Pre-5G-NR Signal Generation and Analysis

Application Note

Products:

- R&S®SMW200A
- R&S®SMW-K114
- R&S®FSW
- R&S®FSVA
- R&S®FPS
- R&S®VSE
- R&S®VSE-K96

This application note shows how to use Rohde & Schwarz signal generators and analyzers for testing early 5G New Radio components, chipsets and devices. Methods for easy creation and analysis of custom OFDM are explained. The solution provides

- a single user interface for signal generation and analysis configuration
- Flexible OFDM configuration and signal generation incl. flexible pilot and data allocation
- User defined modulation schemes including complex scenarios, e.g. 5G NR signals

Note:

The latest version of this document is available on our homepage:
https://www.rohde-schwarz.com/appnote/1MA308

Application Note
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1 Introduction

This application note explains how to use Rohde & Schwarz signal generators and analyzers for testing early 5G-NR components, chipsets and devices. Since components have to be tested before finalization of a standard with regard to different requirements, many different test signals exist and are subject to constant change.

Rohde & Schwarz offer solutions for custom CP-OFDM (cyclic prefix orthogonal frequency division multiplexing), as needed in pre-5G-NR development, providing a robust framework for creating and analyzing CP-OFDM test signals with

- a single user interface for signal generation and analysis configuration
- flexible OFDM configuration and signal generation
- user defined modulation schemes including complex scenarios
- Flexible pilot and data allocation

This application note describes how to configure an R&S signal generator and analyzer based on a simplified pre-5G-NR signal specification. While the solution applies to any custom OFDM signal, a specific signal configuration (see 1.1) is used as an example.

In this application note, the R&S®SMW200A (SMW) signal generator is used with the R&S®SMW-K114 "OFDM Signal Generation" option to create the custom OFDM signals as well as the configuration for signal analysis.

The R&S®VSE Vector Signal Explorer Software (VSE) with option R&S®VSE-K96 OFDM VSA (Vector Signal Analysis) is used to analyze the OFDM signal. R&S®VSE can either load a signal from file or directly capture a signal from a compatible R&S® analyzer.

Chapter 2 describes how to easily set up OFDM generation in SMW-K114. Chapter 3 then describes the required steps to analyze the generated signal in VSE-K96.

1.1 Signal Configuration

In this application note, a signal configuration following the 3GPP TR 38.211 v1.12 will be used:

- FFT size: 4096
- Number of occupied subcarriers: 3276
- Subcarrier spacing: 30 kHz
- Sequence length: 280 OFDM symbols
- Cyclic prefix length:
  - First OFDM symbol: 352 samples
  - Following 13 OFDM symbols: 288 samples
  - Repeating every 14 symbols
- Resulting sampling rate: 122.88 MHz

- Subframe length: 14 symbols
- control channel QPSK: once each slot, over all subcarriers, one symbol long
- Synchronization Block with following RB mapping:

