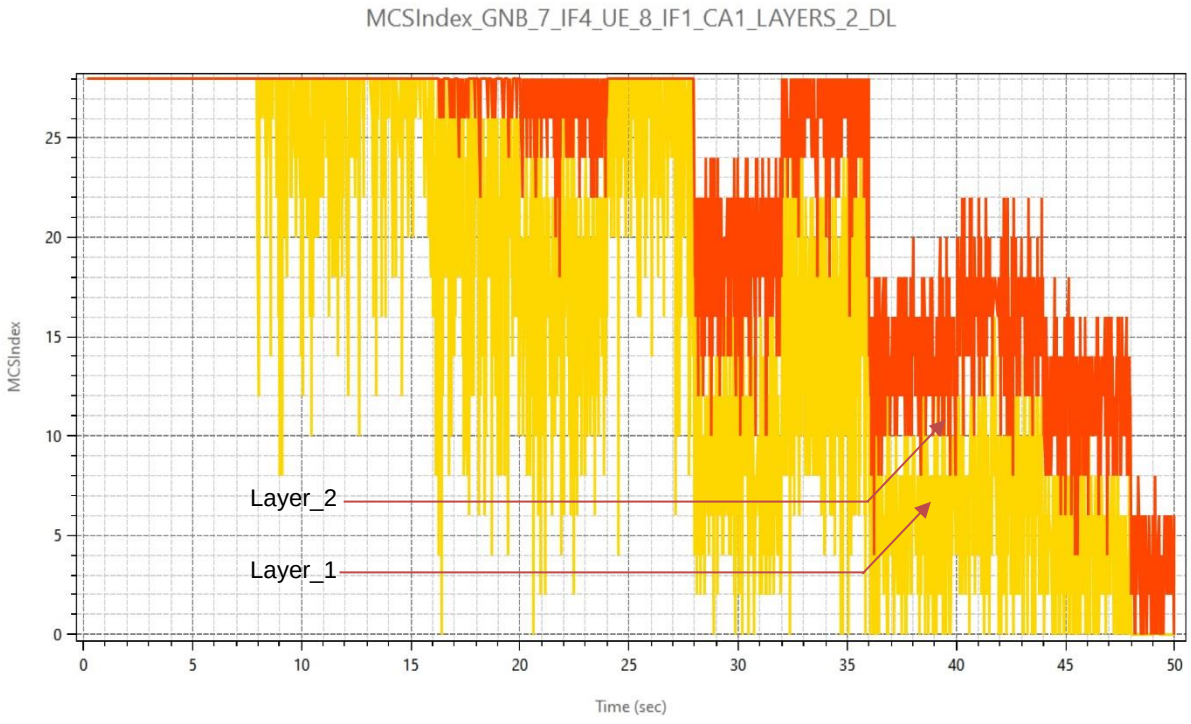


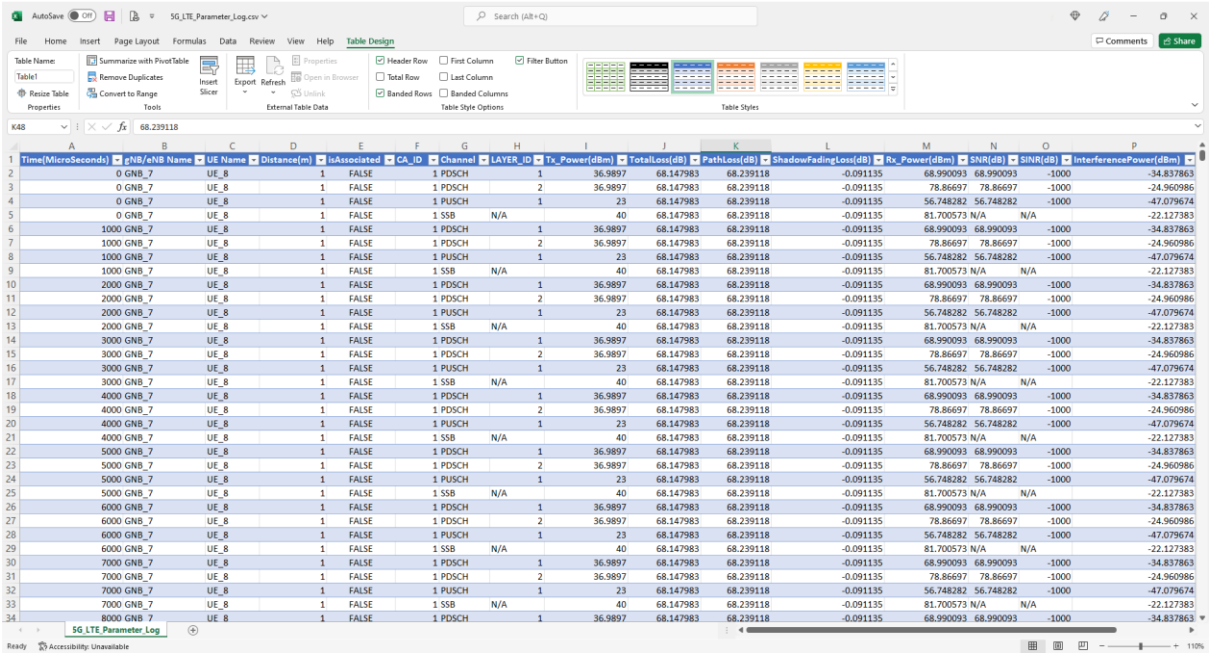
Figure 10: MCS Index Plot in NetSim

The parameters such as the SNR, Rx_Power, Beam Forming Gain, CQI Index, MCS Index are plotted for all MIMO layers. In case of multiple carriers, plot files are generated per carrier. The file name and the chart title consist of information such as

- Parameter

- gNB ID
- gNB Interface
- UE ID
- UE Interface
- Carrier ID
- Layer Count
- Channel information (DL/UL)

