## **Application Note**

# 5G FR1 DOWNLINK MIMO PHASE COHERENT SIGNAL ANALYSIS

## **Products:**

- ► R&S®RTP
- ► R&S®RTO
- ► R&S®VSE
- ► R&S®NRQ6
- ► R&S<sup>®</sup>SMW200A

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# 1 Overview

5G New Radio (NR) FR1 MIMO or beamforming downlink signal analysis especially the phase measurement of each MIMO layer and the determination of the phase difference between the MIMO layers are essential for the 5G base station product design.

In this application note, it describes two test solutions from R&S<sup>®</sup> to cope with the 5G FR1 downlink MIMO signal analysis challenges either using R&S<sup>®</sup>RTP/RTO oscilloscope or R&S<sup>®</sup>NRQ6 frequency selective power sensor as RF frontend to capture the signal and together with R&S<sup>®</sup>VSE as post-processing tool for the IQ analysis.

The aim of this application note is to walk the user through the necessary steps on both test solutions to enable the 5G FR1 downlink MIMO signal analysis.

The entire application note is organized with following structure:

Chapter 2 gives a high level introduction of both test solutions

Chapter 3 outlines the test solution with oscilloscope R&S<sup>®</sup>RTP/RTO as RF frontend that includes its environment setup as well as the related settings in R&S<sup>®</sup>VSE

Chapter 4 describes the test solution with R&S®NRQ6 as RF frontend

Appendix A lists the parameters of the applied example 5G FR1 downlink 2x2 MIMO signal

Appendix B gives a guide on how the example signal is generated on a vector signal generator R&S®SMW200A

Appendix C provides the informative content about 5G NR antenna port

Throughout the whole application note, the following abbreviations are used for Rohde & Schwarz test equipments:

- ► R&S<sup>®</sup>RTP High-Performance Oscilloscope is referred to as RTP
- ► R&S<sup>®</sup>RTO Oscilloscope is referred to as RTO
- ▶ R&S®RTP/R&S®RTO-K11 I/Q software interface is referred to as RTP/RTO-K11
- ► R&S<sup>®</sup>VSE Vector Signal Explorer is referred to as VSE
- ▶ R&S<sup>®</sup>VSE-K144 5G NR Uplink and Downlink Measurement Application is referred to as VSE-K144
- R&S<sup>®</sup>VSE-K146 5G NR MIMO Measurement Application is referred to as VSE-K146
- ▶ R&S<sup>®</sup>VSE-K544 User defined frequency response correction by SnP file is referred to as VSE-K544
- R&S®NRQ6 Frequency Selective Power Sensor is referred to as NRQ6
- R&S<sup>®</sup>NRQ6-K1 IQ Data Interface is referred to as NRQ6-K1
- ► R&S®NRQ6-K3 Phase Coherent Measurements is referred to as NRQ6-K3
- R&S<sup>®</sup>SMW200A Vector Signal Generator is referred to as SMW200A

It is assumed that the reader has certain pre-knowledge of 5G NR physical layer. In case a refreshment is needed, please refer to the R&S<sup>®</sup> 5G eBook [1] for further reading.

# 2 Introduction

5G NR, state of the art mobile radio access technology, largely enhances the mobile broadband communication (eMBB), enables the Ultra-Low Latency Communication (URLLC) and massive IoT (mIoT) connectivities to serve the vertical industries.

Massive Multiple-Input Multiple Output (MIMO) antenna system and beamforming are no doubt few of the compelling technologies facilitated by 5G NR. They are the key enablers and foundational components of 5G deployment for improving end-user experience, network capacity and coverage that contribute to the high spectral efficiency in the end.

It is essential for the participants of the 5G network infrastructure eco-system, meaning chipset vendors, R&D, productions as well as the services to ensure the specification conformed and high performance of the MIMO or beamforming system before the product launch and commercial deployment. Market driven test solutions of 5G MIMO signal analysis are asked. Rohde & Schwarz<sup>®</sup>, active player in the test and measurement business field of mobile telecommunications over years, offers the test solutions based on this market needs.

In Fig. 2-1 shows a general concept for 5G FR1 downlink MIMO signal analysis based on MIMO conducted test mode. Meaning all the MIMO layers are connected to the used RF frontend per RF cables directly. In this application note, two test solutions from R&S<sup>®</sup> product family are described. As RF frontend, either RTP/RTO or NRQ6 with required software options can be utilized to capture the MIMO signal. Both solutions facilitate the VSE with option K144 and K146 as a post-processing tool to demodulate and decode the baseband IQ signal. Thanks to the multi-channel capability of the RF frontend as well as MIMO measurement featured by VSE-K146, simultaneous phase coherent measurement of the MIMO layers becomes true. Furthermore, the phase difference between any two of the MIMO layers can be determined easily and effectively.

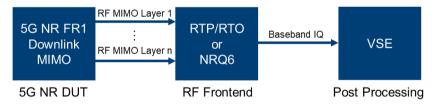




Table 2-1 summarizes the entire measurement items out of VSE-K144 and K146 personality.

Measurement	Description						
EVM vs. Carrier	Error Vector Magnitude (EVM) of the subcarriers within the channel bandwidth						
EVM vs. Symbol	Error Vector Magnitude (EVM) of the OFDM symbols						
EVM vs. RB	Error Vector Magnitude (EVM) of the PDSCH resource block						
Freq Error vs. Symbol	Frequency error of each symbol						
Power Spectrum	Power density of captured signal in capture buffer						
Flatness vs. Carrier	Relative power offset caused by the transmit channel for each subcarrier						
CCDF	Complementary Cumulative Distribution Function (CCDF) is the probability of an amplitude exceeding the mean power measured over the entire captured signal						
Constellation	A diagram indicates the quality of the modulation of the signal						
Allocation Summary	Tabular representation of various parameters of the measured resource allocations						
Bitstream	Demodulated data stream for the data allocations						
Channel Decoder	Shows the characteristics of various channels in a specific subframe						
Result Summary	Shows all relevant measurement results in numerical form, combined in one table						
EVM vs. Symb x Carrier	EVM for each carrier in each symbol						
Power vs. Symb x Carrier	Power for each carrier in each symbol						
Alloc ID vs. Symb x Carrier	Graphical representation of the allocation type of each subcarrier in each symbol of the captured signal						
RS Phase	Shows the phase of the carriers occupied by various reference signals (PDSCH, PDCCH etc.) on different antenna ports (AP).						
RS Phase Diff	Shows the phase difference of different antenna ports (AP) relative to a reference antenna port defined in VSE						
Beamforming Summary	Shows the phase characteristics for each allocation used by the UE-specific reference signals (PDSCH, CORESET, CSI-RS etc.) in numerical form						

Table 2-1: R&S<sup>®</sup>VSE-K144 / K146 5G NR measurements

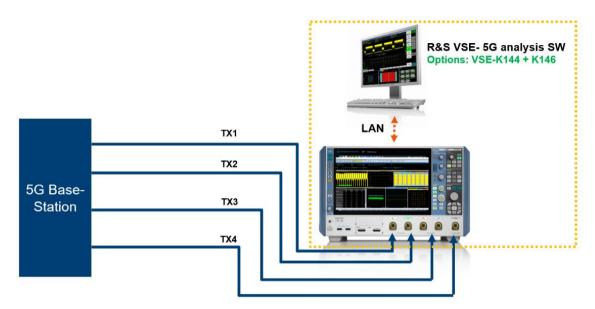
VSE performs not only the signal analysis, but also takes care of the remote controlling of the connected RF frontend. In short, VSE is the only GUI that the user needs to interact with.

For sake of simplicity, a 5G FR1 downlink MIMO 2x2 signal is considered as an example signal in this application note. The details of the signal parameters can be found in Appendix A.

The solutions described in this application note are however not limited to two MIMO layers. By adding more RF frontend capacity, it can be extended to maximum eight MIMO layers from the VSE perspective.

# **3 Test Solution with Oscilloscope RTP/RTO**

# 3.1 Setup



#### Fig. 3-1: 5G FR1 MIMO signal analysis with RTP/RTO and VSE

Fig. 3-1 illustrates the entire setup of the test solution with RTP/RTO as RF frontend. The DUT, e.g. 5G base station, feeds the downlink MIMO signals to RTP/RTO. With the help of RTP/RTO-K11 option, the RF signals are down-converted and down sampled. The generated IQ data are then stored in the memory and later on transferred to VSE for analysis. The controlling part of the RTP/RTO is integrated in the VSE tool. Therefore, VSE serves as both controller and analyzer.

An RTP/RTO is a multichannel oscilloscope with maximum support of four channels. Due to this hardware capacity, phase coherent measurement can be performed with up to four MIMO data streams simultaneously based on one single RTP/RTO together with VSE.

## 3.2 Calibration and Frequency Response Correction

In order to achieve the best possible measurement performance, the fixtures, e.g. RF cables, connectors, connected between the DUT and RF frontend (either RTP/RTO or NRQ6) have to be calibrated with respect to their amplitude and phase characteristics in frequency domain beforehand. With proper calibration or frequency response correction (FRC), the imperfection of the frequency response on the measurement results can be eliminated. The FRC feature in VSE requires VSE-K544 option.

One of the ideal instrument to conduct such calibration is the Vector Network Analyzer (VNA). See [2] to understand the basics of the calibration using VNA.

Based on the 2-ports cable calibration result out of VNA, an S-Parameter Touchstone file (\*.s2p) is generated. The created Touchstone file can then be imported in the VSE as user defined frequency response correction to be applied to each MIMO layer individually.

