

Analyze IEEE 802.11ac signals using the R&S FS-K96 Software

Application Note

Products:

R&S®FS-K96	R&S®FSG
R&S®FSW	R&S®FSVR
R&S®FSQ	R&S®SMU
R&S®FSV	R&S®SMBV

This application note provides a guide through the measurements for IEEE 802.11ac WLAN transmitter signals using the general purpose OFDM analysis software R&S FS-K96.

Step-by-step instructions for performing the measurements are provided and the different result types available with the R&S FS-K96 Software are discussed.

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1 Introduction

Since its first release, the 802.11 (Wireless Local Area Network) standard has constantly advanced in order to increase data throughput. In the course of this, the development of the IEEE 802.11ac standard (referred to as 802.11ac in the following) was started in 2008 [1].

The 802.11ac standard is still under active development. In order to react quickly to eventual changes, it is therefore advantageous to use a generic test environment, which is user configurable to a great extent.

For this purpose Rohde & Schwarz offers the R&S FS-K96 OFDM Vector Analysis Software, which allows modulation measurements on generic OFDM signals. Its freely configurable OFDM demodulator is very flexible and also capable of analyzing 802.11ac signals. The configuration of the OFDM demodulator is possible by loading special configuration files. These files contain precise descriptions of the frame structure and the modulation type of the signal to be tested.

This application note comes with a set of 802.11ac example I/Q data files and corresponding configuration files. The example signals cover bandwidths from 20 MHz up to 160 MHz and most modulation types supported by the 802.11ac standard.

Besides using the provided example files, it is also possible to create custom configuration files in order to analyze user-specific 802.11ac signals.

Proceed to the next chapter to learn how to analyze 802.11ac signals using existing configuration files (supplied with the R&S FS-K96 Software and this application note).

2 Measuring IEEE 802.11ac signals using existing configuration files

This chapter will briefly describe how to analyze one of the provided 802.11ac example signals. The applicable I/Q data file and the corresponding R&S FS-K96 configuration file are supplied with the R&S FS-K96 Software and this application note, respectively.

There are two different possibilities for capturing the test signal with the R&S FS-K96 Software. The first is to import the I/Q data file directly into the software. The second is to use a vector signal generator (e.g. R&S SMU or R&S SMBV) to generate a baseband or a radio frequency signal and capture it with a spectrum analyzer (e.g. R&S FSW, R&S FSQ, R&S FSG, R&S FSUP, R&S FSVR or R&S FSV).

This application note supplies different ARB files (= arbitrary waveform file) for using different vector signal generator types as signal source. The files for the R&S SMU are in the subfolder "SMU" and the files for the R&S SMBV are in the subfolder "SMBV". Please refer to chapter 6.1 for a description on how to playback an ARB file on an R&S Vector Signal Generator.

The following step-by-step description shows how to analyze the WLAN 802.11ac example signal contained in the file "**WLANac_64QAM_ShortCP.iqw**". The signal file is supplied with the R&S FS-K96 Software. It is located in the subfolder "SIGNALS" in the installation folder of the software.

Please use R&S FS-K96 Software version 3.2 or higher.



Hint

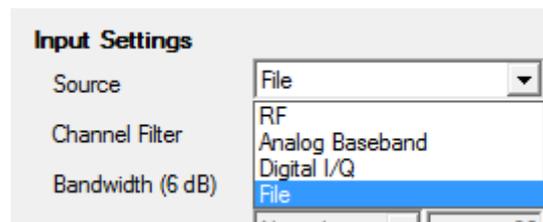
A tutorial video on how to analyze a signal using a given configuration file is supplied with the R&S FS-K96 Software. It can be started directly from within the R&S FS-K96 Software. Click the "HELP"-button and select "WATCH VIDEOS". Select the Video "Quickstart: Measure from File" to start the video.

1. Start the R&S FS-K96 Software and perform a preset operation.

"PRESET"

2. Select the signal source to be used. Possible signal sources are "File", "RF" (= Radio Frequency), "Analog Baseband" and "Digital I/Q".

"MAIN → GENERAL SETTINGS → Source <Select Signal Source>"



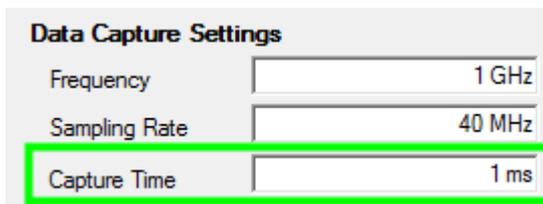
3. *Only if the I/Q data is to be captured via RF:*
Make sure that autoleveling is enabled.

"MAIN → GENERAL SETTINGS → Auto Level: ON"



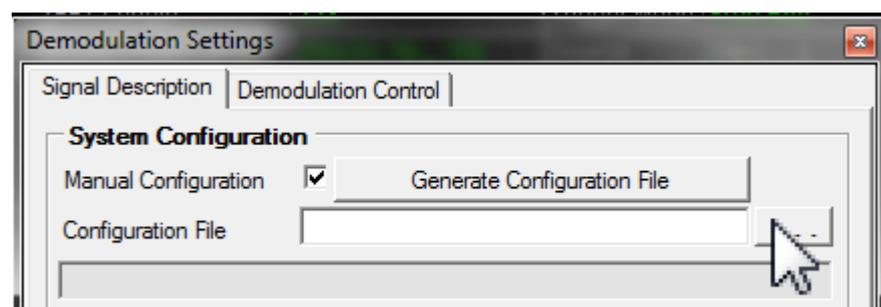
4. *Only if the I/Q data is to be captured via RF, Digital I/Q or Analog Baseband:*
The example signal has a frame duration of approximately 0.3 ms. Therefore a capture time of 1 ms is sufficient to make sure that at least one frame is included in the capture buffer.

"MAIN → GENERAL SETTINGS → Capture Time: 1 ms"



5. Open the Demodulation Settings dialog and click on the "..." button to load a configuration file.

"MAIN → DEMOD SETTINGS → . . ."



- Select the configuration file "**WLANac_40MHz_ShortCP.xml**". Note that the supplied configuration file is also valid for modulation types other than the 64QAM used in this example. (A detailed explanation for this use case is given later.)

"<Load the configuration file "WLANac_40MHz_ShortCP.xml" >"



A configuration can also be loaded by using the mouse to drag the configuration file into the R&S FS-K96 main window.

Hint

After successful loading of the configuration file, the Demodulation Settings dialog should look like that shown in Figure 1.

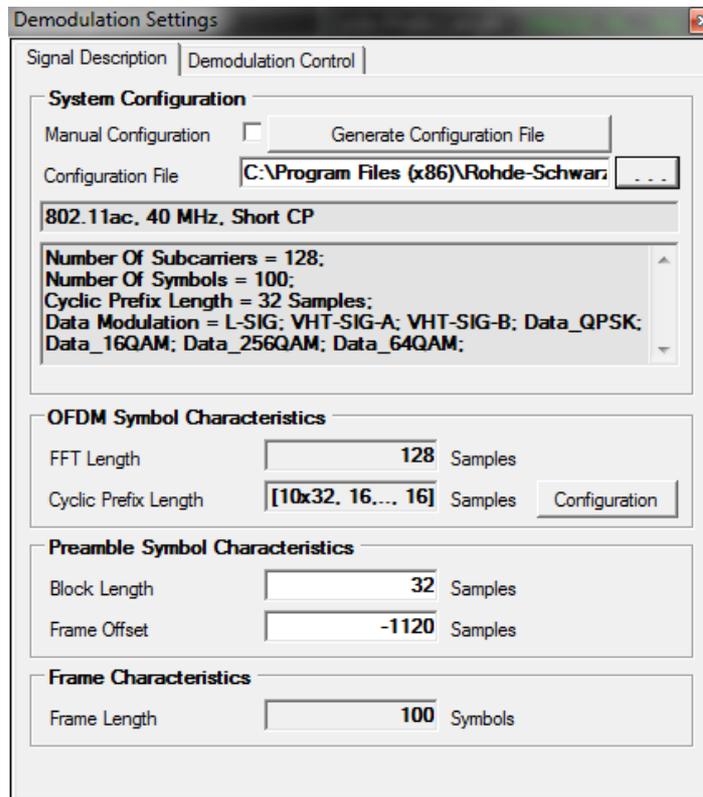
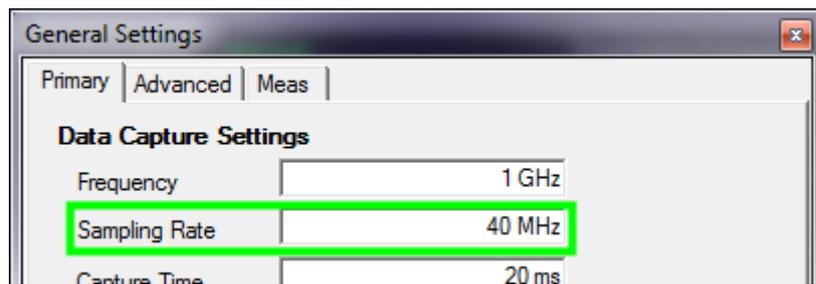


Figure 1: Demodulation settings after loading the configuration file for the 40 MHz example.

- Enter the correct sampling rate for the 802.11ac signal. In this case the sampling rate is 40 MHz.

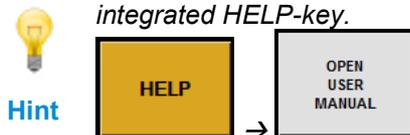
"MAIN → GENERAL SETTINGS → Sampling Rate: 40 MHz"



The available RF bandwidth on a spectrum analyzer depends on the sampling rate of the measurement. For a spectrum analyzer a typical ratio of sampling rate to usable bandwidth would be around 0.8. That is to say that the bandwidth of the test signal must not exceed 80% of the sampling rate because otherwise signal content would be lost or attenuated at the band edges. 802.11ac signals, however, use a bandwidth of up to 97.5% of the sampling rate. This makes oversampling necessary to increase the usable bandwidth on the analyzer side.

The R&S FS-K96 Software offers 2-times oversampling in combination with its integrated Channel Filter. It is necessary to activate the integrated Multicarrier Filter of the R&S FS-K96 Software if the I/Q signal is to be captured via RF, Digital I/Q or Analog Baseband. The equalized bandwidth of the filter depends on the Filter Order (refer to the manual of the R&S FS-K96 Software for more details). For 802.11ac the default filter order "Normal" is sufficient to avoid unwanted filter effects.

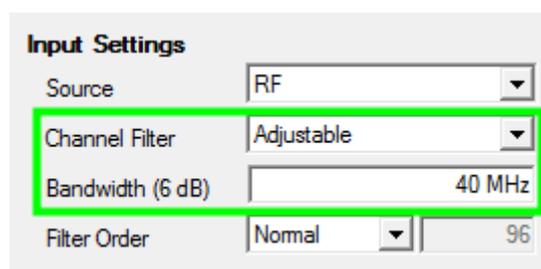
The manual of the R&S FS-K96 Software can be accessed quickly by using the integrated HELP-key.



8. *Only if the I/Q data is to be captured via RF, Digital I/Q or Analog Baseband:* Activate the Multicarrier Filter. Configure its bandwidth equal to the sampling rate (40 MHz for this example).

"MAIN → GENERAL SETTINGS → Channel Filter: Adjustable"

"MAIN → GENERAL SETTINGS → Bandwidth (6dB): 40 MHz"



9. *Only if the I/Q data is to be captured via RF:*
Enter the correct center frequency in the R&S FS-K96 Software.

"MAIN → GENERAL SETTINGS → Frequency <Center frequency to be used>"



10. Start a single measurement.

"RUN SGL"

11. *Only if "File" is selected as signal source:*
A file dialog will open. Select the waveform file
"WLANac_64QAM_40MHz_ShortCP.iqw" as signal source in the dialog and
press the Open Button.

