Automatic plotting of 5G parameters in NetSim

Contents

1 Features

Using this workspace:

1. Users can plot Pathloss, Shadow Fading Loss, Total Loss, Rx_Power, SNR, Beam Forming Gain, MCS Index, and CQI Index vs. time using NetSim Plot.
2. User need to give a file based input (per a certain format) at the start of simulation for the parameters to be plotted.
3. The plots are unique to
    a. Each gNB-UE pair
    b. Carrier ID
    c. DL or UL
4. The output parameters for different MIMO layers ($Min\ (N_t, N_r)$) are stacked in a single plot
5. Parameters are logged every slot time (1ms) and plotted
6. There is no restriction in NetSim on the number of gNBs / UE in the network.

2 Code Changes

A file LTE_NR_Plot.c has been added in LTE_NR project which is responsible for defining all the used function, calling function in NetSim plot API, and creating user input file.

The function fn_NetSim_LTE_NR_Init_Plots 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();
   isplotinit= true;
   }
        return fn_NetSim_LTE_NR_Init_F();
}
```

The initialization of plot functions has been made as follows in LTENR_PHY_initAMCInfo function.

```
#pragma region PHY_AMCINFO
static void LTENR_PHY_initAMCInfo(ptrLTENR_GNBPHY phy, ptrLTENR_ASSOCIATEDUEPHYINFO assocInfo)
{
        NETSIM_ID i = 0;
        for (i = 0; i < phy->ca_count; i++)
        {
                if (!assocInfo->downlinkAMCInfo[i])
                {
                        ptrLTENR_UEPHY uePhy = LTENR_UEPHY_GET(assocInfo->ueId, assocInfo->ueIf);
                        UINT layerCount = LTENR_PHY_GET_DLLAYER_COUNT(uePhy);
                        assocInfo->downlinkAMCInfo[i] = calloc(layerCount, sizeof * assocInfo->downlinkAMCInfo[i]);
                        for (UINT j = 0; j < layerCount; j++)
                                assocInfo->downlinkAMCInfo[i][j] = calloc(1, sizeof * assocInfo->downlinkAMCInfo[i][j]);
                }
                if (!assocInfo->uplinkAMCInfo[i])
                {
                        ptrLTENR_UEPHY uePhy = LTENR_UEPHY_GET(assocInfo->ueId, assocInfo->ueIf);
                        UINT layerCount = LTENR_PHY_GET_ULLAYER_COUNT(uePhy);
                        assocInfo->uplinkAMCInfo[i] = calloc(layerCount, sizeof * assocInfo->uplinkAMCInfo[i]);
                        for (UINT j = 0; j < layerCount; j++)
                                assocInfo->uplinkAMCInfo[i][j] = calloc(1, sizeof * assocInfo->uplinkAMCInfo[i][j]);
                }

                LTENR_PHY_calculateSpectralEfficiency(phy, assocInfo->ueId, assocInfo->ueIf, i);
                LTENR_PHY_setAMCInfo(phy, assocInfo, i);
        }
```

```
	fn_NetSim_LTE_NR_init_AMCInfo_Plots(phy, assocInfo);
}
```

In function LTENR_PHY_ASSOCIATION

```
void LTENR_PHY_ASSOCIATION(NETSIM_ID gnbId, NETSIM_ID gnbIf,
                                                NETSIM_ID ueId, NETSIM_ID ueIf,
                                                bool isAssociated)
{
	ptrLTENR_GNBPHY phy = LTENR_GNBPHY_GET(gnbId, gnbIf);
	ptrLTENR_ASSOCIATEDUEPHYINFO info = phy->associatedUEPhyInfo;
	fn_NetSim_LTE_NR_init_PropagationInfo_Plots(phy, info);
	fn_NetSim_LTE_NR_init_Power_Plots(phy, info);
	if (isAssociated)
		LTENR_PHY_associateUE(gnbId, gnbIf, ueId, ueIf);
	else
		LTENR_PHY_deassociateUE(gnbId, gnbIf, ueId, ueIf);
}
```

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);
}
```