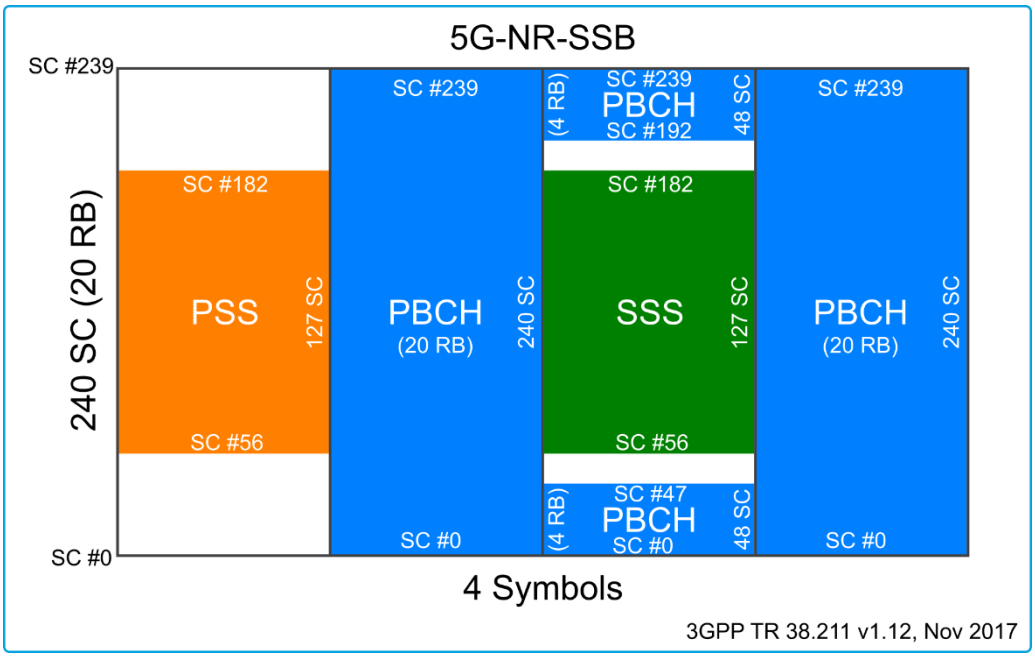


Figure 1: Synchronization Block Mapping

1.2 Full Standard Compliant 3GPP 5G NR Testing

This application note describes the flexible OFDM signal generation, which can be used to create signals which have a certain degree of standard compliance on the physical layer. For full standard compliant testing of 5G NR signals, please refer to the dedicated 5G NR options available on R&S®SMW200A and R&S®FSW.

2 Signal Definition in SMW-K114

The SMW-K114 5G Candidate Waveforms option makes defining and generating a custom OFDM signal fast and simple.

The following steps make sure, that a standard OFDM signal is generated:

- First, select "5G Candidates" from the baseband button
- Change the Modulation Type to "f-OFDM"
- Open "General Settings…" and under "Filter", select filter type "None

Now, the basic OFDM signal parameters as discussed in Ch. 1.1 will be defined:

- Select the "Physical" tab and set the values as shown:

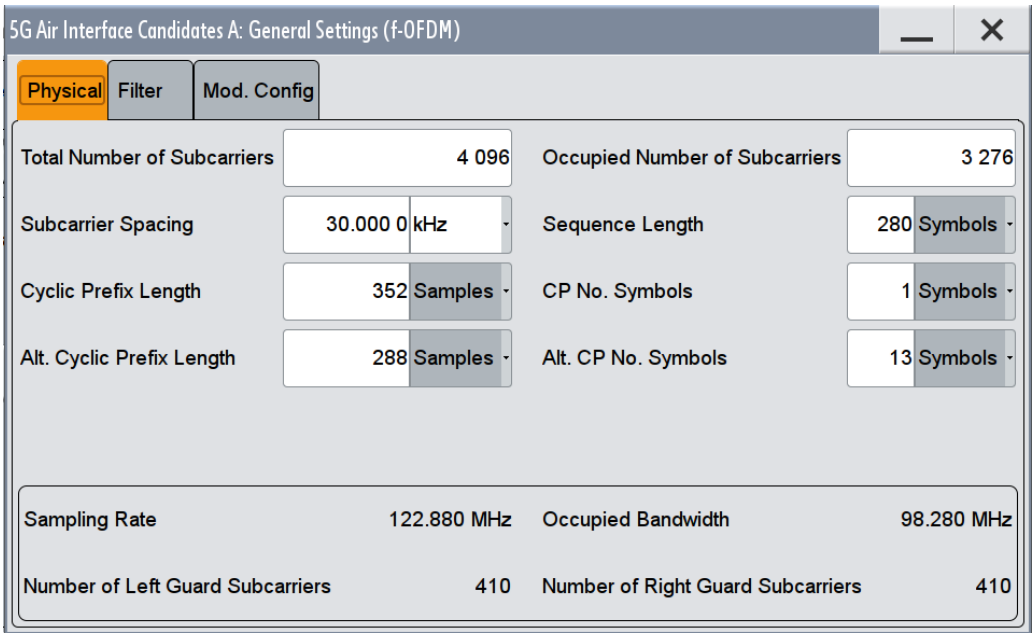


Figure 2: SMW-K114 Physical Settings

Close the "General Settings" window and open the "Allocation Settings". In the user tab, different virtual users can be assigned individual data sources. This may be interesting for allocating a user to specific data blocks in the signal in the next step and quickly changing the data that is sent for this individual user. For now, leave the default setting.