"<Select the correct Waveform File In the File Manager>"



*It is also possible to start a measurement from file by dragging the desired I/Q file
into the main window of the R&S FS-K96 Software.*

Hint

The screen should now look as displayed in Figure 2:

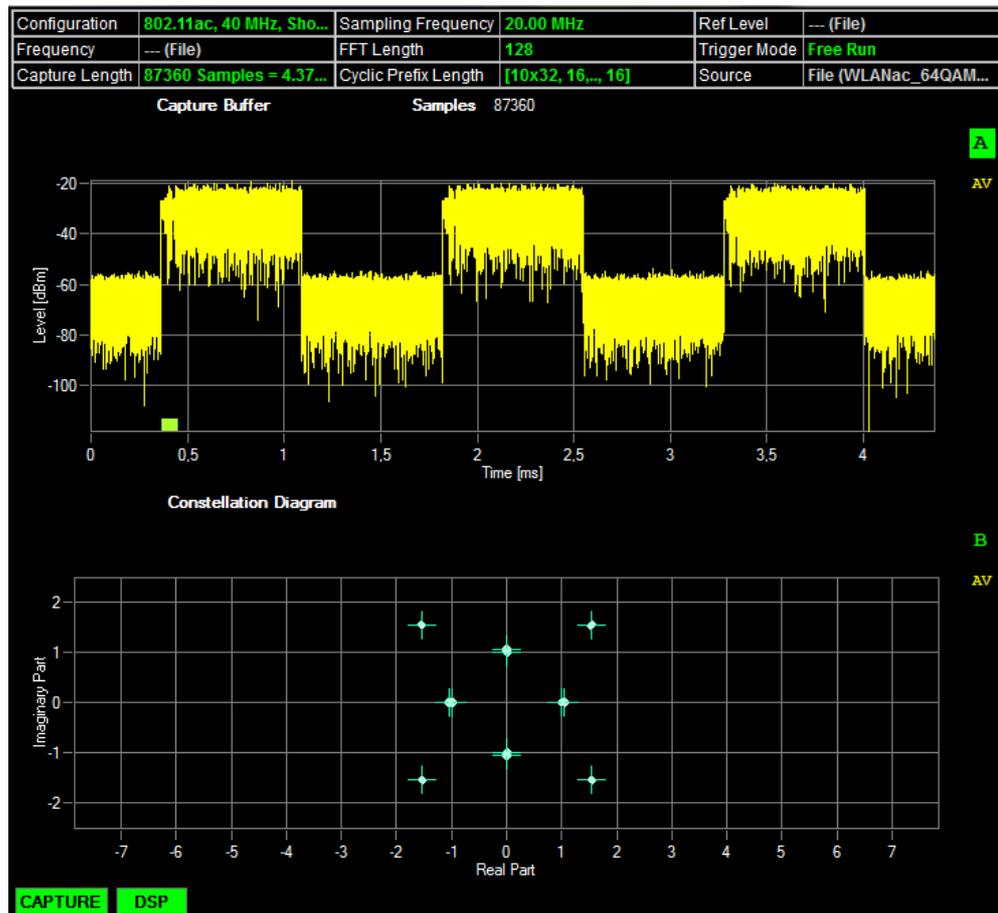


Figure 2: Results of a successful measurement of the 40 MHz, 256 QAM example file.

The expected 64 QAM is not yet visible in the constellation diagram. The reason for this is that the result range currently doesn't cover the complete 802.11ac frame. The green bar in the upper graph (Capture Buffer display) displays the current result range. Currently the result range only covers training symbols which don't use a 64 QAM. To analyze the entire frame the number of result range symbols needs to be adjusted:

- Increase the result range in order to analyze the complete frame. The example signal has a frame length of 100 symbols.

"MAIN → DEMOD SETTINGS → Demodulation Control → Result Length: 100"
"REFRESH"

With this adjustment the screen should look as displayed in Figure 3:

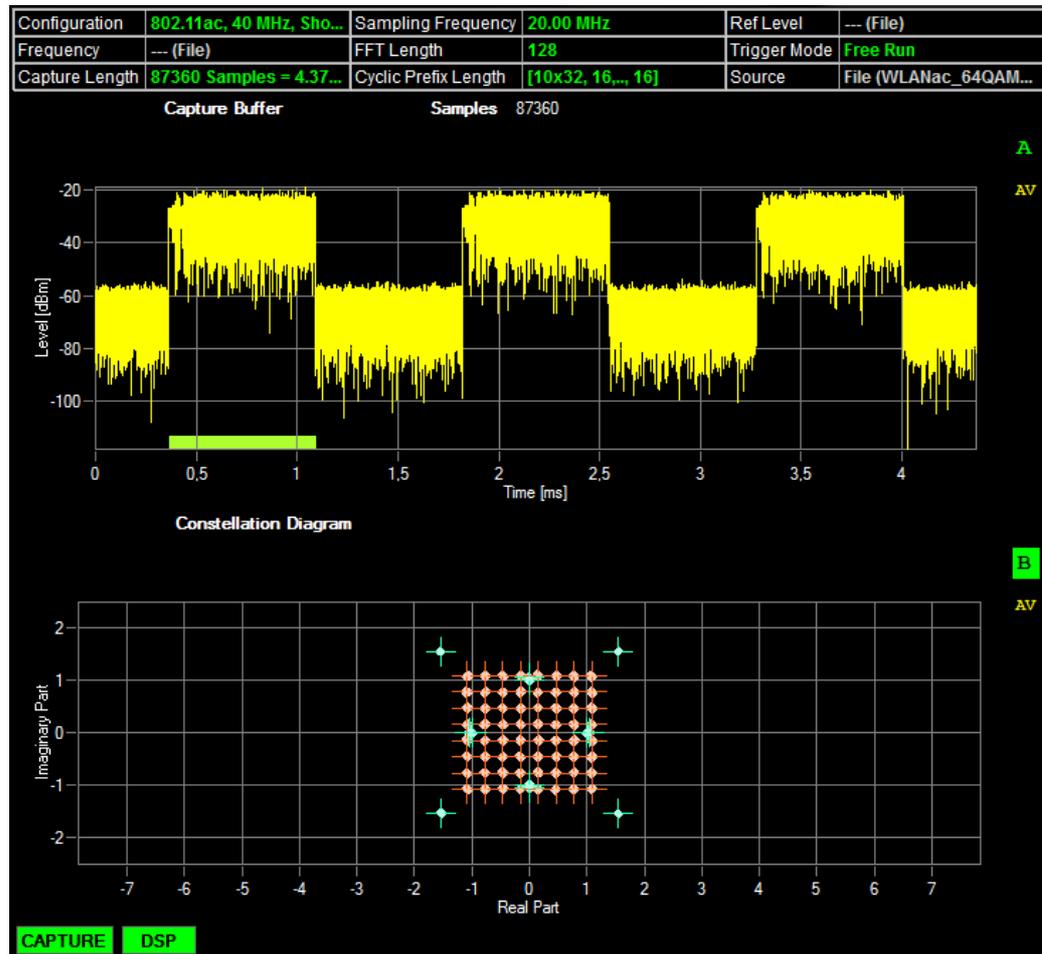
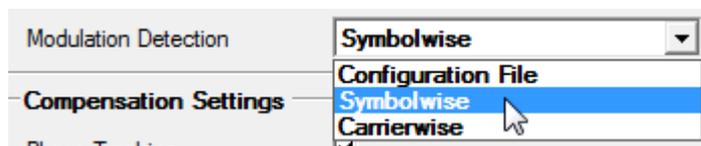


Figure 3: Results of a successful measurement of the 40 MHz, 64QAM example file with a result range that covers the whole 802.11ac frame.

The example configurations supplied with the R&S FS-K96 Software are also capable of other modulation types than 64QAM. Change the "Modulation Detection" parameter to "Symbolwise" for analyzing 802.11ac signals with different modulation types.



"DEMOD SETTINGS → Demodulation Control → Modulation Detection Symbolwise"



Hint

It is possible to display more than two result screens at a time. All graphical results can be opened in separate windows. This can be done by selecting the desired result screen and pressing the **"OPEN IN SEPARATE WINDOW"** button (see Figure 4).



Figure 4: Open a variable number of result displays in separate windows.

3 How to create a custom IEEE 802.11ac Configuration File

The 802.11ac standard allows different modulation types (BPSK, QPSK, 16QAM, 64QAM and 256QAM), different bandwidths (20 MHz, 40 MHz, 80 MHz and 160 MHz), different Cyclic Prefix lengths ("Long" and "Short") and a freely configurable frame length. The configuration files supplied with the R&S FS-K96 Software cover most possible 802.11ac signal configurations.



Change the "Modulation Detection" parameter to "Symbolwise" for analyzing 802.11ac signals to cover all 802.11ac modulation types.

Hint

"DEMOD SETTINGS → Demodulation Control → Modulation Detection Symbolwise"

If still none of the supplied example configuration files are suitable for the specific 802.11ac signal to be analyzed, a custom configuration file needs to be created. To create an applicable configuration file with minimal effort, the R&S FS-K96 Software provides the R&S FS-K96 Configuration File Wizard. This wizard contains a graphical user interface which guides the user step-by-step through the creation process.

The basis for an appropriate 802.11ac signal configuration file is the signal itself. Therefore the first step is to capture the I/Q data of the signal under test. The following chapter explains how the required I/Q data can be captured.



A short version of the following guide is also available in the form of a tutorial video. The corresponding video can be started directly from within the R&S FS-K96 Software. Click the "HELP"-button and select "WATCH VIDEOS". Select the video "Advanced: Create your own Configuration File" to start the 802.11ac tutorial.

Hint

3.1 Capture I/Q data with the R&S FS-K96 Software

As the basis for the configuration file, the I/Q data of the signal to be measured are necessary. The following step-by-step instructions explain how to capture I/Q data with the R&S FS-K96 Software:

1. Start the R&S FS-K96 Software and perform a preset operation.

"PRESET"

2. Open the Configuration File Generation dialog (see Figure 5).

“MAIN → DEMOD SETTINGS → Generate Configuration File”

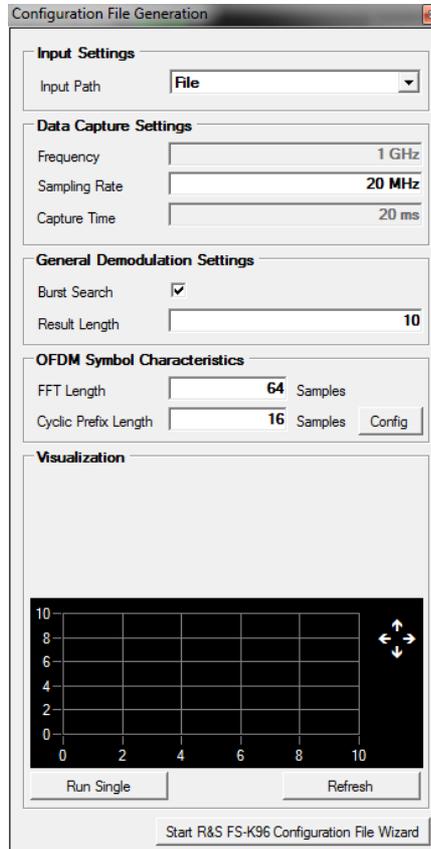
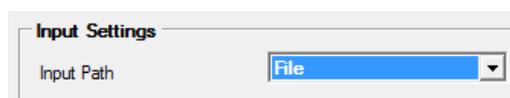


Figure 5: Overview of the File Generation dialog.

The R&S FS-K96 Software supports different data acquisition sources. The data source can be specified in the Input Settings dialog. This application note as much as the R&S FS-K96 Software provide several example 802.11ac I/Q data files. These files may be either analyzed directly by the R&S FS-K96 Software or may be used as the input to the ARB generator of a Rohde & Schwarz vector signal analyzer such as the R&S SMU or the R&S SMBV.

