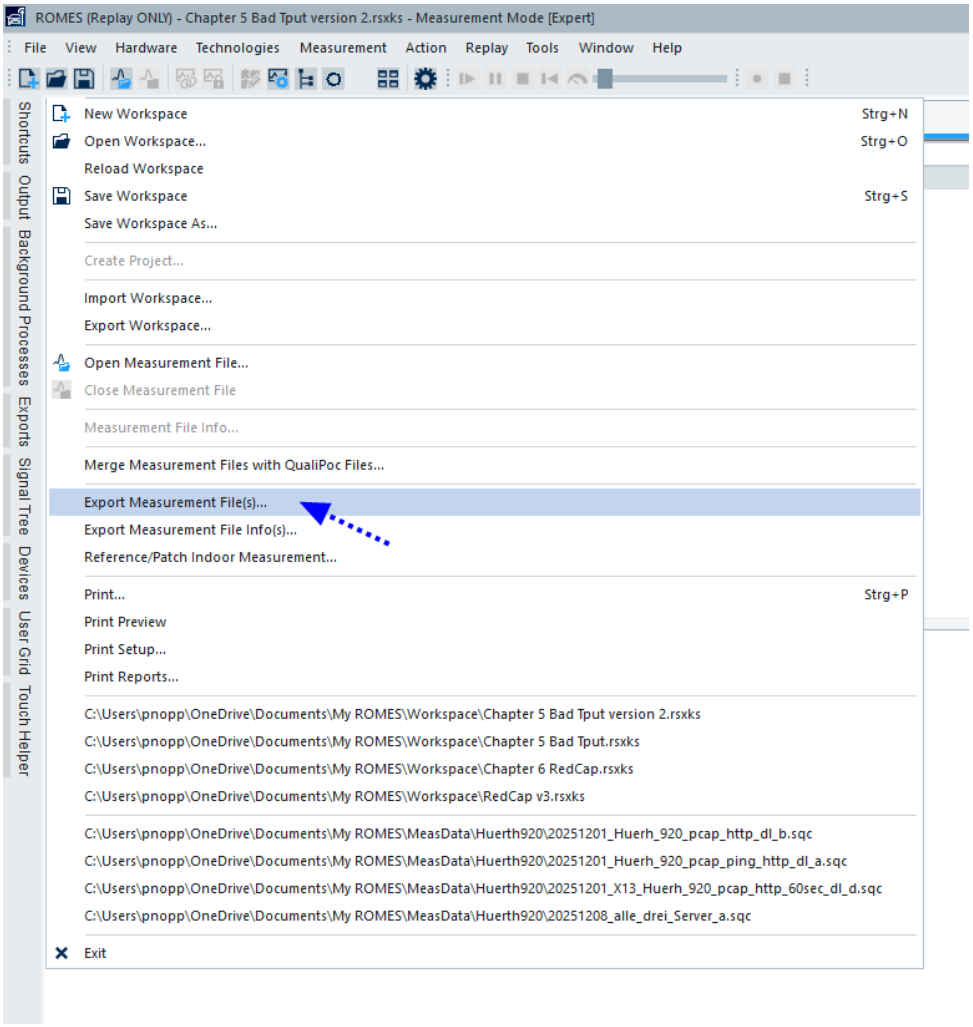
5G DL Spectral Efficiency

Spectral Efficiency (SE) is the user downlink throughput per unit of used radio bandwidth, expressed in bits/s/Hz.

With ROMES Export Measurement Files (s), it is possible to export data to calculate the theoretical Spectral Efficiency using:

1. MCS/Layer (gNB perspective)
2. CQI/RI (UE perspective)



Picture 1 illustrates the ROMES Exporting Measurement Files.

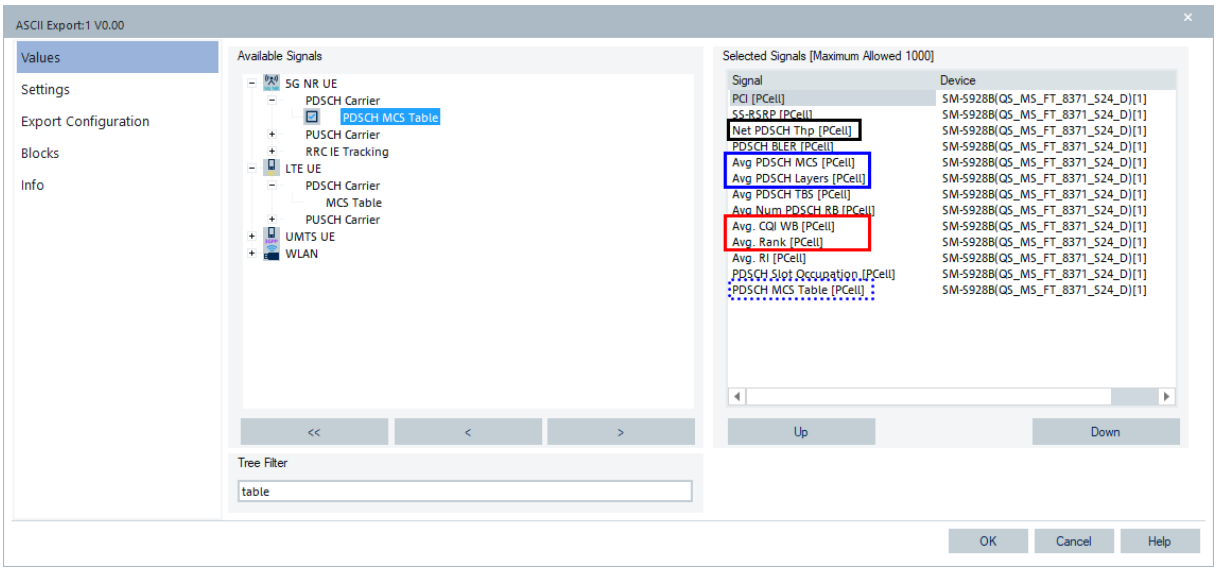
The export result is saved under .asc which is required to be converted with "Text to Columns" in Excel.

