5G NR Signal Generation and Analysis Application Note

Products:

- I R&S[®]SMW200A I R&S[®]FSW-K145
- I R&S[®]SMW-K144 I R&S[®]VSE
- I R&S[®]FSW43
- I R&S[®]FSW-K144

This application note is step by step guide on 5G New Radio (5G NR) signal generation and analysis capabilities using the R&S[®]SMW200A Vector Signal Generator equipped with software option SMW-K144 (5G NR option), in combination with the R&S[®]FSW Signal and Spectrum Analyzer and the software options FSW-K144 & FSW-K145 (5G NR Downlink & Uplink Signal Analysis). The R&S[®]VSE Vector signal explorer has also been used for analysis purpose in parallel to the FSW-K144 & FSW-K145 software options.

It is assumed that the reader already has a deep understanding of the 5G New Radio standard as well as the testing aspects. If not, then please refer to the 5G eBook more a detailed overview on the fundamentals, procedures, testing aspects of the 5G NR technology.

5G NR eBook: https://www.rohde-schwarz.com/5G-ebook.

Note:

Please find the most up-to-date document on our homepage

https://www.rohde-schwarz.com/appnote/GFM322



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1 Introduction

In previous mobile technology generations, voice communication have always been the major focus. Progressively, new services were added, e.g. text massaging in 2G, video calls in 3G and always-on data connectivity in 4G. The upcoming generation, 5G, seeks to make further major changes to services with a wide range of requirements. The networks are capable of providing services ranging from high data rate mobile broadband to ultra-reliable low-latency communications.

5G is designed to support a variety of different services. 5G New Radio (NR) employs a much higher bandwidth (up to 400 MHz per carrier) compared with 4G. 5G NR is designed for deployment in two main frequency ranges. FR1 comprises spectrum from 410 MHz to 7.125 GHz and FR2 from 24.25 MHZ to 52.6 GHz.

In case of waveform, 5G NR retains the OFDM-based waveform just like in LTE. However, certain fundamental differences enable the high configuration flexibility required in this generation. 5G NR introduces flexible numerology and thus allowing subcarrier spacing (SCS) of 15 KHz, 30 KHz, 60 KHz, 120 KHz and 240 KHz. This leads to different symbol time durations since the SCS is inversely proportional to the symbol duration. Therefor the number of symbol in a fixed time duration is now variable. The synchronization signals and data channels may use a different SCS. Moreover, the synchronization signals and broadcast signals are no longer placed in the center of the carrier. This requires the definition of a reference point for allocation of resources in the frequency domain.

In 5G NR, the nominal channel bandwidth per frequency band can be segmented into smaller sub bands known as resource grids or bandwidth parts (BWP). Mixed numerology can be an option to provide various Quality of Service (QoS) on the radio interface. One BWP is one fixed numerology. BWPs are allocated to UEs.

This application note is a step-by-step guide on 5G New Radio (5G NR) signal generation and analysis. The R&S[®]SMW200A Vector Signal Generator equipped with software option SMW-K144 (5G NR option), SMW-K114 (OFDM Signal Generation option) in combination with the R&S[®]FSW Signal and Spectrum Analyzer and the options FSW-K144 (5G NR Downlink Signal Analysis) & FSW-K145 (5G NR Uplink Signal Analysis) is used in this application note. The R&S[®]VSE Vector signal explorer has also been used for analysis purpose in parallel to the FSW-K144 & FSW-K145 software options. The R&S[®]VSE Vector signal explorer is an analysis software that can be used remotely on a user PC in a multi-user environment but with the same test bench.

Abbreviations

The following abbreviations are used in this application note for Rohde & Schwarz products:

- The R&S[®]SMW200A Signal Generator is referred to as SMW
- The R&S[®]FSW Signal and Spectrum Analyzer is referred to as FSW
- The R&S[®]VSE Vector signal explorer is referred to as VSE

2 5G NR DL & UL Signal Generation and Analysis

The standardization body, 3GPP creates the specification, which provides a comprehensive definition of the complete system. More specifically, the 3GPP RAN4 and RAN5 working groups define the base station and user equipment requirements to be tested and verified.

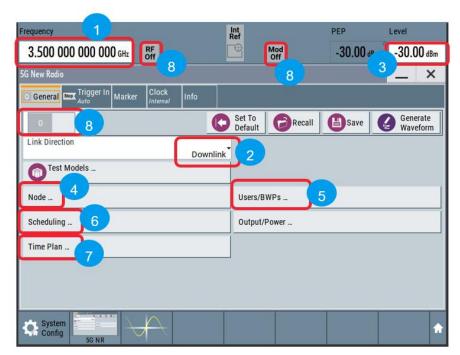
The radio transmission and reception (i.e. RF) requirements define the transmitter capabilities (e.g. maximum output power and transmit quality such as EVM and frequency error) and receiver capabilities (e.g. the sensitivity of an end-user device or its ability to maintain a certain throughput in the presence of an interferer or blocking signal).

The different 5G NR physical layer parameter can be generated and analyzed with ease. This chapter will explain systematically how this is performed, for both downlink and uplink, using the signal generator SMW and the spectrum analyzer FSW.

2.1 Downlink signal generation and analysis

This section describes a step-by-step guide on how to setup a FR1 Downlink (DL) cell where the maximum Bandwidth is 100MHz. The signal is centered at 3.5GHz.

2.1.1 Signal generator setting on the SMW



To start off, open the 5G NR option from the Baseband menu on the SMW

Fig. 2-1: 5G NR main configuration window on the SMW

Fig. 2-1 shows the main configuration window of the 5G NR physical layer baseband signal generation. The step numbers are marked in correct order in the figure to configure the physical layer downlink parameters. Follow the numerical sequence from from Fig. 2-1 and the configuration description is listed below:

- 1. Set Frequency: 3.5 GHz
- 2. Link direction : Downlink
- 3. Output power level: -30dBm
- 4. Node configuration settings

Sc Ma	hedulir Inual	^{ng} Carri	iers	TxBW Cell 0	S	S/PBCH Dummy	RES Carrier	Mapping			
1	lumber	of Carr	iers				1	RF Phase	Compensation		0
	Carrier	Cell Indicator	Cell IC	N1 ID	N2 ID	Deployment	Frequency /GHz	Channel BW	DMRS TypeA Position	SUL	
	Cell 0	0	1	0	1	3 GHz < f <= 6 GHz	1.000 000	100 MHz	2	Off	

Fig. 2-2: Node settings window configuration for carrier

Under node setting, the sub windows Carriers, TxBW , SS/PBCH need to be configured as shown in Fig. 2-2.

Scheduli _{Manual}	ng Ca	arriers	TxB Cell 0		SS/PBCH Cell 0	Dummy REs ^{Cell 0}	Carrie	er Mapping			
Carrier:	Cell				<u> </u>		0 0				
Point A	to Ca	arrier C	enter			-49.320 N	1Hz	Resolve C	onflicts		
	Use	N_RB	TxBW Offset	k0µ							
30 kH z	\checkmark	273	0	-6.0							
60 kHz	\checkmark	135	1	0.0							

Carrier: Cell ID: 1, Deployment: 3 GHz <f <= 6 GHz, Channel BW : 100 MHz

Fig. 2-3: Node settings window configuration for TxBW

Т

Select both 30 KHz and 60 KHz and hit Resolve Conflicts as shown in Fig. 2-3

5G	New Radio	A: N	ode	Settin	gs												_	×
Sc Ma	heduling ^{nual}	Carr	iers	TxB Cell		S/PB(ell 0	СН	Dumi Cell 0	my REs	Carrier M	apping							
C	arrier: Ce									ø 0								
N	lumber of	SS/	BC	H Pat	terns	1		Anten	na Port			400		ffset R	elativ	re to		TxBw
	SC Spacin CP		RB ffset	SC Offset	∆f to Carr (Centers /MHz	s) Ca	ise	L	Positions	Burst Set Periodicity	РВСН	PSS Power /dB		PBCH Power /dB				
0	30 kHz NC	P	80	6	-16.740 00	00 E	3	8	1100 0	10 ms	Config	0.00	0.00	0.00	On			

Fig. 2-4: Node settings window configuration for SS/PBCH

- Select SC spacing: 30 KHz NCP, RB offset:80, SC offset: 6, Case: B, Position: 1100 0000 as shown in Fig. 2-4
- 5. Users/ BWPs configuration from Fig. 2-1

Ge		Properties			3WP Con1 0 / Cell 0 / 1		Ps UL BWP Config Cell 0 User 0 / Cell 0 / BWP 0
U	Jser:					0	Carrier: Cell
N	lumbor	of DL BWPs				0	0
IN	umber	DI DL DWPS				2	
2	BWP Indicator	SC Spacing / CP	No. RBs	RB Offset in TxBW	RB Offset to PointA	Δf to Carrier (Centers) /MHz	
0	0	30 kHz NCP	30	135	135	4.680 000	
1	1	60 kHz NCP	35	0	1	-36.000 000	

Fig. 2-5: User/BWPs setting window configuration for DL BWPs

- As shown in Fig. 2-5, Insert Number of DL BWPs: 2
- Configure BWP indicator 0 with SC spacing: 30 KHz, no RBs: 30 & RB offset: 135
- Configure BWP indicator 1 with SC spacing: 60 KHz, no RBs: 35 & RB offset: 0

6. Now that there are two BWPs, both needs to be configured separately from the Scheduling window in Fig. 2-1. The first BWP is indicated with 0 and the second BWP is associated 1 in Fig. 2-6.

Cell			SubfranO	me						0	C	Prev		Next
	Content	No. Alloc	SC Spacing / CP	Slot	Мар Туре	Slot Fmt.	No. Sym.	Sym. Offset	No. RBs	RB Offset	Settings	Power /dB	State	Repetition
	SS/PBCH		30 kHz NCP	0		0	4	4	20	-	Config	0.00	On	
	SS/PBCH		30 kHz NCP	0		0	4	8	20	•	Config	0.00	On	
•	User 0, BWP 0	2									Config			
	CORESET		30 kHz NCP	0		0	2	0	30	0	Config	0.00	On	Slot
	PDSCH		30 kHz NCP	0	Α	0	12	1	30	0	Config	0.00	On	Slot
	CORESET		30 kHz NCP	1		0	2	0	30	0	-	0.00		of SF 0
	PDSCH		30 kHz NCP	1		0	12	1	30	0		0.00		of SF 0
•[User 0, BWP 1	2									Config			
	CORESET		60 kHz NCP	0		0	2	0	24	0	Config	0.00	On	Slot
	PDSCH		60 kHz NCP	0	А	0	12	1	32	0	Config	0.00	On	Slot
	CORESET		60 kHz NCP	1		0	2	0	24	0		0.00		of SF 0

Fig. 2-6: Scheduling setting for the first BWP

Configure the two BWP as shown in Fig. 2-6

- I BWP 0 : 30 KHz NCP
 - CORESET, slot: 0, No. Sym: 2, Sym Offset: 0, No RB: 30
 - PDSCH, slot: 0, Map type: A, No. Sym: 12, Sym Offset: 1, No RB: 30, Config: Mod: QPSK
- I BWP 1 : 60 KHz NCP
 - CORESET, slot: 0, No. Sym: 2, Sym Offset: 0, No RB: 24
 - PDSCH, slot: 0, Map type: A, No. Sym: 12, Sym Offset: 1, No RB: 32, Config: Mod: 64QAM

7. The time plan window (in Fig. 2-1) depicts a graphical overview of the configured physical layer parameters. Fig. 2-7 shows a signal with two BWPs with different SCSs as configured in this section.