In VSE main menu, goto Meas Setup > User Correction (Fig. 3-2)

#### 🚸 R&S VSE

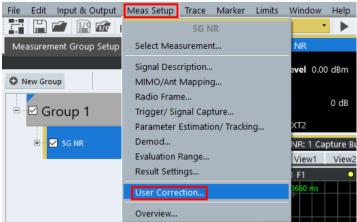


Fig. 3-2: Menu to access to user correction

- 1. As shown in Fig. 3-3, select "**Channel**". This allows the multiple input sources to apply the FRC separately.
- 2. Select each MIMO layer source and **add the Touchstone file** of the connected RF components individually
- 3. Turn on the Frequency Response Correction

User Defined Frequency Response Correction	×
State On Off Adjust Adjust Ref Level Auto Manual	Apply to All Channel Settings Load Save Clear
Source 1, Blave 1, RF       Source 2 Slave 2, RF       Link Sources         ID       Test Setup, S-Parameter (Touchstone Files) Filename       Active       To       From         ID       Test Setup, S-Parameter (Touchstone Files) Filename       Active       To       From         ID       Test Setup, S-Parameter (Touchstone Files) Filename       Remove       Remove         Frequency Response active       ID       Frequency Response Filename       Magnitude       Phase         ID       Frequency Response Filename       Magnitude       Phase	Previews           Selected File         IQ. Mode           Frequency Range         0.0 Hz 0.0 Hz           Number of Points         0           Magnitude         1.00 dB           0.33 dB         0           0.00 dB         -0.67 dB           -0.00 dB         -0.67 dB           -0.67 *         0           0.33 *         -0.67 *           0.33 *         -0.67 *           0.00 *         -0.67 *

Fig. 3-3: Enter and enable the Touchstone file

Fig. 3-4 shows an example of a loaded Touchstone file with graphical representation of magnitude and phase compensation value over the calibrated frequency range.

r Defined Frequency Response Correction	G. 🗖
Adjust Ref Level Auto Manual	Apply to All Channel Settings Load Save Clear
Source 1, Slave 1, RF         Source 2, Slave 2, RF         Lunk Sources           ID         Test Setup, S-Parameter (Touchstone Files) Filename         Active         To         From           1         1.52p         Image: 2 mining 1 mining 2 mining 1 mining 2 mining 2 mining 1 mining 2 mining 1 mining	Previews Selected File IQ Mode D(1.12p Frequency Range 3.4 GHz 3.59998 GHz
	Number of Points         6667         S11         S21         S12         S22
	Magnitude
	10.00 dB 
	-10.00 dB
Add Touchstone File     Remove Frequency Response active	-26,00 dB -30,00 dB
Prequency Response active D Frequency Response Filename Magnitude Phase	-40.00 dB
	Phase
	200.00 ° 133.33 ° 66.67 ° -06.67 ° -133.33 ° -200.00 °
Add Freq. Resp Remove	3.4 GHz 3.59998 GHz

Fig. 3-4: Example of loaded Touchstone file

As long as the FRC is enabled, an indicator "**FRCORR**" in the status window of VSE as shown in Fig. 3-5 is given.

5G NR							
Ref Level 0.00	dBm <b>Freq</b> 3.5	GHz <b>Mode</b>	Downlink, 100 MHz	Capture Time	20.0 ms	View1	Src1 F1
Att	0 dB	Frame Coun	nt 1 of 1(1)	BWP/SS	All	View2	Src2 F1
TRG:EXT2 FRCC	RR						

Fig. 3-5: Indication of frequency correction

Alternative to Touchstone file, a so called frequency response (FRES) file (\*.fres) can be loaded for FRC as well. Please refer to Chapter 4.5 of [3] for details.

# 3.3 Required Software Options

## 3.3.1 RTP/RTO with RTP-K11 / RTO-K11 Option

RTP/RTO is time domain instrument of R&S® oscilloscope family [4].

RTP-K11 or RTO-K11 is a software option of RTP/RTO that enables the oscilloscope to be run under I/Q operation mode. This option allows the RTP/RTO to acquire digitally modulated signals and export the captured I/Q data with an adjustable sampling rate for the post processing tool, like MATLAB, LabView or VSE.

### 3.3.2 VSE with VSE-K144 and VSE-K146

VSE [5] is a high performance analysis software for various analysis tasks and can handle inputs from various instruments, e.g. RTP/RTO, NRQ6 etc.

For the 5G FR1 phase coherent MIMO signal analysis, minimum requirement of the VSE version should be greater than 1.70.

VSE-K144 is a firmware application running in the VSE environment that measures 5G NR signal measurement application on downlink direction for single layer.

VSE-K146 is the VSE application on top of the VSE-K144 that enables up to 8x8 true MIMO measurements for 5G downlink signal. It demodulates and decodes each MIMO layer and phase difference between the different antenna ports can be measured. A summary of the beamforming showing the phase characteristics for each allocation used by the UE-specific reference signals (PDSCH, CORESET, CSI-RS etc.) is presented by this option as well.

## 3.4 Measurements with VSE

## 3.4.1 Create the Test Environment in VSE

Before the MIMO measurements can be started in VSE, following test environments need to be setup beforehand:

- 1. Create the instrument (RTP/RTO) (3.4.1.1)
- 2. Setup the instrument (3.4.1.2)
- 3. Load 5G NR Channel in the measurement group and map the created instrument to the channel (3.4.1.3)
- 4. Enter the frequency response correction (3.4.1.4)
- 5. Specify the carrier frequency and set the trigger (3.4.1.5)

## 3.4.1.1 Create the Instrument Control for RTP/RTO in VSE

Proceed the following steps to create the instrument in VSE

- 1. Select tap "Instruments" and click on "New Instrument" to add a new instrument
- 2. Enter a name for instrument identity, e.g. RTP. See Fig. 3-7
- 3. Enter the IP address of the connected instrument in the "IP Address" field. Alternatively, the domain name of the instrument is also accepted in this configuration field. See Fig. 3-7. The way of how to locally check the computer name and IP address on RTP is shown in Fig. 3-6
- 4. Press "Connect". See Fig. 3-7. VSE is now going to create a remote connection to RTP/RTO

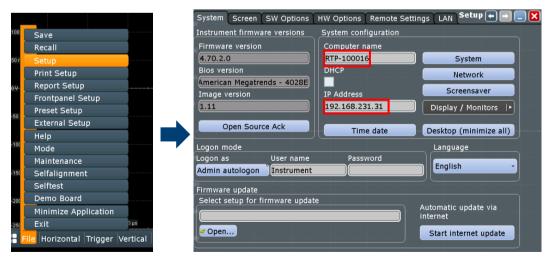


Fig. 3-6: Check computer name and IP address of RTP locally

Measurement Grou	p Setup	Instrun	nents	
				a ×
New Instrument		O Sea	rch	
RTP				×
Interface Type				
Vxi-11				-
IP Address	_			
192.168.231.31				~
Resource String	-			
TCPIP::192.168.2	231.31::INST	R		~
	Adv	anced		
Calibration State	N/A		Self-Aligni	ment
Connection State	not conne	ected		
Info & Setti	ngs		Connect	3

Fig. 3-7: Create a new instrument, e.g. RTP

5. As long as the connection to the instrument is established, the connection state of the instrument is changed to "connected". See Fig. 3-8.

Measurement Group Setup	Instruments
	⊡ ×
New Instrument	• Search
RTP	×
Interface Type	
Vxi-11	•
IP Address	
192.168.231.31	~
Resource String	
TCPIP::192.168.231.31::INST	R ∽
Adv	anced
Calibration State calibrated	Self-Alignment
Connection State connected	1
Info & Settings	Disconnect

Fig. 3-8: Check status and setup the instrument

6. Press "Info & Settings" (see Fig. 3-8) to configure the instrument. Details are explained in Chapter 3.4.1.2

#### 3.4.1.2 Setup the Instrument

1. Goto "General" tab, enable the VISA lock state is recommended. See Fig. 3-9.

fo & Settings: RTP								
erence	Info							
Off	On							
Off	On							
VISA Connection								
off	on							
	Off Off							

#### Fig. 3-9: General settings of RTP/RTO

2. Goto "Reference" tab, ensure the "Internal Reference" is selected. See Fig. 3-10,

fo & Settings: RTP				
General Reference Info				
Reference Frequency Input				
Internal Reference				
<ul> <li>External Reference 10 MHz</li> </ul>	5			
O External Reference 120 MHz	Frequency 10.0 MHz			
<ul> <li>Sync Trigger</li> </ul>				
Reference Frequency Output				
	1			
Output 100 MHz On Off	Output Sync Trigger On Off			
Output 640 MHz On Off				
Set T	o Default			
2011				

Fig. 3-10: Reference setting of RTP/RTO

## 3.4.1.3 Load 5G NR Channel and Source Mapping

🚸 R&IS VSE							
File Edit Input & Output Meas Setup Trace Marker L							
📑 🔛 🜌 🔛 🚾 😐 🗔 🗛 🗔 IQ Analyzer	-	🍷 电 🖒 📔	None 👻 🚊	<u>~~~~</u> ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	v v v		S & S
Measurement Group Setup Instruments	IQ Analyzer						×
	Mode						
New Group     O Channel     Channel	Signal + Spectru	um Analyzer					
🗹 Group 1 🛛 ► 🛚 🛎 🔍	New						
🕀 🗖 IQ Analyzer 🕨 🕨 💌	Channel	3G FDD BTS		3G FDD UE		SG NR SG NR	•
	Replace						
	Current Channel	~~	-	80	-	Ð	
		Analog Demod		GSM		IQ Analyzer	
		_					
		ite UTE	-	NB-IOT	-	OFDM VSA	-
		ue		ND-IO1		OFDIM VSA	
		1979				[:::::]	
		Pulse	•	Transient Analysis	-	VSA	•
		WLAN					
			_				
		$\bigoplus \xrightarrow{\mathbf{1:1}} \bigoplus$	H				
		Duplicate Current Channel					
		current channel					

Goto "Measurement Group Setup" and add there "5G NR" as the new channel. See Fig. 3-11.

Fig. 3-11: Load 5G NR channel in a measurement group

As per default setting in VSE, a single input source is configured. Since we test here 2x2 MIMO, 2 input sources need to be enabled. The following steps shows how to add multiple sources.