The main part of the SMW-K114 signal definition process is the allocation table found under "Allocations". Here, the OFDM allocation matrix is constructed. Using the

allocation table, parts of the subcarrier-symbol grid of the OFDM signal are defined to follow certain modulation schemes and encode the bits from a defined data source.

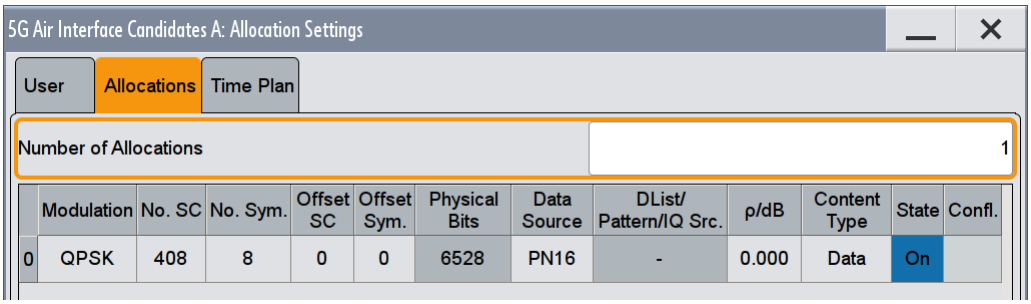
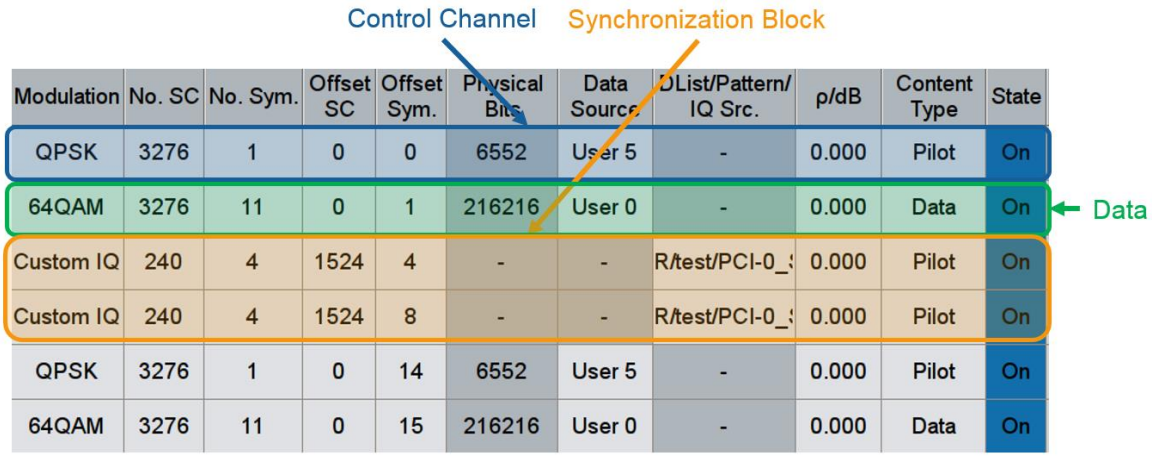