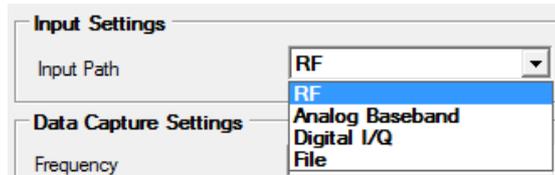
3. Configure the Input Path.
 - a) If using an I/Q data file as data source please select “File” as input path and continue with step 8.

“DEMOD SETTINGS → Generate Configuration File → Input Path: File”



- b) If a vector signal generator or a custom RF signal source is to be used, please select the appropriate connection type as input path.

“DEMOD SETTINGS → Generate Configuration File → Input Path: RF”



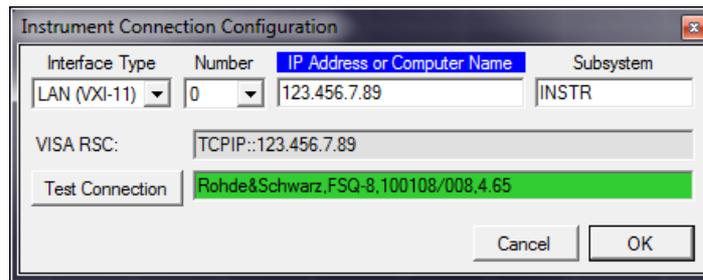
4. When measuring an RF or a baseband signal, a spectrum analyzer is required to capture the I/Q data. The capturing process will be controlled automatically by the R&S FS-K96 Software. For the 802.11ac measurement the R&S FSW, R&S FSQ, R&S FSG, R&S FSV and the R&S FSVR spectrum analyzers can be used. Be aware that the maximum signal bandwidth available depends on the analyzer model. The following table gives an overview of the supported bandwidths of the different analyzer models:

Usable I/Q bandwidths of the supported spectrum analyzer models	
Spectrum analyzer model	Maximum usable I/Q bandwidth
R&S FSW	10 MHz (without bandwidth extension)
	28 MHz (With R&S FSW B28 bandwidth extension)
	40 MHz (With R&S FSW B40 bandwidth extension)
	80 MHz (With R&S FSW B80 bandwidth extension)
	160 MHz (With R&S FSW B160 bandwidth extension)
R&S FSQ	28 MHz (Without R&S FSQ-B72 bandwidth extension)
	120 MHz (With R&S FSQ-B72 bandwidth extension)
R&S FSG	28 MHz
R&S FSV	28 MHz (Without R&S FSV-B70 bandwidth extension)
	40 MHz (With R&S FSV-B70 bandwidth extension)
R&S FSVR	40 MHz

Table 1: Supported I/Q bandwidths of different R&S spectrum analyzers capable of analyzing 802.11ac signals.

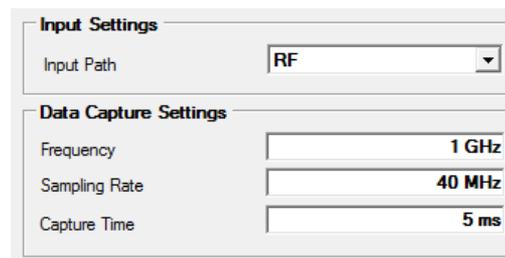
In order to enable the R&S FS-K96 Software to connect to the spectrum analyzer it is necessary to configure the instrument connection.

“SETUP → CONFIGURE ANALYZER CONNECTION → <Enter the appropriate instrument connection configuration>”



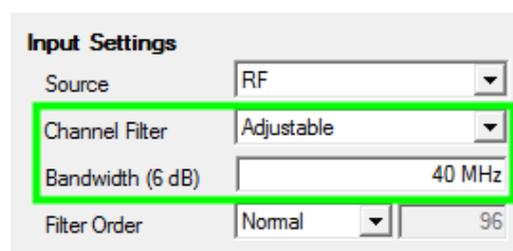
5. *Only if the I/Q data is to be captured via RF, Digital I/Q or Analog Baseband:* The appropriate Frequency (RF only), Sampling Rate and Capture Time need to be configured. For this example a 802.11ac signal with a bandwidth of 40 MHz is being used. Therefore the Sampling Rate should be set to 40 MHz and the Capture Time should be set to 5 ms.

**“DEMOD SETTINGS → Generate Configuration File
 → Frequency: <Center Frequency to be used for RF input>
 → Sampling Rate: 40 MHz
 → Capture Time: 5 ms”**

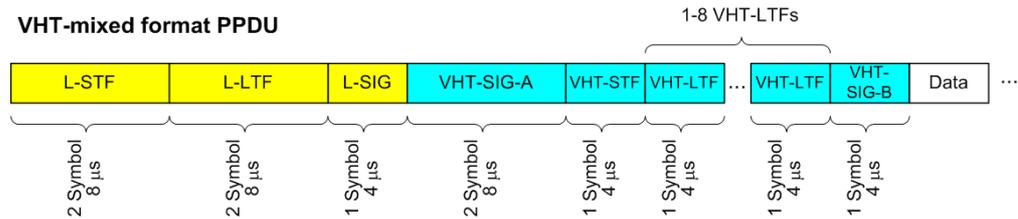


6. *Only if the I/Q data is to be captured via RF, Digital I/Q or Analog Baseband:* Activate the Channel Filter. Configure its bandwidth equal to the sampling rate (40 MHz for this example).

**“MAIN → GENERAL SETTINGS → Channel Filter: Adjustable”
 “MAIN → GENERAL SETTINGS → Bandwidth (6dB): 40 MHz”**



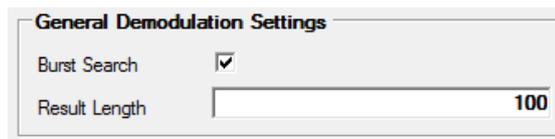
7. The R&S FS-K96 Software needs to know the number of symbols to be analyzed (= Result Length). The format of a 802.11ac frame is defined as follows:



The R&S FS-K96 Software is capable of demodulating the complete 802.11ac frame. The number of symbols of one frame is the sum of symbols from all fields including the data part. The number of VHT-LTFs depends on the number of MIMO (= Multiple Input Multiple Output) users and is considered to be one for the case of SISO (= Single Input Single Output). The number of symbols contained in the data part depends on the characteristics of the specific signal.

In addition to the legacy part and the VHT training fields the example signal contains 90 data symbols. Hence, the resulting overall number of symbols for this example is 100.

“*DEMOD SETTINGS* → *Generate Configuration File* → *Result Length: 100*”



The 802.11ac standard offers the possibility to increase data throughput by using a short cyclic prefix instead of a long cyclic prefix. For signals which use a short cyclic prefix, the cyclic prefix length is not identical for all symbols of a 802.11ac frame. Only the data part of the signal makes use of the short cyclic prefix. The header of the signal still uses the long cyclic prefix in order to remain backward compatible to 802.11a and 802.11n devices.

In order to ensure correct synchronization, the R&S FS-K96 Software needs to know the correct FFT length as much as which cyclic prefix length is used by which symbols.

8. Configure the OFDM Symbol Characteristics according to the signal to be measured. In the case of 802.11ac the following settings are possible:

OFDM Symbol Characteristics of a 802.11ac signal		
Long Cyclic Prefix		
Signal Bandwidth	FFT Length	Cyclic Prefix Length
20 MHz	64 Samples	16 Samples
40 MHz	128 Samples	32 Samples
80 MHz	256 Samples	64 Samples
160 MHz	512 Samples	128 Samples
Short Cyclic Prefix		
20 MHz	64 Samples	8 Samples
40 MHz	128 Samples	16 Samples
80 MHz	256 Samples	32 Samples
160 MHz	512 Samples	64 Samples

Table 2: Overview of FFT and Cyclic Prefix Lengths of 802.11ac signals.

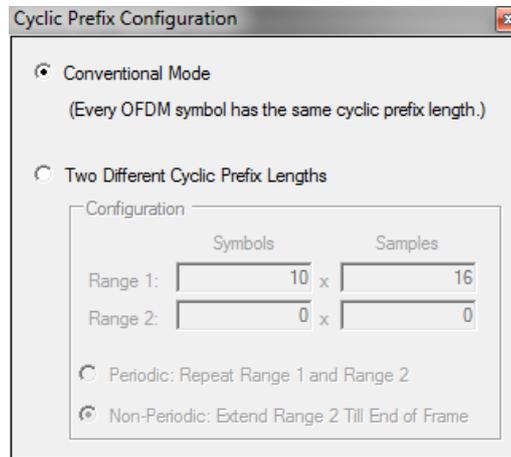
For this example a short cyclic prefix with a bandwidth of 40 MHz shall be used.

**“DEMOD SETTINGS → Generate Configuration File
→ FFT Length: 128**

The screenshot shows a dialog box titled "OFDM Symbol Characteristics". It contains two input fields: "FFT Length" with the value "128" and "Samples" next to it, and "Cyclic Prefix Length" with the value "16" and "Samples" next to it. A "Config" button is located to the right of the Cyclic Prefix Length field.

9. Open the Cyclic Prefix Configuration dialog.

"DEMOD SETTINGS → Generate Configuration File → Configuration"



10. Select "Two Different Cyclic Prefix Lengths"

"Cyclic Prefix Configuration → Two Different Cyclic Prefix Lengths"

Figure 6 shows the structure of an 802.11ac frame:

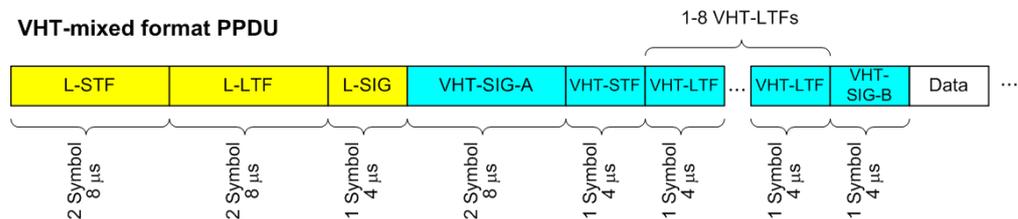


Figure 6: Structure of an 802.11ac signal.

The L-STF, L-LTF and L-SIG (marked in yellow) fields are legacy frames which are backwards compatible to 802.11a and 802.11n. Therefore, any 802.11 devices working in the 5 GHz frequency band will be able to understand this preamble. The VHT ("Very High Throughput") fields (marked in cyan) are 802.11ac fields and will only be understood by 802.11ac devices.

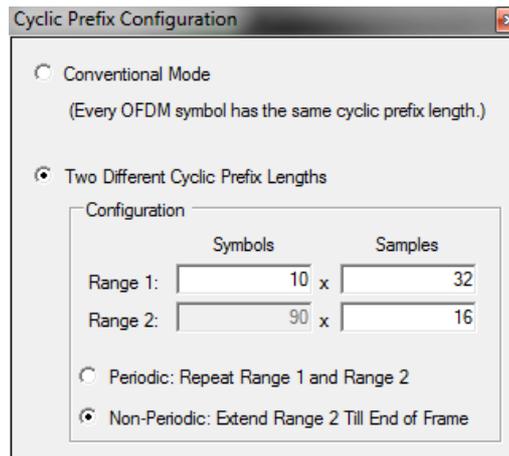
According to Table 2, for the current example, all fields except the Data-field use a cyclic prefix of 32 samples. As already described in step 7 the total number of header symbols is 10. All cells of the Data-field use a short cyclic prefix of 16 samples.

11. Enter the appropriate cyclic prefix configuration for an 802.11ac signal with a bandwidth of 40 MHz:

“Cyclic Prefix Configuration → Range 1 → Symbols: 10”

“Cyclic Prefix Configuration → Range 1 → Samples: 32”

“Cyclic Prefix Configuration → Range 2 → Samples: 16”



12. The software is now ready to record the 802.11ac I/Q data. Press Run Single to capture the I/Q data.

Please use the file **“WLANac_64QAM_40MHz_ShortCP.iqw”** supplied with the R&S FS-K96 Software for this example. Either open it directly in the R&S FS-K96 Software (Input Path = “File”) or use the ARB generator of a R&S signal generator to playback the file and capture it with a R&S spectrum analyzer (Input Path = RF / Analog Baseband / Digital I/Q).