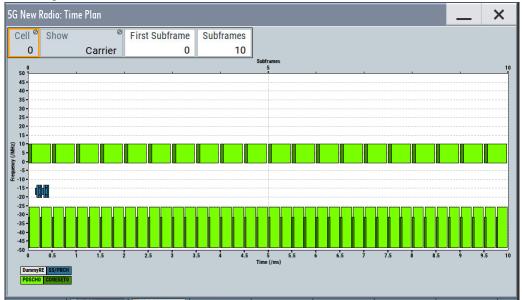


Fig. 2-7: Downlink signal parameter setting as visualized on the Time Plan window

8. Switch ON the Baseband signal, Modulator and RF using the buttons as marked on Fig. 2-1 .

2.1.2 Spectrum Analyzer setting on the FSW

I To get started, switch ON the 5G NR measurement personality from MODE

Mode		ado Dowalak 1	00 MHz – Castura Tinaa	70 1 over RMD /SS All	() X
Signal + S	pectrum Analyzer	Multi-Standard Ra	adio Analyzer		
New Channel	ഹ്പ Spectrum	[™] 1×EV-DO BTS	■ 1×EV-DO ™ MS	3G FDD 36 BTS	3G FDD 3G UE
Replace Current	5G NR 5G NR	🤶 802.11ad	奈 802.11ay EDMG	- Amplifier	≁ Analog Demod
Channel	→ Avionics	CDMA2000 BTS	CDMA2000 MS	🗮 DOCSIS 3.1	Ğ≣) GSM
	-IQ Analyzer		Ⅲ MC Group Delay		where Noise
	🍂 OneWeb	کر Phase Noise	∭ Pulse	III Spurious	TD-SCDMA BTS
	TD-SCDMA ^{TD} UE	∫~ Transient Analysis	vsetF V5GTF	VSA	후 WLAN
	SGNR SGNR Duplicate Current Channel				

Fig. 2-8: Measurement Modes selection window on the FSW

- 🖆 🖺 📥	🔿 🐼 🐼 k		£ SCPI ₹	? ?			O	5G NR
MultiView 📑 Spectru Ref Level 0.00 dBm Free	and a second	200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200 - 200	100 MHz Ca	pture Time 20.1 n	BWP/SS	۵	•	Signal Descriptio
Att 10 dB	Frame C			ame	1		· · · · · · · · · · · · · · · · · · ·	Radio
YIG Bypass								Frame Config
Capture Buffer	01 Clrw	3 EVM vs Car	rrier 01 Av			s Symbol X Cari		oomig
gerne Start Offset 8.81920P412 ms) dBm		15 %			PSS CORESET DMRSP	SSS PBCH BCH DMRSPDSCH DMR	PTRS CORESET	
		10 %						Trigger/ Signal Capture
-60 dam -80 dam		5.%						Paramete (Estimation Tracking
0.0 ms 2.01 ms	/ 20.1 ms	0.0 Hz	9.83 MHz	/ 98.28 MHz				an arresta
Result Summary		Sel	lected Averaged	5 Power Spectr	um 01 Clrw	6 Constellatio	n Diagram	Demod
Frame Results Averaged	Mean Limi	it Max	Min			Politik Measured		
EVM PDSCH QPSK (%)	*148.00 18.50		148.00			Barris Contraction of the second		Evaluatio
EVM PDSCH 160AM (%)	13.50							4 Range
EVM PDSCH 64QAM (%)	9.00	0						, and the second s
EVM PDSCH 256QAM (%)	4.50			-70 dBm/Hz		2 M		
EVM All (%)	147.74	147.74	147.74					Result Setting
EVM Phys Channel (%)	147.83	147.83	147.83	-80 dBm/Hz				1 Setting
EVM Phys Signal (%)	146.08	146.08	146.08	100 100 200				
Frequency Error (Hz)	-43129.33	-43129.33	-43129.33	-90 dBm/Hz-		1 () () () () () () () () () (Display
Sampling Error (ppm)				-100 dBm/Hz				• Config
I/Q Offset (dB)	-43.48	-43.48	-43.48			1. Sec. 1. Sec		
I/Q Gain Imbalance (dB)				-110 dBm/Hz				
I/Q Quadrature Error (°)	-65,50	65.50	55.50					
OSTP (dBm)	-65.52	-65.50	-65.50	-120 dBm/Hz				
	-65.52	-05.52	-03.52				1	
Power (dBm)	11.40							
	11.40						States and States	Overview
Power (dBm) Crest Factor (dB)	11.40			0.0 Hz	122.88 MHz			Overview
	11.40	Sync	Failed	0.0 Hz	122.88 MHz	Measuring		m 01.08.201
Crest Factor (dB)	11.40	Sync	Failed	0.0 Hz	122.88 MHz			Overview 01.08.201 11:07:4
Crest Factor (dB)		_				Measuring		m 01.08.201
Crest Factor (dB)		_	Failed	7	122.88 MHz	Measuring	····· · · · · · ·	m 01.08.201
Crest Factor (dB)		2 MKR	PEAK	н 7	8 9 abc def	Measuring GHz s -dBm V	Ŷ	01.08.201 11:07:4
Crest Factor (dB) UNCAL • PRESET MODE SETUR		MKR	PEAK	H 7	8 9 abc def 5 6	Measuring GHz s -dBm V MHz ms		m 01.08.201
Crest Factor (dB)	· [8-0] (69)	MKR MKR FUNC	PEAK SEARCI MKR	H 7 4 ghi	8 9 abc def 5 6 jkl mo	Measuring GHz s -dBm V MHz ms dBm mV	Ŷ	01.08.201 11:07:4
Crest Factor (dB) UNCAL		MKR MKR FUNC	PEAK SEARCI MKR RUN	H 7 4 ghi	8 9 abc def 5 6 jkl mm	Measuring GHz s -dBm V MHz ms dBm mV	Ŷ	01.08.201 11:07:4
Crest Factor (dB) UNCAL • PRESET MODE SETUR		MKR MKR FUNC	PEAK SEARCI MKR	H 7 4 ghi	8 9 abc def 5 6 jkl mo	Measuring GHz s -dBm V MHz ms dBm mV kHz µs	ن ج ج	01.08.201 11:07:4

Fig. 2-9: 5G NR measurement Mode on the FSW

- I Set Frequency: 3.5 GHz as shown in Fig. 2-9
- In the Signal description window, the signal parameter of the received signal needs to be configured

Signal Description	Radio Fram	e Config	Ant Port Mapping	Advanced Settin	gs	
Mode [Downlink	-	Test Mo	del: Not selected yet		J
Number of Component Carriers	1	с	C Signal Capture	Auto	Single	Ī
Deploy Frequency ange	8GHz < f <= 6G	Hz 🔹				
Physical Settings						
Channel Bandwidth 1	00MHz	- Sampl	e Rate 122.88 MHz			
Auto All	On Off	Лах				
Synchronization	Auto <mark>Manual</mark>	Configure	: SCS		Delta to CF	
Bandwidth Parts	Auto <mark>Manual</mark>	Configure	1 BWPs		SCS 30ki	Hz
nal (%) 146. Slot (z) 3597. or (com)		Configure	Slot Format 0			
PDSCH/PDCCH		Configure	QPSK			
Auto Detection Cell ID		Cell ID	1			

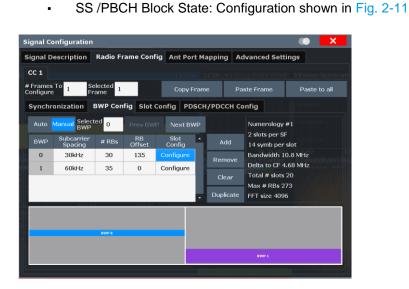
Fig. 2-10: Signal description configuration window in the 5G NR mode on the FSW

- I Signal description settings is in Fig. 2-10,
 - Set Mode: Downlink, Number of component Carriers: 1
 - Deploy frequency Range: 3GHz < f <=6GHz
 - Channel Bandwidth: 100MHz
 - Bandwidth Part: 1 BWPS and SCS 30 KHz
 - PDSCH/PDCCH: QPSK
 - Cell ID: 1

	on											
ignal Descriptio	n Radio Frame Confi	g Ant Port Mapping	Advanced Setti	ngs								
CC 1					um							
Frames To onfigure	Selected Frame	Copy Frame	Paste Frame	Paste to all								
Synchronization	BWP Config Slot C	onfig PDSCH/PDCCH	H Config									
Detection Auto	1anual	an damaa										
Subcarrier Spacing	30kHz -	SS/PBCH Block Pattern	CASE B									
SS/PBCH Block Off	set							_				-
					SS Blo	ock Sta	te Con	nfig				×
Offset rel to	^{dean} 0.9.1 TxBW	 Delta: SS/PBCH Block Center to CF 	nesser of 10-16.74	MHz	Number	r of SS/	РВСН Ь	olocks 8				
Offset rel to RB Offset	0.00 T×BW	Delta: SS/PBCH Block Center to CF Additional Subcarrier Offset	6	MHz	Number	r of SS/ A	_	olocks 8		N	one	
RB Offset Burst Set	0.94	Center to CF Additional Subcarrier Offset	6	MHz	Index	A State		State	Index	State	Index	_
RB Offset Burst Set Periodicity	30 10ms -	Center to CF Additional Subcarrier Offset SS/PBCH Block State	6 Configure	MHz		A				State Off		Of
RB Offset Burst Set	80 80	Center to CF Additional Subcarrier Offset SS/PBCH Block State SSS Rel Power	6	MHz	Index 0 4	A State On Off	II Index 1 5	State On Off	Index 2 6	State Off Off	Index 3 7	Sta Of Of
RB Offset Burst Set Periodicity	30 10ms -	Center to CF Additional Subcarrier Offset SS/PBCH Block State	6 Configure	MHz	Index 0	A State On	ll Index 1	State On	Index 2	State Off	Index 3	Of Of

Fig. 2-11: Radio Frame Configuration window in the 5G NR mode on the FSW

- From the Radio Frame Config window, the sub categories (shown in Fig. 2-11) need to be configured
- In the Synchronization,
 - Select Detection: Manual, Subcarrier Spacing: 30 KHz
 - SS/PBCH Block Pattern : CASE B
 - Offset rel to: TxBW
 - RB Offset: 80, Additional Subcarrier Offset: 6



Burst Set Periodicity: 10ms

.

Fig. 2-12: BWP configuration settings in Radio Frame Config menu

- BWP o and 1 needs to be configured as shown in Fig. 2-12
 - BWP 0: SCS 30KHz, #RBs: 30, RB Offset: 135
 - BWP1: SCS 60KHz, #RBs: 35, RB Offset: 0

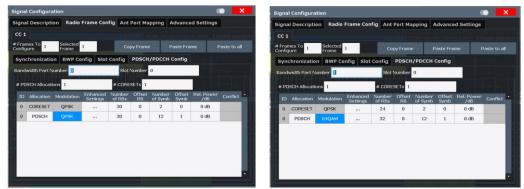
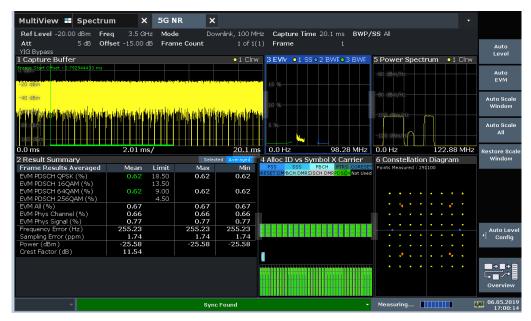


Fig. 2-13: PDSCH/PDCCH config settings in Radio Frame Configuration menu

 Fig. 2-13 shows the PDSCH/PDCCH configuration for the two BWPs and needs to be configured accordingly

Signal Configurati	on					X
Signal Description	n Radio Frame Config	Ant Port P	Aapping	Advanced Setting	js	
CC 1						
	k_0 configured numerologie	s				
Global Settings	SCS 15kHz 0	→ SCS 30kH	lz -6	- SCS 60kHz	0	
Reference	Reference Point A					
Point A	Relative to CF -49.32 MH	z	Absolute Fre	equency 3.45068 GH		
			TxBW Offse			

Fig. 2-14: Advanced Settings configuration in Signal Description menu



Reference point A relative to CF is -49.32 MHz

Fig. 2-15: Measurement Display Window of the 5GNR analysis personality on the FSW

Fig. 2-1 shows the measurement display of the 5G FR1 signal at 3.5 GHz. The auto EVM can be selected to optimize the analysis of the signal. The EVM for PDSCH QPSK is 0.62% and PDSCH 64QAM is 0.62%.

2.1.3 Spectrum Analysis on the VSE

Configuring the 5G NR measurement personality on the VSE.