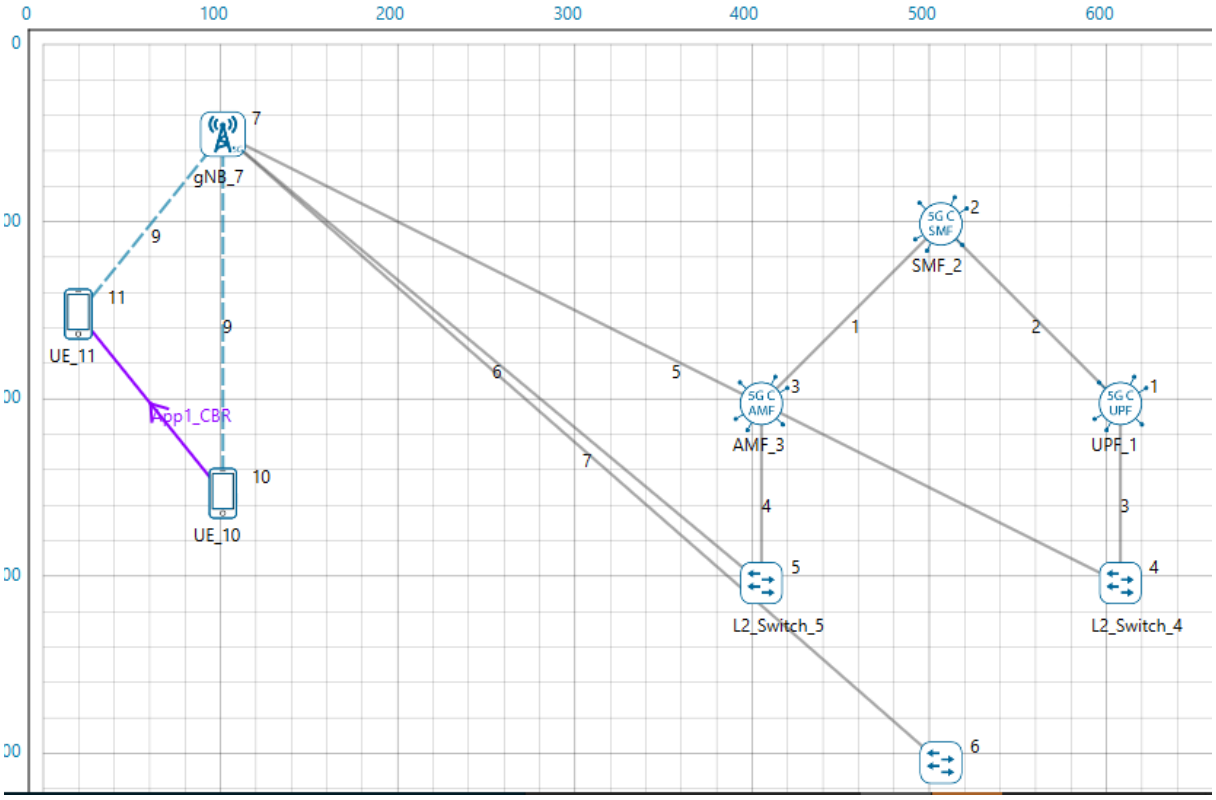
In function LTENR_handleStartSlotEvent,

```
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;
	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);
		info = LTENR_ASSOCIATEDUEPHYINFO_NEXT(info);
	}

	LTENR_NotifyMACForStartingSlot();
```

3 Example

In the below scenario

- The RAN portion has a MIMO layer count of 2, and both FastFading and ShadowFadingLoss are enabled.
- UE-10 moves in a straight line away from the gNB
- The network is simulated for 60 s.



Upon running the simulation, a text file will open for the user to input the parameters and devices (tx-rx pair) for which parameters need to be logged and plotted. The input is per the format of <parameter>,<device1>,<device2> in the text file. To log gNB – UE (DL) data flow the gNB would be the 1st device while the UE would ve 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 paris. Inputs are not case sensitive.

For the above example the input text file is as follows.