“DEMODO SETTINGS → Generate Configuration File → Run Single”

or

<Use drag-and-drop to import the I/Q data file>

The Visualization frame is useful to check if the burst detection and the time synchronization have worked correctly. The frame should look like displayed in Figure 7.

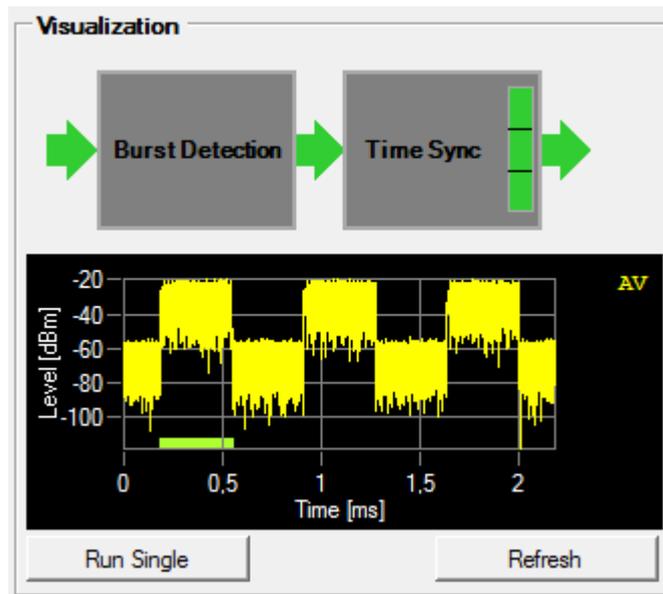


Figure 7: Signal configuration is correct.

Make sure that the whole burst is included in the range to be analyzed. The green bar on the bottom of the graph should cover the whole burst. If the configured Result Length is too short, the capture buffer display will look similar to the following screenshot:

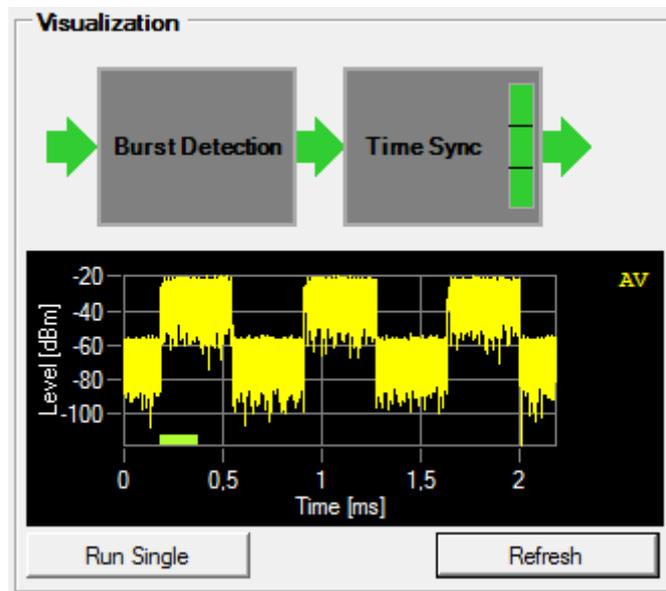


Figure 8: Result length is too short. The entire burst is not included in the range to be analyzed.

If the digital signal processing failed for some reason, the DSP field on the bottom of the screen is red. In this case please refer to the following subsections 3.1.1 and 3.1.2 for further instructions.

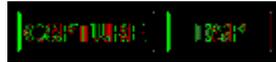
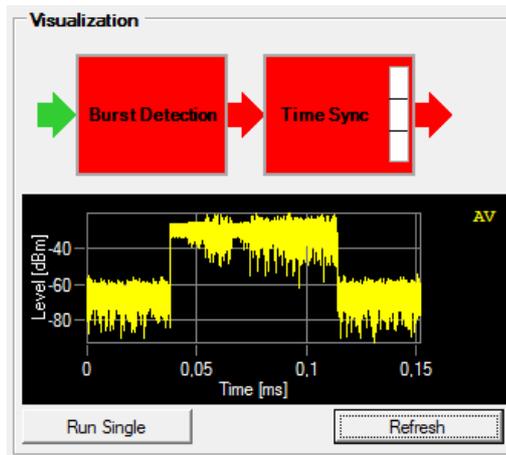


Figure 9: Digital signal processing failed. Check the configuration.

3.1.1 Burst Detection failed

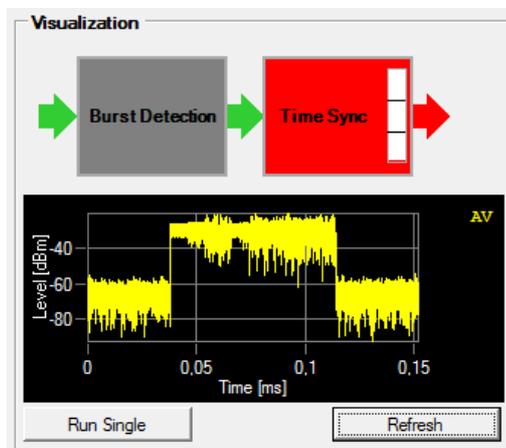
One possibility of an incorrect configuration is that the Result Length is configured too long and the burst search is not able to detect a burst with an adequate length. The signal flow diagram shows if the burst detection failed:



Reduce the Result Length and press refresh until the burst detection block is no longer red.

3.1.2 Time Sync failed

If the Burst Detection works correctly but the time synchronization fails, the OFDM Symbol Characteristics are probably incorrect.



Please check Table 2 again and make sure that the FFT length and the cyclic prefix lengths match the current 802.11ac signal.

3.2 Create the Configuration File

Some of the results are already available even if no OFDM configuration has been loaded (Power vs. Symbol X Carrier, a coarse Constellation Diagram, CCDF). If more specific information such as EVM of data and pilots are necessary, the R&S FS-K96 Software requires a signal description of the OFDM signal. This signal description needs to be provided via a R&S FS-K96 specific configuration file. The following step-by-step instructions describe how to create an appropriate configuration file:

1. Open the R&S FS-K96 Configuration File Wizard from within the R&S FS-K96 Software
“DEMOD SETTINGS → Generate Configuration File → Start R&S FS-K96 Configuration File Wizard”

The R&S FS-K96 Configuration File Wizard can alternatively be opened from the Microsoft Windows Start Menu. In this case, it would be necessary to load an I/Q file manually and optionally to extract parts of the I/Q signal. If the R&S FS-K96 Wizard has been started with a time-division duplex signal (= a signal containing bursts) from within the R&S FS-K96 Software these two steps can be skipped. Therefore, the step-by-step guide on the upper side of the R&S FS-K96 Wizard frame comes up with step 3 highlighted (see Figure 10).

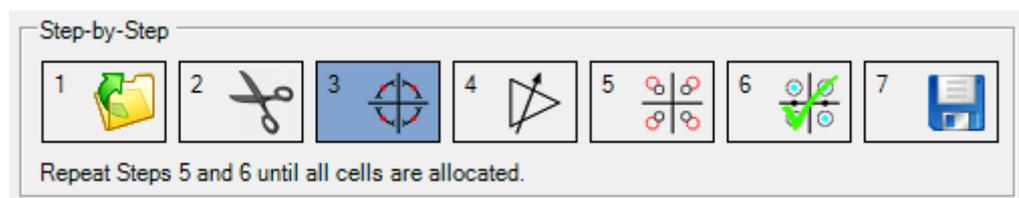


Figure 10: Step-by-step guide of the R&S FS-K96 Configuration File Wizard.

2. Step 3 offers the possibility to synchronize timing, frequency and phase of the signal. To perform the synchronization automatically, press the “Auto” button.

“Step 3 → Auto”

- In some cases, the detected constellation diagram might be shifted by 45°.

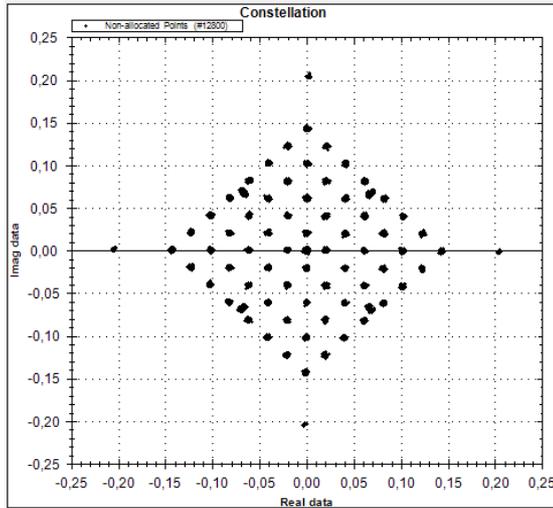


Figure 11: Constellation diagram is shifted by 45°.

In such a case, the phase slider can be used to rotate the diagram in steps of 45°.

“Step 3 →Manual Synchronization → <Click the phase slider>”



Figure 12: Use the Phase slider to rotate the constellation diagram.

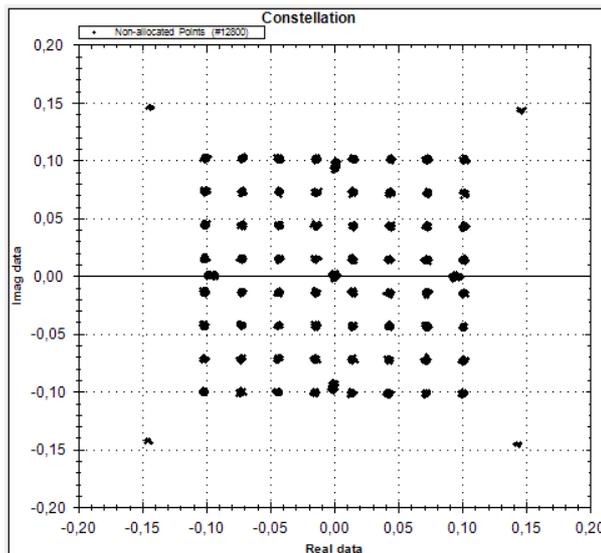


Figure 13: Constellation diagram with the expected phase.

- In the next step, the overall gain is configured. This value defines the reference power used as 0 dB boosting. The automatic gain estimation uses all signal parts matching a certain reference constellation previously selected by the user. For a 802.11ac signal it is reasonable to select the constellation that matches the data part, because it covers many cells of the signal. Furthermore, this choice ensures that all cells within the Data part have a constant boosting factor. By contrast the WLAN training fields would be a bad choice because they use an identical constellation but slightly different boosting factors.

For the given example signal, the user data part contains 64 QAM symbols.

“Step 4 → Selection of Reference → Constellation 64QAM”

“Step 4 → Gain Adjustment → Auto”

The screen should now look similar to the screenshot in Figure 14.