Sign	Signal Configuration	× ×
	Signal Description Radio Frame Config A	dvanced Settings
		e Signal Description
	Deploy Frequency Range 3GHz < f <= 6GHz *	
	Physical Settings	
	Channel Bandwidth 100MHz Sample Rate 122.88 MHz	
	Synchronization Configure SCS 30kHz	Delta to CF -16.74 MHz
5G NR	Bandwidth Parts Configure 2 BWPs	SCS 30kHz, 60kHz
2		
	PDSCH/PDCCH Configure QPSK, 64QAM	
	Auto Detection On Off Cell ID	1

Fig. 2-16: 5G NR measurement Mode Signal Description configuration on the VSE

 Fig. 2-16 shows the Signal Description configuration of the 5G NR measurement modes

- Mode: Downlink, Deploy frequency Range: 3GHz < f <= 6GHz
- Channel Bandwidth: 100 MHz
- Synchronization: SCS 30KHz
- Bandwidth Parts: 2 BWPs
- DPSCH/PDCCH: QPSK, 64QAM
- Auto Detection: OFF, Cell ID: 1

Sig	nal Co	onfiguration										×								
	Si	gnal Description		Radio I	Frame Config	Ac	dvanced Settings													
		frames To 1	Selected Frame	1			Copy Frame	Past	e Frame	P	aste to all									
		Synchronization	BWP	Config	Slot	t Config	PDSCH/PE	оссн со	onfig			_								
		Detection Auto	Manual																	
		Subcarrier Spacing			 SS/PBCH 	Block Pattern	CASE B	•			-	ss	Block St	ate Cor	ıfig			-	•	×
		SS/PBCH Block O	ffset		Additio								Numbe	r of SS/P	BCH blo	cks 8				
5G NR		RB Offset	80		Subcar	rier Offset	6		-					A	JI			No	ne	
ß		Delta: SS/PBCH E	Block Center	to CF -1	16.74 MHz								Index	State	Index	State	Index	State	Index	State
		Burst Set Periodicity	10ms		▼ SS/PBCH	Block State	Configure						0	On	1	On	2	Off	3	Off
		PSS Rel Power	0.0 dB		SSS Rel P	ower	0.0 dB						4	Off	5	Off	6 10	Off	7	Off
		PBCH Rel Power	0.0 dB		PBCH DN Rel Powe	IRS er (to PBCH)	0.0 dB						12	Off	13	Off	14	Off	15	Off
	l												16	Off	17	Off	18	Off	19	Off
													20	Off	21	Off	22	Off	23	Off
													_							
	_																			

Fig. 2-17: Radio Frame Config on the VSE

- From the Radio Frame Config window, the sub categories (shown in Fig. 2-17) need to be configured
- I Under the Synchronization tab,
 - Select Detection: Manual, Subcarrier Spacing: 30 KHz
 - SS/PBCH Block Pattern : CASE B
 - RB Offset: 80, Additional Subcarrier Offset: 6
 - Burst Set Periodicity: 10ms
 - SS /PBCH Block State: Configuration shown in Fig. 2-17

Sig	nal Configuration			·····	· · ·			X
	Signal Description	Radio Frame Config		Advance	d Settings			
	# Frames To 1 Selected Configure 1 Frame	1		Сору	Frame	Paste Frame	Paste to all	
	Synchronization BWF	Config Slo	t Config		PDSCH/PI	DCCH Config		_
	Selected 1 Prev BWF	Next BWP			Numerolo 4 slots pe			
	BWP Subcarrier # RBs	RB Slot Offset Config		Add	14 symb p	oer slot		
	0 30kHz 30	135 Configure		Remove		th 25.2 MHz CF -36.0 MHz		
5G NR	1 60kHz 35	0 Configure		Clear	Total # slo Max # RB			
ŝ			-	Duplicate	FFT size 2	048		
ļ								

Fig. 2-18: BWP configuration settings in Radio Frame Config menu

- BWP o and 1 needs to be configured as shown in Fig. 2-18
 - BWP 0: SCS 30KHz, #RBs: 30, RB Offset: 135
 - BWP1: SCS 60KHz, #RBs: 35, RB Offset: 0

Configu	ration				-					×	Signal (_				<u></u>
Signal D	escription	Rac	lio Frame Co	nfig	Adva	nced Settin	igs			_	5	ignal D	escription	Rad	io Frame Co	nfig	Adva	nced Setti	ngs		
Frames	To 1	Selected 1			C	opy Frame	Pa	ste Frame	Paste to all		ł	Frames	To 1	Selected 1			0	opy Frame	Pa	iste Frame	Paste to a
Synch	ronization	BWP Con	fig	Slot Confi	9	PDSCH	I/PDCCH	Config				Synchi	ronization	BWP Conf	ig	Slot Confi	ig	PDSC	ң/россн	Config	
Bandw	idth Part No	imber 🚦		Slot Number	0							Bandw	idth Part Numb	er 🚹		Slot Number	0				
# PD	SCH Allocat	ons 1			1							* PD:	5CH Allocation	s 1		CORESETS	1				
ID	Allocatio	n Modulation	Enhanced Settings	Number of RBs	Offset RB	Number of Symb	Offset Symb	Rel. Power /dB	Conflict			ID	Allocation	Modulation	Enhanced Settings	Number of RBs	Offset RB	Number of Symb	Offset Symb	Rel. Power /dB	Conflict
0	CORESE	T QPSK	-	30	0	2	0	0 d8			SG NR	0	CORESET	QPSK		24	0	2	0	0 dB	
0	PDSCH	QPSK	-	30	0	12	1	0 d8			2	0	PDSCH	64QAM		32	0	12	1	0 dB	
									ļ												

Fig. 2-19: PDSCH/PDCCH config settings in Radio Frame Configuration menu

Fig. 2-19 shows the PDSCH/PDCCH configuration for the two BWPs and needs to be configured accordingly

- I BWP 0 configuration:
 - CORESET: Modulation: QPSK, No of RBs: 30, No of Symbol: 2
 - PDSCH: Modulation: QPSK, No of RBs: 30, No of Symbol: 12, Offset Syb: 1
- I BWP 1 configuration:
 - CORESET: Modulation: QPSK, No of RBs: 24, No of Symbol: 2
 - PDSCH: Modulation: 64QAM, No of RBs: 32, No of Symbol: 12, Offset Syb: 1

Sig	nal Configuration			🔬 🗶
	Signal Description	Radio Frame Config	Advanced Settings	
	Global Settings	nfigured numerologies SkHz o s s ence Point A ve to CF MHz	CS 30kHz SCS 60	OkHz 0 •
5G NR	Reference Point A			

Fig. 2-20: Advanced Settings configuration

Reference point A : Relative to CF is -49.32 MHz

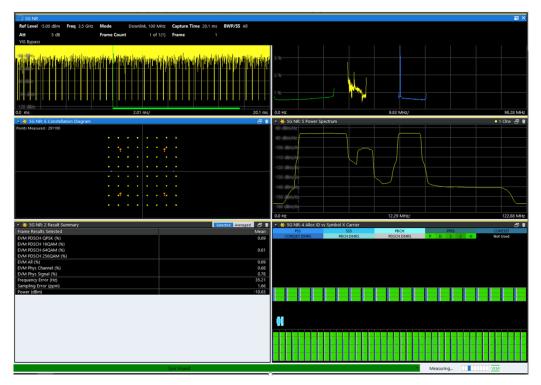


Fig. 2-21: Measurement Display Window of the 5GNR analysis personality on the FSW

Fig. 2-21 shows the measurement display of the 5G FR1 signal at 3.5 GHz. The EVM for PDSCH QPSK is 0.69% and PDSCH 64QAM is 0.61%.

2.2 Uplink signal generation and analysis

Frequency	1	Int Ref		PEP	Level
3.500 000 000 00	O GHz RF	T [®]	Mod Off	-10.00	-10.00 dBm
5G New Radio	8		8		³ _ ×
General Blopx Trigger In Auto	Marker Clock Internal Info	2			
		Set To Default	Recall	Save	Generate Waveform
Link Direction		Uplink			
Test Models		2			
Node 4		Users/E	WPs 5		
Scheduling 6		Output	Power		
Time Plan 7					
System Config 5G NR					•

2.2.1 Signal generator setting on the SMW

Fig. 2-22: 5G NR main uplink configuration window on the SMW

Fig. 2-22 shows the main configuration window of the 5G NR physical layer baseband signal generation. The steps numbers are marked in correct order in the figure to configure the physical layer uplink parameters. Following Fig. 2-22:

- 1. Set Frequency: 3.5 GHz
- 2. Link direction : Uplink
- 3. Output power level: -10dBm
- 4. Node configuration settings from Fig. 2-22

re	quency						Int Re	t f	PE	Р		Level	
	3.500	000 (0 00	00 Gł	łz	RF Off				10.00) dBm	-10.0	0 dBm
5G	New Ro	idio A: No	ode Sett	ings								_	×
Ca	arriers	TxBW Cell 0	Dur Cell	nmy R 0	Es Ca	arrier Mapping							
1	lumbe	of Carri	ers				ø 1	RF Phase C	ompensation			0	
	Carrier	Cell Indicator	Cell ID	N1 ID	N2 ID	Deployment	Frequency /GHz	/ Channel BW	DMRS TypeA Position	SUL			
0	Cell 0	0	1	0	1	3 GHz < f <= 6 GHz	1.000 000	100 MHz	2	Off			

Fig. 2-23: Node settings window configuration for carrier

Under node setting, the sub windows Carriers, TxBW needs to be configured as shown in Fig. 2-23.

- 5G New Radio A: Node Settings × TxBW Cell 0 Dummy REs Carrier Mappin Carrier: Cell 0 Point A to Carrier Center **Resolve Conflicts** -49.320 MHz Use N_RB TxBW k0µ 30 kH z 273 0 -6.0 60 kHz 135 1 0.0
- Carrier: Cell ID: 1, Deployment: 3 GHz <f <= 6 GHz, Channel BW : 100 MHz

Fig. 2-24: Node settings window configuration for TxBW

Select both 30 KHz and 60 KHz and hit Resolve Conflicts as shown in Fig. 2-24

5G	New Rad	io A: Users/B\	NP Settin	ıgs							_	×
G		Properties U			VP Config / Cell 0 / BW							
	User:					0	Carr	ier: Cell	 	 		0
	Number o	of UL BWPs				1			 	 		0
	-	70	· · · · ·									
	BWP Indicator	SC Spacing / CP	No. RBs	RB Offset in TxBW	RB Offset to PointA	Δf to Carrier (Centers) /MHz						
0	0	60 kHz NCP	75	0	1	-21.600 000						

Fig. 2-25: User/BWPs setting window configuration for UL BWP

- Users/ BWPs configuration is shown in Fig. 2-25,
 - Insert Number of UL BWPs: 1
 - Set BWP indicator 0 with SC spacing: 60 KHz, no RBs: 75 & RB offset: 0

6. Now the BWP needs to be configured separately from the scheduling window in Fig. 2-22. The BWP configuration is shown in Fig. 2-26.

Frequency				Int Ref				PE	P		Leve	ļ
3.500 000 000 000 GH	RF Off			T)	Mo			-	30.00	dBm	-3	0.00 dBm
5G New Radio A: Scheduling Settir	ıgs										_	. ×
Cell	C	Subfram	e					0	C	Prev		Next
Content	No. Alloc	SC Spacing / CP	Slot	Map Type /Format.	No. Sym.	Sym. Offset	No. RBs	RB Offset	Settings	Power /dB	State	Repetition
▼ Common												
▼ User 0, BWP 0	1	60 kHz NCP					75		Config			
PUSCH	_	60 kHz NCP	0	A	14	0	75	0	Config	0.00	On	Slot
PUSCH		60 kHz NCP	1		14	0			Info	0.00		of SF 0

Fig. 2-26: Scheduling setting for the BWP

- I BWP 0 has No allocation :1
 - Sub carrier spacing 60 KHz NCP , content: PUSCH, Map format: A
 - Slot: 0, No Sym: 14, No RBs: 75; Config: Mod: 64QAM

7. The time plan (from Fig. 2-22) window shown in Fig. 2-27 depicts a graphical overview of the configured physical layer parameters.