TOTALLOSS,gNB_7,UE_10

pathloss,gNB_7,UE_10

SHADOWFADINGLOSS,gnb_7,ue_11

SHADOWFADINGLOSS,gnb_7,UE_10

RX_POWER,gNB_7,UE_10

SNR,gNB_7,UE_10

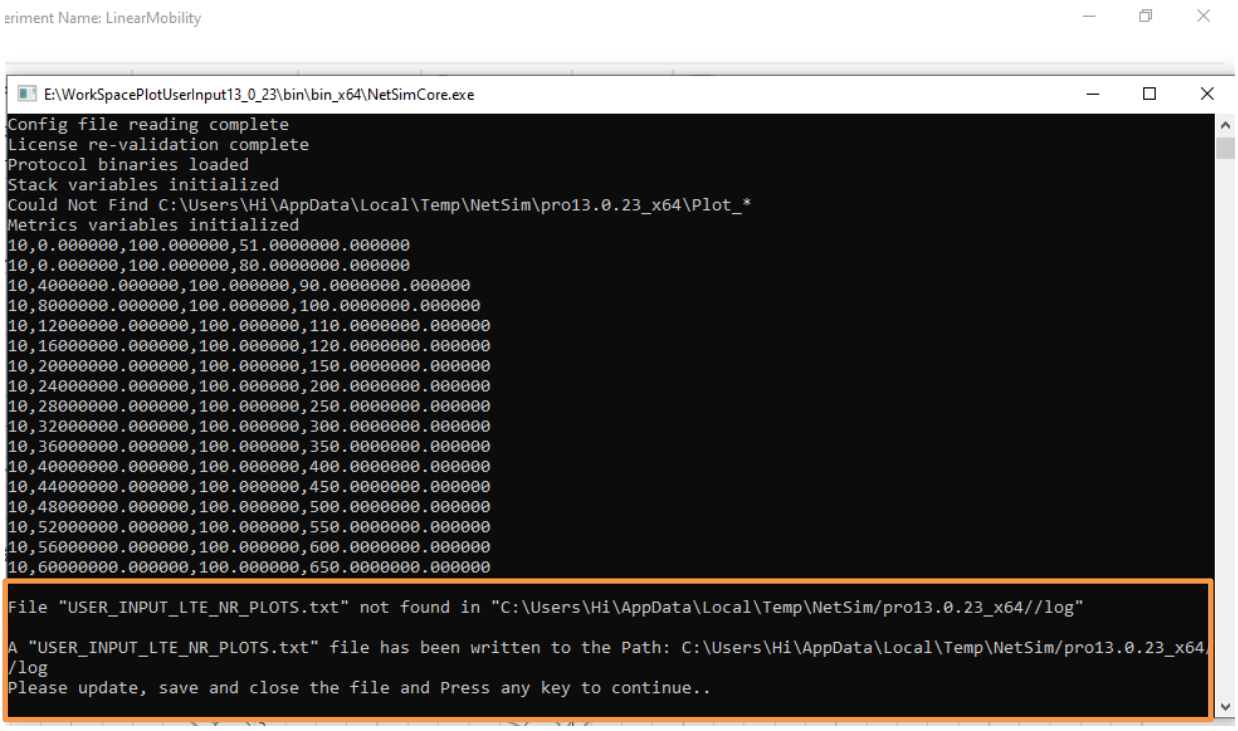
BEAMFORMINGGAIN,gNB_7,UE_10

cqi,gNB_7,UE_10

MCS,gNB_7,UE_10

SNR,gNB_7,UE_11

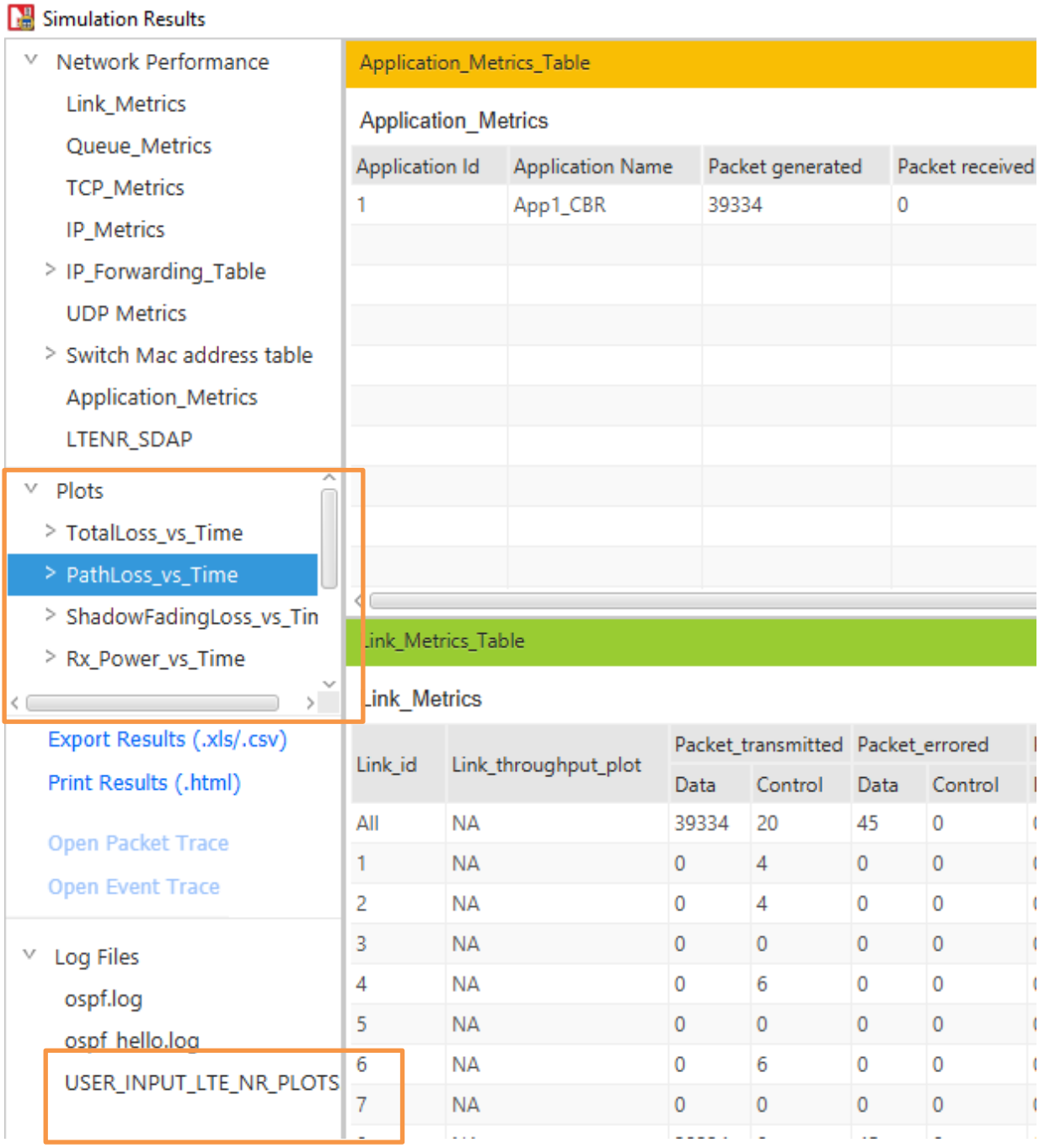
Once the simulation starts, the cmd window would look as shown below