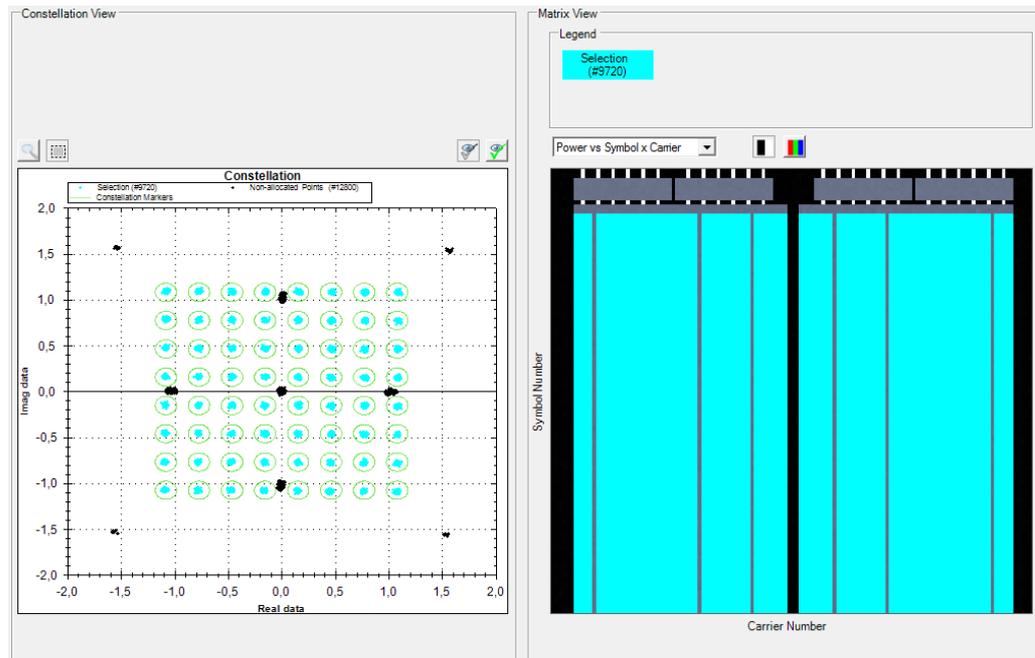


Figure 14: Selection of the user data part (64QAM) as reference for the gain adjustment.

The Matrix View on the right side of the screenshot in Figure 14 shows where the selected constellation points are located in the symbol to carrier domain (cyan selection).

- After the gain has been set correctly, the specific parts of the signal need to be mapped to the appropriate modulation types. Firstly, select the constellation point at the center of the diagram. Allocate as "Zero" since these cells are defined unallocated by the 802.11ac standard.

“Step 5 → Constellation Markers → <Select Zero in the dropdown menu>”

“Step 6 → Allocation → Allocate as: Zero”

OR

<Use the cursor to select the centered constellation point manually>

“Step 6 → Allocation → Allocate as: Zero”

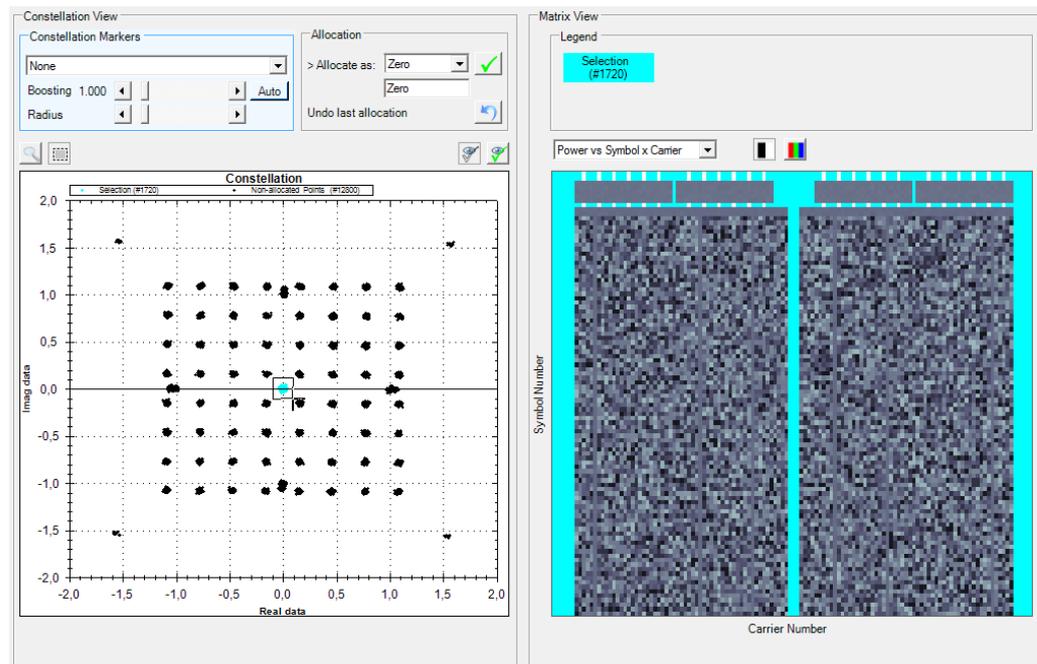


Figure 15: Manual selection of the zero allocation.

- Confirm the selection by pressing the check mark button (). The Matrix View will automatically switch to “Allocation Matrix”-display. Select “Power vs Symbol x Carrier” in the dropdown menu above the graph to return to the prior display.

“Step 6 → <Press the check mark button>”

Per default all constellation points that have already been allocated will no longer be displayed in the constellation diagram. The buttons on the upper right of the constellation diagram within the Constellation View can be used to configure which constellation points shall be displayed.



- Use the dropdown menu on the upper left of the matrix view to switch back to the "Power vs Symbol x Carrier" display.

"Matrix View → Power vs Symbol x Carrier"

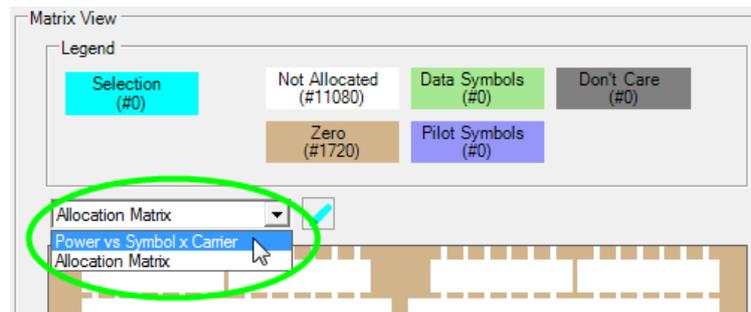


Figure 16: Switch back to the "Power vs Symbol x Carrier" view.

At this point the allocation of the actual 802.11ac specific data begins.

- Selection of the 802.11n Legacy Short Training fields ("L-STF").



The first two symbols of the 802.11ac frame contain the L-STFs. The boosting and the modulation of these pilots is identical for the VHT-LTF. Therefore they can be allocated together in the R&S FS-K96 Configuration File Wizard.

These training fields make use of two overlapping, shifted BPSKs. Hence the R&S FS-K96 Software may interpret these fields as QPSK. Select QPSK as modulation type.

"Step 5 → Constellation View → Constellation Markers → QPSK"

The 802.11ac standard defines the boosting of the different signal fields. The following table contains all boosting values in relation to the power of the data part of the signal. Because the data part has been set as 0 dB reference in step 4 the values from the table can be taken directly as the boosting factor in the R&S FS-K96 Configuration File Wizard.

802.11ac boosting factors relative to the "Data"-part of the signal				
Field	Boosting factor			
	20 MHz	40 MHz	80 MHz	160 MHz
L-STF	2.160247	2.179449	2.245366	2.245366
L-LTF	1.037749	1.046974	1.078639	1.078639
L-SIG				
VHT-SIG A				
VHT-STF	2.160247	2.179449	2.245366	2.245366
VHT-LTF	1	1	1	1
VHT-SIG B				

Table 3: Boosting factors of the 802.11ac signal relative to the "Data"-part of the signal. Enter these values as boosting factor for the corresponding signal fields.

The 802.11ac signal used for this example has a bandwidth of 40 MHz, therefore a boosting factor of 2.179449 needs to be used for the L-STF and the VHT-STF. Click directly on the boosting value next to the slider to edit the boosting factor:

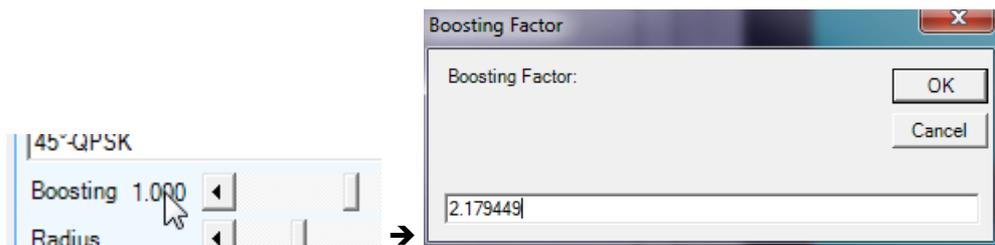


Figure 17: Enter the boosting factor manually.

“Step 5 → Constellation View → Constellation Markers → Boosting 2.179449”

Check the matrix view and the constellation diagram to make sure that the correct symbols and carriers have been selected. The correct selection is displayed in Figure 18 and Figure 19:

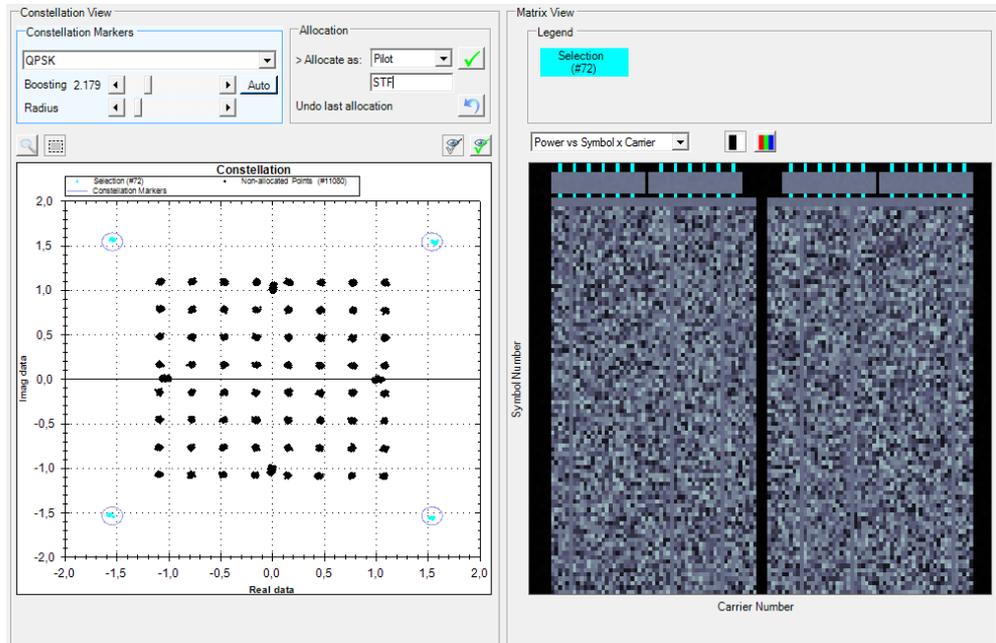


Figure 18: Selection of the L-STF and the VHT-STF signal parts.

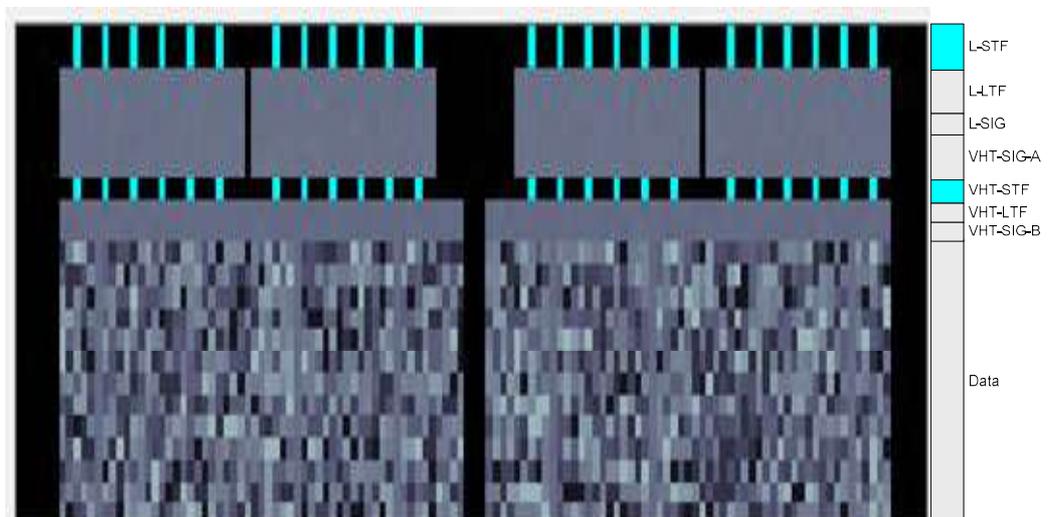


Figure 19: Selection of the L-STF and the VHT-STF signal parts (zoomed).