The example of exported values is shown below. It is important to include parameters under "5G NR UE" for PCell (i.e. in EN-DC mode, SCG-PSCell) :

- Net PDSCH Thp
- Avg. PDSCH MCS

- Avg. PDSCH Layers
- Avg. CQI WB
- Avg. Rank

Other parameters e.g. PCI, SS-RSRP, PDSCH BLER and so on would be optional for individual interests or other purpose of evaluations.



Remark:

Although ROMES supports exporting the "5G NR UE/ PDSCH MCS Table", the values should be treated with caution. The logfile measured with ROMES older than version 25.3 [Build 4759- Dated: Sep 30 2025], numerous entries contain "?", denoting that the corresponding information was not available.

Once the data is successfully converted, there are 2 tasks need to be processed before the spectral efficiency can be calculated.

1. VLOOKUP Table for MCS Values
2. VLOOKUP Table for CQI Values

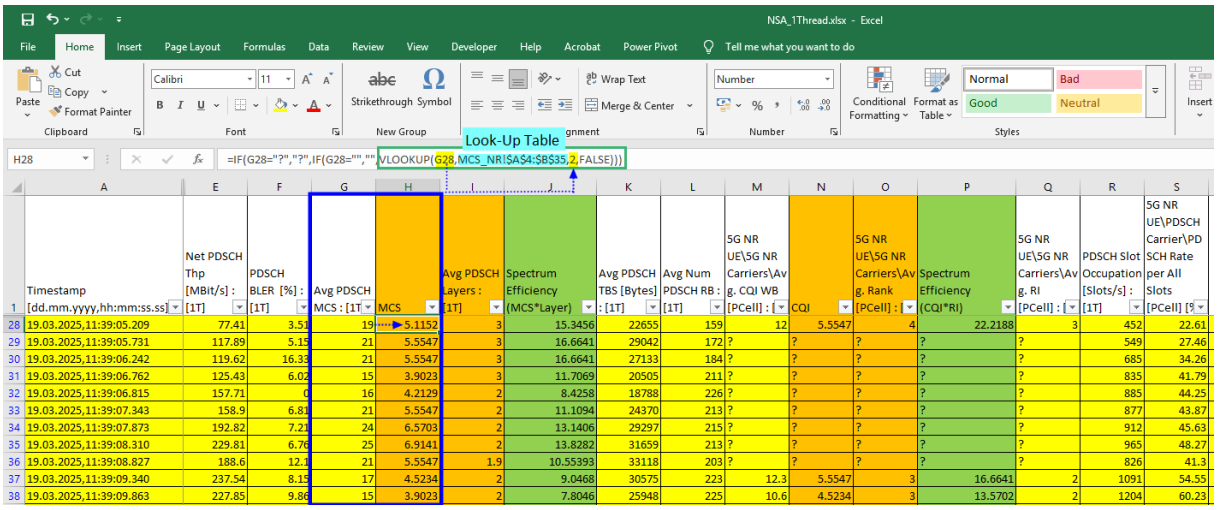
VLOOKUP Table for MCS

The exported PDSCH MCS data (Column G) must be converted to the corresponding Spectral Efficiency using Excel VLOOKUP function. See example in Picture 3.

The Avg PDSCH MCS in Column G, example G28, MCS = 19 --> its Spectral Efficiency = 5.1152 when the MCS Table is 256QAM.

Note:

The below example logfile was measured using ROMES Version 24.02 which does not contains the PDSCH MCS Table value in the exported file, hence, it is required an extra look-up into the ROMES L3 View.