Next, close the input text file and press any key.

Simulation starts running.

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

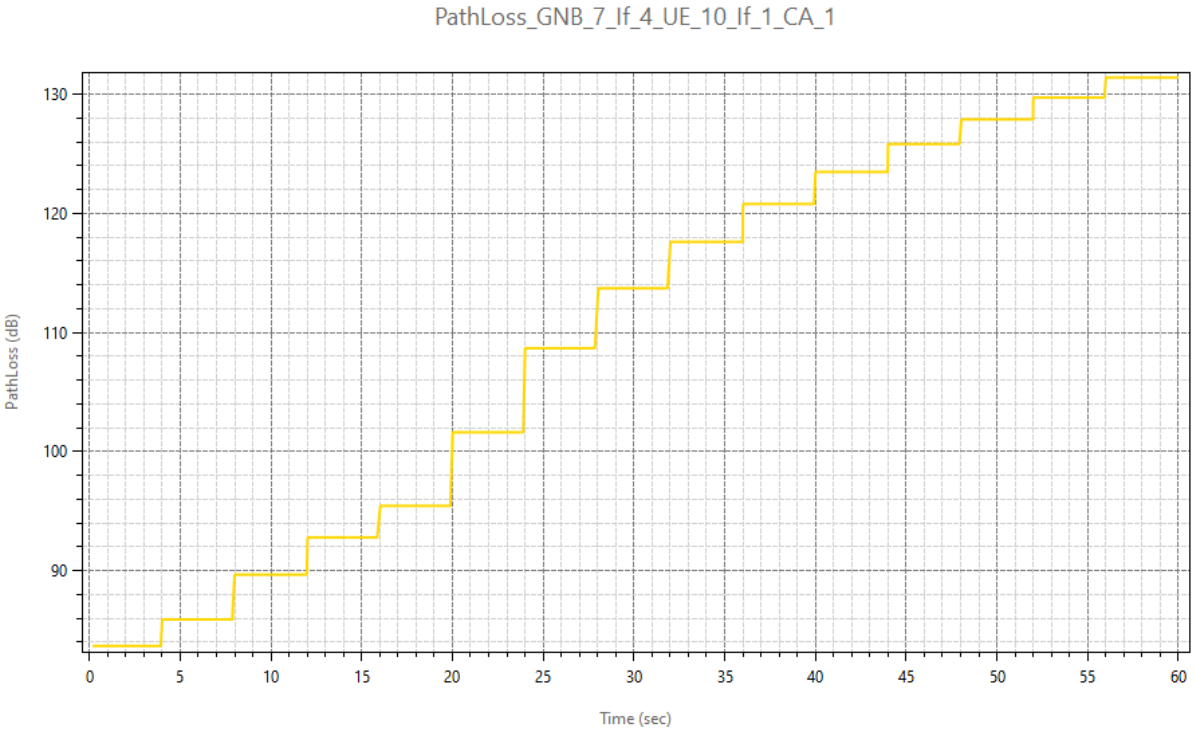


For each carrier a separate plot is plotted with all the MMO layers stacked in a single plot.