Figure 3: SMW-K114 Allocation Settings

- At the top, set the number of entries in the allocation table. This can be changed at anytime if more or fewer entries are required to build up the required signal. Note that existing allocations are removed when the number of allocations is reduced below the defined allocation entry index.
- The occupied subcarriers and symbols for each allocation is defined by the "No. SC", "No. Sym.", "Offset SC" and "Offset Sym." values. The two offset values define where the allocation begins in the grid, starting from both the lower frequency (SC) and earlier time (Symbol). The two number values ("No.") define the amount of subcarriers and symbols occupied.
- Set the "Modulation" and "Data Source" for each entry. For "Custom IQ" modulation and "Data List" data source, a custom source file has to be set. This can be used to encapsulate own I/Q symbol points or to transmit defined bit patterns. Here, it is used to load the synchronization block samples as *.dat files.
- Define the "Content Type" of this allocation. The value is only used for analysis of the signal. VSE-K96 can successfully analyze a signal, if it is at least 4 symbols long and at least 2 symbols contain pilot definitions. Distributing the pilots over the OFDM cells improves the signal analysis.
- Different allocations may overlap each other, with the higher index allocation overwriting the lower index allocation. Overlapping allocations are identified by an alert in the last column. This is just a warning, not indicating an error. Using partial overwriting of allocation entries, complex allocations can be created with a reasonable number of definitions.



Modulation	No. SC	No. Sym.	Offset SC	Offset Sym.	Physical Bits	Data Source	DList/Pattern/ IQ Src.	ρ/dB	Content Type	State
QPSK	3276	1	0	0	6552	User 5	-	0.000	Pilot	On
64QAM	3276	11	0	1	216216	User 0	-	0.000	Data	On
Custom IQ	240	4	1524	4	-	-	R/test/PCI-0_	0.000	Pilot	On
Custom IQ	240	4	1524	8	-	-	R/test/PCI-0_	0.000	Pilot	On
QPSK	3276	1	0	14	6552	User 5	-	0.000	Pilot	On
64QAM	3276	11	0	15	216216	User 0	-	0.000	Data	On

Figure 4: SMW-K114 Allocation Table

At all times, a graphical representation of the current allocation matrix can be viewed in the "Time Plan" tab. Define the symbol range to be displayed in the top left. Now, the time plan represents the current allocation with different colors depending on the data source outlined in the legend below the time plan.

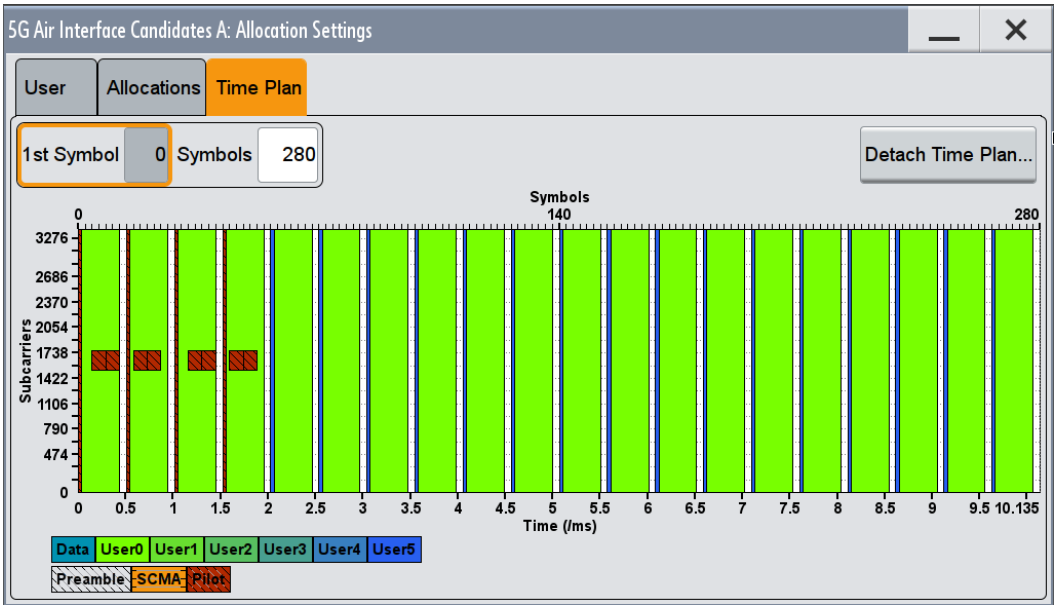


Figure 5: SMW-K114 Allocation Time Plan

When the signal allocation is finished, close the allocation settings window and switch the 5G Air Interface Candidates option "On". After the signal is calculated, it is available for playback and can be written to a waveform file using the "Generate Waveform" button. Save the current settings, if they should be used again later on using the "Save" and "Recall" buttons.