	Timestamp [dd.mm.yyyy,hh:mm:ss.ss]	Net PDSCH Thp [MBit/s] : [1T]	PDSCH BLER [%] : [1T]	Avg PDSCH MCS : [1T]	MCS	Avg PDSCH Layers : [1T]	Spectrum Efficiency (MCS*Layer)	Avg PDSCH TBS [Bytes] : [1T]	Avg Num PDSCH RB : [1T]	5G NR UE\5G NR Carriers\Avg. CQI WB [PCell] : [	CQI	5G NR UE\5G NR Carriers\Avg. Rank [PCell] :	Spectrum Efficiency (CQI*RI)	5G NR UE\5G NR Carriers\Avg. RI [PCell] :	PDSCH Slot Occupation [Slots/s] : [1T]	5G NR UE\PDSCH Carrier\PDSCH Rate per All Slots [PCell] [
28	19.03.2025,11:39:05.209	77.41	3.51	19	5.1152	3	15.3456	22655	159	12	5.5547	4	22.2188	3	452	22.61
29	19.03.2025,11:39:05.731	117.89	5.15	21	5.5547	3	16.6641	29042	172	?	?	?	?	?	549	27.46
30	19.03.2025,11:39:06.242	119.62	16.33	21	5.5547	3	16.6641	27133	184	?	?	?	?	?	685	34.26
31	19.03.2025,11:39:06.762	125.43	6.02	15	3.9023	3	11.7069	20505	211	?	?	?	?	?	835	41.79
32	19.03.2025,11:39:06.815	157.71	0	16	4.2129	2	8.4258	18788	226	?	?	?	?	?	885	44.25
33	19.03.2025,11:39:07.343	158.9	6.81	21	5.5547	2	11.1094	24370	213	?	?	?	?	?	877	43.87
34	19.03.2025,11:39:07.873	192.82	7.21	24	6.5703	2	13.1406	29297	215	?	?	?	?	?	912	45.63
35	19.03.2025,11:39:08.310	229.81	6.76	25	6.9141	2	13.8282	31659	213	?	?	?	?	?	965	48.27
36	19.03.2025,11:39:08.827	188.6	12.1	21	5.5547	1.9	10.55393	33118	203	?	?	?	?	?	826	41.3
37	19.03.2025,11:39:09.340	237.54	8.15	17	4.5234	2	9.0468	30575	223	12.3	5.5547	3	16.6641	2	1091	54.55
38	19.03.2025,11:39:09.863	227.85	9.86	15	3.9023	2	7.8046	25948	225	10.6	4.5234	3	13.5702	2	1204	60.23

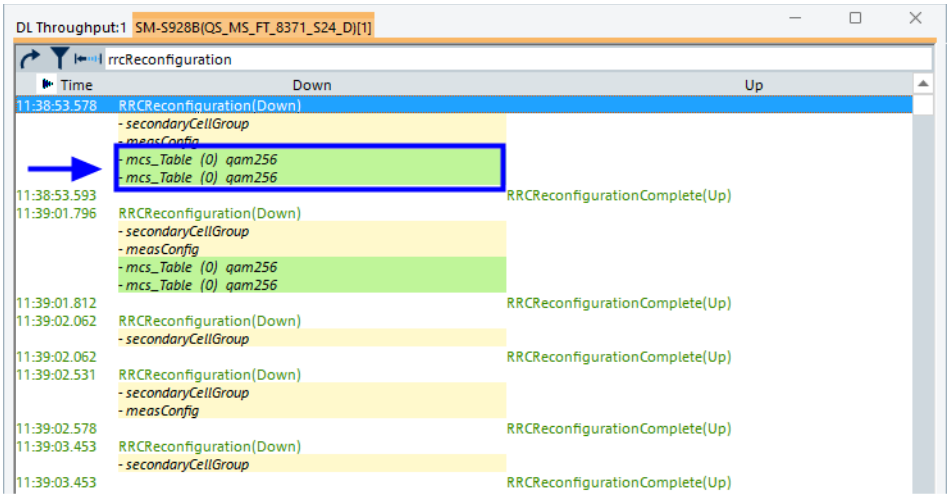
How to find out what is the configured 5G MCS table ?

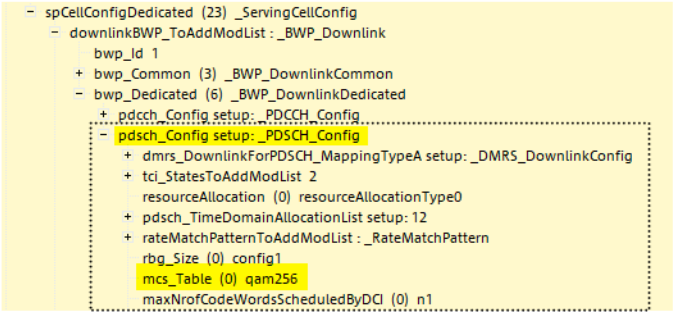
In 5G NR, the L3 message "RRC Reconfiguration" contains parameter "mcs-Table" in PDSCH-Config.

The "mcs-Table" tells UE which MCS table to be used.

In DL (PDSCH), there are 3 MCS table:

- table 1 (64QAM)
- table 2 (256QAM)
- table 3 (64QAM with Low Spectral Efficiency)





RRC Reconfiguration message shows that the PDSCH is configured with 256QAM table.