If the quality of the signal to be measured is bad, the constellation markers might not select all the correct symbols and carriers (see Figure 20).

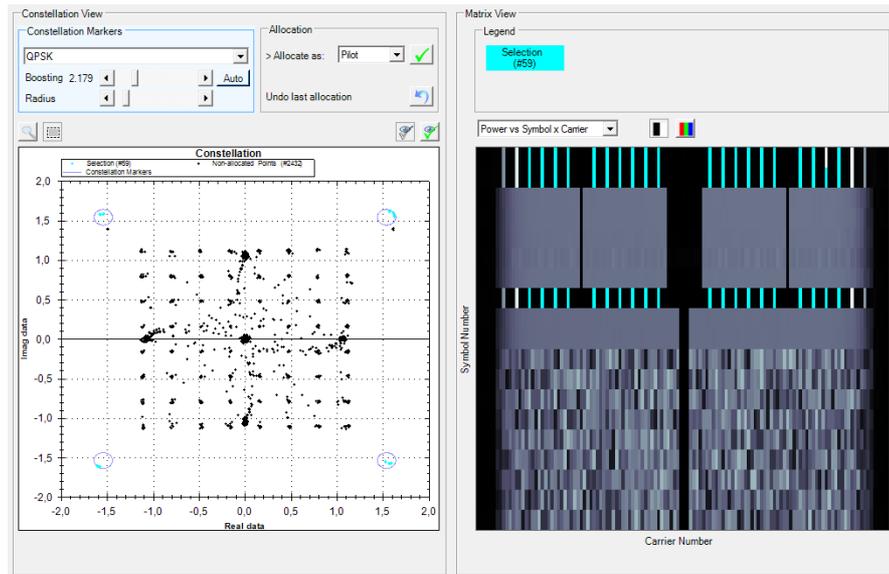


Figure 20: Incorrect selection of the L-STF and the VHT-STF due to bad signal quality.

In this case, there are two different ways to select the missing cells. The first is to increase the radius of the constellation markers in the Constellation View (see Figure 21).

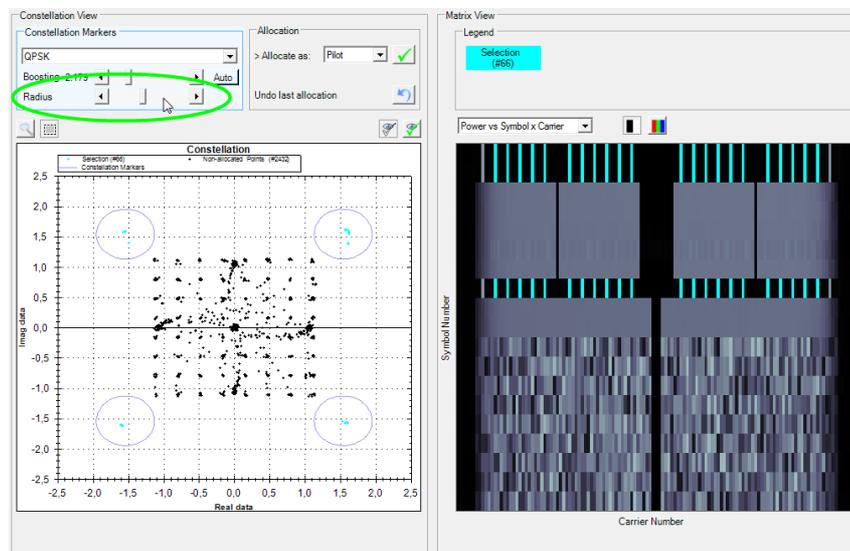


Figure 21: Increase the radius of the constellation markers to select all desired cells.

If there are still cells missing in the selection (see Figure 21) there is also the possibility to select via mouse. For this purpose hold the CTRL-key on the keyboard and click on the appropriate cells in the Matrix View (see Figure 22). Note that cell selection via mouse is also possible in the Constellation View.

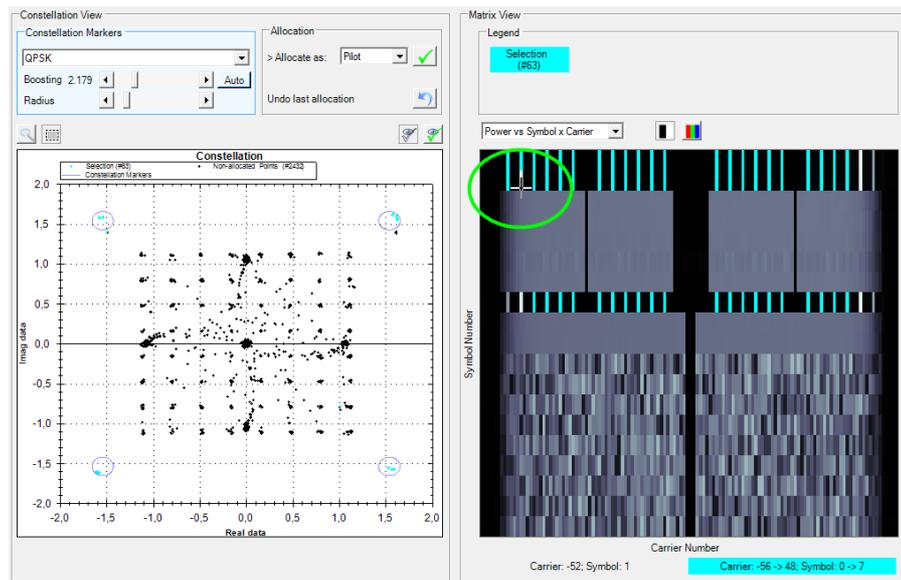
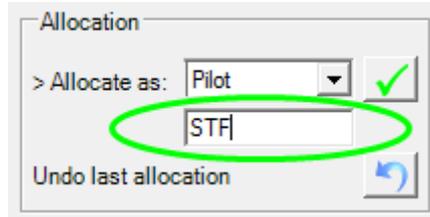


Figure 22: Select missing cells in the Matrix View.

9. *Optional:*

Enter a customized description for the fields to be allocated.

“Step 5 → Constellation View → <enter allocation description>”



10. Allocate the selected cells as pilots.

**“Step 5 → Constellation View → Allocation
 → Allocate as: Pilot
 → <Press confirmation key>”**

After allocating the L-STF and the VHT-STF the screen should look as displayed in Figure 23.

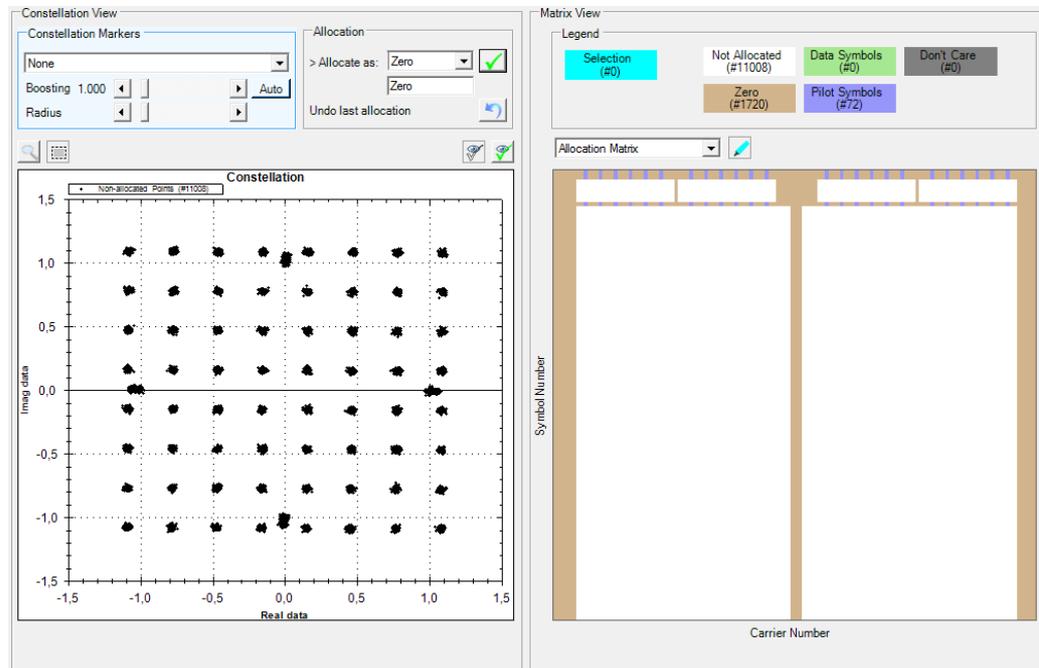


Figure 23: Screenshot after allocating the L-STF and the VHT-STF

11. Selection of the Legacy Long Training Field (“L-LTF”).



The next two symbols contain the L-LTF. The L-LTF consists of a BPSK as well as a BPSK shifted by 90° . The combination of these two modulation types can very well be modeled as QPSK with a 45° phase shift.

Set a 45° QPSK as the constellation type for this field:

“Step 5 → Constellation View → Constellation Markers → 45° -QPSK”

According to Table 3 the boosting factor for this field is 1.046974.

“Step 5 → Constellation View → Constellation Markers → Boosting 1.046974”

The L-SIG, VHT-SIG-A, VHT-LTF and the VHT-SIG-B parts of the 802.11ac signal use identical modulation types. As a result of this the constellation points of these signal parts are located very close to the constellation points of the L-LTF, which is currently being allocated. If there is any noise on the I/Q data it will become difficult or even impossible to exclusively select the desired fields in the constellation display.

For such cases the R&S FS-K96 Configuration File Wizard offers the possibility to select the correct ranges in the Matrix View instead of the Constellation view. Use the mouse to select a contiguous range of cells. Hold the CTRL-key and use the mouse to add additional ranges to the selection. Figure 24 and Figure 25 show how the correct selection should appear:

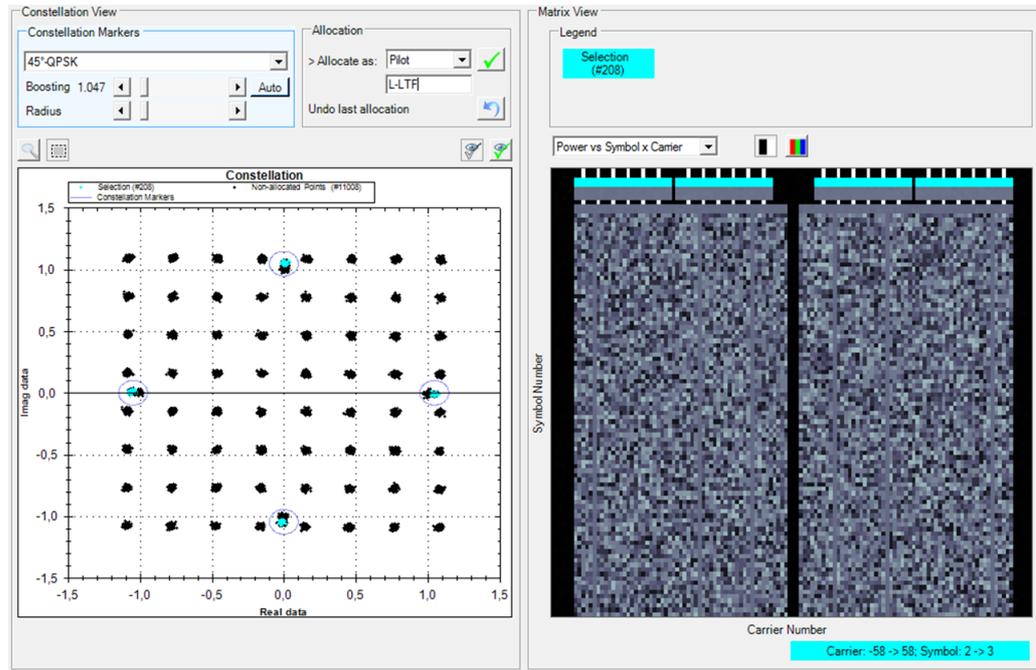


Figure 24: Constellation and modulation selection of the L-LTF part of an 802.11ac signal.