Parameter log file



Time(MicroSeconds)	gNB/eNB Name	UE Name	Distance(m)	isAssociated	CA_ID	Channel	LAYER_ID	Tx_Power(dBm)	TotalLoss(dB)	PathLoss(dB)	ShadowFadingLoss(dB)	Rx_Power(dBm)	SNR(dB)	SINR(dB)	InterferencePower(dBm)
0	GNB_7	UE_8	1	FALSE	1	PDSCH	1	36.9897	68.147983	68.239118	-0.091135	68.990093	68.990093	-1000	-34.837863
0	GNB_7	UE_8	1	FALSE	1	PDSCH	2	36.9897	68.147983	68.239118	-0.091135	78.86697	78.86697	-1000	-24.960986
0	GNB_7	UE_8	1	FALSE	1	PUSCH	1	23	68.147983	68.239118	-0.091135	56.748282	56.748282	-1000	-47.079674
0	GNB_7	UE_8	1	FALSE	1	SSB	N/A	40	68.147983	68.239118	-0.091135	81.700573	N/A	N/A	-22.127383
1000	GNB_7	UE_8	1	FALSE	1	PDSCH	1	36.9897	68.147983	68.239118	-0.091135	68.990093	68.990093	-1000	-34.837863
1000	GNB_7	UE_8	1	FALSE	1	PDSCH	2	36.9897	68.147983	68.239118	-0.091135	78.86697	78.86697	-1000	-24.960986
1000	GNB_7	UE_8	1	FALSE	1	PUSCH	1	23	68.147983	68.239118	-0.091135	56.748282	56.748282	-1000	-47.079674
1000	GNB_7	UE_8	1	FALSE	1	SSB	N/A	40	68.147983	68.239118	-0.091135	81.700573	N/A	N/A	-22.127383
2000	GNB_7	UE_8	1	FALSE	1	PDSCH	1	36.9897	68.147983	68.239118	-0.091135	68.990093	68.990093	-1000	-34.837863
2000	GNB_7	UE_8	1	FALSE	1	PDSCH	2	36.9897	68.147983	68.239118	-0.091135	78.86697	78.86697	-1000	-24.960986
2000	GNB_7	UE_8	1	FALSE	1	PUSCH	1	23	68.147983	68.239118	-0.091135	56.748282	56.748282	-1000	-47.079674
2000	GNB_7	UE_8	1	FALSE	1	SSB	N/A	40	68.147983	68.239118	-0.091135	81.700573	N/A	N/A	-22.127383
3000	GNB_7	UE_8	1	FALSE	1	PDSCH	1	36.9897	68.147983	68.239118	-0.091135	68.990093	68.990093	-1000	-34.837863
3000	GNB_7	UE_8	1	FALSE	1	PDSCH	2	36.9897	68.147983	68.239118	-0.091135	78.86697	78.86697	-1000	-24.960986
3000	GNB_7	UE_8	1	FALSE	1	PUSCH	1	23	68.147983	68.239118	-0.091135	56.748282	56.748282	-1000	-47.079674
3000	GNB_7	UE_8	1	FALSE	1	SSB	N/A	40	68.147983	68.239118	-0.091135	81.700573	N/A	N/A	-22.127383
4000	GNB_7	UE_8	1	FALSE	1	PDSCH	1	36.9897	68.147983	68.239118	-0.091135	68.990093	68.990093	-1000	-34.837863
4000	GNB_7	UE_8	1	FALSE	1	PDSCH	2	36.9897	68.147983	68.239118	-0.091135	78.86697	78.86697	-1000	-24.960986
4000	GNB_7	UE_8	1	FALSE	1	PUSCH	1	23	68.147983	68.239118	-0.091135	56.748282	56.748282	-1000	-47.079674