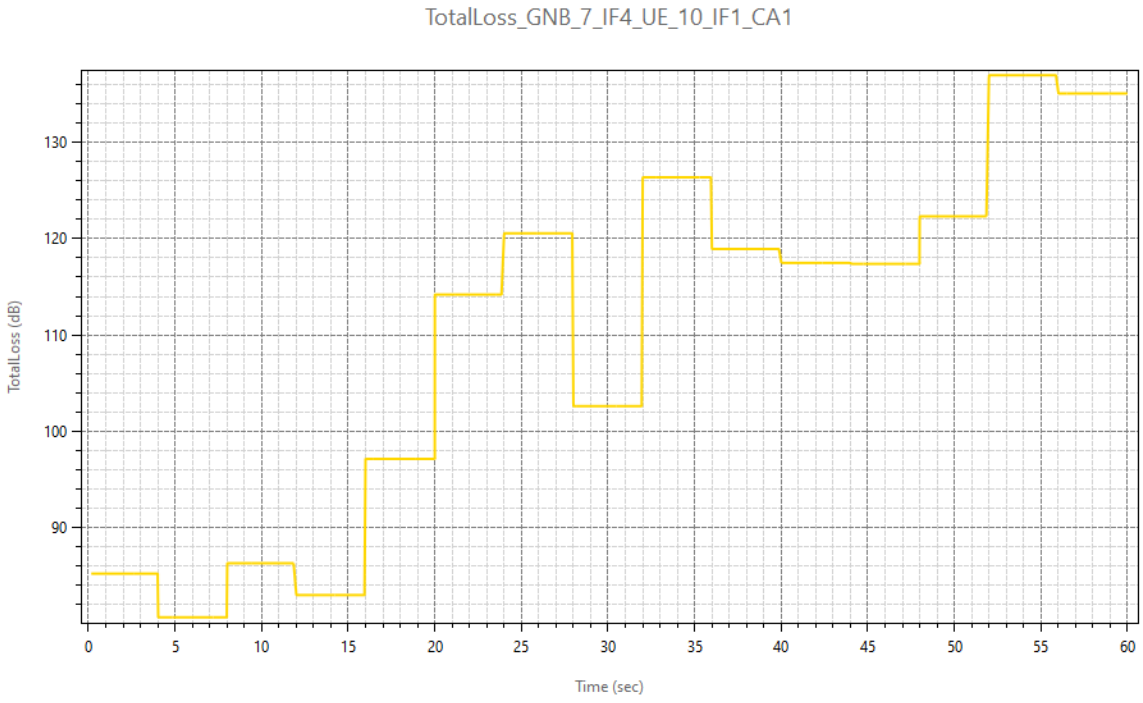
The pathloss, shadowfading loss, and total loss remains same across the layers. Hence, for these parameters there is a single plot for all layers.