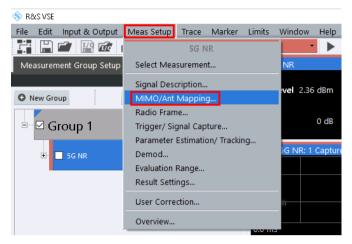


Fig. 3-12: Enter MIMO/Antenna Mapping to enable MIMO scenario

- 1. In VSE menu bar, goto Meas Setup > MIMO/Ant Mapping. See Fig. 3-12.
- 2. In the opened configuration window (see Fig. 3-13), enter the number of MIMO layers in the field "Number of Input Sources". For example, "2" for 2x2 MIMO case.
- 3. Ensure the input source type is set to "instrument"
- 4. Select "MIMO" and "Conducted" as measurement setup
- 5. The antenna port to physical port mapping is automatically carried out, i.e. Config 1 corresponds to MIMO layer 1 with PDSCH Antenna Port configured as 1000, and Config 2 for MIMO layer 2 with PDSCH Antenna Port configured as 1001. See Appendix C or [1] for more information about the antenna ports.
- 6. In the simultaneous signal capture setup section, ensure that the input source (physical connection) matches the configuration mentioned in the step 5. In our example here, RTP Channel 1 is physically connected to MIMO layer1 which is mapped to Config 1, so as the mapping from Channel 2 to Config 2.

ignal Descripti	on MIMO/Ant Map	ping	Radio Frame Config	Advanced S	ettin	gs		
Number of Input	Sources 2		Measurement Setup I	Helper	_			
							<b>.</b> Ľ	$p_o$
Input Source Type Instrument File								n.
NRQ Master	NONE	~			_	<i>p</i> . •	• •	_ <b>p</b> /
CC 1								
r Antenna Port t	o Physical Antenna Mapp	oina ——						
	PSS, SSS, PBCH		PDSCH		PI	оссн	CSI-RS	4
Config 1	4000		1000		2	:000	3000	
Config 2	4000		1001		2000		3000	
Config 3	4000				2	2000	3000	
Config 4	4000				2	2000	3000	
Confia 5	4000				2	.000	3000	•
Simultaneous	ignal capture setup —							
Source	State		Instrument	Input Source		Ant	tenna Port Mapping	·
	Connected	RTP	Ŧ	CHAN1	Ŧ	Config 1		•
1	Connected							

Fig. 3-13: MIMO setup and antenna port (AP) to physical antenna mapping with RTP/RTO

7. After the above steps are completed, close the window will save the settings automatically. In the "Measurement Group Setup" tab, the applied instrument, its configured number of sources from the previous step, and its physical input source assignments is shown in Fig. 3-14. Double check if these assignments reflect the physical connections.

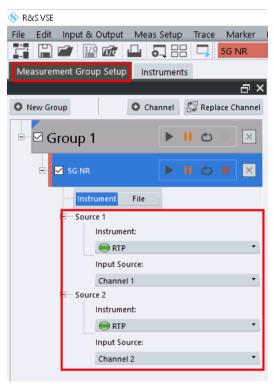


Fig. 3-14: Instrument and input source mapping

## 3.4.1.4 Enter Frequency Response Correction Values

See chapter 3.2

## 3.4.1.5 Specify the Carrier Frequency and Set the Trigger

1. Set the carrier center frequency. For example, enter 3.5 GHz as center frequency for FR1. See Fig. 3-15

🚸 R&S VSE				Freq	uency 🔊 🔨 🗙
Eile Edit	Input & Output 5G NR Amplitude Scale	Meas <u>S</u> etup			Center GHz Center Frequency GHz
• New Gro	Trigger Input Source	innel	•	5G NR	Stepsize Manual Value 1.0 MHz Frequency Offset Value 0.0 Hz

Fig. 3-15: Enter carrier center frequency

2. Set "External Trigger 1" as source trigger. See Fig. 3-16.

	Trigger/Signal Capture	X
	Signal Capture Trigger	7
🚸 R&S VSE	Trigger Source Ext Trigger 1	
<u>File Edit Input &amp; Output</u> Meas <u>S</u> etup	FS-Z11 Trigger On Off	
5G NR 📮 🗄	Trigger Slope Rising Falling	
Measuren Amplitude rument		-
Scale	Source 1 Source 2	-
New Gro     Frequency     Innel	Trigger Port	
Trigger	Trigger Level 1.4 V	
□ G Input Source	Trigger Offset 0.0 s	
🖃 🧧 Output		



### 3.4.2 VSE Signal Configuration

This section describes the necessary settings on VSE for 5G MIMO testing.

Example 5G FR1 2x2 MIMO signal parameters can be referred in Appendix A.

## 3.4.2.1 Signal Parameter Settings

## 3.4.2.1.1 Signal Description

To access to the signal description as shown in Fig. 3-17, enter VSE main menu: Meas Setup > Signal Description

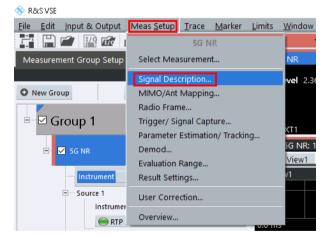


Fig. 3-17: Access to signal description

Main parameters settings are listed in Table 3-1

Field	Value	Remark				
Mode	Downlink					
Deploy Frequency Range	3 GHz < f <= 6 GHz	DUT dependent				
Channel Bandwidth	100 MHz	DUT dependent				
Synchronization	Auto					
Auto Detection Cell ID	Off					
Cell ID	0	The Cell ID should match the one configured on DUT				

Table 3-1 Main parameter settings of signal description

Fig. 3-18 shows the signal description configuration page in VSE.

Sigr	al Configuration				
	Signal Description	MIMO/Ant Mappir	ng Rad	dio Frame Config	Advanced Settings
	Mode	Downlink		Test Models / Us	er Defined Sets
	Number of Component Carriers	1	CC Sign	al Capture	Auto Single
	Deploy Frequency Range	3GHz < f <= 6GHz ▼			
	Physical Settings	L			
	Channel Bandwidth	100MHz *	Sa	ample Rate 122.88 MH	łz
	Auto Demod	All On All	Off		
	Synchronization	Auto Manual Co	onfigure	SCS 30kHz	Delta to CF 0.0 Hz
NR	Bandwidth Parts	Auto Manual C	onfigure	1 BWPs	SCS 30kHz
56.5	Slot	C	onfigure	Slot Format 0	
	PDSCH/PDCCH	C	onfigure	QPSK	
	Auto Detection Cell ID	On Off Cell ID		0	

Fig. 3-18: Signal description

#### 3.4.2.1.2 Radio Frame

In VSE main menu, enter Meas Setup > Radio Frame

Following four configuration sections need to be went through.

- 1. Synchronization
- 2. BWP Config
- 3. Slot Config
- 4. PDSCH/PDCCH Config

## Synchronization

Table 3-2 gives a brief summary of major parameter settings for synchronization radio frame

Field	Value	Remark					
Detection	Auto						
Offset rel to	TxBW	Shall match the signal configuration on the DUT					
Table 3-2 Main parameter settings of synchronization radio frame							

Fig. 3-19 shows the synchronization configuration page in VSE.

#### Signal Configuration Signal Description MIMO/Ant Mapping Radio Frame Config Advanced Settings CC 1 # Frames To Configure Selected Frame 1 Copy Frame Paste Frame Paste to all Synchronization BWP Config Slot Config PDSCH/PDCCH Config Detection Auto Manual SS/PBCH Block Pattern CASE B Subcarrier Spacing 30kHz SS/PBCH Block Offset - Delta: SS/PBCH Block Center to CF T×BVV Offset rel to 0.0 Hz Additional Subcarrier 6 RB Offset 126 Burst Set Periodicity SS/PBCH Block State Configure PSS Rel Power 0.0 dB SSS Rel Power 0.0 dB PBCH DMRS Rel Power (to PBCH) PBCH Rel Power 0.0 dB L Selection

Fig. 3-19: Radio frame configuration - Synchronization

## **BWP** Configuration

Table 3-3 gives a summary of one BWP configuration

Field	Value	Remark
Subcarrier Spacing	30 kHz	
#RBs	273	Maximum number of Resource Blocks
RB Offset	0	

Table 3-3 Main parameter settings of synchronization radio frame

Fig. 3-20 shows the BWP configuration page in VSE.

	ionfiguration Signal Description MIMO/Ant Mapping Radio Frame Config	Advanced Settings						
ľ	CC 1 # Frames To 1 Selected 1 Configure 1 Frame 1 Synchronization BWP Config Slot Config PDSCH/PDCCD	Copy Frame Paste Frame Paste to all						
~	Auto         Manual         Selected         O         Prev BWP         Next E           BWP         Subcarrier         # RBs         RB         Slot         Config           0         30kHz         273         O         Configure	Numerology #1       2 slots per SF       14 symb per slot       Bandwidth 98.28 MHz       Delta to CF 0.0 Hz       Clear       Total # slots 20       Max # RBs 273       FFT size 4096						
5G NR	BARA							

Fig. 3-20: Radio frame configuration - BWP Config

### **Slot Configuration**

Table 3-4 gives a summary of the major parameter settings for slot configuration in the given BWP 0

Field	Value	Remark				
BWP Number	0	1 BWP is configured, the numbering begins with 0				
Slot Allocation	Data	Slot configured for user data transmission				
Slot Format	0	Defines the usage of the OFDM symbols. "0" stands for downlink				

Table 3-4 Main parameter settings of slot configuration

In Fig. 3-21, it shows the slot configuration page in VSE. Since the SCS is 30 kHz, altogether 20 slots are available in one radio frame. In our example here, all 20 slots have the same configuration. Therefore, we actually duplicate the slot configuration from 0 to the remaining 19 slots. The copy-paste operation can be performed easily and flexibly in VSE as highlighted in Fig. 3-21.

	rames To 1 nfigure	Sele Fran	cted 1			Co	opy Frame	Paste Frame P	aste to all
;	Synchronizat	ion BV	/P Config	Slot Config	PDSCH/PD	CCH Config			
E	Bandwidth Pa	rt Number	0				CSI	Settings	
[	Selected Slo	t 0	Prev Slot	Next Slot		er Configurab at remaining)		Сору	
	SF Number	Slot Number	Slot Allocation	Slot Format	PDSCH Allocations	Repeated Slot No	Ref Signals	Paste (Slot 0)	
		0	Data	0	Configure	User	None	Paste to all	
	0	1	Data	0		0	None	Design of the damage	
	1	2	Data	0		0	None	Periodicity 10ms 500.0 μs	
		3	Data	0		0	None		
	2	4	Data	0		0	None	20 slots in BWP 0	
	2	5	Data	0		0	None	Reset Slot Config	

Fig. 3-21: Radio frame configuration - Slot Config

## PDSCH/PDCCH Config

PDCCH(CORESET) and PDSCH can be configured individually in VSE main menu under Radio Frame Config > PDSCH/PDCCH Config section.