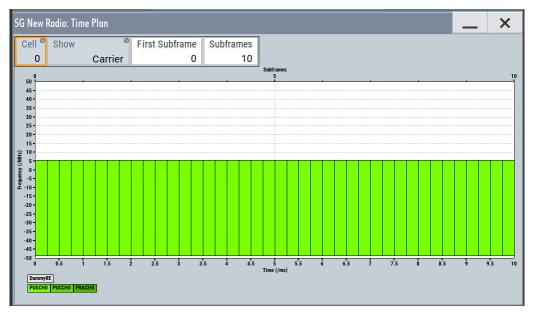


Fig. 2-27: Uplink signal parameter setting as visualized on the Time Plan window

8. Switch ON the Baseband signal, Modulator and RF using the buttons as marked on Fig. 2-22.

2.2.2 Spectrum Analyzer setting on the FSW

I To get started, switch ON the 5G NR measurement personality from MODE

Mode		lada Dawaliak 1	00 Mile - Contura Tinya	20.1 ms BWP/SS All	() X
Signal + S	pectrum Analyzer	Multi-Standard Ra	ndio Analyzer		
New Channel	ഹ്പ Spectrum	™ 1×EV-DO ™ BTS	■ 1×EV-DO ™ MS	3G FDD 3G BTS	3G FDD 3G UE
Replace Current	5G NR 5G NR	奈 802.11ad		- Amplifier	·∕·∕ Analog Demod
Channel	→ Avionics	CDMA2000 BTS	CDMA2000 MS	🗮 DOCSIS 3.1	GSM GSM
	-IQ Analyzer		MC Group Delay		
	🍂 OneWeb	└ Phase Noise	∭ Pulse	III Spurious	☆ TD-SCDMA ™ BTS
	I TD-SCDMA ™ UE	∫~ Transient Analysis	vser V5GTF	VSA	후 WLAN
	‱ — ^{1:1} → ‱ Duplicate Current Channel				

Fig. 2-28: Measurement Modes selection window on the FSW



Fig. 2-29: 5G NR measurement Mode on the FSW

- Set Frequency: 3.5 GHz as shown in Fig. 2-29
- In the Signal description window, the signal parameter of the received signal needs to be configured

Signal Configuration	on				×
Signal Description	n Radio F	rame Config	Ant Port Mapping	Advanced Settings	
Mode	Uplink	-	Us	er Defined Sets	
Number of Component Carriers	1	d	C Signal Capture	Auto Single	
Deploy Frequency Range	3GHz < f <	= 6GHz 🛛 🕶			
Physical Settings					
Channel Bandwidth	100MHz	▼ Sampl	e Rate 122.88 MHz Tr 20.1 ms 0.0 Hz	ansform Precoding Off	
Bandwidth Parts	Configure	1 BWPs		Symbol X Carrier SCS 30kHz	
Slot M (%) 640 AM (%) 2560 AM (%)	Configure	Slot Format 1			
PUSCH/PUCCH	Configure	QPSK			
Cell ID	9.90 0.) 0.00) 0.00			

Fig. 2-30: Signal description configuration window in the 5G NR mode on the FSW

- Signal description settings is in Fig. 2-30,
 - Set Mode: Uplink, Number of Component Carriers: 1
 - Deploy frequency Range: 3GHz < f <= 6GHz
 - Channel Bandwidth: 100MHz
 - Bandwidth Part: 1 BWPS and SCS 30 KHz
 - PDSCH/PDCCH: QPSK
 - Cell ID: 1

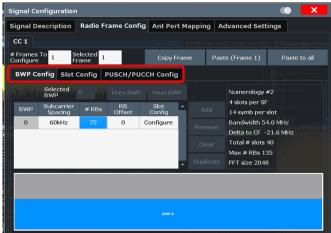


Fig. 2-31: Radio Frame Configuration window in the 5G NR mode on the FSW

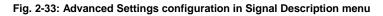
- I From the Radio Frame Config window, the sub categories need to be configured as shown in Fig. 2-31
- In the BWP Config sub category,
 - Subcarrier Spacing: 60 KHz
 - #RBs: 75, RB offset: 0

ignal Config									
Signal Desci	ription	Radio	Frame Conf	ig Ant	Port Ma	pping	Advance	ed Settings	
CC 1									
⊭ Frames To Configure		Selected Frame	1	Coj	oy Frame	: Pa	aste (Fran	ne 1) f	Paste to al
BWP Config	g Slot	Config	PUSCH/PI	ЈССН С₀	nfig				
Bandwidth Pa	art Numl	oer 0		Slot	Number	0		-10	
# PUSCH Alle	ocations	1		# PUCCI	H Allocati	ions 0		-1	
ID Allocat	ion Mo	dulation	Enhanced Settings	Number of RBs	Offset RB	Number of Symb		Rel. Power /dB	Conflict
0 PUSC	н (54QAM		75	0	14	0	0 dB	

Fig. 2-32: PUSCH/PUCCH config settings in Radio Frame Configuration menu

Fig. 2-32 shows the PUSCH/PUCCH configuration for the BWPs and needs to be configured accordingly

Signal Configurati	on		0	×
Signal Descriptio	Radio Frame Config	Ant Port Mapping	Advanced Settings	
CC 1				
	k_0 configured numerologie	s		
Global Settings	SCS 15kHz 0	→ SCS 30kHz -6	- SCS 60kHz	
Reference	Reference Point A			
Point A	Relative to CF -49.32 MH	z Absolute Fr	requency 3.45068 GHz	
		TxBW Offs	et 0 -12	



Reference point A relative to CF is -49.32 MHz as shown in Fig. 2-33

RefLevel-6.00 dBm Freq 3.3 Att 4 dB		ode ame Coun		00 MHz Ca of5(1) Fra	pture Time 20.1 ms BWP All ame 1		Auto
'IG Bypass						V	Level
Capture Buffer				O1 Clrv	v 3 EVN ●1 Avg●2 Min●3 Max	5 Power Spectrum • 1 Clrw	
ame Start Offset : 7.410636172 ms					15 %		Auto EVM
20 dBm						-80 dBm/Hz	Auto Scale
il din ana ana ana ana ana ana ana ana ana a	A Abbilin in colo	ini papura	l a fill bahilu	a ile districte del		-100 dBm/Hz	Window
50 dBm	· · · · · · · · ·				5.96	-120 dBm/Hz-	Auto Scale All
.0 ms	2.01 ms/			20.1 m	is 0.0 Hz 5.4 MHz/ 54.0 MHz	0.0 Hz 122.88 MHz	Restore Sca
Result Summary			Selecte	d Averaged	4 Alloc ID vs Symbol X Carrier	6 Constellation Diagram	Window
rame Results Averaged	Mean	Limit	Мах	Min	PTRSPUCCHUCCH DMRUSCH DMRPUSCHNot Use	d Points Measured : 504000	million
	Mean	Limit 17.50			PTRSPUCCHJCCH DMRJSCH DMRPUSCH Not Use	Points Measured : 504000	
rame Results Averaged VM PUSCH QPSK (%) VM PUSCH 16QAM (%)	Mean			Min	PTRSPUCCHJCCH DMRJSCH DMRPUSCHNot Use	Points Measured : 504000	
Tame Results Averaged VM PUSCH QPSK (%) VM PUSCH 16QAM (%) VM PUSCH 64QAM (%)	Mean 0.23	17.50			PTRSPUCCHJCCH DMRJSCH DMRJUSCH Not Use	Points Measured : 504000	
Tame Results Averaged VM PUSCH QPSK (%) VM PUSCH 16QAM (%) VM PUSCH 64QAM (%) VM PUSCH 256QAM (%)		17.50 12.50 8.00	Max	Min	HANDLO D'S SYNDO'A CATHEI PARSPUCCH CH DMRJSCH DMRPUSCH Vie Use 1501	d Points Measured : 504000	
Tame Results Averaged VM PUSCH QPSK (%) VM PUSCH 16QAM (%) VM PUSCH 26QAM (%) VM PUSCH 256QAM (%) VM DMRS PUSCH QPSK (%)		17.50 12.50 8.00 17.50	Max	Min	A RINGLED VS SYNIDDI X CAT HE PARSPUCCHICCH DMUSCH DMPUSCH Vot Use 1501 1381 1281 1281	d Points Measured : 504000	
rame Results Averaged VM PUSCH 0PSK (%) VM PUSCH 16QAM (%) VM PUSCH 64QAM (%) VM PUSCH 256QAM (%) VM DWRS PUSCH 0PSK (%) VM DWRS PUSCH 16QAM (%)	0.23	17.50 12.50 8.00 17.50 12.50	Max 0.24	Min 0.23	A MIDC 1D VS Symbol X Call Fer Metropole (Call Sectors) Metro	d Points Measured : 504000	
rame Results Averaged VM PUSCH QPSK (%) VM PUSCH 16QAM (%) VM PUSCH 54QAM (%) VM PUSCH 256QAM (%) VM PUSCH 256QAM (%) VM DMRS PUSCH 16QAM (%) VM DMRS PUSCH 16QAM (%) VM DMRS PUSCH 16QAM (%)		17.50 12.50 8.00 17.50	Max	Min	Hold 10 v3 symbol Call for the formation of the form	d Points Measured : 504000	
Tame Results Averaged VM PUSCH QPSK (%) VM PUSCH 16QAM (%) VM PUSCH 256QAM (%) VM PUSCH 256QAM (%) VM DMRS PUSCH 16QAM (%) VM DMRS PUSCH 16QAM (%) VM DMRS PUSCH 16QAM (%) VM DMRS PUSCH 266QAM (%) VM DMRS PUSCH 256QAM (%)	0.23	17.50 12.50 8.00 17.50 12.50 8.00	Max 0.24	Min 0.23	YANDO 1D VS SYNDON & Call Fer Jacobie (1) USCAT Drait USCAT VI Jacobie (1) USCAT Drait USCAT VI Jacobie (1) USCAT Drait USCAT VI Jacobie (1) USCAT VI	d Points Measured : 504000	- Auto Lev
Frame Results Averaged VM PUSCH QPSK (%) VM PUSCH 16QAM (%) VM PUSCH 54QAM (%) VM PUSCH 2560AM (%) VM DMRS PUSCH QPSK (%) VM DMRS PUSCH QPSK (%) VM DMRS PUSCH 46QAM (%) VM DMRS PUSCH 56QAM (%) VM PUCR (%)	0.23	17.50 12.50 8.00 17.50 12.50	Max 0.24	Min 0.23	1001 10 3 3 10 1 <td>d Points Measured : 504000</td> <td></td>	d Points Measured : 504000	
rame Results Averaged VM PUSCH QPSK (%) VM PUSCH 16QAM (%) VM PUSCH 54QAM (%) VM PUSCH 54QAM (%) VM PUSCH 54QAM (%) VM DMRS PUSCH 16QAM (%) VM DMRS PUSCH 16QAM (%) VM DMRS PUSCH 256QAM (%) VM DMCH (%) VM PUSCH 46QAM (%) VM PUSCH 46QAM (%)	0.23	17.50 12.50 8.00 17.50 12.50 8.00	Мах 0.24 0.26	Min 0.23 0.26	Handball 10 VS Symbol Call Ter 1501 1001 VS Set Net Use 1503 1001 VS Set Net Use 1303 1101 VS Set Net Use 1303 1101 VS Set Net Use 1303 1101 VS Set Net Use 1304 VS Set VS Set Net Use 1305 VS Set VS Set Net Use	d Points Measured : 504000	- Auto Lev
rame Results Averaged VM PUSCH QPSK (%) VM PUSCH 16QAM (%) VM PUSCH 256QAM (%) VM PUSCH 256QAM (%) VM DMRS PUSCH QPSK (%) VM DMRS PUSCH 46QAM (%) VM DMRS PUSCH 426QAM (%) VM DMRS PUSCH 426QAM (%) VM DMRS PUSCH 426QAM (%) VM PUSCH 256QAM (%) VM PUCCH (%) VM PUCCH (%) VM All (%) VM All (%)	0.23	17.50 12.50 8.00 17.50 12.50 8.00	Мах 0.24 0.26 0.24	Min 0.23 0.26	A MICLUD VS SYMIDOL & Call Fer Microsoft OutSige Deal Use Net Use 1500 1301 100	d Points Measured : 50-4000	- Auto Lev
rame Results Averaged VM PUSCH 0PSK (%) VM PUSCH 16QAM (%) VM PUSCH 54QAM (%) VM PUSCH 256QAM (%) VM DMRS PUSCH 16QAM (%) VM DMRS PUSCH 16QAM (%) VM DMRS PUSCH 256QAM (%) VM DMRS PUSCH 26QAM (%) VM DMRS PUSCH 256QAM (%) VM DMRS PUSCH 256QAM (%) VM DMRS PUSCH 26QAM (%) VM PUSCH (%) VM M PMS CHARNEl (%) VM M PMS CHARNEl (%)	0.23 0.26 0.24 0.23	17.50 12.50 8.00 17.50 12.50 8.00	Max 0.24 0.26 0.24 0.24	Min 0.23 0.26 0.23 0.23	A MICL ID VS Symbol X Call Her Inspectored (Inspect Program) 1991 1995 1995 1995 1997 199	d Points Measured : 504000 1 4 7 7 7 8 1 2 2 3 1 5 7 7 8 1 2 2 3 1 5 7 7 8 1 2 4 8 3 1 5 7 7 8 1 4 1 2 3 1 5 7 7 8 1 4 1 4 1 2 3 1 5 7 7 8 1 4 1 4 1 2 3 1 5 7 8 1 7 8 1 4 1 4 1 2 3 1 5 7 8 1 7 8 1 4 1 4 1 2 3 1 5 7 8 1 2 1 1 2 1 1 2 1 2 1 2 1 2 1 2 1 2 1	Auto Lev 4 Config
Teame Results Averaged VM PUSCH QPSK (%) VM PUSCH 16QAM (%) VM PUSCH 256QAM (%) VM PUSCH 256QAM (%) VM DMRS PUSCH QPSK (%) VM DMRS PUSCH 40QAM (%) VM MMRS PUSCH 40QAM (%) VM MAI (%) VM MAI (%) VM Phys Channel (%) VM Phys Gnand (%)	0.23 0.26 0.24 0.23 0.26	17.50 12.50 8.00 17.50 12.50 8.00	Мах 0.24 0.26 0.24 0.24 0.24 0.26	Min 0.23 0.26 0.23 0.23 0.23 0.26	A MICL ID VS Symbol X Call fer prepare and the second sec	d Points Measured : 504000 t 4 7 9 4 4 7 t 5, 4 7 9 4 4 7 t 5, 7 7 8 4 4 7 4 3 7 7 8 1 4 4 7 4 3 7 7 7 7 7 7 7 7 7 7 4 4 7 7 7 7 7 7 7 7 7 7 7 4 4 7 7 7 7 7 7 7 7 7 7 7 7	Auto Lev 4 Config
rame Results Averaged VM PUSCH 0PSK (%) VM PUSCH 16QAM (%) VM PUSCH 54QAM (%) VM PUSCH 256QAM (%) VM DMRS PUSCH 16QAM (%) VM DMRS PUSCH 16QAM (%) VM DMRS PUSCH 256QAM (%) VM DMRS PUSCH 26QAM (%) VM DMRS PUSCH 256QAM (%) VM DMRS PUSCH 256QAM (%) VM DMRS PUSCH 26QAM (%) VM PUSCH (%) VM M PMS CHARNEl (%) VM M PMS CHARNEl (%)	0.23 0.26 0.24 0.23	17.50 12.50 8.00 17.50 12.50 8.00	Max 0.24 0.26 0.24 0.24	Min 0.23 0.26 0.23 0.23	A RAIDCLED VS Symbol X Call Her Instruction of the second	d Points Measured : 504000 1 4 7 7 7 8 1 2 2 3 1 5 7 7 8 1 2 2 3 1 5 7 7 8 1 2 4 8 3 1 5 7 7 8 1 4 1 2 3 1 5 7 7 8 1 4 1 4 1 2 3 1 5 7 7 8 1 4 1 4 1 2 3 1 5 7 8 1 7 8 1 4 1 4 1 2 3 1 5 7 8 1 7 8 1 4 1 4 1 2 3 1 5 7 8 1 2 1 1 2 1 1 2 1 2 1 2 1 2 1 2 1 2 1	- Auto Lev