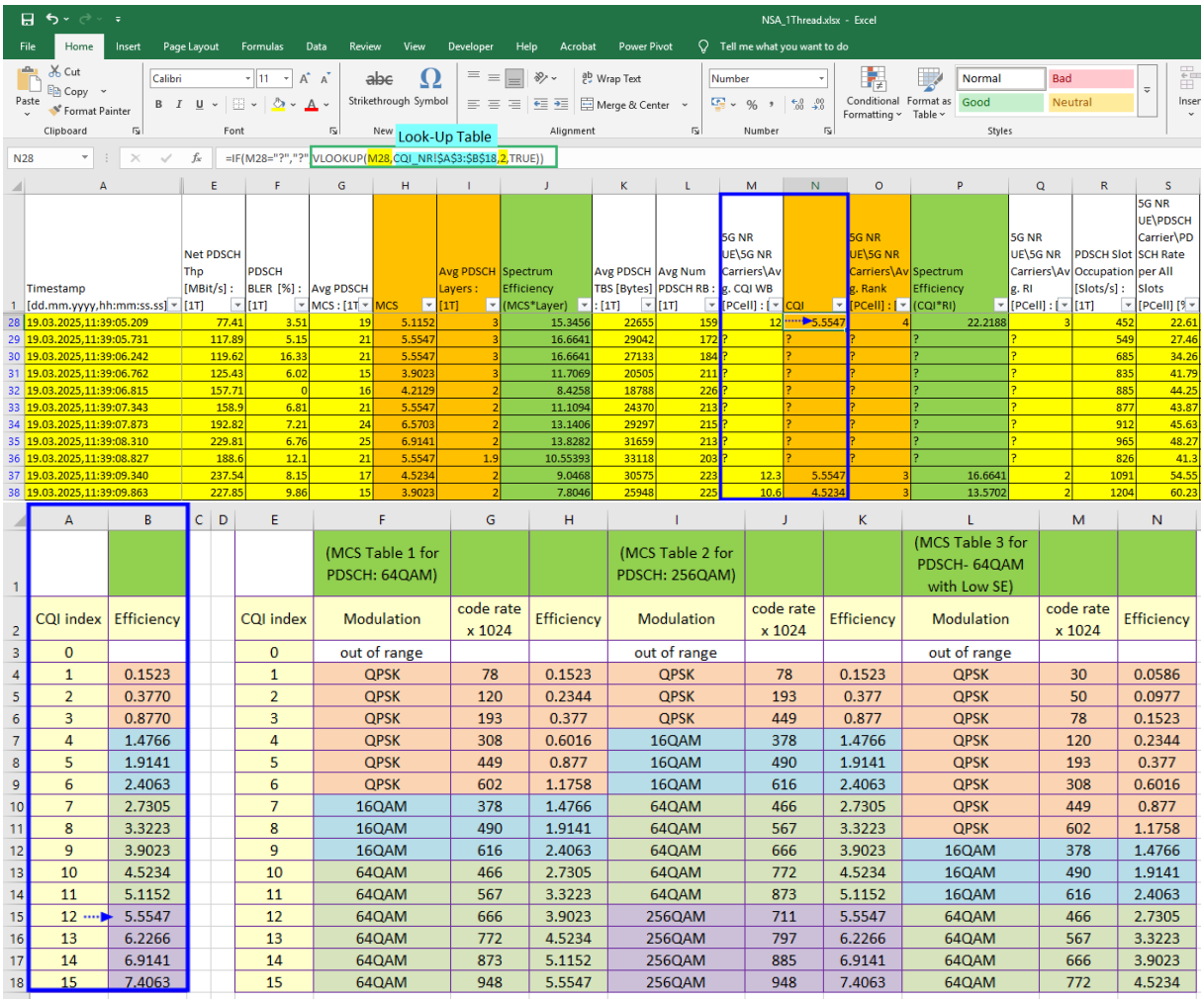
Hence, the VLOOKUP table must provide Column A for MCS Index and Column B for Spectral Efficiency for 256QAM table.