It includes the configuration of the modulation coding scheme of the PDSCH, the number of RBs, offset RB, number of symbol, offset symbol of PDSCH and CORESET etc. plus more additional enhanced configurations. e.g. MIMO layers/codewords.

Table 3-5 lists the resource scheduling of PDCCH(CORESET) and PDSCH. Apparently those scheduling parameters should all match the settings given at the DUT side.

Field	Value	Remark
CORESET Number of RBs	270	
CORESET Offset RB	0	
<b>CORESET Number of Symbols</b>	1	
CORESET Offset Symb	0	
Enh.CORESET Precoder Granularity	REG Bundle	
PDSCH Modulation	64 QAM	
PDSCH Number of RBs	273	
PDSCH Offset RB	0	
PDSCH Number of Symbols	13	
PDSCH Offset Symb	1	
Enh.PDSCH Layers/Codewords	2/1	For 2x2 MIMO

Table 3-5 Main parameter settings of PDSCH/PDCCH configuration

Fig. 3-22 shows the setting page of PDSCH/PDCCH in VSE.

Fig. 3-23 and Fig. 3-24 shows the enhanced settings for CORESET and PDSCH (setting of PDSCH DMRS) , respectively

ign	al Des	cription N		nt Mapping	Radio Fran	ne Config	Advan	ced Setting	gs		
СС											
	rames 1 nfigure		elected	1			C	opy Frame	Pa	aste Frame	Paste to
		onization ith Part Numb	BWP Co	nfig Slot C	Slot Numb	SCH/PDCC	H Config				
	# PDS	CH Allocations	1		# CORESETS	1					
	ID	Allocation	Code Word	Modulation	Enhanced Settings	Number of RBs	Offset RB	Number of Symb	Offset Symb	Rel. Power /dB	Conflict
	0	CORESET		QPSK		270	0	1	0	0 dB	
								13			

Fig. 3-22: Radio frame configuration - PDSCH/PDCCH Config

со	RE	SET Enhanced S	Settings							Х			
	[	General				CORESET DMRS Config							
		Precoder Granul	arity	REG Bundle			el Power (to COR	ESET)	0.0 dB				
		Use DMRS Scram	ıbling ID	On Off 0			eference Point		Ref Point A	•			
	ſ	Interleaving											
¥		State		On Off			dle Size		6	Ŧ			
ß		Shift Index		n_shift • 0			rleaver Size		2				
		PDCCH Config											
		RNTI	RNTI Agg		CCE Index		Pattern Length						
		0		1	0		44						
	l	,											

#### Fig. 3-23: Enhanced CORESET settings

PD:	CH Enhanced Settings		×
	User ID 0		
	PDSCH DMRS Config	Phase-tracking RS Config (PTRS)	Scrambling/Coding
	Config Type	1	Codeword to Layer Mapping
	First DMRS symb rel to (Mapping Type)	Slot start (A)	Layers/Codewords 2/1
NR	First DMRS Symb (Type A Pos)	2	▼ Antenna Ports 1000 + 0,1 ▼
5	DMRS Add Position Index	0	CDM groups w/o data 1
	DMRS Length	1	▼ Reference Point Ref Point A ▼
	Sequence Generation	N_ID^CELL • 0	
	n_SCID	0 1	
	Rel Power (to PDSCH)	0.0 dB	
	-		

Fig. 3-24: Enhanced PDSCH settings - PDSCH DMRS Config for 2-layer MIMO

If 4-layer MIMO is under tested, then the codeword to layer mapping in DMRS settings should be set as shown in Fig. 3-25

PDS	CH Enhanced Settings		X
	User ID 0		
	PDSCH DMRS Config	Phase-tracking RS Config (PTRS)	crambling/Coding
	Config Type First DMRS symb rel to (Mapping Type)	1 The start (A) The start (A)	Codeword to Layer Mapping
R	First DMRS Symb (Type A Pos)	2	Antenna Ports 1000 + 0-3
ß	DMRS Add Position Index	0 -	CDM groups w/o data 2
	DMRS Length	1	Reference Point A
	Sequence Generation	N_ID^CELL ▼ 0	
	n_SCID	0 1	
	Rel Power (to PDSCH)	3.0 dB	]

Fig. 3-25 Enhanced PDSCH settings - PDSCH DMRS Config for 4-layer MIMO

Layers/Codewords: 4/1

Antenna Ports 1000+: 0-3

CDM groups w/o data: 2

The antenna port of each MIMO layer is assigned as follows:

AP = 1000 for MIMO Layer 1

AP = 1001 for MIMO Layer 2

AP = 1002 for MIMO Layer 3

AP = 1003 for MIMO Layer 4

Phase Tracking Reference Signal (PTRS) Config

PTRS is disabled in our example signal. Thus, the PTRS is turned off in VSE setting accordingly. See Fig. 3-26.

PD:	SCH Enhanced Settings	5		
	User ID d			
	PDSCH DMRS Config	Phase-tracking RS Config (PTRS)	Scrambling/Coding	
	State	On Off		
	State			
	Rel Power (to PDSCH)	0.0 dB		
ž	L_PTRS	1		
ß	K_PTRS	2 *		
	DL-PTRS-RE-offset	00 ×		

Fig. 3-26: Enhanced PDSCH settings - Phase Tracking Reference Signal (PTRS) Config

#### Scrambling/Coding

The configuration of scrambling and channel coding of the PDSCH is shown in Fig. 3-27

PD:	CH Enhanced Settings			
	User ID d			
	PDSCH DMRS Config Phase-trac	king RS Config (PTRS)	Scrambling/Coding	
	Channel Coding			
	MCS Table 64QA	м *		
~	I_MCS 17			
5G NR	Redundancy Version Index 0			
	Scrambling			
	Scrambling N_ID^CELL	• 0		

Fig. 3-27: Enhanced PDSCH settings - Scrambling and Channel Coding Config

### 3.4.2.1.3 Advanced Settings

#### **Global Settings**

In order to optimize the measurement results in VSE, global settings as listed in Table 3-6 need to be configured. Misconfiguration or mismatch of the settings between the VSE and DUT will lead to bad EVM values in the signal analysis.

Field	Value	Remark
Set Handling of Carrier Leakage	Ignore DC	R&S VSE removes the DC carrier from all results by ignoring the corresponding subcarriers. The DC carrier is assumed to be in the center of the channel bandwidth.
Phase Compensation	On / Off	From the base station side, it is necessary to upconvert the baseband signal to the radio frequency. The upconversion requires a frequency related phase compensation after each symbol according to 3GPP 38.211: 5.4 "Modulation and Upconversion". When "Phase Compensation" is off, the VSE assumes that the applied signal is not phase- compensated and analyzes the signal accordingly. When "Phase Compensation" is on, the VSE assumes that the applied signal is already phase- compensated for a specific frequency. This frequency is either the current center frequency ("CF"), e.g. 3.5 GHz in our example here or an arbitrary frequency ("Manual)". The setting here needs to match the settings on the DUT side, i.e. Base Station.

Table 3-6 Global advanced settings

Fig. 3-28 shows the global configuration page in VSE.

gnal Configuration				X
Signal Description	MIMO/Ant Mapping	Radio Frame Config	Advanced Settings	
CC 1				
Global Settings	Handling of Carrier Leaka	age Ignore DC	•	
Reference Point A	Phase Compensation	On Off		
	f_0 =	CF Manua	1	
		3.5 GHz		

Fig. 3-28: Advance settings - Global settings

#### Reference Point A

Fig. 3-29 shows reference point A configuration in VSE where the user can define the location of the reference point relative to the carrier center frequency.

Sign	al Configuration		x
	Signal Description	MIMO/Ant Mapping Radio Frame Config Advanced Settings	
	Global Settings Reference Point A	k_0 configured numerologies       SCS 15kHz       0       SCS 15kHz       0       SCS 50kHz       0       Reference Point A       Relative to CF       49.14 MHz       Absolute Frequency 3.45086 GHz       TxBW Offset	

Fig. 3-29: Advance settings - Reference Point A settings

#### 3.4.3 Add MIMO Personalities and Run Measurement

If a valid VSE-K146 option license is in place, then 5G MIMO measurement personalities are enabled. These special MIMO measurement personalities include RS Phase, RS Phase Difference measurement and Beamforming summary.

As shown in Fig. 3-30, to visualize those MIMO measurements, goto VSE menu bar, select:

Window > New Window > RS Phase

Window > New Window > RS Phase Diff

Window > New Window > Beamforming Summary

🚸 R&S VSE	
Eile Edit Input & Output Meas Setup Trace Marker	
🚰 💾 🜌 🔛 🚾 🖵 🎝 🖽 🗔 5g nr	Player + None 🔻 👗 👗 🦓 🌾 🤟
Measurement Group Setup Instruments	5 🗸 Instruments
a >	X Ref Measurement Group Setup
New Group     O Channel     Channel	
	Att Channel Information
🖻 🗹 Group 1 🛛 🕨 💌 💌	TRG Active Windows
	Kuve windows     EVM vs RB     SG NR: 1 Capture Buffer
🖻 🗹 5G NR 🛛 🕨 🔛	All View1 View2
	1 1 View1
Instrument File	E Flatness vs Carrier
Source 1	0 dBm
Instrument:	Constellation
RTP	0.0 ms 2.01 ms/ Allocation Summary
Input Source:	💌 🔆 5G NR: 6 Constellation Diagram 🔤 Bitstream
Channel 1	All View1 View2 🖽 Channel Decoder
🗄 ···· Source 2	6.1 View1  Result Summary
Instrument:	Points Measured : 0 International Internationa International International Internation
RTP	🔃 EVM vs Symb X Carrier
Input Source:	Power vs Symb X Carrier
Channel 2	🔝 Alloc ID vs Symb X Carrier
	💌 🌟 5G NR: 2 Result Summary 🔤 RS Phase
	All View1 View2 🔤 RS Phase Diff
	2.1 All 🔲 Beamforming Summary
	mean value

Fig. 3-30: Add VSE-K146 MIMO measurement personalities

Goto Meas Setup > Overview opens a summary of the settings as shown in Fig. 3-31.