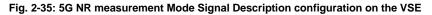
Fig. 2-34: Measurement Display Window of the 5GNR analysis personality on the FSW

Fig. 2-34 shows the uplink measurement display of the 5G FR1 signal at 3.5 GHz. The auto EVM can be selected to optimize the analysis of the signal. The EVM for PUSCH 64QAM is 0.23% and the DMRS PUSCH 64QAM is 0.26%.

2.2.3 Spectrum Analysis setting on the VSE

Configuring the 5G NR measurement personality on the VSE.

Sig	nal Configuration			x
	Signal Description	Radio Frame Config	Advanced Settings	
	Mode Upli Deploy Frequency Range 3GH	nk Loa z < f <= 6GHz	d/Save Signal Description	
	Physical Settings			
	Channel Bandwidth 100	MHz Sample Rate 122.88 MHz	ransform Precoding Off	
	Bandwidth Parts Co	nfigure 1 BWPs	SCS 60kHz	
¥	Slot Co	nfigure Slot Format 1		
5G NR	PUSCH/PUCCH Co	nfigure 64QAM		
	Cell ID 1			
	-			



- Fig. 2-35 shows the Signal Description configuration of the 5G NR measurement modes
 - Mode: Uplink, Deploy frequency Range: 3GHz < f <= 6GHz
 - Channel Bandwidth: 100 MHz
 - Synchronization: SCS 60KHz
 - Bandwidth Parts: 1 BWPs
 - PUSCH/PUCCH: 64QAM
 - Cell ID: 1

Signa	I Configuration	Radio Frame Config	Advanced Settings
	# Frames To Configure 1 Selected Frame BWP Config	1 Slot Config	Copy Frame Paste Frame Paste to all PUSCH/PUCCH Config
5G NR	Selected 0 Prev BWF BWP Subcarrier # RBs 0 60kHz 75	Next BWP	Add Numerology #2 4 slots per SF Add Bandwidth 54.0 MHz Delta to CF -21.6 MHz Clear Total # slots 40 Max # RB 135 FFT size 2048
			SMP 0

Fig. 2-36: Radio Frame Config on the VSE

- From the Radio Frame Config window, the sub categories (shown in Fig. 2-36) need to be configured
- Under the BWP Config tab,
 - Subcarrier Spacing: 60 KHz
 - #RBs: 75, RB offset: 0

Signa	al Co	onfig	uration									X
	Sig	gnal I	Description	Radi	o Frame Coi	nfig	Adva	nced Settir	igs			
		Frame		Selected 1 Frame			C	opy Frame	Pas	te Frame	Paste to a	ill
		BWP	Config	Slot	Config		PUSC	H/PUCCH (Config			_
	E	Bandv	vidth Part Numb	oer 0	5	ilot Number	0					
		# PL	ISCH Allocation	s 1	# 5	PUCCH Alloc	ations 0					
		ID	Allocation	Modulation	Enhanced Settings	Number of RBs	Offset RB	Number of Symb	Offset Symb	Rel. Power /dB	Conflict	
5G NR		0	PUSCH	64QAM		75	0	14	0	0 dB		
20												•

Fig. 2-37: PUSCH/PUCCH configuration settings in Radio Frame Config menu

- PUSCH/PUCCH needs to be configured as shown in Fig. 2-37
 - PUSCH 0, Mod: 64QAM, #RBs: 75, RB Offset: 0, #Symbols: 14, Offset Symb: 0

Sigr	nal Configuration			X
	Signal Description	Radio Frame Config Advanced Settings		
	Global Settings	nfigured numerologies 5kHz 0 ··· SCS 30kHz 0 ··· SCS 60kH ence Point A ··· ve to CF 49.32 MH2 Absolute Frequency 3.45068 GHz	Hz 0	•
5G NR	Reference Point A			

Fig. 2-38: Advanced Settings configuration

Reference point A : Relative to CF is -49.32 MHz as shown in Fig. 2-38

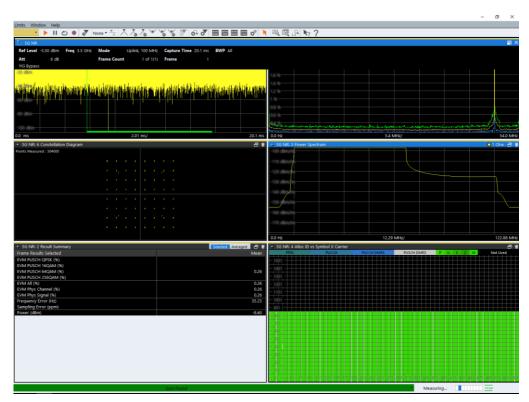


Fig. 2-39: Measurement Display Window of the 5GNR analysis personality on the FSW

Fig. 2-39 shows the measurement display of the 5G FR1 uplink signal at 3.5 GHz. The EVM for PUSCH 64QAM is 0.26%.

3 Measurement result for FR1 & FR2 signals

This chapter is a summary of the measurement results for the signal quality of the generated 5G NR uplink and downlink signals. The signals are centered at 3.5 GHz in the FR1 band and at 26 GHz in FR2 band. The same signal has been used and the measurement result are analyzed using the FSW on device software as well as the VSE signal analysis software. The measurements are performed for both uplink and downlink signals.

3.1 FR1 Measurement Results

This chapter is a summary of the measurement results for the signal quality of the generated 5G NR uplink and downlink signals. The signals are centered at 3.5 GHz in the FR1 band and at 26 GHz in FR2 band. The same signal has been used and the measurement result are analyzed using the FSW on device software as well as the VSE signal analysis software. And is the case for both uplink and downlink signals.

3.1.1 FR1 DL Measurement result on the FSW

Signal Description:

Frequency: 3.5 GHz (Downlink); Bandwidth: 100 MHz SC spacing: 30 KHz NCP, RB offset: 80, SC offset: 6, Case: B, Position: 1100 0000 BWP 1: indicator 0 with SC spacing: 30 KHz, no RBs: 30 & RB offset: 135, Mod: QPSK BWP2: indicator 1 with SC spacing: 60 KHz, no RBs: 35 & RB offset: 0, Mod: 64QAM

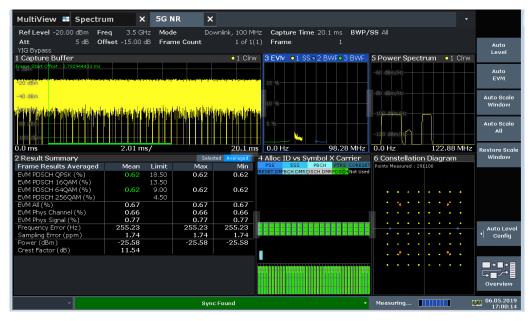


Fig. 3-1: Measurement Results of the 5GNR FR1 downlink signal at 3.5 GHz on the FSW

Fig. 3-1 shows the measurement display of the 5G FR1 downlink signal at 3.5 GHz. The auto EVM can be selected to optimize the analysis of the signal. The EVM for PDSCH QPSK is 0.62% and PDSCH 64QAM is 0.62%.

3.1.2 FR1 DL Measurement result on the VSE

Signal Description:

Frequency: 3.5 GHz (Downlink); Bandwidth: 100 MHz SC spacing: 30 KHz NCP, RB offset: 80, SC offset: 6, Case: B, Position: 1100 0000 BWP 1: indicator 0 with SC spacing: 30 KHz, no RBs: 30 & RB offset: 135, Mod: QPSK BWP2: indicator 1 with SC spacing: 60 KHz, no RBs: 35 & RB offset: 0, Mod: 64QAM

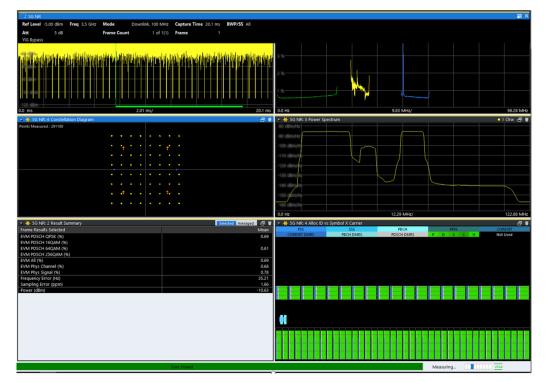


Fig. 3-2: Measurement Results of the 5GNR FR1 downlink signal at 3.5 GHz on the VSE

Fig. 3-2 shows the measurement display of the 5G FR1 downlink signal at 3.5 GHz. The auto EVM can be selected to optimize the analysis of the signal. The EVM for PDSCH QPSK is 0.69% and PDSCH 64QAM is 0.61%.

3.1.3 FR1 UL Measurement result on the FSW

Signal Description:

Frequency: 3.5 GHz (Uplink); Bandwidth: 100 MHz SC spacing: 60 KHz NCP, No. RBs: 75, RB offset: 0

BWP 0, Allocation: 1, Sub carrier spacing 60 KHz NCP, content: PUSCH, Map format: A, Slot : 0, No Sym: 14, Mod: 64QAM



Fig. 3-3: Measurement Results of the 5GNR FR1 uplink signal at 3.5 GHz on the FSW

Fig. 3-3 shows the measurement display of the 5G FR1 uplink signal at 3.5 GHz. The auto EVM can be selected to optimize the analysis of the signal. The EVM for PUSCH 64QAM is 0.23%.

3.1.4 FR1 UL Measurement result on the VSE

Signal Description:

Frequency: 3.5 GHz (Uplink); Bandwidth: 100 MHz SC spacing: 60 KHz NCP, No. RBs: 75, RB offset: 0

BWP 0, Allocation: 1, Sub carrier spacing 60 KHz NCP, content: PUSCH, Map format: A, Slot : 0, No Sym: 14, Mod: 64QAM

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				- 351				
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				- 157				

Fig. 3-4: Measurement Results of the 5GNR FR1 uplink signal at 3.5 GHz on the VSE

Fig. 3-4 shows the measurement display of the 5G FR1 uplink signal at 3.5 GHz. The auto EVM can be selected to optimize the analysis of the signal. The EVM for PUSCH 64QAM is 0.26%.

3.2 FR2 Measurement Results

3.2.1 FR2 DL Measurement result on the FSW

Signal Description:

Frequency: 26 GHz (Downlink); Bandwidth: 100 MHz

SC spacing: 120 KHz NCP, RB offset: 23, SC offset: 0, Case: D, Position: 1100 0000 ... BWP 1: indicator 0 with SC spacing: 120 KHz NCP, no RBs: 45 & RB offset: 0, Mod: 64QAM

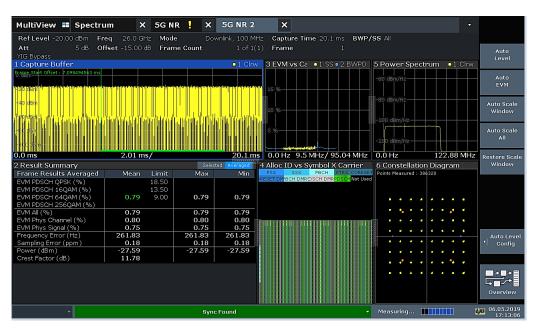


Fig. 3-5: Measurement Results of the 5GNR FR2 downlink signal at 26 GHz on the FSW

Fig. 3-5 shows the measurement display of the 5G FR2 downlink signal at 26 GHz. The auto EVM can be selected to optimize the analysis of the signal. The EVM for PDSCH 64QAM is 0.79%.