	A	B	C	MCS Table 1: 64QAM				H	MCS Table 2: 256QAM				M	MCS Table 3: 64QAM with Low SE			
2	MCS Index	Row 2 Spectral		MCS Index	Modulation Order	Target code Rate	Spectral		MCS Index	Modulation Order	Target code Rate	Spectral		MCS Index	Modulation Order	Target code Rate	
3	I_{MCS}			I_{MCS}	Q_m				I_{MCS}	Q_m				I_{MCS}	Q_m		
4	0	0.2344		0	2	120	0.2344		0	2	120	0.2344		0	2	30	0.0586
5	1	0.3770		1	2	157	0.3066		1	2	193	0.377		1	2	40	0.0781
6	2	0.6016		2	2	193	0.377		2	2	308	0.6016		2	2	50	0.0977
7	3	0.8770		3	2	251	0.4902		3	2	449	0.877		3	2	64	0.125
8	4	1.1758		4	2	308	0.6016		4	2	602	1.1758		4	2	78	0.1523
9	5	1.4766		5	2	379	0.7402		5	4	378	1.4766		5	2	99	0.1934
10	6	1.6953		6	2	449	0.877		6	4	434	1.6953		6	2	120	0.2344
11	7	1.9141		7	2	526	1.0273		7	4	490	1.9141		7	2	157	0.3066
12	8	2.1602		8	2	602	1.1758		8	4	553	2.1602		8	2	193	0.3770
13	9	2.4063		9	2	679	1.3262		9	4	616	2.4063		9	2	251	0.4902
14	10	2.5703		10	4	340	1.3281		10	4	658	2.5703		10	2	308	0.6016
15	11	2.7305		11	4	378	1.4766		11	6	466	2.7305		11	2	379	0.7402
16	12	3.0293		12	4	434	1.6953		12	6	517	3.0293		12	2	449	0.8770
17	13	3.3223		13	4	490	1.9141		13	6	567	3.3223		13	2	526	1.0273
18	14	3.6094		14	4	553	2.1602		14	6	616	3.6094		14	2	602	1.1758
19	15	3.9023		15	4	616	2.4063		15	6	666	3.9023		15	4	340	1.3281
20	16	4.2129		16	4	658	2.5703		16	6	719	4.2129		16	4	378	1.4766
21	17	4.5234		17	6	438	2.5664		17	6	772	4.5234		17	4	434	1.6953
22	18	4.8164		18	6	466	2.7305		18	6	822	4.8164		18	4	490	1.9141
23	19	5.1152		19	6	517	3.0293		19	6	873	5.1152		19	4	553	2.1602
24	20	5.3320		20	6	567	3.3223		20	8	682.5	5.332		20	4	616	2.4063
25	21	5.5547		21	6	616	3.6094		21	8	711	5.5547		21	6	438	2.5664
26	22	5.8906		22	6	666	3.9023		22	8	754	5.8906		22	6	466	2.7305
27	23	6.2266		23	6	719	4.2129		23	8	797	6.2266		23	6	517	3.0293
28	24	6.5703		24	6	772	4.5234		24	8	841	6.5703		24	6	567	3.3223
29	25	6.9141		25	6	822	4.8164		25	8	885	6.9141		25	6	616	3.6094
30	26	7.1602		26	6	873	5.1152		26	8	916.5	7.1602		26	6	666	3.9023
31	27	7.4063		27	6	910	5.332		27	8	948	7.4063		27	6	719	4.2129
32	28			28	6	948	5.5547		28	2	reserved			28	6	772	4.5234
33	29			29	2	reserved			29	4	reserved			29	2	reserved	
34	30			30	4	reserved			30	6	reserved			30	4	reserved	
35	31			31	6	reserved			31	8	reserved			31	6	reserved	

VLOOKUP Table for CQI

The exported Avg. CQI WB data (Column M) must be also converted to the corresponding Spectral Efficiency using Excel VLOOKUP function. See example in the picture below.

The Avg. CQI WB in Column M, example M28, Wideband CQI = --> its Spectral Efficiency = 5.5547 when the MCS Table is 256QAM.