3.1 Result Plots

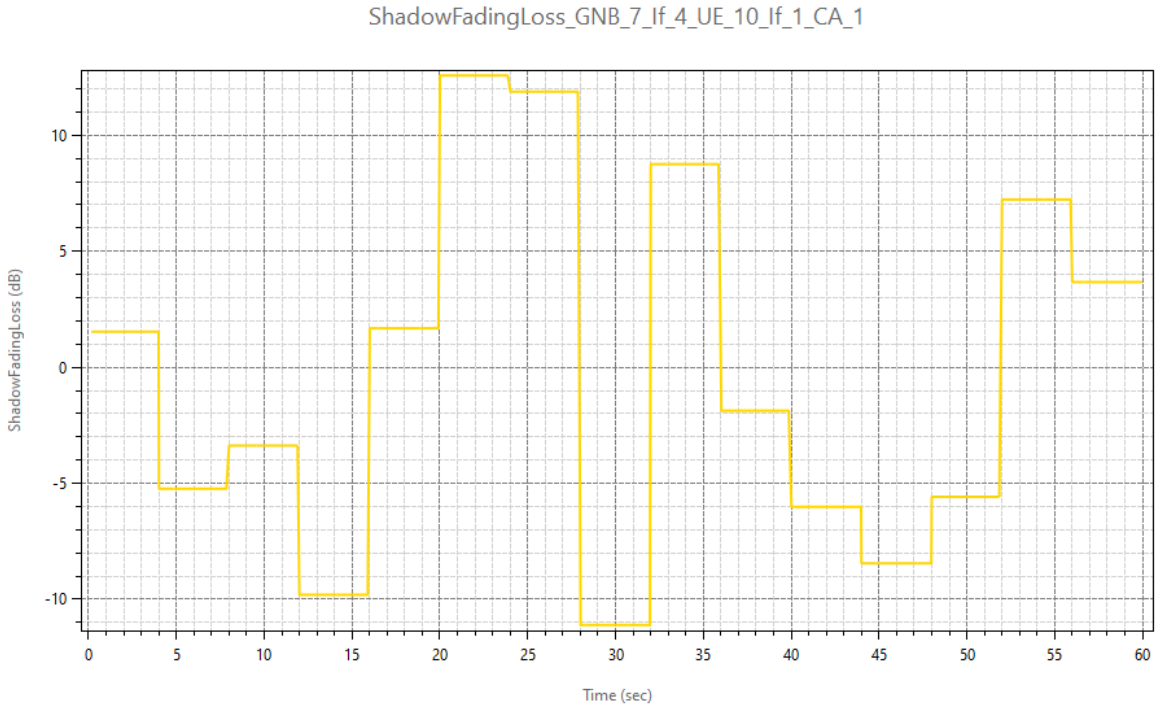
3.1.1 Pathloss Plot



3.1.2 Total Loss (Shadow Fading loss plus Path loss)

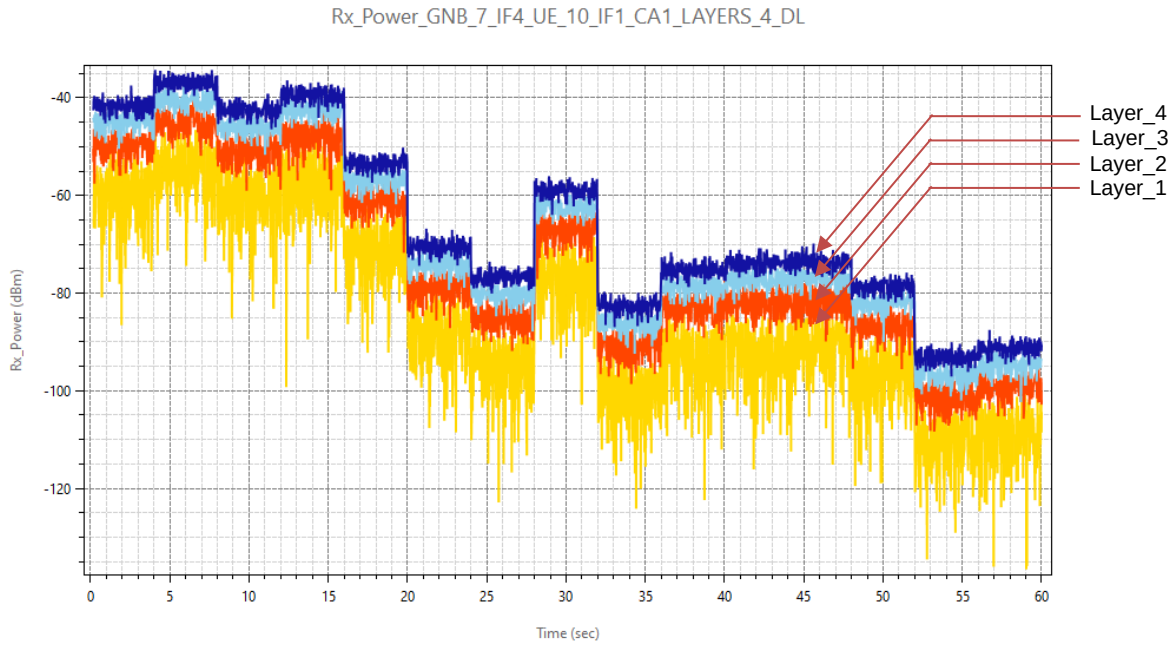


3.1.3 Shadow Fading Loss

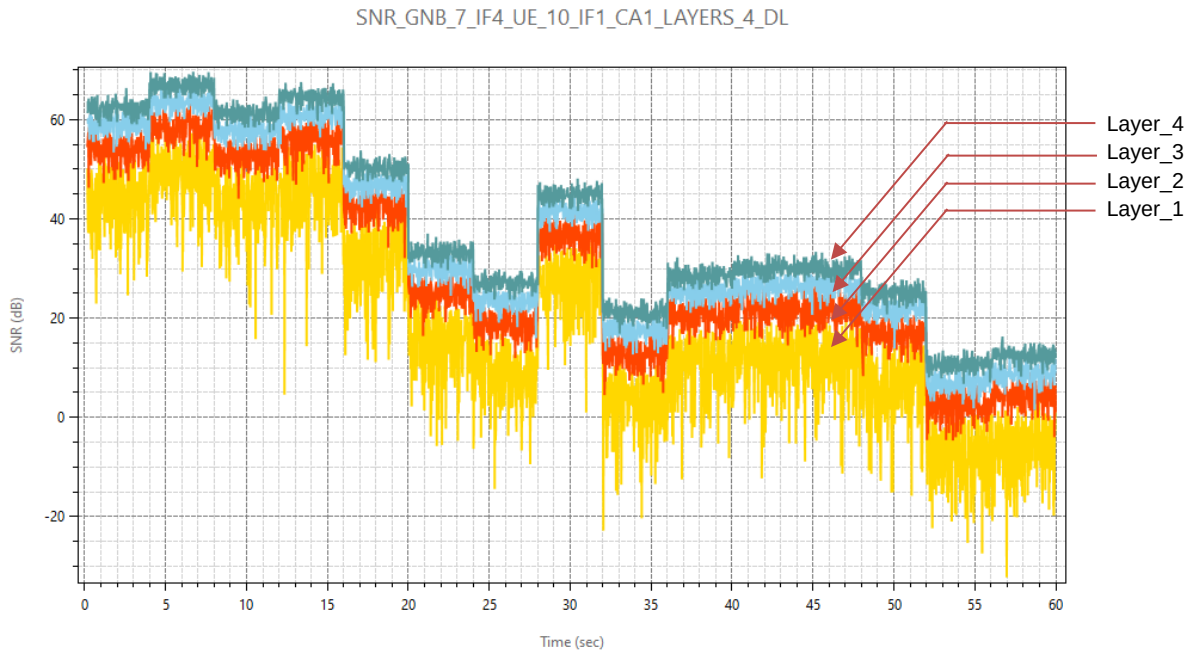


The plot title is ShadowFadingLoss_GNB_7_IF4_UE_10_IF1_CA1. And the naming convention is <ParameterType>_GNB_<ID>_IF<InterfaceID>_UE_<ID>_IF<InterfaceID>_CA<Carrier_ID>