3.2.2 FR2 DL Measurement result on the VSE

Signal Description:

Frequency: 26 GHz (Downlink); Bandwidth: 100 MHz SC spacing: 120 KHz NCP, RB offset: 23, SC offset: 0, Case: D, Position: 1100 0000 ... BWP 1: indicator 0 with SC spacing: 120 KHz NCP, no RBs: 45 & RB offset: 0, Mod: 64QAM

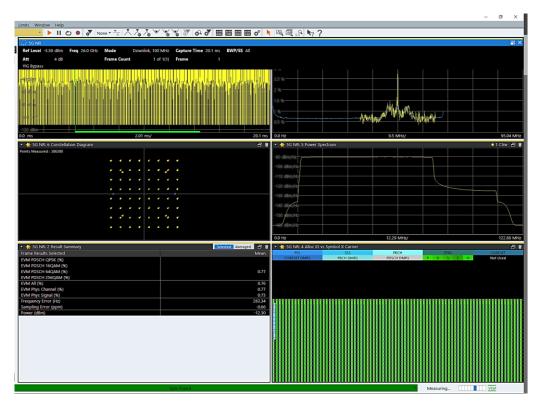


Fig. 3-6: Measurement Results of the 5GNR FR2 downlink signal at 26 GHz on the VSE

Fig. 3-6 shows the measurement display of the 5G FR2 downlink signal at 26 GHz. The auto EVM can be selected to optimize the analysis of the signal. The EVM for PDSCH 64QAM is 0.77%.

3.2.3 FR2 UL Measurement result on the FSW

Signal Description:

Frequency: 26 GHz (Uplink); Bandwidth: 100 MHz SC spacing: 120 KHz NCP, No. RBs: 66, RB offset: 0 BWP 0: Allocation: 1, SCS 120 KHz NCP, content: PUSCH, Map format: A, Slot: 0, No Sym: 10, No. RB: 35, Mod: 16QAM

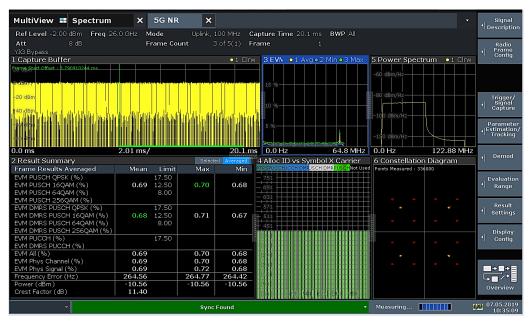


Fig. 3-7: Measurement Results of the 5GNR FR2 uplink signal at 26 GHz on the FSW

Fig. 3-7 shows the measurement display of the 5G FR2 uplink signal at 26 GHz. The auto EVM can be selected to optimize the analysis of the signal. The EVM for PUSCH 16QAM is 0.69%.

3.2.4 FR2 UL Measurement result on the VSE

Signal Description:

Frequency: 26 GHz (Uplink); Bandwidth: 100 MHz SC spacing: 120 KHz NCP, No. RBs: 66, RB offset: 0

BWP 0: Allocation: 1, SCS 120 KHz NCP, content: PUSCH, Map format: A, Slot: 0, No Sym: 10, No. RB: 35, Mod: 16QAM



Fig. 3-8: Measurement Results of the 5GNR FR2 uplink signal at 26 GHz on the VSE

Fig. 3-8 shows the measurement display of the 5G FR2 uplink signal at 26 GHz. The auto EVM can be selected to optimize the analysis of the signal. The EVM for PUSCH 16QAM is 0.79%.

4 Advanced Measurement Methods

4.1 Phase Noise

Wireless communication at mmW frequencies provide many challenges. Phase noise effects are very significant at those frequencies. The two type of errors due to phase noise are Common Phase Error (CPE) and Inter-Carrier Interference (ICI).

ICI is addressed through wider subcarrier spacing (SCS): Data and control channel could utilize 60 or 120 KHz and synchronization Signal Block (SSB) can utilize the 120 or 240 KHz.

The CPE is addressed by adding Phase Tracking Reference Signal (PTRS). The PTRS is optional in the standard and can be applied both in the downlink and as well in the uplink. This should be implemented in the receiver to compensate for the CPE. Nevertheless, in order to emulate the phase noise in the development phase, in the AWGN block of the SMW, there is a configurable sub block for Phase Noise.



Fig. 4-1: Phase noise configuration window on the SMW vector signal generator

Fig. 4-1 shows the window to configure phase noise. On the right side of this window, there is a numerical representation model and on the left side, there is a graphical representation model.

The frequencies and the corresponding phase noise parameters can be adjusted here. The profile can be saved and loaded here. After activation, the current signal quality will be adjusted with the controlled phase noise setting. This enables the testing of performance of the DUT behavior under different emulated phase noise settings.

4.1.1 Performance check of PTRS signals

For this example, a 100 MHz, 64QAM signal 5G NR signal is configured on the SMW200A. The downlink signal has no PTRS active for PDSCH and has a single symbol PDSCH DMRS. With the Phase Tracking ON (3GPP Definition) on the FSW, the corresponding EVM measurement result -40.85 dB is shown in Fig. 4-2.



Fig. 4-2: EVM measument with no PTRS active on 100MHz 5G NR DL signal at 28 GHz

No change in measurement result is observed with phase tracking to OFF, as shown in Fig. 4-3.

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I/Q Offset (dB)	-44.00	I/Q Parameter					4 Settings	File	Mode
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	н		nc Found	640AM		-40.61/	17.10.2019 21:12:51		

Fig. 4-3: EVM measurement with no PTRS active and Phase tracking switched off on FSW

The signal in this example is almost ideal as the signal generator is connected to the analyzer. There is actually nothing to compensate for. The using the SMW it is possible to add phase noise to emulate a more realistic real world RF environment.

For simplicity, the pre-defined module 'pll1' is loaded and set the starting point for PSD to -55 dBc/Hz as shown in Fig. 4-4.



Fig. 4-4: Phase noise configuration on the SMW

With the phase noise emulation switched ON the EVM of the signal on FSW with phase tracking set to OFF or "EVM definition", degrades to -26.15 dB as shown in Fig. 4-5.

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Frequency Error (Hz) Sampling Error (ppm)	-32.33 1.92 0.11	Phase Tracking		Off			Result	Setup	Print
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	CORESET D	MRS 0	0.000	QPSK	-47.536	-36.270			
	PC	DSCH 0 66	0.000 vnc Found	640AM	-41.314	-26.412 *	17.10.2019		

Fig. 4-5: EVM measurement with no PTRS active and emulated phase noise

The Phase tracking configured to "Pilot only" on the FSW does not improve the EVM performance of the signal as shown in Fig. 4-6:

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Fig. 4-6: EVM measurement with Phase tracking switch ON

In this case, "Pilot only" means to perform phase tracking based on the PDSCH DMRS as no other pilot signals are configured. As PDSCH DMRS is only in OFDM symbol, of course there is not much of a compensation possible. The compensation improves when signals are being used on a per symbol basis. That is why the situation always improves when the "Pilot & Payload", because Payload is PDSCH present in this case in every symbol and thus compensation works much better.

To see performance of PTRS, it is now clear to compare "Pilot only" case when PDSCH DMRS and PTRS is active. Therefore, the PTRS is configured in every symbol and every second PRB on the SMW200A and FSW. As shown in Fig. 4-7, EVM improved by about 5 dB, -26.71 dB to -31.96 dB.

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MultiView 💶 Spectrun	n X 5G NR	×					Signal Description	Freq.	Spar
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EVM All (dB) EVM Phys Channel (dB)	-31.95 -31.87	Phase Tra	cking	Pilot Only	•	****	Evaluation	Run Single	Ru Cor
EVM Phys Signal (dB)	-32.95	I/Q Parame	eter -32.95					-	
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	PDSCH 0	66	0.000	640AM	-41.35		++=	kHz µs	HZ
	POSCH DMRS U		0.000	ODSK	-41.32	-34.386		dB µV	dB
	PTRS 0		0.000	QPSK	-41.31	-34.230	Overview		eset
	CORESET 0 CORESET DMRS 0	12	0.000	QPSK OPSK	-47.55 -47.53		·	PA	ostor
	Surreger Brinks o		Sync Found	or or		Measuring	17.10.2019 22:18:39		

Fig. 4-7: EVM measurement with Phase tracking switch ON

To prove the theory about density in time, the PTRS is configured to less symbols, e.g. for every second OFDM symbol, the improvement is only about 2 dB compared to PDSCH DMRS only, as shown in Fig. 4-8.

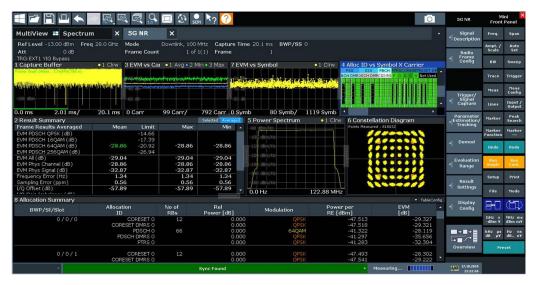


Fig. 4-8: EVM measurement with Phase tracking switch ON

For every fourth OFDM symbol, the improvement is only about 1 dB compared to PDSCH DMRS only, as shown in Fig. 4-9.

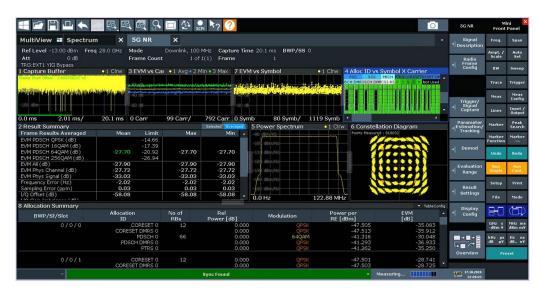


Fig. 4-9: EVM measurement with Phase tracking switch ON

Phase tracking and compensation on the FSW is implemented according to 38.104, Annex C.6 and 38.141-2, Annex L.6

4.2 DC sub carrier

The handling of the DC subcarrier is up to the receiver implementation. In LTE, it was specially notched out. For 5G NR, FSW offers three options of do nothing, ignore DC and compensate. In this application note, Ignore DC configuration in the Advanced Settings menu for Handling of Carrier Leakage was configured and is shown in Fig. 4-10.

5	ignal Configurati	ion			×
	Signal Description	n Radio Frame Config	Ant Port Mapping	g Advanced Settings	
	CC 1				
	Global Settings	Handling of Carrier Leakage	Ignore DC		
		Transform Precoding	None		
	Reference Point A	PUSCH Structure	Ignore DC		
		Hopping	Compensate		
		RF Upconversion			
		Phase Compensation	On O	Off	
		f_0 =			
		Frame number n_f	0		

Fig. 4-10: Configuration of the Advanced Settings menu

4.3 IF overload, Optimized EVM and Crest Factor

In order to alleviate IF overload and optimize EVM, Auto Level and Auto EVM could be used as shown in Fig. 4-11 .

The Auto level automatically determines the ideal reference level. The automatic leveling process measures the signal and defines the ideal reference signal for the measured signal. Auto Level will also optimize RF attenuation.

The Auto EVM adjusts the amplitude settings to achieve the optimal EVM using the maximum dynamic range. This routine measure the signal several times at various levels to achieve the best results.