4000	GNB_7	UE_8	1	FALSE	1	SSB	N/A	40	68.147983	68.239118	-0.091135	81.700573	N/A	N/A	-22.127383
5000	GNB_7	UE_8	1	FALSE	1	PDSCH	1	36.9897	68.147983	68.239118	-0.091135	68.990093	68.990093	-1000	-34.837863
5000	GNB_7	UE_8	1	FALSE	1	PDSCH	2	36.9897	68.147983	68.239118	-0.091135	78.86697	78.86697	-1000	-24.960986
5000	GNB_7	UE_8	1	FALSE	1	PUSCH	1	23	68.147983	68.239118	-0.091135	56.748282	56.748282	-1000	-47.079674
5000	GNB_7	UE_8	1	FALSE	1	SSB	N/A	40	68.147983	68.239118	-0.091135	81.700573	N/A	N/A	-22.127383
6000	GNB_7	UE_8	1	FALSE	1	PDSCH	1	36.9897	68.147983	68.239118	-0.091135	68.990093	68.990093	-1000	-34.837863
6000	GNB_7	UE_8	1	FALSE	1	PDSCH	2	36.9897	68.147983	68.239118	-0.091135	78.86697	78.86697	-1000	-24.960986
6000	GNB_7	UE_8	1	FALSE	1	PUSCH	1	23	68.147983	68.239118	-0.091135	56.748282	56.748282	-1000	-47.079674
6000	GNB_7	UE_8	1	FALSE	1	SSB	N/A	40	68.147983	68.239118	-0.091135	81.700573	N/A	N/A	-22.127383
7000	GNB_7	UE_8	1	FALSE	1	PDSCH	1	36.9897	68.147983	68.239118	-0.091135	68.990093	68.990093	-1000	-34.837863
7000	GNB_7	UE_8	1	FALSE	1	PDSCH	2	36.9897	68.147983	68.239118	-0.091135	78.86697	78.86697	-1000	-24.960986
7000	GNB_7	UE_8	1	FALSE	1	PUSCH	1	23	68.147983	68.239118	-0.091135	56.748282	56.748282	-1000	-47.079674
7000	GNB_7	UE_8	1	FALSE	1	SSB	N/A	40	68.147983	68.239118	-0.091135	81.700573	N/A	N/A	-22.127383
8000	GNB_7	UE_8	1	FALSE	1	PDSCH	1	36.9897	68.147983	68.239118	-0.091135	68.990093	68.990093	-1000	-34.837863

Figure 11: 5G log file with various parameters recorded over simulation time

The 5G_LTE_Parameter_Log.csv file logs the following details by default:

1. Time in Microseconds
2. gNB/eNB Name
3. UE Name
4. Distance between the gNB/eNB and the UE
5. Association Status (True/False)
6. Carrier ID
7. Channel Type (PDSCH/PUSCH/SSB)
8. MIMO Layer ID
9. Transmitter Power in dBm

Further based on the parameters specified in the user input file the following details are logged:

1. Total Loss in dB
2. Pathloss in dB
3. Shadow Fading Loss in dB
4. Received Power in dBm
5. SNR in dB
6. SINR in dB
7. Interference Power in dBm
8. Beamforming gain in dB
9. CQI Index
10. MCS Index