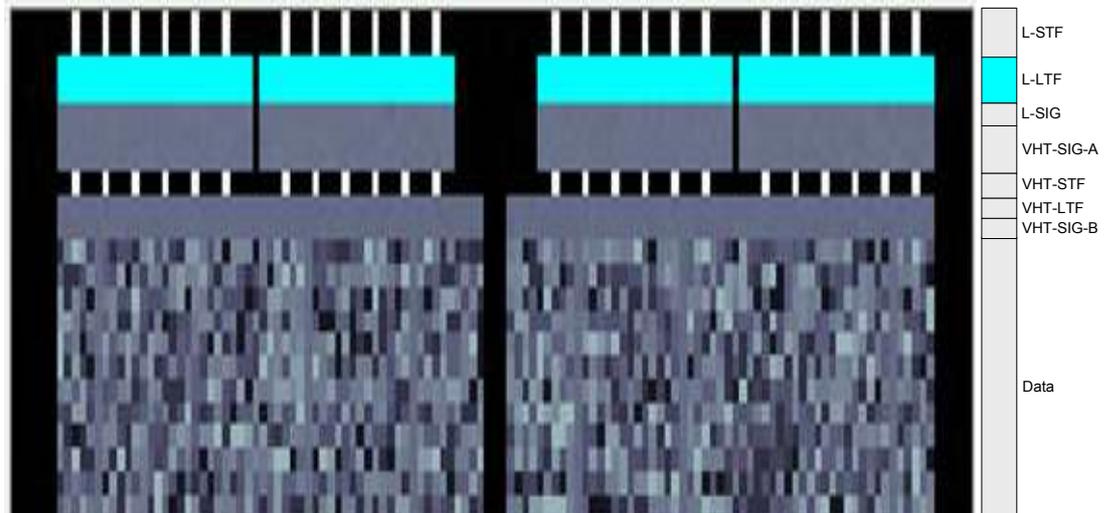


Figure 25: Constellation and modulation selection of the L-LTF part of an 802.11ac signal (zoomed).

Allocate the selected cells as pilots.

**“Step 5 → Constellation View → Allocation
→ Allocate as: Pilot
→ <Enter allocation description> (optional)**

→ <Press confirmation key>”

12. Selection of the Legacy Signal Field (“L-SIG”) and the Very High Throughput Signal A field (“VHT-SIG-A”).



The next symbol contains the L-SIG and the two symbols after that one contain the VHT-SIG-A. Both signal fields use the same modulation and the same boosting factor. Therefore, they can be allocated together in the R&S FS-K96 Configuration File Wizard.

Parts of the L-SIG and the VHT-SIG-A consist of a BPSK while other parts consist of a BPSK that is phase-shifted by 90°.

The SIG-fields of a WLAN signal contain different information about the current signal. The modulation type and the boosting factors stay the same as long as the bandwidth of the signal does not change. The information contained in these fields, however, changes depending on the current signal. Therefore the SIG-fields should not be allocated as pilots, but as data instead.

Set a 45°-QPSK as the constellation type for these fields.

“Step 5 → Constellation View → Constellation Markers → 45°-QPSK”

According to Table 3 the boosting factor for these fields is 1.046974.

“Step 5 → Constellation View → Constellation Markers → Boosting 1.046974”

The correct selection should look as shown in Figure 26 and Figure 27:

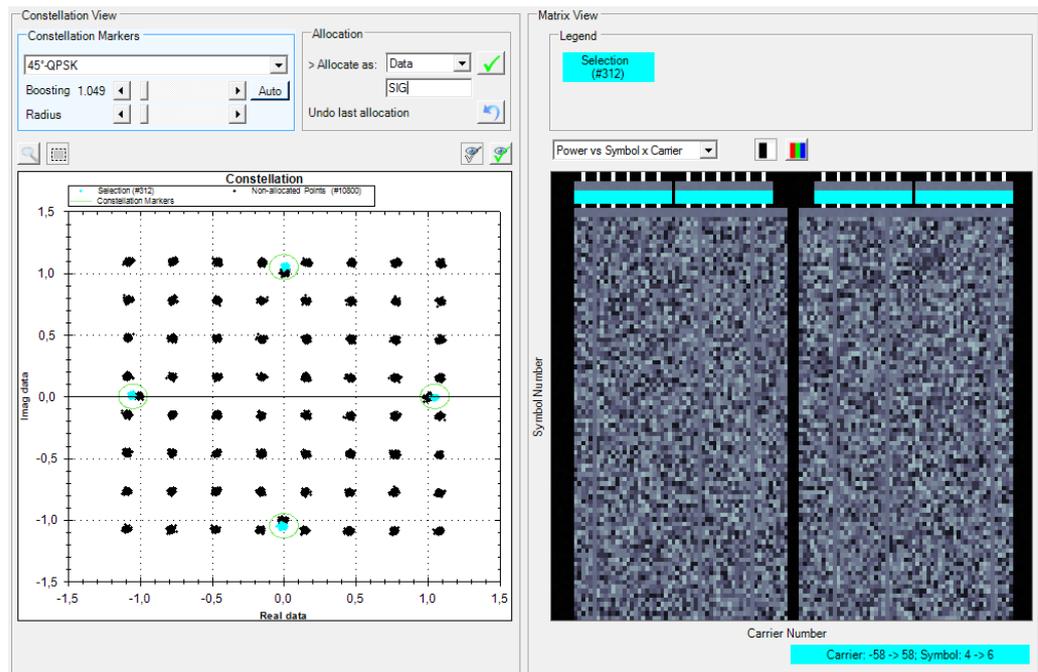


Figure 26: Constellation and modulation selection of the L-SIG and the VHT-SIG-A parts of an 802.11ac signal.

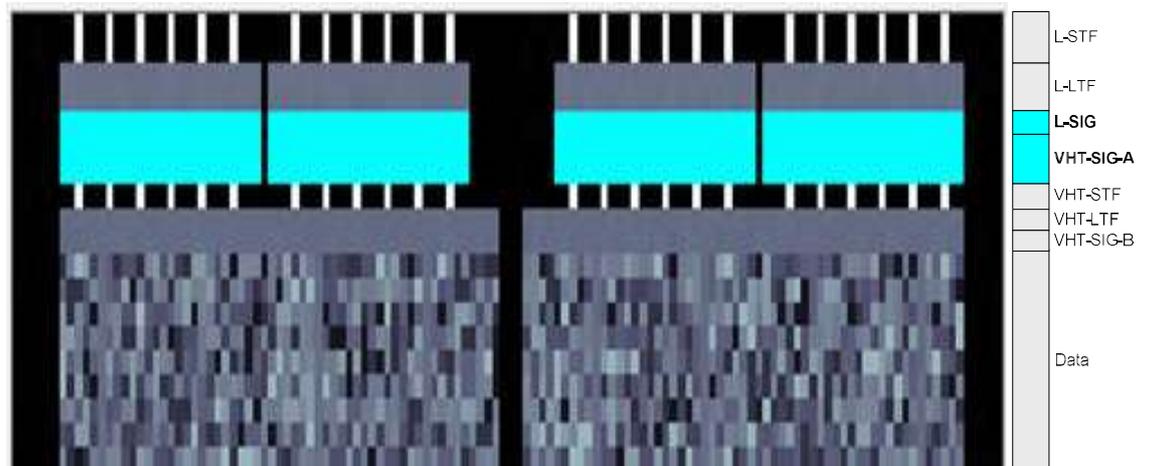


Figure 27: Constellation and modulation selection of the L-SIG and the VHT-SIG-A parts of an 802.11ac signal (zoomed).

Allocate the selected cells as data.
**“Step 5 → Constellation View → Allocation
 → Allocate as: Data
 → <Enter allocation description> (optional)
 → <Press confirmation key>”**

13. Allocation of the Very High Throughput Signal B Field (“VHT-SIG B”).



The 10th symbol contains the VHT-SIG-B field. Again a 45°-QPSK and a boosting factor of 1 are to be used. Since the field is a signal field, it should be allocated as data.

Select the correct modulation scheme.

“Step 5 → Constellation View → Constellation Markers → 45°-QPSK”

According to Table 3 these fields are not boosted (boosting factor is 1)

“Step 5 → Constellation View → Constellation Markers → Boosting 1”

The resulting selection should look as displayed in Figure 28 and

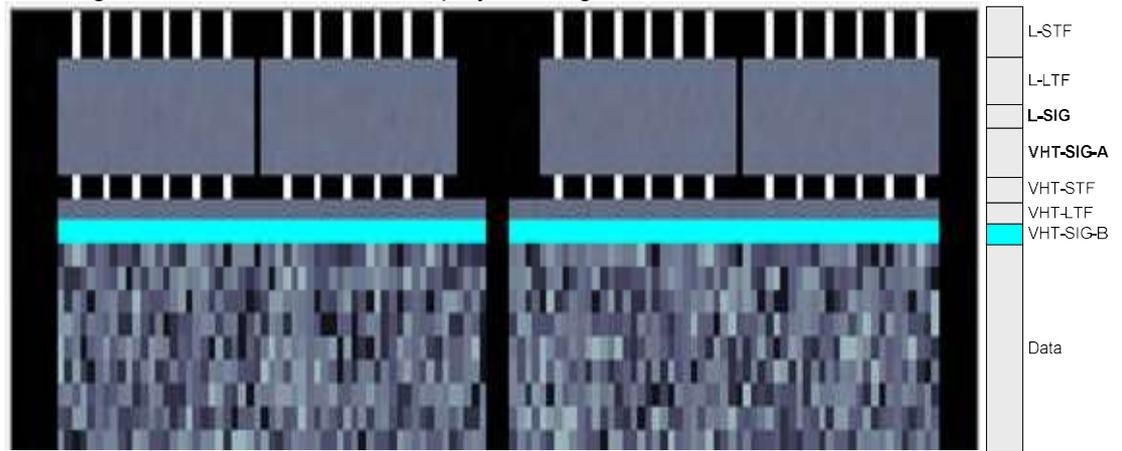


Figure 29:

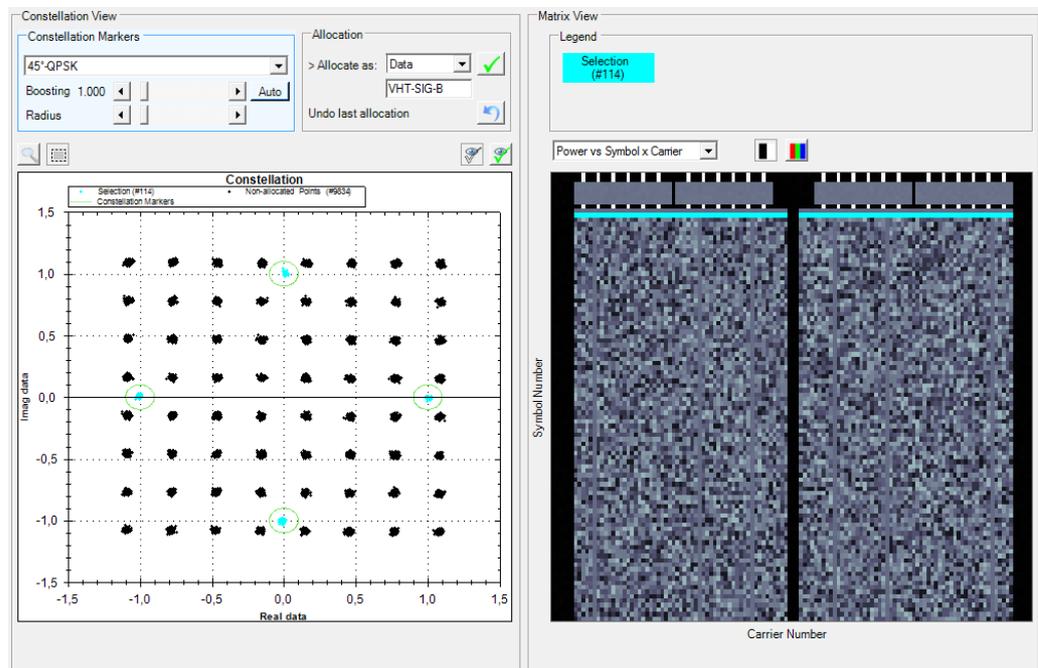


Figure 28: Constellation and modulation selection of the VHT-SIG-B part of the 802.11ac signal.