MultiView 🎫 Spectrum	×	5G NR									
RefLevel 1.00 dBm Freq 26.		ode	Uplink, 1		ture Time 20.0 n	ns BWP	All			_	
Att 11 dB YIG Bypass		ame Cou		of60(1) Fran		1					Auto Level
Capture Buffer	<u> </u>	Cirw 3 E	VM vs Car	rier ollav	vg • 2 Min • 3 Ma			ymbol X Car	rier H DMRS PUSCH	LOMBS	
rame Start Offset 7.406445220 ms		15					RS P			Used	Auto EVM
20 dBm		10				- 551					
60 dBm		5.9				- 353					Auto Scale All
80 dBm 2.0 ms 2.0 ms/	20 0) ms 0.		9.5 MHz/	95.04 MF	- 151		401-521-641	- 761 - 881 - 1	.001	
Result Summary	20.0			ected Averaged	5 Power Spect		1 Clrw 6	Constellatio	n Diagram		
	0.01	12.00	0.00	0.77	3 Power speci			oints Measured : S			
VM PUSCH 64QAM (%)	0.81	8.00	0.85	0.78 1							
VM PUSCH 256QAM (%) VM DMRS PUSCH OPSK (%)	0.77	17.50	0.83	0.73							
VM DMRS PUSCH QPSK (%)	0.77	12.50	0.83	0.73							
VM DMRS PUSCH 160AM (%)	0.82	8.00	0.89	0.71							
VM DMRS PUSCH 2560AM (%)		0.00	0.52	0.71	-80 dBm/Hz			••••	· · · ·	•	
VM PUCCH (%)		17.50			-80 dBm/H2						
VM DMRS PUCCH (%)					-90 dBm/Hz					· .	
VM All (%)	0.80		0.81	0.78							Auto Lev
VM Phys Channel (%)	0.80		0.81	0.78	-100 dBm/Hz-						' Confiq
VM Phys Signal (%)	0.78		0.82	0.75						•	
requency Error (Hz)	-250.80		-248.57	-253.57	-110 dBm/Hz					· _	
/Q Offset (dB) /O Gain Imbalance (dB)	-48.58		-47.19	-50.15						•	-++
/Q Gain Imbalance (dB) /Q Quadrature Error (°)					-120 dBm/Hz						
ower (dBm)	-5.51		-5.51	-5.52							Overviev
Crest Factor (dB)	10.67		0.01	•	0.0 Hz	122.8	8 MHz				Overviev
-			Sync	Found			•	Measuring		1,00	25.10.20 02:21:
PRESET MODE SETUP	8-0	 	MKR	PEAK	H 7	8 abc	9 def	GHz s -dBm V		Ŷ	
FREQ SPAN AM		UTO	MKR	MKR -	- 4 ghi	5 jkl	6 mno	MHz ms dBm mV	\$	Ŷ	₽
BW SWEEP TRA		SET	RUN	RUN		2 tuv	3 WXVZ	kHz μs dB μV	•	0	•
MEAS MEAS LIN		NPUT/	REDO		0			Hz ns	ESC	васк	ENTER
MEAS CONFIG LIN		UTPUT				*#	A - a	dB., nV			ENIER

Fig. 4-11: Auto Set configuration window

4.4 Capture time and Tigger setting

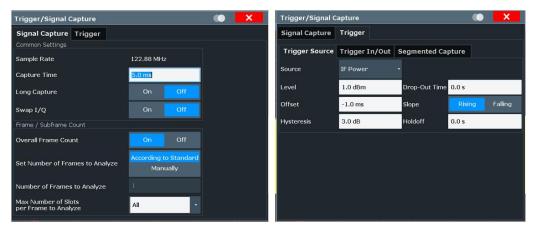


Fig. 4-12: Signal and Trigger configuration window

In order to analyze the signal faster and only the part of the signal that is of interest, i.e. for signal capturing length less than the default 20.1ms, the settings can be configured for the Trigger and Signal capture window as shown in Fig. 4-12. The capture time can be set as desired (for example here is set to 5 ms). The trigger source is set as IF power and the corresponding IF power lever and time offset is configured as shown.

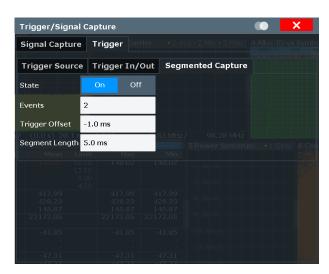


Fig. 4-13: Segmented Capture configuration window

In order to measure and analyze a particular section of the frame, the segmented capture window can be configured and the segment length can be predefined and analyzed. The settings are shown in Fig. 4-13 and segment length of 5ms is shown in the example.

4.5 Parameter/ Estimation Tracking

In order to optimize and compensate measurement results for various errors, the parameter/estimation tracking feature can be used. The channel estimation can be configured for Pilot and payload, linear interpolation or according to the 3GPP EVM specification. As a measure of good practice for the channel estimation setting, the pilot and payload can be configured, which performs the channel estimation by examining both the reference signal and the payload resource elements. The linear interpolation can also be configured but in this case, the channel estimation is performed by interpolating the missing information.

Parameter Estim	ation/T	racking			×	
Parameter Estimatio	on					
Channel Estimation	ı		Pilot and Payl	oad		-
Channel Estimation		eraging 9.83 MHz/	per Allocation			
Tracking						
Mean Limit						
Phase Tracking			EVM 3GPP De	finitio	'n	Ť
I/Q Parameter						
Gain Imbalance / Quadrature Error			On	C	Off	

Fig. 4-14: Parameter Estimation/ Tracking menu configuration

Fig. 4-14 shows the tracking configuration menu. The channel estimation time averaging can be performed for each allocation or every 10ms according to the 3GPP definition. For phase tracking, there is a possibility of choosing between 3 options. Phase tracking with "pilot only" will enable phase estimation using only the reference signal. The "Pilot and Payload" option uses the reference and the payload resource

elements for phase estimation and lastly the 3GPP EVM Definition is according to the 3GPP specification.

4.6 Slot Allocation and Slot format

5G NR supports FDD and TDD in the duplex mode.

Slot formats are a fundamentally new concept in 5G NR. Unlike LTE, 5G NR doesnot have defined UL-DL configurations. In 5G NR there are 62 different slot formats defined. They help to realize different downlink and uplink allocations, particularly in time division duplex (TDD) mode.

Based on an example with 120 kHz subcarrier spacing, the chapter explains some unique characteristics compared to TD-LTE, such as the mismatch between required periodicity and subframe duration.

FDD uses only slot format "0" (downlink) or slot format "1" (uplink) which is dependent on direction. In case of TDD, the information is provided via RRC signaling or by Downlink Control Information DCI (Slot format indicator) transmitted on PDCCH.

As an example, for FR2 TDD-UL-DL configuration,

 SCS: 120KHz, Periodicity (ms): 1.25, NrDL slots: 7, NrDL Sym: 6, NrUL slots: 2 and NrULSym: 4

Based on this information,

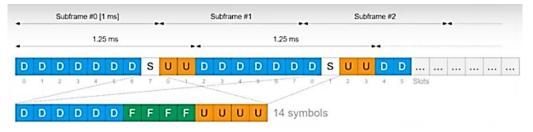


Fig. 4-15: Slot allocation for FR2 TDD-UL-DL 5G NR configuration

A slot is 14 symbols and Subframe is 1ms. However, the periodicity is 1.25ms. This means the subframe boundaries and periodicity do not align and makes signal configuration more challenging. The flexible special slot in Fig. 4-15 contains 6 DL symbols, followed by 4 flexible symbols and 4 UL symbols.

4.7 Generate and analyze 5G NR TDD signals

In this chapter, the generation of the uplink portion of a 5G NR TDD signal is explained. The 5G NR signal uses a subcarrier spacing of 120 kHz by applying a periodicity of 1.25 ms and is generated with the SMW vector signal generator. Detailed signal analysis is performed using the FSW signal and spectrum analyzer. Fig. 4-16 shows the TDD frame structure.

																			anno faithe					
			1.25	5 ms		_	_	•	•		_	_	1.2	5 ms	_	_			•					
D D	D	D	D	D	D	S	U	U	D	D	D	D	D	D	D	S	U	U	D	D		 		
0 1	2	3	4		6	7	0	-1	2	3		5	6	7	0	-	2	з	4	5	Slots		-	

Fig. 4-16: 5G NR Uplink TDD frame structure

The configuration steps are explained for setting up the frame structure shown in Fig. 4-16. The frame comprises of 2 subframes. In the first subframes, slot #7 is special slot with 6 DL symbols, 4 blank symbols and 4 UL symbols. The second sub frame has 2 UL slots (slot #2 & #3) and slot #1 is a special flexible slot.

4.7.1 Signal Generator configuration

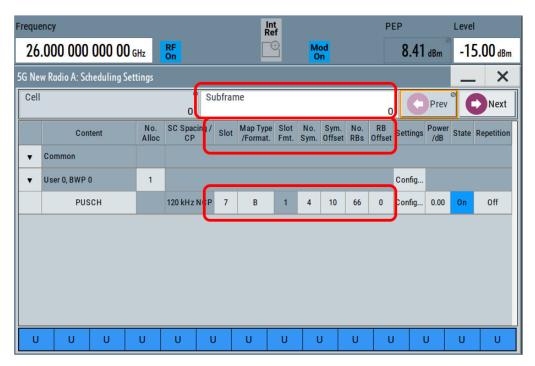


Fig. 4-17: Subframe 0 configuration for 5G NR TDD UL

Fig. 4-17 shows the signal generation configuration of the first subframe. In this case, the first 7 DL slots are left blank. Slot #7 is configured with Map format B. Out of the 14 symbols in slot #8, the first 10 symbols are left blank and 4 UL symbols are configured with a symbol offset of 10 symbols.

Cel	l		0 SI	ubfrar	ne					1	C	Prev		Next
	Content	No. Alloc	SC Spacing / CP	Slot	Map Type /Format.	Slot Fmt.	No. Sym.	Sym. Offset	No. RBs	RB Offset		Power /dB	State	Repetition
•	Common													
•	User 0, BWP 0	2									Config			
	PUSCH		120 kHz NCP	0	В	1	14	0	66	0	Config	0.00	On	Off

Fig. 4-18: Subframe 1 configuration for 5G NR TDD UL

In the second subframe, the first two slots are UL and the rest 6 slots are all DL slots.

In this case, two PUSCH allocations are configured. Slot 0 and slot 1 are configured to have Map format B, No of symbol 14 and symbol Offset 0. The modulation of the UL

5G New Ra	dio A (U0/BC)/A1)PUSC	H Settings				X
General	TxScheme	DMRS	Antenna Ports				
PUSCH	Туре						
			DC	I Format 0_1			
Modulat	ion				Number of Physical Bits		0
				16QAM		4	2 768

Fig. 4-19: Modulation configuration for 5G NR TDD UL signal

can be configured as shown in Fig. 4-19. For subframe 1, the two PUSCH UL slots are configured with 16QAM modulation scheme.

Cel			© Su	ıbfran	ne					2	C	Prev		Next
	Content	No. Alloc	SC Spacing / CP	Slot	Map Type /Format.	Slot Fmt.	No. Sym.	Sym. Offset	No. RBs	RB Offset		Power /dB	State	Repetition
•	Common													
•	User 0, BWP 0	3									Config			
•	User 0, BWP 0 PUSCH	3	120 kHz NCP	1	В	1	4	10	66	0	Config Config	0.00	On	Off
•		3	120 kHz NCP 120 kHz NCP	1	BB	1	4	10 0	66 66	0		0.00	On On	Off Off

Fig. 4-20: Subframe 2 configuration for 5G NR TDD UL

Fig. 4-20 shows the configuration of the subframe 2. Here there are 3 PUSCH allocations. Slot 0 is a special slot with 4 UL symbols at 10 symbol offset. Slot 1 and 2 are 14 symbol UL with no symbol offsets.

5G New R	adio A (U0/BC)/A2)PUS	CH Settings			_	×
General	TxScheme	DMRS	Antenna Ports				
PUSCH	Туре						
			DC	Format 0_1			
Modula	tion				Number of Physical Bits		
				64QAM		6	64 152

Fig. 4-21: Modulation configuration for 5G NR TDD UL signal

Fig. 4-21 shows the modulation configuration of subframe 2. The 2 UL slots are configured with 64QAM modulation.