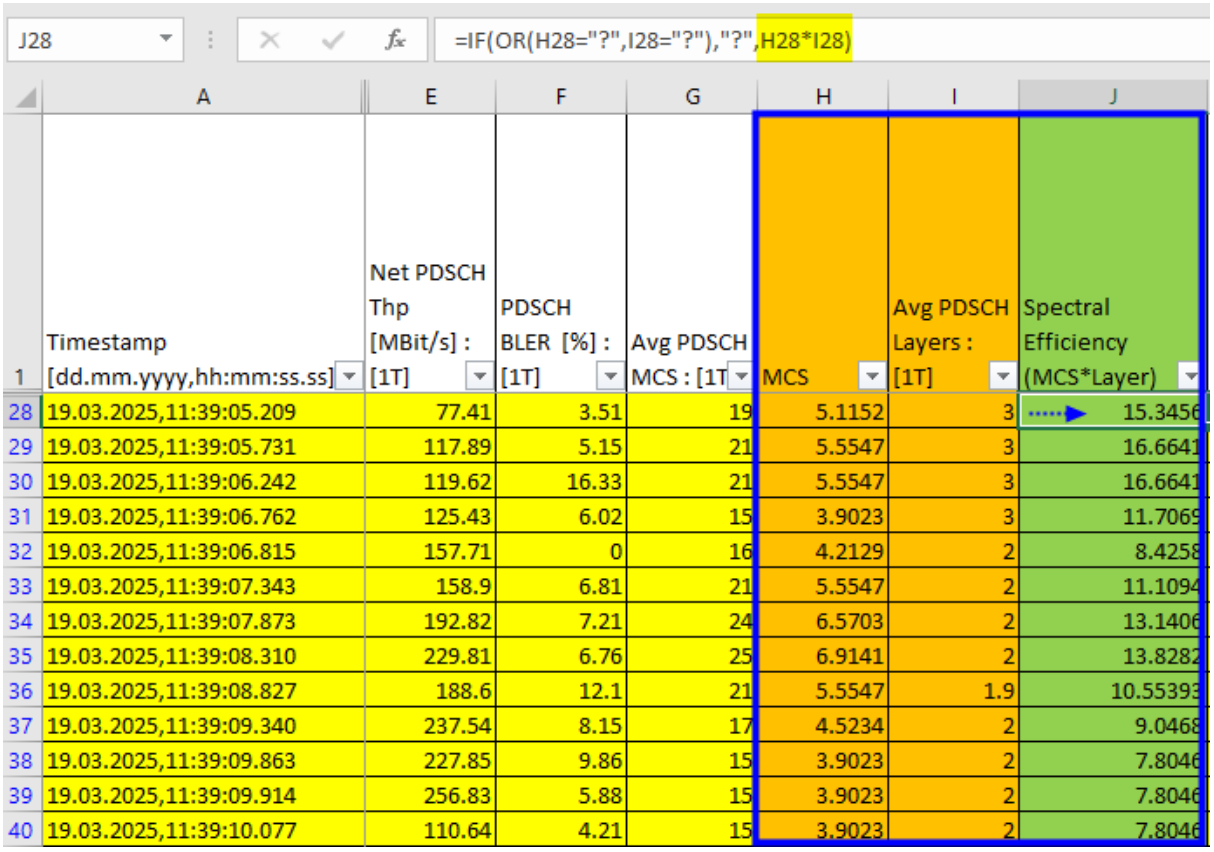
	A	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1	Timestamp [dd.mm.yyyy,hh:mm:ss.ss]	Net PDSCH Thp [MBit/s] : [1T]	PDSCH BLER [%] : [1T]	Avg PDSCH MCS : [1T]	MCS	Avg PDSCH Layers : [1T]	Spectrum Efficiency (MCS*Layer)	Avg PDSCH TBS [Bytes] : [1T]	Avg Num PDSCH RB : [1T]	5G NR UE\5G NR Carriers\Avg. CQI WB [PCell] : [	CQI	5G NR UE\5G NR Carriers\Avg. Rank [PCell] : [	Spectrum Efficiency (CQI*RI)	5G NR UE\5G NR Carriers\Avg. RI [PCell] : [	PDSCH Slot Occupation [Slots/s] : [1T]	5G NR UE\PDSCH Carrier\PDSCH Rate per All Slots [PCell] [%
28	19.03.2025,11:39:05.209	77.41	3.51	19	5.1152	3	15.3456	22655	159	12	5.5547	4	22.2188	3	452	22.61
29	19.03.2025,11:39:05.731	117.89	5.15	21	5.5547	3	16.6641	29042	172	?	?	?	?	?	549	27.46
30	19.03.2025,11:39:06.242	119.62	16.33	21	5.5547	3	16.6641	27133	184	?	?	?	?	?	685	34.26
31	19.03.2025,11:39:06.762	125.43	6.02	15	3.9023	3	11.7069	20505	211	?	?	?	?	?	835	41.79
32	19.03.2025,11:39:06.815	157.71	0	16	4.2129	2	8.4258	18788	226	?	?	?	?	?	885	44.25
33	19.03.2025,11:39:07.343	158.9	6.81	21	5.5547	2	11.1094	24370	213	?	?	?	?	?	877	43.87
34	19.03.2025,11:39:07.873	192.82	7.21	24	6.5703	2	13.1406	29297	215	?	?	?	?	?	912	45.63
35	19.03.2025,11:39:08.310	229.81	6.76	25	6.9141	2	13.8282	31659	213	?	?	?	?	?	965	48.27
36	19.03.2025,11:39:08.827	188.6	12.1	21	5.5547	1.9	10.55393	33118	203	?	?	?	?	?	826	41.3
37	19.03.2025,11:39:09.340	237.54	8.15	17	4.5234	2	9.0468	30575	223	12.3	5.5547	3	16.6641	2	1091	54.55
38	19.03.2025,11:39:09.863	227.85	9.86	15	3.9023	2	7.8046	25948	225	10.6	4.5234	3	13.5702	2	1204	60.23

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1						(MCS Table 1 for PDSCH: 64QAM)			(MCS Table 2 for PDSCH: 256QAM)			(MCS Table 3 for PDSCH- 64QAM with Low SE)		
2	CQI index	Efficiency			CQI index	Modulation	code rate x 1024	Efficiency	Modulation	code rate x 1024	Efficiency	Modulation	code rate x 1024	Efficiency
3	0				0	out of range			out of range			out of range		
4	1	0.1523			1	QPSK	78	0.1523	QPSK	78	0.1523	QPSK	30	0.0586
5	2	0.3770			2	QPSK	120	0.2344	QPSK	193	0.377	QPSK	50	0.0977
6	3	0.8770			3	QPSK	193	0.377	QPSK	449	0.877	QPSK	78	0.1523
7	4	1.4766			4	QPSK	308	0.6016	16QAM	378	1.4766	QPSK	120	0.2344
8	5	1.9141			5	QPSK	449	0.877	16QAM	490	1.9141	QPSK	193	0.377
9	6	2.4063			6	QPSK	602	1.1758	16QAM	616	2.4063	QPSK	308	0.6016
10	7	2.7305			7	16QAM	378	1.4766	64QAM	466	2.7305	QPSK	449	0.877
11	8	3.3223			8	16QAM	490	1.9141	64QAM	567	3.3223	QPSK	602	1.1758
12	9	3.9023			9	16QAM	616	2.4063	64QAM	666	3.9023	16QAM	378	1.4766
13	10	4.5234			10	64QAM	466	2.7305	64QAM	772	4.5234	16QAM	490	1.9141
14	11	5.1152			11	64QAM	567	3.3223	64QAM	873	5.1152	16QAM	616	2.4063
15	12	5.5547			12	64QAM	666	3.9023	256QAM	711	5.5547	64QAM	466	2.7305
16	13	6.2266			13	64QAM	772	4.5234	256QAM	797	6.2266	64QAM	567	3.3223
17	14	6.9141			14	64QAM	873	5.1152	256QAM	885	6.9141	64QAM	666	3.9023
18	15	7.4063			15	64QAM	948	5.5547	256QAM	948	7.4063	64QAM	772	4.5234