To play the signal at the RF port of the SMW, set the desired frequency and power level and switch RF on.

3 Signal Analysis with VSE-K96

VSE-K96 can be used to analyze a custom OFDM signal given the required base parameters. The I/Q data can be automatically imported from a Rohde & Schwarz signal analyzer, or can be supplied in a supported I/Q file format, like *.iq.tar. Once the I/Q data is loaded in into VSE, the OFDM VSA option (VSE-K96) analyzes the signal based on the provided settings.

3.1 Setup OFDM VSA Measurement

After a preset, the VSE has a single "IQ Analyzer" channel active. Replace the active Channel with a "OFDM VSA" channel.

Based on the signal specification in Ch. 1.1, the following physical parameters have to be set manually:

- Signal input, source and trigger
- Carrier frequency
- Sampling rate
- Capture time
- Amplitude (or use auto level)

Shorter capture times significantly speed up the analysis and demodulation times. When instruments are in free run mode, a capture time of 2 times the period or frame length ensures that at least one full frame exists in the capture buffer.

The signal description is loaded from the configuration file created by SMW-K114. The file is automatically saved on the SMW at
\user\K114\Exported_K114_settings_K96.xml
and can be accessed using the shared network drive under
\\[IP_Address]\share\K114\Exported_K114_settings_K96.xml
The file can also be copied to an USB stick using the SMW file manager.

- Load the configuration into VSE by clicking "Meas Setup" → "Signal Description…" in the menu bar
- Click "Load Config. File" and select the configuration file
- Set the result length to analyze under "Meas Setup" → "Result Range…".

With these settings, the VSE OFDM VSA is ready to demodulate the OFDM signal:

- Start the process by clicking the capture button (▶) either in the top bar or at the OFDM VSA channel on the left
- The VSE will now capture the IQ data on the instrument and the VSE-K96 demodulates the signal based on the supplied OFDM configuration.

3.2 Result Display and Analysis

The VSE-K96 OFDM VSE software option provides multiple result windows and numeric result summaries to analyze the OFDM signal. In VSE, windows can be added, rearranged and removed as desired by the user.