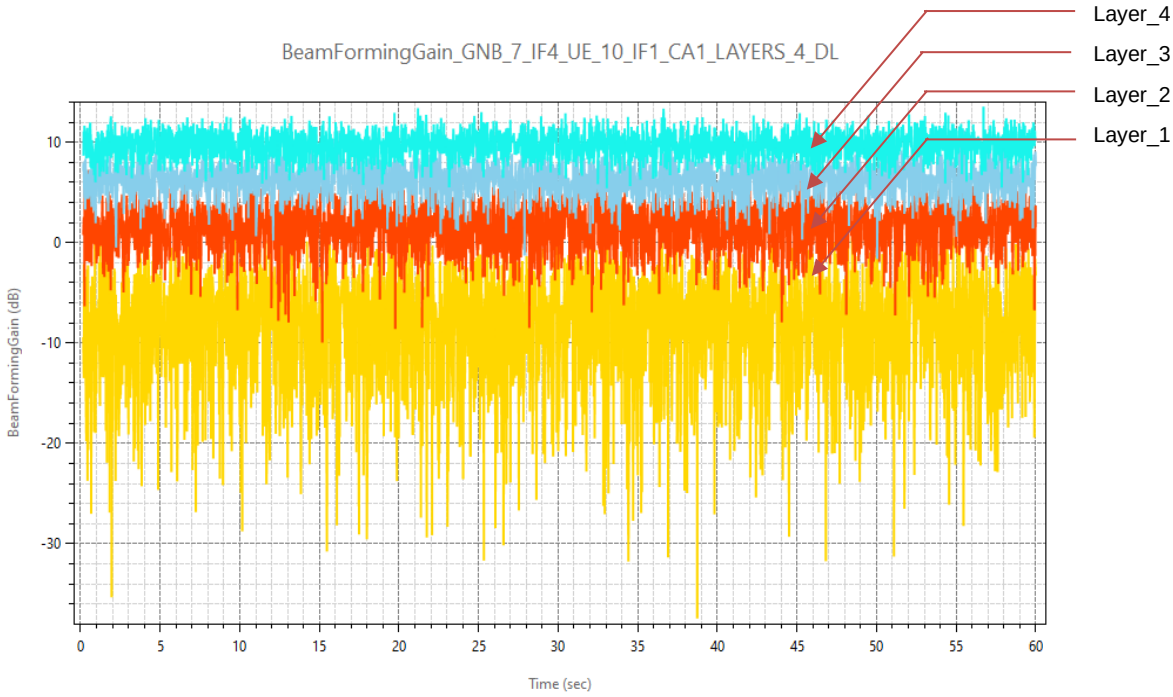
3.1.4 Rx_Power Plot



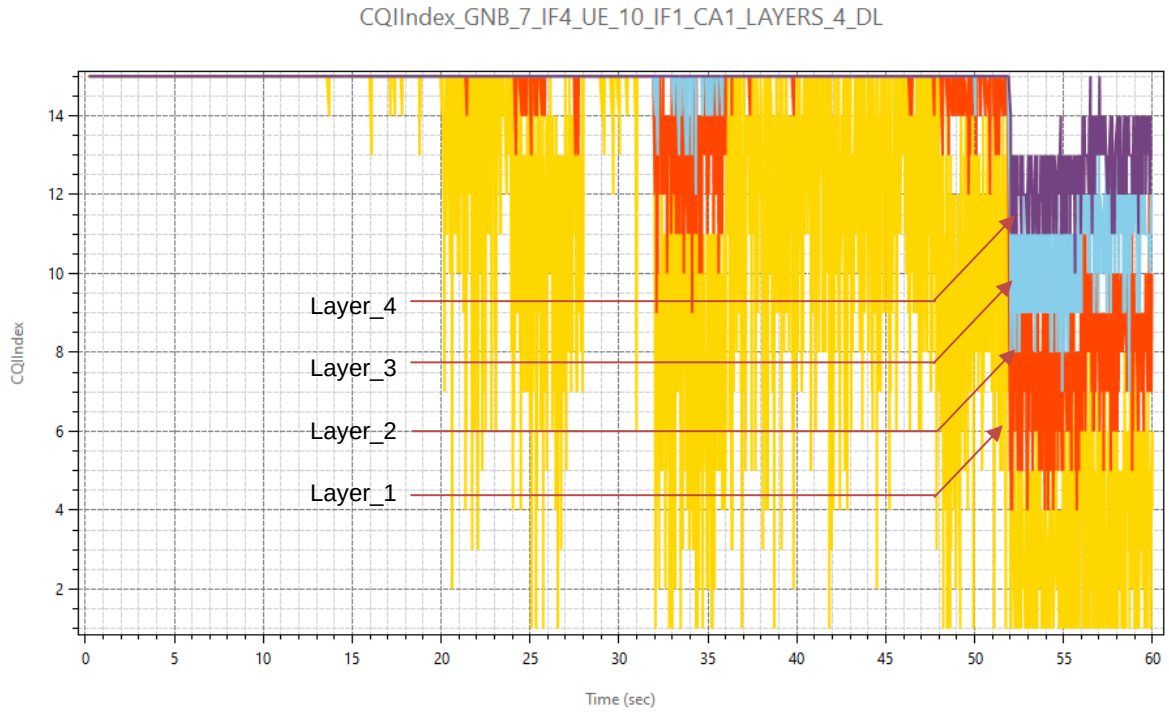
3.1.5 SNR Plot



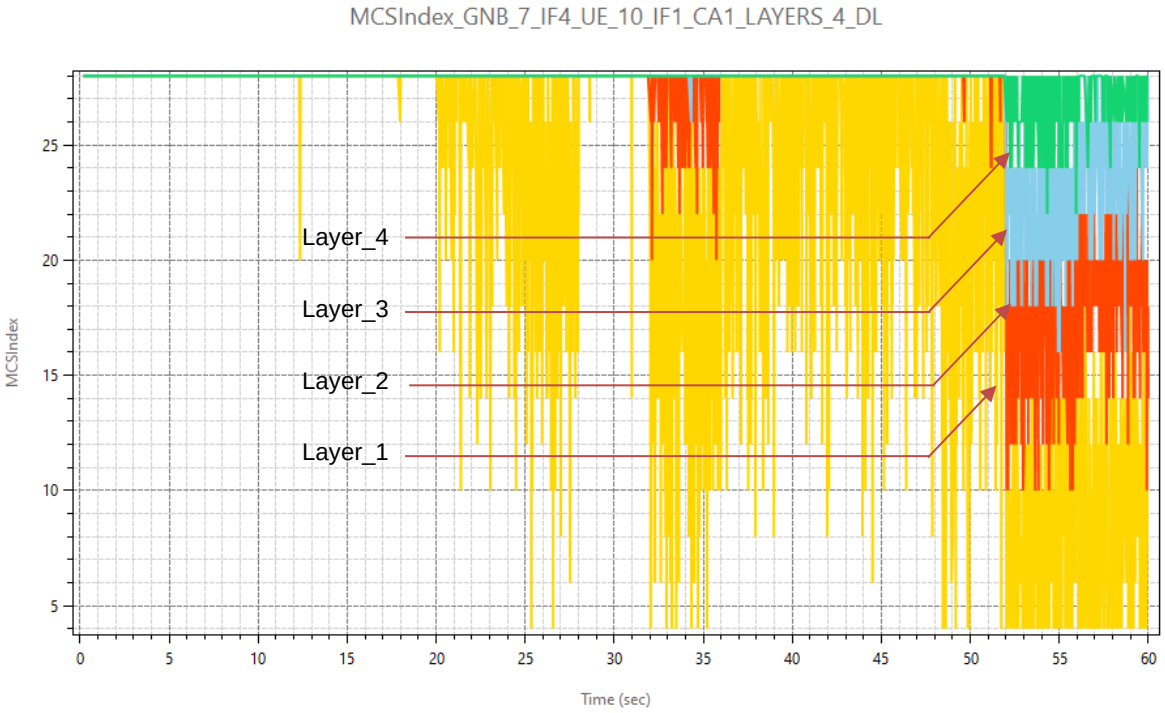
3.1.6 Beam Forming Gain



3.1.7 CQI Index Plot



3.1.8 MCS Index Plot



The SNR, Rx_Power, Beam Forming Gain, CQI Index, MCS Index plots are plotted for all MIMO layers for a Carrier 1. In the chart title layer count and application direction (DL/UL) are also present.