Spectral Efficiency Calculation

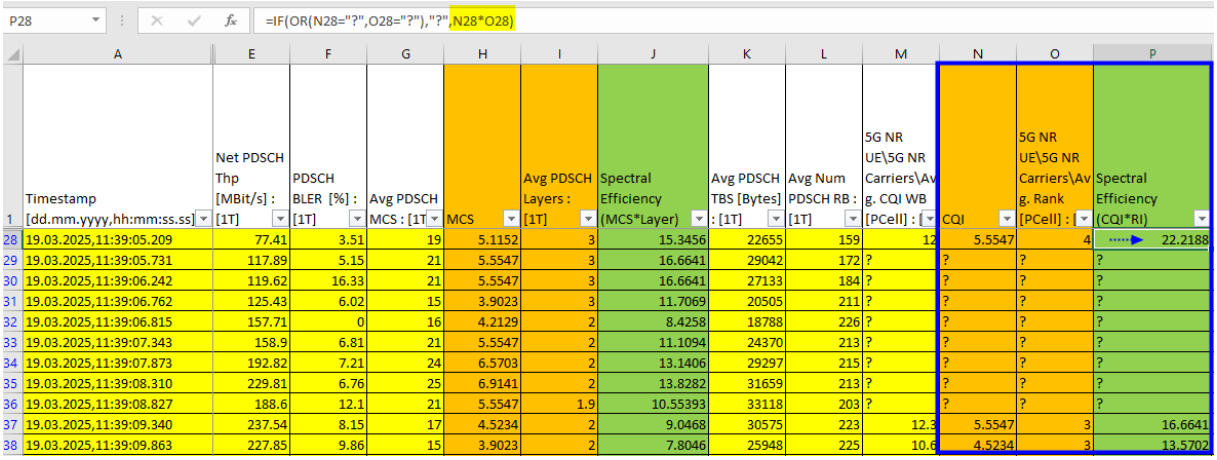
The last step is to calculate Spectral Efficiency using:

1. MCS * PDSCH Layer i.e. Column H * Column I
2. CQI * Rank i.e. Column N * Column O



J28 =IF(OR(H28="?",I28="?"),"?",H28*I28)

	A	E	F	G	H	I	J
1	Timestamp [dd.mm.yyyy,hh:mm:ss.ss]	Net PDSCH Thp [MBit/s] : [1T]	PDSCH BLER [%] : [1T]	Avg PDSCH MCS : [1T	MCS	Avg PDSCH Layers : [1T]	Spectral Efficiency (MCS*Layer)
28	19.03.2025,11:39:05.209	77.41	3.51	19	5.1152	3	15.3456
29	19.03.2025,11:39:05.731	117.89	5.15	21	5.5547	3	16.6641
30	19.03.2025,11:39:06.242	119.62	16.33	21	5.5547	3	16.6641
31	19.03.2025,11:39:06.762	125.43	6.02	15	3.9023	3	11.7069
32	19.03.2025,11:39:06.815	157.71	0	16	4.2129	2	8.4258
33	19.03.2025,11:39:07.343	158.9	6.81	21	5.5547	2	11.1094
34	19.03.2025,11:39:07.873	192.82	7.21	24	6.5703	2	13.1406
35	19.03.2025,11:39:08.310	229.81	6.76	25	6.9141	2	13.8282
36	19.03.2025,11:39:08.827	188.6	12.1	21	5.5547	1.9	10.55393
37	19.03.2025,11:39:09.340	237.54	8.15	17	4.5234	2	9.0468
38	19.03.2025,11:39:09.863	227.85	9.86	15	3.9023	2	7.8046
39	19.03.2025,11:39:09.914	256.83	5.88	15	3.9023	2	7.8046
40	19.03.2025,11:39:10.077	110.64	4.21	15	3.9023	2	7.8046



P28 =IF(OR(N28="?",O28="?"),"?",N28*O28)