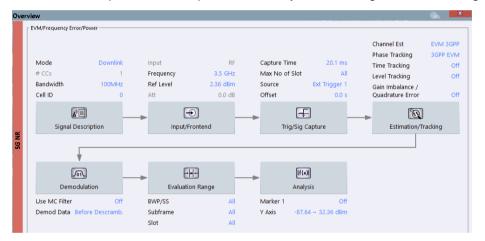


Fig. 3-31: Overview of the measurement settings

Now, the measurements can be started by pressing the capture button in the VSE function bar as indicated in Fig. 3-32.

🚸 R&S VSE File Edit Input & Output Meas Setup Trace Marker Limits Window Help 🚰 🗎 ┛ 🔛 🚾 🖵 🎝 🖽 🤜 • 🕨 II 🖒 🔍 • 5G NR



VSE delivers the measurement results as shown in Fig. 3-33.

🛞 RAS VSE					- a ×
•	and the second second				- 0 ^
File Edit Input & Output Meas Setup Trace N		~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~			
		/`o/o ~ `o `o @ 0+0' mm mm mm 0"			
Measurement Group Setup Instruments	5G NR				
	Ref Level 2.00 dBm Freq 3.5 GHz Mode Downli	nk, 100 MHz Capture Time 20.1 ms View1 Src1 F1			
O New Group O Channel	hannel				
	Att 0 d6 Frame Count	1 of 1(1) BWP/SS All View2 Src2 F1			
🖻 🗹 Group 1 🔹 🕨 🔿 🖉	TRGEXT1				
	- FCAID: 1 Cardon Bullion	5G NR: 7 RS Phase		G NR: 10 EVM vs Symbol X Carrier 5G NR: 3 EVM vs Car	
🖹 🗹 SG NR 🔰 👛 🔴	All View1 View2	All View1 View2		IS NIC TO EVM VS Symbol X Carrier 3G NR 3 EVM VS Car	ler
- Instrument File	1.1 Src1 F1 0 1 Clrw 1.2 Src2 F1 0 1 Clrw	7.1 Src1 F • 1 AP 4000 • 2 AP 1000 • 3 AP 2000 7.2 Src2 F	• 1 AP 4000 • 2 AP 1001 • 3 AP 2000	View1 View2	,
Source 1	35.726965066 ns 35.726965066 ns	RS Weights : All RS Vieights :		1 Src1 F1 10.2 Src2 F1	
instrument:	Contraction of the second s	200 * 200 *		53, 10% 15% 200 5%	15% 200
e RTP	· ·				
Input Source:	Contraction of the second s	-200 *			
Channel 1	- 0.0 ms 2.01 ms/ 20.1 ms 0.0 ms 2.01 ms/ 20.1 ms	0.0 Hz 9.83 MHz/ 98.28 MHz 0.0 Hz	9.83 MHz/ 98.28 MHz		
- Source 2	5G NR: 8 RS Phase Diff 5G NR: 6 Constellation Diagram		<ul> <li>5G NR: 5 Power Spectrum</li> </ul>		
Instrument:	So fac o constenation biagram		All View1 View2		
e RTP	All View1 View2		5.1 Src1 F1	1 Clrw 5.2 Src2 F1	• 1 Clrw
Input Source:	8.1 Src1 F1 0 1 AP 4000 0 2 AP 2000	8.2 Src2 F1 0 1 AP 4000 0 2 AP 1001 0 3 AP 2000	-60 dBm/Hz	-60 dBm/Hz	
Channel 2	Reference AP : AP 1000	Reference AP : AP 1000			
	Référence Antenna : RX 1	Reference Antenna : RX 1	-80 dBm/Hz	-80 dBm/Hz	و و الما الما أ
	••••••••••••••••••••••••••••••••••••••	<u>a+</u>	-100 dBm/Hz	-100 dBm/Hz	
	-200 *	-200 *	100 dBm (Ar	-120 dilm 0/2	
	0.0 Hz 9.83 MHz/ 98.28 MHz	0.0 Hz 9.83 MHz/ 98.28 MHz	0.0 Hz 12.29 MHz/	122.88 MHz 0.0 Hz 12.29 MHz/	122.88 MH2
			0.0 H2 12.29 MH2/		122.88 MH2
	SG NR: 2 Result Summary     Selected Averaged     All View1 View2	SG NR: 9 Beamforming Summary     View1 View2		SG NR: 4 Alloc ID vs Symbol X Carrier PSS SSS PBCH PTRS	CORESET CORESET DWE
	2.1 All View2	9.1 Src1 F1		POCH DMRS PDSCH DMRS CSI-RS P D	S C H Not Used
	Mean Value	BWP/Sf/Slot Allocation Ant			
	Frame Results Averaged View1 View2	BWP/St/Siot Type Port	Phase [*] Phase Diff [*]		
	EVM PDSCH QPSK (%)	SS/0/0 PBCH AP	4000 -0.000 -0.00		
	EVM PDSCH 16QAM (%) EVM PDSCH 64QAM (%) 1.05	1.16 0/0/0 PDSCH AP	1000 -0.000		
	EVM PDSCH 256QAM (%)	CORESET AP	2000 -1.403 -1.40	3	
		1.14 1.16 0/0/1 PDSCH AP	1000 0.000		
			2000 -1.097 -1.05	7	
	Frequency Error (Hz) -69.69 -6	9.69			
► Play CONT	Sampling Error (ppm) -0.01		1000 0.000 2000 -1.401 -1.40		
		Sync Found	2000 -1.40	Paused	VISA
		Sync Found		Paused	V154

Fig. 3-33: VSE measurements (2x2 MIMO)

Here we would like to highlight some MIMO specific measurements, namely, the RS Phase, RS Phase difference and beamforming summary.

Fig. 3-34 is the measurement result of RS Phase that shows the phase of the carriers occupied by different reference signals, e.g. PDCCH, PDSCH, SSB etc, on each MIMO layer.

5G NR: 7 RS Phase					
All View1 View2					
7.1 Src1 F1	O 1 AP 4000 O 2 AP 1	000 • 3 AP 2000 7.2 Src	2 F1 O	1 AP 4000 🖸 2 AP 100	1 O 3 AP 2000
RS Weights : All 300 °		RS Wei	phts : All		
		200 *-			
		100 *			
*		0			
		-100 *			
		-200 *			
		-300 *			
0.0 Hz	9.83 MHz/	98.28 MHz 0.0 Hz	9.83	3 MHz/	98.28 MHz



Fig. 3-35 shows the phase difference of different antenna port relative to the reference antenna port. The reference antenna port can be user defined in VSE.

5G NR: 8 RS Phase Diff				
All View1 View2				
3.1 Src1 F1	O 1 AP 4000 O 2 AP 2000	8.2 Src2 F1	○ 1 AP 4000 ● 2 AP 100	1 • 3 AP 2000
Reference AP : AP 1000 Beference Antenna : RX 1		Reference AP : AP 1000 Reference Antenna : RX 1		
		200 °		
		100 *		
		0.		
		-100 *		
		-200 *		
		-300 °		
0.0 Hz 9.83 M	Hz/ 98.28 MHz	0.0 Hz	9.83 MHz/	98.28 MHz

Fig. 3-35: Measurement of 5G MIMO phase difference

The beamforming summary shown in Fig. 3-36 gives an overview of the phase characteristics of each resource allocation used by the UE specific reference signals (PDSCH, CORESET etc.).

5G NR: 9 Beamformin /iew1 View2	g Summary			
Src1 F1				
BWP/Sf/Slot	Allocation Type	Ant Port	Phase [°]	Phase Diff [°]
SS / 0 / 0	PBCH	AP 4000	-0.000	-0.000
0/0/0	PDSCH CORESET	AP 1000 AP 2000	-0.000	-1.403
0/0/1	PDSCH	AP 1000 AP 2000	0.000	-1.097
0/1/2	PDSCH CORESET	AP 1000 AP 2000	0.000 -1.401	-1.401
0/1/3	PDSCH CORESET	AP 1000 AP 2000	0.000 -1.245	-1.245
0/2/4	PDSCH CORESET	AP 1000 AP 2000	0.000 -1.400	-1.400
0/2/5	PDSCH CORESET	AP 1000 AP 2000	-0.000 -1.178	-1.178

#### Fig. 3-36: Beamforming summary

The reference antenna port can be defined through VSE's "evaluation range ..." function as shown in Fig. 3-37.

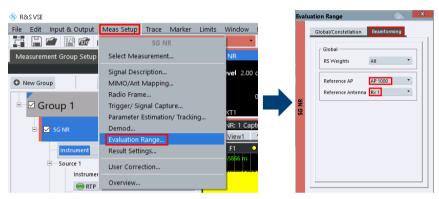
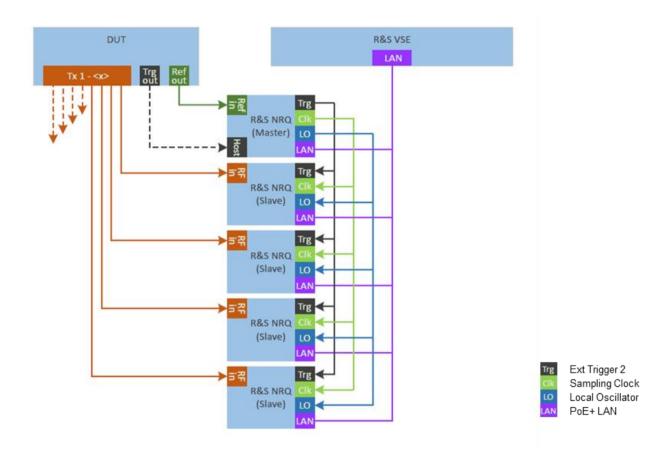


Fig. 3-37: Change reference antenna port (AP)

# 4 Test Solution with Frequency Selective Power Sensor NRQ6

# 4.1 Setup



#### Fig. 4-1: Block diagram of test solution with NRQ6 and VSE

Fig. 4-1 shows a block diagram of test solution with NRQ6 and VSE to analyze the 5G FR1 with 4-layer MIMO signal.