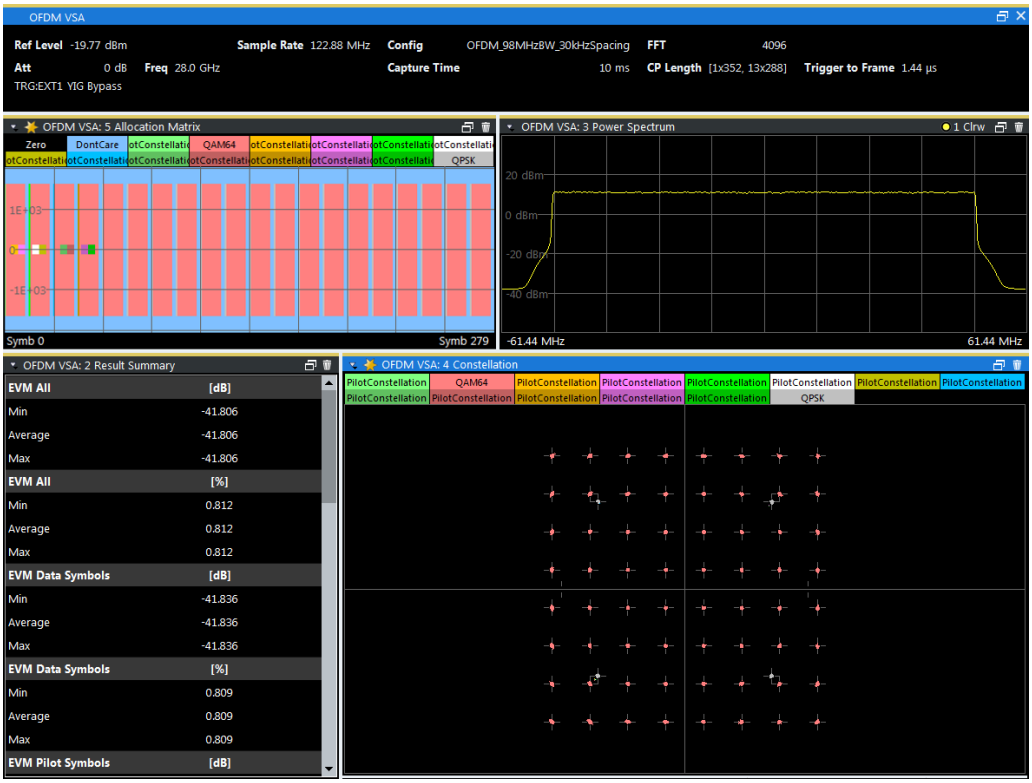


Figure 6: VSE-K96 OFDM VSA Result Display

By default, the time- and frequency domain representation of the signal are shown together with the result summary and constellation view. The result summary gives insight to the EVM, MER, IQ Offset, Frequency Error and other useful indicators of the signal quality. The constellation diagram shows the I/Q samples of the different allocations with different colors. The legend can be found directly above the diagram.

To add a new measurement window, click and select the desired display, e.g. the "Allocation Matrix". The allocation matrix gives a graphical representation of the loaded OFDM configuration, indicating different allocations over subcarriers and symbols with different colors. This view is similar to the "Time Plan" view in SMW-K114 (c.f. Figure 5). A list of all measurement windows is shown on the right.

Open measurement windows can be closed by clicking the recycle bin in the top right of each window.

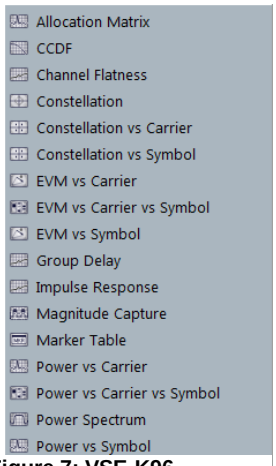


Figure 7: VSE-K96 Measurement Window List

4 Ordering Information

Designation	Type	Order No.
Vector Signal Generator example: (other Freq.ranges and 2nd Ch available)		
SMW Vector Signal Generator	R&S®SMW200A	1412.0000.02
Frequency range: 100kHz to 40GHz	R&S®SMW-B140	1413.0604.02
Wideband baseband main module	R&S®SMW-B13XT	1413.8005.02
Wideband baseband generator, 500 MHz, 256 MS	R&S®SMW-B9	1413.7350.02
Enhanced phase noise performance and FM/Phim mod.	R&S®SMW-B22	1413.2207.02
5G Air Interface Candidates	R&S®SMW-K114	1414.1985.02
Vector Signal Analysis example configuration:		
Vector Signal Explorer Software	R&S®VSE	1320.7500.06
VSE OFDM VSA option	R&S®VSE-K96	1320.7922.06
Signal and Spectrum Analyzer examples: (other frequency limits available)		
FSW Signal and Spectrum Analyzer	R&S®FSW43	1312.8000.43
FSVA Signal and Spectrum Analyzer	R&S®FSVA40	1321.3008.40
FPS Signal and Spectrum Analyzer	R&S®FPS40	1319.2008.40

Rohde & Schwarz

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The electronics group is among the world market leaders in its established business fields. The company is headquartered in Munich, Germany. It also has regional headquarters in Singapore and Columbia, Maryland, USA, to manage its operations in these regions.

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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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