Implementation details and Assumptions:

- The PDSCH channel corresponds to downlink.
- The PUSCH channel corresponds to uplink.
- Parameters associated with PDSCH and PUSCH channels are logged only for associated gNB-UE pairs.
- Initially only SSB channel entries will be found in the log since association takes time.
- Interference is not modelled for uplink.
- The SSB control channel is independent of Layers.
- Analog Beamforming gain is logged for this channel and is used for received power computation.
- Interference is not modelled for this channel and hence SINR and Interference Power parameters are not logged.
- The SNR computed for SSB channel is used for control decisions such as Association and Handover and is not used to calculate the MCS Index or CQI Index.

Appendix: NetSim source code modifications

Open the Source codes in Visual Studio by going to Your work-> Workspace Options and Clicking on Open code button.

To the in LTE_NR project, files LTE_NR_Plot.c and LTE_NR_Parameter_Log.c has been added. These files contain the definitions of the functions that responsible for plotting and logging parameters associated with 5G/LTE networks in NetSim.

The function fn_NetSim_LTE_NR_Init_Plots and fn_NetSim_LTE_NR_init_Parameter_Log has been called in LTENR.c file for initializing the plot.

```
static bool isplotinit= false;
//Function prototype
int fn_NetSim_LTE_NR_Init_F();
int fn_NetSim_LTE_NR_Configure_F(void** var);
int fn_NetSim_LTE_NR_Finish_F();
#pragma endregion

#pragma region LTENR_INIT
_declspec(dllexport) int fn_NetSim_LTE_NR_Init()
{
    if(!isplotinit)
    {
    fn_NetSim_LTE_NR_Init_Plots();
    fn_NetSim_LTE_NR_init_Parameter_Log();
    isplotinit= true;
    }
return fn_NetSim_LTE_NR_Init_F();
}
```

The initialization of functions and functions to add values to the plot and CSV logs are called from the LTENR_handleStartSlotEvent() function which is part of the LTENR_PHY.c file as highlighted below:

```
void LTENR_handleStartSlotEvent()
{
NETSIM_ID gnbId = pstruEventDetails->nDeviceId;
```

```
NETSIM_ID gnbIf = pstruEventDetails->nInterfaceId;
ptrLTENR_GNBPHY phy = LTENR_GNBPHY_GET(gnbId, gnbIf);

#pragma warning (disable : 4047)
int CA_ID = pstruEventDetails->szOtherDetails;
#pragma warning (default : 4047)

ptrLTENR_CA ca = phy->spectrumConfig->CA[CA_ID];

LTENR_resetSlot(phy, CA_ID);
print_ltenr_log("Starting new slot for gNB %d:%d\n", gnbId, gnbIf);
print_ltenr_log("CA_ID for Slot = %d\n", CA_ID);
print_ltenr_log("\tFrame Id = %d\n", phy->frameInfo[CA_ID]->frameId);
print_ltenr_log("\tSubFrame Id = %d\n", phy->frameInfo[CA_ID]->subFrameId);
print_ltenr_log("\tSlot Id = %d\n", phy->frameInfo[CA_ID]->slotId);
print_ltenr_log("\tSlot start time (us) = %lf\n", phy->frameInfo[CA_ID]->slotStartTime);
print_ltenr_log("\tslot end time (us) = %lf\n", phy->frameInfo[CA_ID]->slotEndTime);
print_ltenr_log("\tSlot type = %s\n", strLTENR_SLOTTYPE[phy->frameInfo[CA_ID]->slotType]);

phy->currentFrameInfo = phy->frameInfo[CA_ID];
phy->currentFrameInfo->Current_CA_ID = CA_ID;
if (phy->frameInfo[CA_ID]->slotId != ca->slotPerSubframe)
	LTENR_addStartSlotEvent(gnbId, gnbIf,
		phy->frameInfo[CA_ID]->slotEndTime, CA_ID);

ptrLTENR_ASSOCIATEDUEPHYINFO info = phy->associatedUEPhyInfo;
//
if (pstruEventDetails->dEventTime ==0 || pstruEventDetails->dEventTime==200000)
{
	for (NETSIM_ID d = 1; d <= NETWORK->nDeviceCount; d++)
	{
		for (NETSIM_ID in = 1; in <= DEVICE(d)->nNumOfInterface; in++)
		{
			if (!isLTE_NRInterface(d, in))
				continue;
			if (!isGNB(d, in))
				continue;

			ptrLTENR_GNBPHY phy_ = LTENR_GNBPHY_GET(d, in);
			ptrLTENR_ASSOCIATEDUEPHYINFO info_ = phy_->associatedUEPhyInfo;

			while (info_)
			{
				fn_NetSim_LTE_NR_init_PropagationInfo_Plots(phy_, info_);
				fn_NetSim_LTE_NR_init_Power_Plots(phy_, info_);
			   LTENR_ASSOCIATEDUEPHYINFO_NEXT(info_);
			}

		}
	}
}
while (info)
{
	if (info->isAssociated)
	{
		for (NETSIM_ID i = 0; i < phy->ca_count; i++)
			LTENR_PHY_setAMCInfo(phy, info, i);
	}

	fn_NetSim_LTE_NR_add_PropagationInfo_Plot_data(info, CA_ID);
```

```
		fn_NetSim_LTE_NR_add_Power_Plot_data(info, CA_ID);
		ptrINFO param_info = parameter_log_info;
		if (param_info->isParameterlog)
			fn_NetSim_LTE_NR_Log_Parameters(phy, CA_ID, info);
		info = LTENR_ASSOCIATEDUEPHYINFO_NEXT(info);
}

LTENR_NotifyMACForStartingSlot();

phy->frameInfo[CA_ID]->prevSlotType = phy->frameInfo[CA_ID]->slotType;
}
```