The setup follows a master-slave principle. Master and slave NRQ6 are hardware identical measurement devices. The role definition is configured in the VSE, details see 4.4.1. All the NRQ6s are power supplied by Power over Ethernet (PoE+) LAN cable. A master NRQ6 is required to simultaneously trigger the slave NRQ6 units for the capturing, provide the identical clock signal and couple the LO signal to the slave NRQ6s. Multiple slave NRQ6s can be deployed in the setup. The number of the slave NRQ6 depends on the number of the MIMO layers. Each slave NRQ6 captures the data stream of one MIMO layer from DUT individually, down-converts the RF signal to baseband IQ data and then transfers them to VSE for the post processing. In this test solution, the master NRQ6 does not capture the data stream. Therefore, no RF connection is needed on master NRQ6.

It is required that the connections from the master to each slave NRQ6 are symmetrical, that means the same cable length of trigger, clock and local oscillator (LO) from master to each slave NRQ6 are expected. The phase coherent measurement is guaranteed, only if the symmetry is fulfilled.

The topology of this test solution allows the easy capacity extension to measure higher order MIMO system. Therefore, in comparison to the test solution based on RTP/RTO oscilloscope described in Chapter 3, this solution covers additionally the phase coherent measurement for MIMO layers greater than four.

# 4.2 Calibration and Frequency Response Correction

See 3.2

# 4.3 Required Software Options

### 4.3.1 NRQ6-K1 and NRQ6-K3

NRQ6 is a power sensor based on the principle of a measurement receiver which has a large dynamic range and can handle large variations in signal strength and deliver accurate measurement. It is an ideal cost effective and compact test equipment for 5G NR base station MIMO measurement.

To fulfill the 5G MIMO phase coherent signal analysis test purpose, software options NRQ6-K1 and NRQ6-K3 are required.

NRQ6-K1 is an essential software option on NRQ6 that enables the interface to output the IQ data from NRQ6 to VSE for the post processing.

In addition, NRQ6-K3 option is needed to deal with the phase coherent measurements between multiple power sensors.

### 4.3.2 VSE with VSE-K144 and VSE-K146

See 3.3.2

## 4.4 Measurements with VSE

## 4.4.1 Create the Test Environment in VSE

Before the MIMO measurements can be started in VSE, following test environments need to be setup beforehand:

- 1. Create the instrument (NRQ6 master and slaves) (4.4.1.1)
- 2. Setup the instrument (4.4.1.2)
- 3. Load 5G NR Channel in the measurement group and map the created instrument to the channel (4.4.1.3)
- 4. Enter the frequency response correction (4.4.1.4)
- 5. Specify the carrier frequency and set the trigger (4.4.1.5)

## 4.4.1.1 Create the Instrument in VSE

To measure 2x2 MIMO signal, all together three NRQ6s are required.

1 x NRQ6 works as Master

- 1 x NRQ6 works as first Slave to capture MIMO layer 1 signal
- 1 x NRQ6 works as second Slave to capture MIMO layer 2 signal

Each NRQ6 has to be defined in VSE with the following steps

- 1. Select tap "Instruments" and click on "New Instrument" to add a new instrument
- 2. Enter a name for instrument identification, e.g. Slave 1. See Fig. 4-3
- 3. Enter the IP address of the connected instrument in the "IP Address" field. See Fig. 4-3. Alternatively, the domain name of the NRQ6 is also accepted in this configuration field. The domain name of the NRQ6 follows the naming convention like NRQ6-<place holder>, where <place holder> is the serial number of the NRQ6. To identify the IP address of the NRQ6, easily ping the domain name on the command prompt of the control PC as shown in Fig. 4-2.

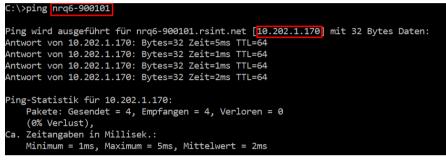


Fig. 4-2 Ping NRQ6 domain name to obtain its IP address

4. Press "Connect". See Fig. 4-3. VSE is now going to create a remote connection to NRQ6

s	lave		×
		Interface Type	
		Vxi-11	•
		IP Address	
		10.202.1.170	~
		Resource String	
		TCPIP::10.202.1.170::INSTR	~
		Advanced	
		Calibration State N/A Self-Alignment	
		Connection State not connected	
		Info & Settings	

Fig. 4-3: Create a new instrument, e.g. NRQ6 slave 1

5. As long as the connection to the instrument is established, the connection state of the instrument is changed to "connected". See Fig. 4-4.

Slave 1	×
Interface Type	
Vxi-11	•
IP Address	
10.202.1.170	$\sim$
Resource String	
TCPIP::10.202.1.170::INSTR	$\sim$
Advanced	
Calibration State calibrated Self-Alignment	
Connection State connected	
Info & Settings Disconnect	

Fig. 4-4 Check NRQ6 status and setup the instrument

- 6. Press "Info & Settings" (see Fig. 4-4) to configure the instrument. For the settings details of master and slave NRQs, refer to Chapter 4.4.1.2.
- 7. Repeat step 1 to 6 until connections to all the NRQ6s are established

#### 4.4.1.2 Setup the Instrument

Master and Slave NRQs work in different operation mode. Therefore, they have to be configured differently in VSE as described in this chapter.

#### 4.4.1.2.1 Master NRQ6

The Master NRQ6 configurations are shown in Fig. 4-5 and Fig. 4-6

1. In tab "General" (See Fig. 4-5), proceed as following:

Sync Mode Master

Master Trigger Source<sup>1</sup> Free Run, Host-Interface (Ext1) or Ext2

Trigger Output Port<sup>2</sup> Host-Interface (Ext1) or Ext2

VISA Lock State<sup>3</sup> On or Off

<sup>&</sup>lt;sup>1</sup> Which type of "Master Trigger Source" is chosen depends on the used input trigger source. The selection between Ext1 and Ext2 depends on the physically connected input trigger source on Master NRQ6. Details about the trigger ports on NRQ6, refer to [6].

<sup>&</sup>lt;sup>2</sup> "Trigger Output Port" is the trigger port that is used by the trigger master to output a trigger signal. Note, for each NRQ6, "Trigger Output Port" has to be different from the "Master Trigger Source".

<sup>&</sup>lt;sup>3</sup> It is recommended to activate "VISA Lock State". If VISA state is locked, then accessing the NRQ6 from other controlling VISA hosts is no longer possible. This prevents the settings of the NRQ6 from being altered by the other hosts.

Remote Display	Master / Slave Settings -			
Local Lockout Off On	Sync Mode	None	Master	Slave
	Master Trigger Source	Free Run	Host-Interface (Ext1)	Ext 2
Display Update Off On	Trigger Output Port	Off	Host-Interface (Ext1)	Ext2
VISA Connection				
VISA Lock State off on				

Fig. 4-5 Example of general settings for Master NRQ6,

2. In tab "Reference" (See Fig. 4-6), proceed as following:

Reference Frequency Input Ext.Reference e.g. Frequency 10 MHz

LO Source Internal

LO Out On

Sample CLK Source automatically set to Internal, not configurable

Sample CLK Out On

General Reference Info	
Reference Frequency Input	LO & Sampling CLK
O Internal Reference	LO Source
External Reference 10 MHz  Frequency 10.0 MHz	LO Out
Ext.Reference 10 20 30 40 MHz	Sampl. CLK Source Int Ext
O Sync Trigger	Sampl. CLK Out On Off
Reference Frequency Output	
Output 100 MHz On Off Output Sync Trigger On Off	
Output 640 MHz On Off	
Set To Default	

Fig. 4-6 Reference settings for Master NRQ6

#### 4.4.1.2.2 Slave NRQ6

Configure each slave NRQ6 with the same settings as shown in Fig. 4-7 and Fig. 4-8.

1. In tab "General" (See Fig. 4-7), proceed as following:

Off

Sync Mode **Slave** Trigger Output Port

VISA Lock State On<sup>4</sup>

<sup>&</sup>lt;sup>4</sup> The same setting as on Master NRQ6 in Chapter 4.4.1.2.1. It is recommended to activate "VISA Lock State"

General Reference Info				
Remote Display	Master / Slave Settings —			
Local Lockout Off On	Sync Mode	None	Master	Slave
	Master Trigger Source	Free Run	Host-Interface (Ext1)	Ext 2
Display Update Off On	Trigger Output Port	Off	Host-Interface (Ext1)	Ext2
VISA Connection	]			
VISA Lock State off on				

#### Fig. 4-7 General settings for Slave NRQ6

2. In tab "Reference" (See Fig. 4-8), proceed as following:

Reference Frequency Input Internal Reference

- LO Source Ext
- LO Out automatically set to OFF, not configurable
- Sampl. CLK Source Ext

Sample CLK Out automatically set to OFF, not configurable

General Reference Info		
Reference Frequency Input		LO & Sampling CLK
Internal Reference     External Reference 10 MHz     Ext.Reference 10[20]30]40 MHz     Sync Trigger	Frequency 10.0 MHz	LO Source Int Et LO Out Onor Sampi. CLK Source Int Et Sampi. CLK Out On Off
Reference Frequency Output           Output 100 MHz           Output 640 MHz             On   Off	Output Sync Trigger	
Set To	Default	

#### Fig. 4-8 Reference settings for Slave NRQ6

When the sample clock source is set to external, confirm the message box shown in Fig. 4-9 after ensuring that the external CLK signal delivered from the master NRQ6 is physically fed into the Sampling CLK port of the slave NRQ6.

Warning ×
Activating 'External Sample CLK' requires a physical feed of an external signal on the corresponding SMA connector of the device. If the external CLK signal is missing, the device will not respond to any further remote commands.
Do you really want to activate this setting in the sensor?
Yes No

Fig. 4-9 Confirm the activating of external sample CLK

#### 4.4.1.3 Load 5G NR Channel and Source Mapping

- 1. Load 5G NR channel as described in Chapter 3.4.1.3.
- 2. In VSE menu bar, goto Meas Setup > MIMO/Ant Mapping

- 3. In the opened configuration window (see Fig. 4-10), enter the number of MIMO layers in the field "Number of Input Sources". For example, "2" for MIMO 2x2
- 4. Ensure the input source type is set to "instrument"
- 5. Select instrument "Master" which is created in 4.4.1.1 as NRQ Master
- 6. Select "MIMO" and "Conducted" as measurement setup
- 7. The antenna port to physical port mapping is automatically carried out, i.e. Config 1 corresponds to MIMO layer 1 with PDSCH Antenna Port configured as 1000, and Config 2 for MIMO layer 2 with PDSCH Antenna Port configured as 1001. See Appendix C or [1] for more information about the antenna ports.
- 8. In the simultaneous signal capture setup section, ensure that the input source (physical connection) matches the configuration mentioned in the step 7. In our example here, Slave 1 is physically connected to MIMO layer1 which is mapped to Config 1, so as the mapping from Slave 2 to Config 2.