	A	E	F	G	H	I	J	K	L	M	N	O	P
1	Timestamp [dd.mm.yyyy,hh:mm:ss.ss]	Net PDSCH Thp [MBit/s] : [1T]	PDSCH BLER [%] : [1T]	Avg PDSCH MCS : [1T	MCS	Avg PDSCH Layers : [1T]	Spectral Efficiency (MCS*Layer)	Avg PDSCH TBS [Bytes] : [1T]	Avg Num PDSCH RB : [1T]	5G NR UE\5G NR Carriers\Avg. CQI WB [PCell] : [	CQI	5G NR UE\5G NR Carriers\Avg. Rank [PCell] : [	Spectral Efficiency (CQI*RI)
28	19.03.2025,11:39:05.209	77.41	3.51	19	5.1152	3	15.3456	22655	159	12	5.5547	4	22.2188
29	19.03.2025,11:39:05.731	117.89	5.15	21	5.5547	3	16.6641	29042	172	?	?	?	?
30	19.03.2025,11:39:06.242	119.62	16.33	21	5.5547	3	16.6641	27133	184	?	?	?	?
31	19.03.2025,11:39:06.762	125.43	6.02	15	3.9023	3	11.7069	20505	211	?	?	?	?
32	19.03.2025,11:39:06.815	157.71	0	16	4.2129	2	8.4258	18788	226	?	?	?	?
33	19.03.2025,11:39:07.343	158.9	6.81	21	5.5547	2	11.1094	24370	213	?	?	?	?
34	19.03.2025,11:39:07.873	192.82	7.21	24	6.5703	2	13.1406	29297	215	?	?	?	?
35	19.03.2025,11:39:08.310	229.81	6.76	25	6.9141	2	13.8282	31659	213	?	?	?	?
36	19.03.2025,11:39:08.827	188.6	12.1	21	5.5547	1.9	10.55393	33118	203	?	?	?	?
37	19.03.2025,11:39:09.340	237.54	8.15	17	4.5234	2	9.0468	30575	223	12.3	5.5547	3	16.6641
38	19.03.2025,11:39:09.863	227.85	9.86	15	3.9023	2	7.8046	25948	225	10.6	4.5234	3	13.5702

Spectral Efficiency Calculation

The last step is to calculate Spectral Efficiency using:

1. MCS * PDSCH Layer i.e. Column H * Column I
2. CQI * Rank i.e. Column N * Column O

Spectral Efficiency Comparison between different HTTP DL Sessions

The figure below is a CDF (cumulative distribution function) comparison of spectral efficiency for different HTTP downlink sessions under 5G EN-DC (NSA) conditions.

The X-axis shows Spectral Efficiency (0 - 30 bps/Hz)

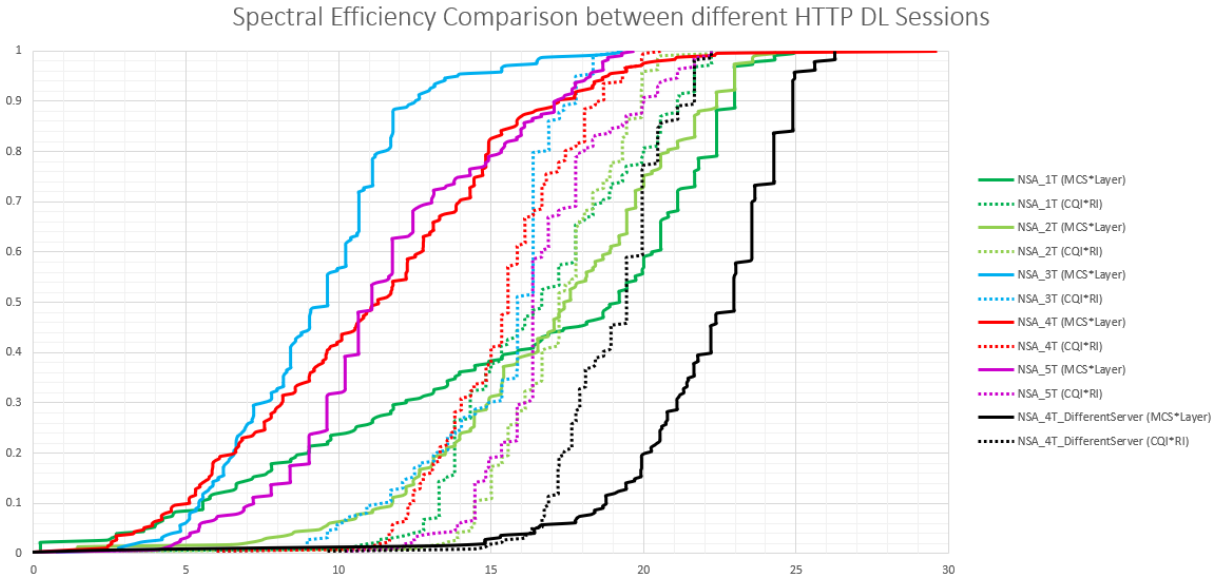
The Y-axis show CDF (0-1)

Each color represents a different number of parallel HTTP DL sessions:

NSA_1T, 2T, 3T, 4T, 5T

For each scenario, two estimation methods are plotted:

- Solid lines: Spectral Efficiency derived from MCS * PDSCH Layer
- Dotted lines: Spectral Efficiency derived from CQI * RI



Key Observation

- Servers plays roles in the above measurement files, as we can see **NSA_4T** and **NSA_4T_DifferentServer** shows significant gap in spectral efficiency.
- With default server, increasing number of parallel HTTP DL sessions does not guarantee higher spectral efficiency. In the measurement, NSA_3T case shows the lowest spectral efficiency distribution, while NSA_1T and NSA_2T provide better spectral efficiency.