4.7.2 Spectrum Analyzer Configuration

For the slot configuration on the FSW, each slot allocation needs to be individually configure. 3 subframes have a total of 24 slot allocations. The special slots are numbered 8 and 18. The UL slots are numbered 9, 10, 19 and 20.

ignal Des	cription		ame Config			Advanced			
CC 1 0 dB									
Frames To Configure		Selected 1 Frame			Copy Frame	Paste	(Frame 1)	Paste	to all
BWP Con	fig Slot	Config P	изсн/рис	CH Config					
Bandwidth	Part Numl	per 0				SRS	S Settings		
Selected S	lot 9	Prev Slot	Next Slot		Configurabl t remaining)		Cop	γý	
SF Number	Slot Number	Slot Allocation	Slot Format	PUSCH Allocations	Repeated Slot No	Ref Signals	Paste (S	Slot 8)	
	17	Unused	1		User	None	Paste	to all	
	18	Data	1	Configure	User	None	Periodicity	10ms	
2	19	Data	1	Configure	User	None	10.0 ms	Ioms	
2	20	Data	1	Configure	User	None	80 slots in E		
	21	Unused	1		User	None	Res		
	22	Unused	1		User	None	Slot Co	onfig	
Preview for	Slot 9								
Uplink U	plink Uplink	Uplink U	olink Uplink	Uplink Uplin	k Uplink L	Jplink Uplink	Uplink Uplink	Uplink	

Fig. 4-22: Radio Frame Slot configuration for TDD UL

Fig. 4-22 shows the slot configuration for the TDD UL 5G NR signal analysis on the FSW. In the slot configuration menu,

- First of all, reset Slot config
- Set 80 User Configurable Slot (This value needs to be 24 or higher)
- Set Slot 0 as unused and copy & paste to all of the 8 slots.
- Now configure only the Special and UL slots individually with data allocation
- Slot 8, 18 are special slot and Slot 9, 10, 19, 20 are UL slots

Configuring the special slots, Slot #7

- Hit Configure on the PUSCH allocation column (shown in Fig. 4-23)
- Next in the configuration window , go into enhanced setting
- Select the DMRS Mapping format: PUSCH start (B) as shown in Fig. 4-24

ignal Con	n Freq z	o.u ghz mi	ae U	MINK, 100 MINZ	Capture II	<u>me zulu ms</u>	BWP AI		
ignal Des	cription	Radio Fr	ame Confi <u>c</u>	Ant Port	Mapping	Advanced	Settings		
CC 1									
≠Frames To Configure		Selected 1 Frame	15 %		Copy Frame	Past	te Frame	Past	e to all
BWP Con	fig Slot	t Config	USCH/PUC	CH Config					
Bandwidth	Part Numl	ber 0				SRS	5 Settings		
Selected S	lot 18	Prev Slot	Next Slot	# User (repea	Configurabl t remaining)	le Slots <mark>80</mark>	Сору		
SF Number	Slot Number	Slot Allocation	Slot Format	PUSCH Allocations	Repeated Slot No	Ref Signals	Paste (Slo	t 20)	
0	4	Unused	1		User	None	Paste to	all	
	5	Unused	1		User	None	Periodicity 10		
	6	Unused	1		User	None	10.0 ms	inis	
	7	Data	1	Configure	User	None	80 slots in BV	VP 0	
	8	Data	1	Configure	User	None	Reset		
	9	Data	1	Configure	User	None -	Slot Con	ifig	
Preview for	Slot 18	-251,43	-247 -46	.36 -254.1 .05 -49.4	3 -120 - 6	IBm/Hz			
Uplink U	plink Uplink	u Uplink U	Jplink Uplink	Uplink Uplin	k Uplink I	Uplink Uplink	Uplink Uplink	Uplink	



PUSCH Enhanced Set	tings		() X
User ID 0			
PUSCH DMRS Config P	hase-tracking RS Config (PTRS)	Scrambling/Coding	
Config Type	1	Codeword to Laye	
First DMRS symb rel to (Mapping Type)	PUSCH start (B)	Layers/Codewo	rds 1/1 -
First DMRS Symb (Type A Pos)		→ Antenna Ports	0 -
DMRS Add Position Inde	< 0		data 1 🔹 🕂
DMRS Length	1		
Sequence Generation	N_ID^CELL → 0		
Rel Power (to PUSCH)	0.0 dB		

Fig. 4-24: PUSCH enhanced settings configuration window

Signal Configuratio	n								×
Signal Description				•••			_		
CC 1 0 dB									
	Selected 1 Frame		Co	oy Frame	: F	aste Fra	me F	aste to al	I
BWP Config Slot	Config PUSC	н/риссн	Config						
Bandwidth Part Numl	ber 0	si	ot Number	8					
# PUSCH Allocations	1	# PU	CCH Alloca	tions 0					
	ode Ord Modulation	Enhanced Settings	Number of RBs	Offset RB	Number of Symb	Offset Symb	Rel. Power /dB	Conflict	•
0 PUSCH 1,	/1 QPSK		66	0	4	10	0 dB		

Fig. 4-25: PUSCH/ PUCCH configuration window for the special slot

Fig. 4-25 shows the PUSCH configuration for the special slot.

- Modulation: QPSK
- # of symbol: 4
- Offset Symbol: 10
- Copy and paste slot 8 to slot 18 as shown in Fig. 4-22

Signal Configuration))	<	
Signal Descriptio		Frame Config					_		
CC 1 0 dB									
# Frames To Configure	Selected Frame	1		Copy Frame	e Pa	ste (Fran	ne 1)	Paste to all	
BWP Config Slot Config PUSCH/PUCCH Config									
Bandwidth Part Nu	imber 0		Slot Nun	nber 9					
# PUSCH Allocations 1 # PUCCH Allocations 0									
	Code Word Mod	ulation Enhan Settir			Number of Symb	Offset Symb	Rel. Power /dB	Conflict	•
0 PUSCH	1/1 10	5QAM	66	0	14	0	0 dB		

Fig. 4-26: PUSCH/ PUCCH configuration window for the UL slot (9 and 10)

Fig. 4-26 shows the PUSCH configuration for the UL slot (9 and 10).

- Modulation: 16QAM
- # of symbol: 4
- Offset Symbol: 10
- Copy and paste slot 9 to slot 10 as shown in Fig. 4-22

CC 1	fer 517.032870650	µs	●1 Clrw	3 EVM vs Ca	rrier •	1 Avg●2	Min • 3 Ma	K 4 Allo	<mark>с ID vs Symbo кs риссн</mark>	DI X Carrie PUCCH D	r MRS
# Frar Config	nes To ure 1	Sele Fran	cted 1		Сој	oy Frame	: P	aste Fra	me P	aste to al	
BWP	BWP Config Slot Config PUSCH/PUCCH Config										
Band	width Part N	lumber		SI	ot Number	19		35			
# PUSCH Allocations 1 # PUCCH Allocations 0											
ID	Allocation	Code Word	Modulation	Enhanced Settings	Number of RBs	Offset RB	Number of Symb	Offset Symb	Rel. Power /dB	Conflict	• iç
0	PUSCH	1/1	64QAM		66	0	14	0	0 dB		

Fig. 4-27: PUSCH/ PUCCH configuration window for the UL slot (19 and 20)

Fig. 4-27 shows the PUSCH configuration for the UL slot (9 and 10).

- Modulation: 64QAM
- # of symbol: 4
- Offset Symbol: 10
- Copy and paste slot 19 to slot 20 as shown in Fig. 4-22

The spectrum analyzer is now properly configured to measure the complex 5G NR TDD UL signal as described at the start of this chapter. Fig. 4-28 shows the measurement results of the signal at 26GHz. The EVM of the QPSK slots are 0.85%, 16QAM signals are 0.87% and 64QAM signals are 0.87%.

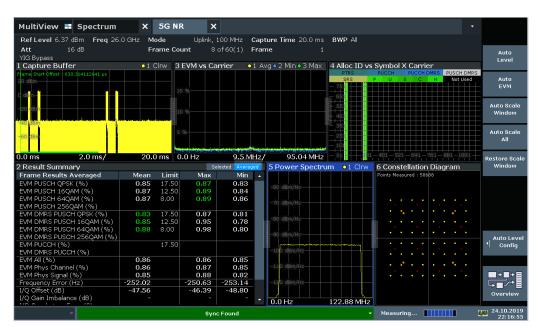


Fig. 4-28: Signal quality Measurement results of 5G NR TDD UL signal at 26GHz

4.8 Evaluation Range and Display setting

In order to analyze with higher granularity and look at a specific part of the 5G NR signal, the FSW offers the flexibility to analyze only the segment of interest. Fig. 4-29 shows the configuration window of the Evaluation Range. From this menu, any specific BWP, Subframe, Slot, modulation type or Symbol can be selected for analysis. Thus making the measurement faster.

Evaluation Ra	nge 💽 🗙					
Global/Constellation 5G NR						
1 Globa ln Freq 11 dB						
Frame	1 -					
BWP	0 -					
Subframe	2 -					
Slot	17 •					
Constellation [Diagram					
Modulation	QPSK -					
Allocation	PUSCH 0 🗸					
Symbol	All 🗸					
Carrier	0 -					

Fig. 4-29: Configuration Window of the Evaluation Range on the FSW

Result Settings	×
Peault Cattingen Table Capfig	800 μs 0.71 %
CC Result All Viewed	000 µs Trigger/ Signal Capture
Displayed Rows EVM PUSCH PI/2 BPSK EVM PUSCH QPSK EVM PUSCH 16QAM EVM PUSCH 64QAM	Parameter ∢ Estimation/ Tracking
EVM PUSCH 256QAM — VM DMRS PUSCH PI/2 BPSK V EVM DMRS PUSCH QPSK V EVM DMRS PUSCH 16	5QAM Demod
EVM DMRS PUSCH 64QAM V EVM DMRS PUSCH 256QAM V EVM PUCCH EVM DMRS PUCCH	, Evaluation
EVM All EVM Phys Channel EVM Phys Signal Frequency Error	4 Range
I/Q Offset I/Q Gain Imbalance I/Q Quadrature Error Power	Result Settings
Crest Factor	Display
Specifics for 7: EVM vs Symbol	•
MI[1] 02(1)	
	Overview 5.7 µs
Sync Found • Measuring	

Fig. 4-30: Result setting configuration menu for EVM vs symbol measurements

Fig. 4-30 shows the configuration window of the Results settings menu.

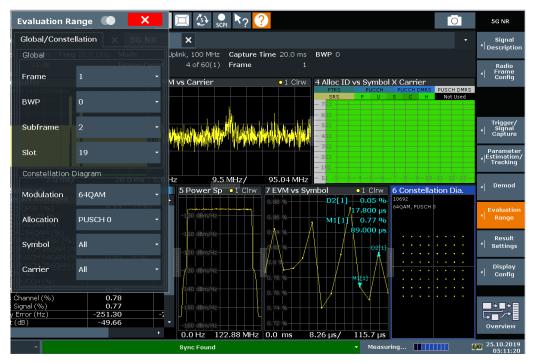


Fig. 4-31: EVM Vs Symbol measurement for a specific part of the signal

Fig. 4-31 shows the EVM VS symbol measurement results of only slot 19 in subframe 2 with 64QAM modulation.

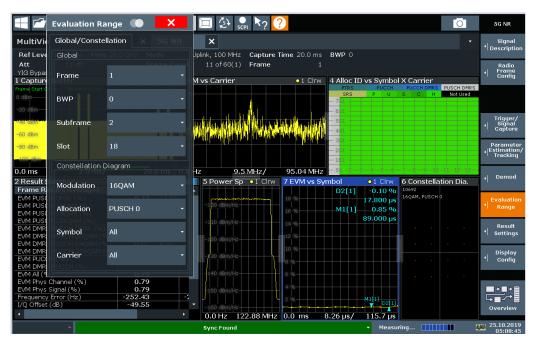


Fig. 4-32: EVM Vs Symbol measurement for a specific part of the signal

Fig. 4-32 shows the EVM VS symbol measurement results of only slot 18 in subframe 2 with 16QAM modulation.

5 Ordering Information

Designation	Туре	Order No.		
Signal- and Spectrum Analyzer 2 Hz to 43 GHz	R&S [®] FSW43	1331.5003.43		
OCXO, precision frequency reference	R&S [®] FSW-B4	1313.0703.02		
Resolution bandwidth >10MHz (HW opt.)	R&S [®] FSW-B8	1313.2464.02		
High pass filter (SL)	R&S [®] FSW-B13	1313.0761.02		
Digital Baseband Interface (SL)	R&S [®] FSW-B17	1313.0784.02		
SSD 128 GB, with FW, for IPC11 CPU board, Win 10	R&S [®] FSW-B18	1313.0790.10		
RF preamplifier, 30dB, 100kHz to 43GHz	R&S [®] FSW-B24	1313.0832.43		
Extension to 160 MHz signal analysis bandwidth	R&S [®] FSW-B160	1325.4850.14		
3GPP 5G-NR DL Measurements	R&S [®] FSW-K144	1338.3606.02		
3GPP 5G-NR UL Measurements	R&S [®] FSW-K145	1338.3612.02		
Vector signal generator, base unit	R&S [®] SMW200A	1412.0000.02		
Frequency range: 100kHz to 40GHz, for RF path A	R&S [®] SMW-B140	1413.0604.02		
Frequency range: 100 kHz to 7.5 GHz	R&S [®] SMW-B207	1434.7350.02		
Baseband main module, one I/Q path to RF section (R&S [®] SMW-B13	1413.2807.02		
Baseband generator with realtime coder and ARB	R&S [®] SMW-B10	1413.1200.02		
5G New Radio	R&S [®] SMW-K144	1414.4990.02		
VSE BASIC EDITIION (PR)	VSE	1345.1011.06		
License dongle for PC software	FSPC	1310.0002.03		
3GPP 5G-NR DL/UL Measurements	VSE-K144	1309.9574.06		

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- Energy efficiency and low emissions
- Longevity and optimized total cost of ownership

Certified Quality Management ISO 9001 Certified Environmental Management ISO 14001

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Version GFM322_1e | R&SG NR Signal Generation and Analysis

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