Con	figuration					6	
Sig	nal Description	MIMO/Ant Mapp	ing Radio Frame Conf	ig Advanced	Settings		
in N	umber of Input Sou Iput Source Type RQ Master		File	Multi SISO	<i>p</i> ,	$\uparrow \dots , \downarrow p_{e}$	p 1
ſ	Antenna Port to Ph	ysical Antenna Mappir PSS, SSS, PBCH	gPDSCH		PDCCH	CSI-RS	
	Config 1	4000	1000			None	
Config 2 4000		1001		2000	None		
	Config 3	4000			2000	None	
	Config 4	4000			2000	None	-
ſ	Simultaneous sign	al capture setup ——					
	Source	State	Instrument	Input Source		Antenna Port Mapping	•
	1	Connected	Slave 1 🔹	RF	▼ Config	1 🔹	
	2	Connected	Slave 2	RF	<ul> <li>Config</li> </ul>	2 .	

Fig. 4-10 MIMO setup and antenna port (AP) to physical antenna mapping with NRQ6

9. After the above steps are completed, close the window will save the settings automatically. In the "Measurement Group Setup" tab, the applied instrument, its associated number of source, with which the physical input source is assigned is shown in Fig. 4-11. The mappings in our example case looks like follows:

MIMO layer 1 - Source 1 - Slave 1

MIMO layer 2- Source 2 - Slave 2

#### 🚸 R&S VSE

,					
ile Edit Input & Output Meas Setup Trace Marker					
🚰 🔛 🕋 🕼 🚾 🖵 🎝 🗛 🗔 5g nr					
Measurement Group Setup Instruments					
New Group     Channel					
⊡ Group 1 🕨 🔛 🗵					
🖃 🗹 SG NR 🛛 🕨 🚺 → 🔍 🗙					
Instrument File					
🖃 Source 1					
Instrument:					
Slave 1					
Input Source:					
RF					
Source 2					
Instrument:					
Slave 2					
Input Source:					
RF					

Fig. 4-11 Instrument and input source mapping with NRQ6

### 4.4.1.4 Enter Frequency Response Correction Values

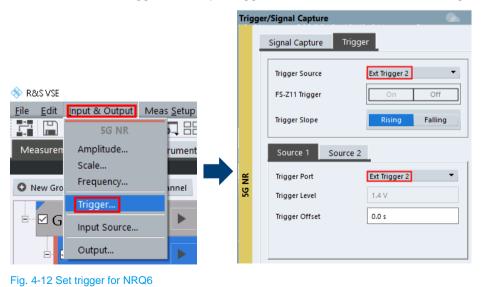
See chapter 3.2

### 4.4.1.5 Specify the Carrier Frequency and Set the Trigger

- 1. Set carrier frequency as described in Chapter 3.4.1.5.
- 2. Set the trigger as follows:

In VSE menu bar, goto Input & Output > Trigger...

Set "External Trigger 2" as input trigger source for Slave NRQ6. See Fig. 4-12



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## 4.4.2 VSE Signal Configuration

This part is test signal dependent. Since we use the same 2x2 MIMO signal here, all the settings can be referred to Chapter 3.4.2

#### 4.4.3 Add MIMO Personalities and Run Measurement

Same procedure as described in Chapter 3.4.3

# **5** Literature

- [1] "5G NR eBook," [Online]. Available: https://www.rohde-schwarz.com/5G-ebook.
- [2] "White Paper Vector Network Analyzer (VNA) Calibration: The Basics," [Online]. Available: https://docplayer.net/4805355-Vector-network-analyzer-vna-calibration-the-basics.html.
- [3] R&S®VSE-K144 / -K146 3GPP 5G NR Measurement Application (Downlink) User Manual.
- [4] R&S®RTP High-Performance Oscilloscope User Manual.
- [5] R&S®VSE Vector Signal Explorer Base Software User Manual.
- [6] R&S®NRQ6 Frequency Selective Power Sensor User Manual.

# **6 Ordering Information**

# 6.1 R&S<sup>®</sup>RTP/RTO

Designation	Туре	Order No.
Oscilloscope		
RTO Digital Oscilloscope (6 GHz BW on 2 channels, 4 GHz BW on 4 channels)	R&S®RTO2064	1329.7002.64
RTP Digital Oscilloscope (8 GHz BW on 4 channels)	R&S <sup>®</sup> RTP804	1320.5007.08
RTP Digital Oscilloscope (13 GHz BW on 2 channels, 8 GHz BW on 4 channels)	R&S <sup>®</sup> RTP134	1320.5007.13
RTP Digital Oscilloscope (16 GHz BW on 2 channels, 8 GHz BW on 4 channels)	R&S <sup>®</sup> RTP164	1320.5007.16
Required options		
I/Q Software Interface	R&S <sup>®</sup> RTO-K11	1329.7360.02
	R&S <sup>®</sup> RTP-K11	1800.6683.02
Recommended options		
Memory upgrade 1GSa per channel (HW opt)	R&S®RTO-B110	1329.7090.02
	R&S <sup>®</sup> RTP-B110	1337.9530.02

# 6.2 R&S<sup>®</sup>NRQ6

Designation	Туре	Order No.
Frequency selective power sensor	R&S®NRQ6	1421.3509.02
I/Q data interface	R&S <sup>®</sup> NRQ6-K1	1421.4705.02
Power servoing	R&S <sup>®</sup> NRQ6-K2	1421.4740.02
Phase coherent measurements	R&S <sup>®</sup> NRQ6-K3	1421.4770.02
Accessories		
Ten-port PoE+ switch	R&S <sup>®</sup> NRP-ZAP2	3639.1902.02
USB interface cable, length: 0.75 m	R&S <sup>®</sup> NRP-ZKU	1419.0658.02
USB interface cable, length: 1.50 m	R&S <sup>®</sup> NRP-ZKU	1419.0658.03
USB interface cable, length: 3.00 m	R&S <sup>®</sup> NRP-ZKU	1419.0658.04
USB interface cable, length: 5.00 m	R&S <sup>®</sup> NRP-ZKU	1419.0658.05
Six-pole interface cable, length: 1.50 m	R&S®NRP-ZK6	1419.0664.02
Six-pole interface cable, length: 3.00 m	R&S <sup>®</sup> NRP-ZK6	1419.0664.03
Six-pole interface cable, length: 5.00 m	R&S®NRP-ZK6	1419.0664.04
USB Sensor Hub	R&S®NRP-Z5	1146.7740.02
Documentation		
Documentation of calibration values (DCV)	R&S <sup>®</sup> DCV-1	0240.2187.06
Hardcopy of DCV (in combination with R&S®DCV-1 only)	R&S®DCV-ZP	1173.6506.02
Accredited calibration for R&S®NRQ6 power sensor	R&S®NRP-ACA	1419.0812.00

# 6.3 R&S<sup>®</sup>VSE

Designation	Туре	Order No.
Vector Signal Explorer		
Vector Signal Explorer Base Software, Basic Edition	R&S <sup>®</sup> VSE	1345.1011.06
License dongle	R&S <sup>®</sup> FSPC	1310.0002.03
Required options		
3GPP 5G-NR downlink and uplink	R&S®VSE-K144	1309.9574.03
3GPP 5G MIMO downlink (requires VSE-K144)	R&S®VSE-K146	1345.1305.02
Recommended options		
User defined frequency response correction by SnP file	R&S <sup>®</sup> VSE-K544	1309.9580.06

# 7 Appendix

# A Example 5G FR1 Downlink 2x2 MIMO Signal Parameters

In this application note, an example 5G FR1 2x2 MIMO downlink test signal is applied with the following parameter settings given in Table 7-1 to Table 7-5.

Parameter	Value
Carrier Frequency	3.5 GHz
Duplexing	FDD
Deployment	3 GHz < f <= 7.125 GHz
Subcarrier Spacing (SCS)	30 kHz
Channel Bandwidth	100 MHz
Cell ID	0
RF Phase Compensation	ON

Table 7-1 General configuration

Parameter	Value
RB Offset	126
SC Offset	6
SS/PBCH case	Case B
L	8
Positions	1100 0000
Burst Set Periodicity	10 ms

Table 7-2: SS/PBCH Configuration

Parameter	Value
Number of DL BWPs	1
No. of Resource Blocks (RB)	273
RB Offset in TxBW	0
RB Offset to PointA	0

Table 7-3: Bandwidth Parts

Since 30 kHz Subcarrier Spacing (SCS) is configured, a radio frame contains 20 slots. For sake of simplicity, CORESET and PDSCH scheduling as listed in Table 7-4 and Table 7-5 showing the scheduling on slot 0 (the first slot). The same scheduling is then duplicated to the rest of the 19 slots.

Parameter	Value
No. of Symbols	1
Symbol Offset	0
No. of RBs	270
RB Offset	0
Precoder Granularity	REG Bundle
Use DMRS scrambling ID	OFF
Use Bitmap for Resources in Frequency Domain	OFF
CORESET ID	1
Interleaving	OFF
Search Space	Aggregation Level 1, 2, 4, 8, 16 Max.Candidates 1

Table 7-4: Scheduling CORESET

Parameter	Value
DMRS Mapping Type	A
No. of Symbols	13
Symbol Offset	1
No. of RBs	273
RB Offset	0
PDSCH Type	DCI Format 1_1
Number of Codewords	1
Scheduled by CORESET 0	OFF
Rate Match Pattern Group	None
Resource Allocation	Type 1
Modulation	64 QAM
CDM Groups w/o Data	1
Number of Layers	2
DMRS Type A Position	2
DMRS Sequence Generation	N_ID^Cell
N_SCID	0
DMRS Antenna Ports	1000, 1001

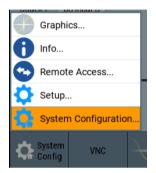
Table 7-5: Scheduling PDSCH

# B Example 5G FR1 Downlink 2x2 MIMO Signal Generation

R&S<sup>®</sup>SMW200A, a high-end vector signal generator from R&S<sup>®</sup>, can be utilized to generate the signal with the parameters described in Appendix A. The generated signal can be considered as a reference signal to the real signal under test.