For adding plot data at every slot time (1 ms) the below highlighted function has been used in LTENR_phy.c file.

```
static void LTENR_PHY_setAMCInfo(ptrLTENR_GNBPHY phy, ptrLTENR_ASSOCIATEDUEPHYINFO info, int CA_ID)
{
UINT layerCount;
ptrLTENR_UEPHY uePhy = LTENR_UEPHY_GET(info->ueId, info->ueIf);

//Downlink
layerCount = LTENR_PHY_GET_DLLAYER_COUNT(uePhy);
for (UINT i = 0; i < layerCount; i++)
{
	print_ltenr_log("\tAMC info between gNB %d:%d and UE %d:%d, Carrier Id = %d, Layer Id = %d for downlink-\n",
			phy->gnbId, phy->gnbIf,
			info->ueId, info->ueIf,
			CA_ID, i);
	info->downlinkAMCInfo[CA_ID][i]->SpectralEfficiency = LTENR_PHY_GetDownlinkSpectralEfficiency(info->propagationInfo[CA_ID], i);
	setAMCInfo(phy, info->downlinkAMCInfo[CA_ID][i]);
}

//Uplink
layerCount = LTENR_PHY_GET_ULLAYER_COUNT(uePhy);
for (UINT i = 0; i < layerCount; i++)
{
	print_ltenr_log("\tAMC info between gNB %d:%d and UE %d:%d, Carrier Id = %d, Layer Id = %d for uplink-\n",
			phy->gnbId, phy->gnbIf,
			info->ueId, info->ueIf,
			CA_ID, i);
	info->uplinkAMCInfo[CA_ID][i]->SpectralEfficiency = LTENR_PHY_GetUplinkSpectralEfficiency(info->propagationInfo[CA_ID], i);
	setAMCInfo(phy, info->uplinkAMCInfo[CA_ID][i]);
}
fn_NetSim_LTE_NR_add_AMCInfo_Plot_data(info, CA_ID);
}
```

Disabling Plotting/Logging

Generation of plots or the parameter log can be disabled by commenting the function calls in the fn_NetSim_LTE_NR_Init() function. The function call fn_NetSim_LTE_NR_Init_Plots can be commented to disable plots and the function call fn_NetSim_LTE_NR_init_Parameter_Log can be commented to disable generation of a parameter log CSV file.

```
_declspec(dllexport) int fn_NetSim_LTE_NR_Init()
{
   if(!isplotinit)
   {
```

```
    fn_NetSim_LTE_NR_Init_Plots(); //comment line to disable plots
    fn_NetSim_LTE_NR_init_Parameter_Log(); //comment line to disable parameter log
    isplotinit = true;
    }
return fn_NetSim_LTE_NR_Init_F();
}
```