A step-by-step description is given here to show the entire setup procedure.

- 1. Press "Preset" hard-button on SMW200A's front panel
- 2. Define 2x2 MIMO system structure
  - a) Goto System Configuration, see Fig. 7-1



#### Fig. 7-1 Access to System Configuration

b) In tab "Fading/Baseband Config", see Fig. 7-2

set Mode	Advanced	
Signal Outp	outs Analog	& Digital
Entities 1		
Basebands	(Tx Antennas)	2
Streams (R	x Antennas)	2
BB Source	Config Co	upled Sources

System Configuration							_	×
Multi Instrument Fadin	g/Baseband Config	I/Q Stream Mapper	Externa	al RF and I/Q	Overview			
Mode		Advan	ced		Basebands			treams
Signal Outputs		Analog & Dig	jital	вв	A	FAA	•••	A
Entities (Users, Cells)	Basebands (Tx Antennas)	Streams (Rx Antenna				FAB		
1 <del>-</del> X	2-	×	2-					
BB Source Config		Coupled Sour	ces			FBA		
				ВВ	в			
						<b>F</b> <sub>88</sub>	••	B ••••
Set to Default	0	Аррly 📿 ок	1	Entity 1				

Fig. 7-2 Fading/Baseband config under system configuration

c) Press "**Apply**" to save the settings and then press "**OK**" to exit the system configuration. The system structure as shown in Fig. 7-3 shall appear.

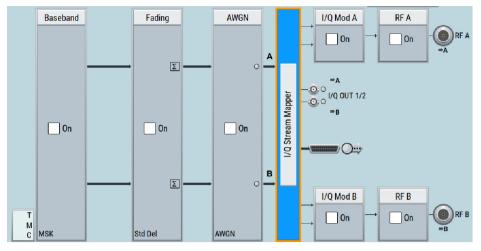


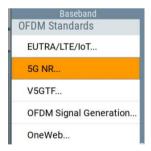
Fig. 7-3 2x2 MIMO system structure on SMW200A

3. Click on Fading module and check option "Bypass if Fading Off". See Fig. 7-4

Fading		AWGN
	Fading	
Fading	Setting	S
Bypass	if Fadin	ig Off
Signal R	outing (	(MIMO)
System	Config	uration
-		c
Std Del		AWGN

#### Fig. 7-4 Bypass Fading module if Fading is Off

4. In Baseband module, select "5G NR". See Fig. 7-5



#### Fig. 7-5 Select 5G NR baseband

- 5. In 5G NR baseband module, following settings are required to be set
  - a) Link Direction **Downlink**. See Fig. 7-6

5G New Radi	o A					_ ×	
• General	Stop Trigger In Auto	Marker	Clock Internal	Info	Quick Settings		
0				(	Set To Defau	II Bave	Generate Waveform
Test	Case Wizard						
Link Direc	tion			Down	nlink		
Test	Models						

#### Fig. 7-6 Select link direction

b) In Node Settings, see Fig. 7-7

Deployment 3 GHz < f <= 6 GHz

Frequency / GHz **3.5 GHz** (carrier frequency), this is required when RF Phase Compensation is enabled

#### RF Phase Compensation Enabled

5G	5G New Radio A: Node Settings												_	×		
	Scheduling Carriers TXBW LTE-CRS Coexistence SS/PBCH Dummy REs Carrier Mapping															
		er of Ca	rriers					© 1	RF Phas	se Com	pensa	ation				
Carrier       Cell ID       N1 ID       N2 ID       Deployment       Frequency /GHz       Channel BW       DMRS TypeA Position       SUL         Cell 0       0       0       0       3 GHz < f <= 6 GHz       3.500 000 0       100 MHz       2       Off																
С	ell 0	0	0	0	0	3 GHz < f <= 6 GHz	3.500	0 000 0	100 MHz	2		Off				

#### Fig. 7-7 5G NR node settings

- c) In Users/BWPs settings, default settings are used
- d) In Scheduling Settings,

Default CORESET scheduling and settings are kept

Default PDSCH scheduling is kept

Config PDSCH settings, click on the "Config...". See Fig. 7-8

5G	Ne	w Radio A: Scheduling Settings											_	. ×
C	ell		Subframe						0	C	Prev		Next	
		Content	No. Alloc	SC Spacing / CP	Slot	Мар Туре	No. Sym.	Sym. Offset	No. RBs	RB Offset	Settings	Power /dB	State	Repetition
	•	Common												
		SS/PBCH		30 kHz NCP	0		4	4	20	-	Config	0.00	On	
		SS/PBCH		30 kHz NCP	0		4	8	20	•	Config	0.00	On	
,	•	User 0, BWP 0	2	30 kHz NCP					273		Config			
		CORESET		30 kHz NCP	0		1	0	270	0	Config	0.00	On	Slot
		PDSCH		30 kHz NCP	0	Α	13	1	273	0	Config	0.00	On	Slot



In tab "General", set Modulation 64 QAM, see Fig. 7-9

5G New Radio A (U0/B0,	_	X			
General TxScheme	DMRS PTRS Manual	Antenna Ports Info			
PDSCH Type		DCI Format 1_1	Number of Codewords		1
Scheduled by CORES	SET 0		Rate Match Pattern Group	1	None
Resource Allocation		Туре 1	-		
Modulation		64QAM	Number of Physical Bits	233	ø 3 604

#### Fig. 7-9 PDSCH general settings

In tab "TxScheme", set Number of Layers 2 (MIMO layers), see Fig. 7-10

5G New Radio A (U0/B0/A1) PDSCH Settings								 ×
General	TxScheme	DMRS	PTRS Manual	Antenna Ports	Info			
CDM Groups w/o Data						Nur	nber of Layers	2
Interleaved VRB-to-PRB								

#### Fig. 7-10 PDSCH TxScheme settings

In tab "Antenna Ports", see Fig. 7-11

Set Mapping Coordia Cylindrical

Map PDSCH antenna port to physical transmission antenna (Baseband). In this example, the mapping is as follows:

AP1000 - MIMO layer 1 - Physical antenna A (baseband A)

AP1001 - MIMO layer 2 - Physical antenna B (baseband B)

No cross component between two MIMO layers are defined here, since the signal is going to be tested under MIMO conducted test mode

Furthermore, the magnitude and phase of the signal on each AP can be set individually. By doing that, we can set phase deviation between two APs, i.e. two MIMO layers.

5G New Radio A (U0/B0/A1) PDSCH Settings									_	×			
Gener	al T	xSchem	e DMRS		PTRS Manual	Antenna Ports	Info						
	DMRS Antenna Port Mapping												
DMF	DMRS Antenna Ports 1000, 1001												
	PDSCH Antenna Port Mapping												
Мар	Mapping Coordinates Cylindrical												
	AP 100 Magn.		AP 1001 Magn.	Phase							 		
BB A	1.000	0.0°	0.000	0.0°									
BB B	0.000	0.0°	1.000	0.0°									

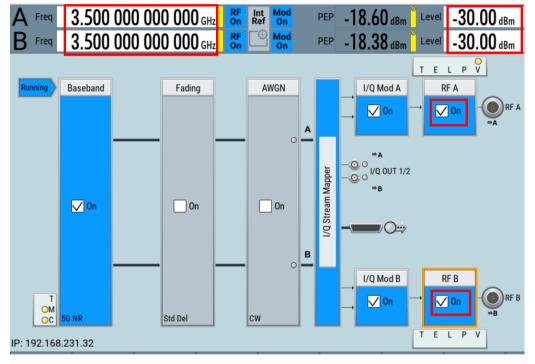
Fig. 7-11 PDSCH DMRS antenna ports settings

6. Switch on Baseband, see Fig. 7-12

5G New Radio A 📃 🗙										X		
🚺 General	Run	Trigger In <sup>Auto</sup>	Marker	Clock Internal	Info	Qui Sett	ck tings					
	l				_	0	Set To Default	Recall	Save	Z	Gener Wave	
Test Case Wizard												
Link Direc	Link Direction Downlink											
Test	Мос	lels			Dow							

#### Fig. 7-12 Turn on the 5G NR baseband

- 7. Last step, see Fig. 7-13
  - a) Set carrier frequency 3.5 GHz
  - b) Set output power level and switch on the RF output on both port A and B





# C Antenna Port

Antenna Port (AP) is a logical concept that was firstly introduced in LTE and now further adopted by 5G NR.

The AP is said to be associated with the transmitted reference signal which is used by the receiver for the channel estimation. The transmitted reference signals over the same AP can be assumed at the receiver side that they experience the same radio channel condition

The set of AP defined in 3GPP specification 38.211 for 5G NR is listed below in Table 7-6 and Table 7-7 for downlink and uplink, respectively. Of course, in this application note, we focus only on downlink APs. The uplink APs listed here is just for the completeness of the information.

Downlink

Channel/Reference Signal	Antenna Port numbers				
PDSCH + DMRS	Starting from 1000 (1000 Series)				
PDCCH	Starting from 2000 (2000 Series)				
CSI-RS	Starting from 3000 (3000 Series)				
SS-Block/PBCH	Starting from 4000 (4000 Series)				

Table 7-6 Overview of 5G NR downlink antenna port

Uplink

Channel/Reference Signal	Antenna Port numbers
PUSCH + DMRS	Starting from 0 (0 Series)
SRS	Starting from 1000 (1000 Series)
PUCCH	Starting from 2000 (2000 Series)
PRACH	Starting from 4000 (4000 Series)

Table 7-7 Overview of 5G NR uplink antenna port

For example, downlink antenna ports starting with 1000 are used for PDSCH DMRS. Different transmission layers for PDSCH DMRS can use antenna ports in this series. For example, 1000 and 1001 for a two-layer PDSCH DMRS transmission, i.e. in 2x2 MIMO case.

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