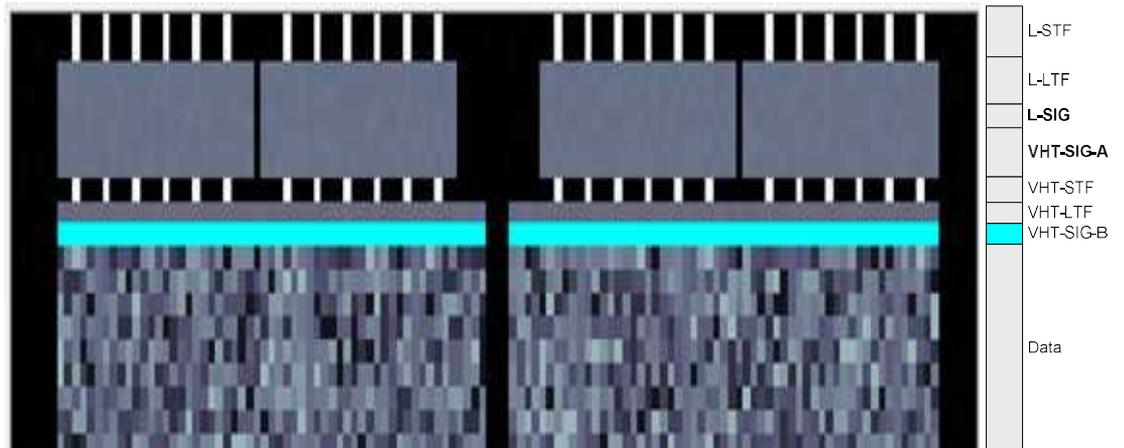


Figure 29: Constellation and modulation selection of the VHT-SIG-B part of the 802.11ac signal (zoomed).

Allocate the selected cells as data.

**“Step 5 → Constellation View → Allocation
→ Allocate as: Data
→ <Enter allocation description> (optional)
→ <Press confirmation key>”**

14. Selection of the Very High Throughput Long Training Field (“VHT-LTF”) and the pilot carriers included in the data part.



The VHT-LTF and the pilot fields included in the data part can be allocated in a single step because they use the same boosting factor as well as the same constellation type.

Note that the number of VHT-LTF fields may be greater than one in the case of MIMO. This application note examines SISO signals and therefore the number of VHT-LTF fields is one.

Again two shifted BPSKs are used for the modulation scheme and a 45°-QPSK can be selected in the R&S FS-K96 Configuration File Wizard to match the constellation points correctly.

“Step 5 → Constellation View → Constellation Markers → 45°-QPSK”

According to Table 3 these fields are not boosted (boosting factor is 1)

“Step 5 → Constellation View → Constellation Markers → Boosting 1”

The resulting selection should appear as displayed in Figure 30 and Figure 31:

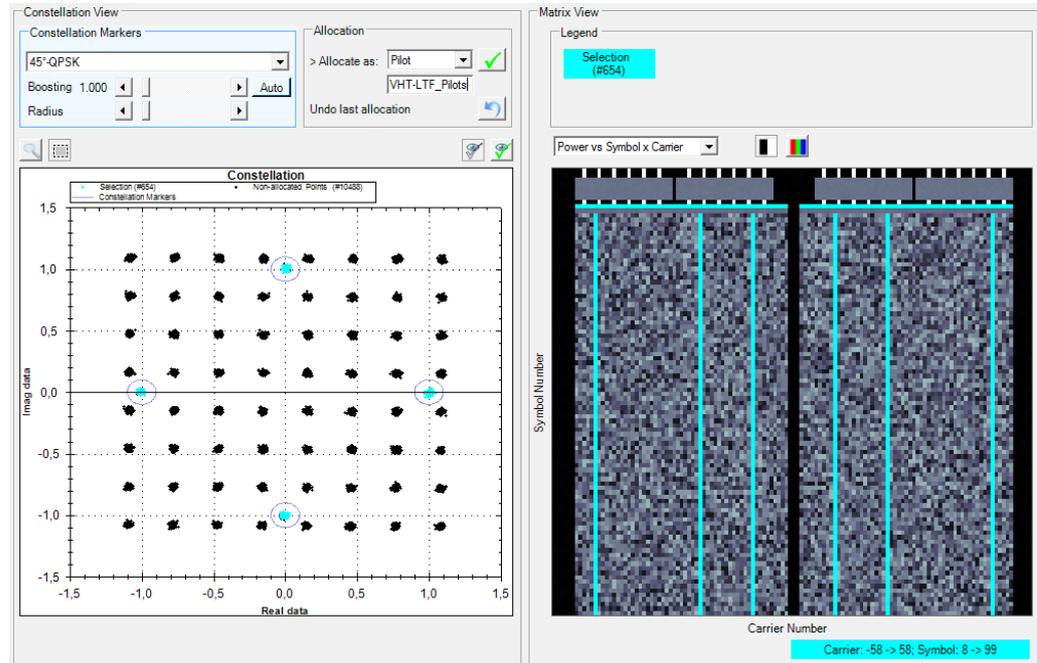


Figure 30: Constellation and modulation selection of the VHT-LTF part of the signal. The selected columns in the lower part of the Matrix View are pilots which are included in the Data-part of the signal. These pilots also have a boosting factor of 1.0 and use 45°-QPSK modulation. Therefore they can be included in the allocation.

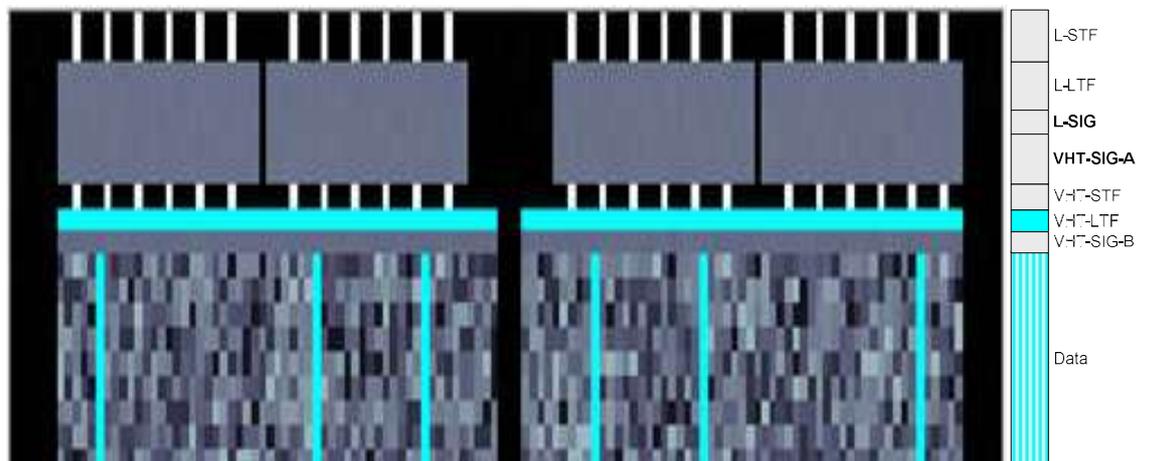


Figure 31: Constellation and modulation selection of the VHT-LTF part and the pilots in the data part (zoomed).

Allocate the selected cells as pilots.
“Step 5 → Constellation View → Allocation
→ <Enter allocation description> (optional)
→ Allocate as: Pilot
→ <Press confirmation key>”

15. Allocation of the Data-part.



All pilot cells have now been allocated and only the data part remains. The modulation type of the data part is user defined. In this example a 64 QAM is used.

Select the correct modulation scheme.

“Step 5 → Constellation View → Constellation Markers → 64QAM”

Since the data part has been used as reference power, the boosting factor is 1.

“Step 5 → Constellation View → Constellation Markers → Boosting 1”

The selection should now appear as in Figure 32:

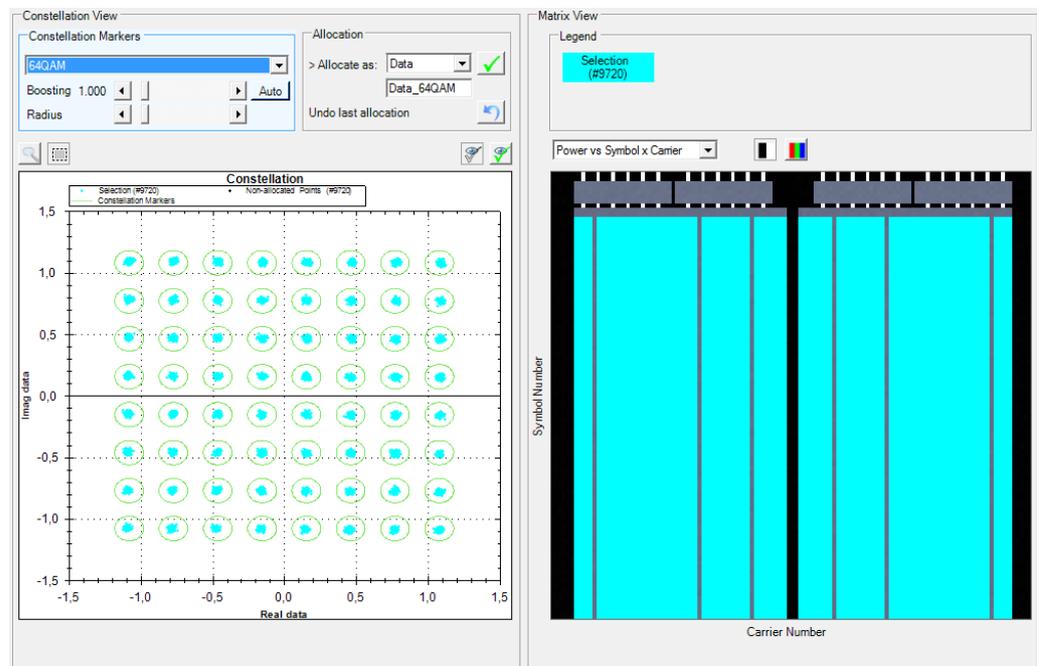
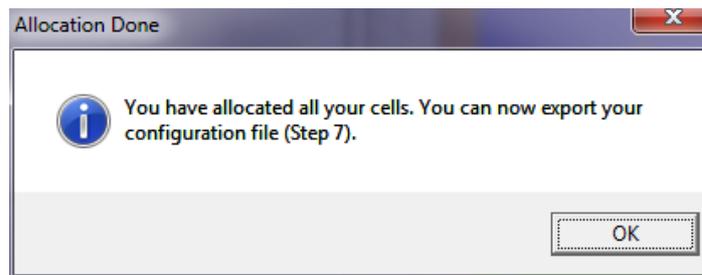


Figure 32: Constellation and modulation selection of the data part of the signal. (64 QAM in this example).

Allocate the selected cells as data.

**“Step 5 → Constellation View → Allocation
→ Allocate as: Data
→ <Press confirmation key>”**

After the confirmation of the data allocation the following window should pop up:



If this message is not displayed, there are still unallocated cells in the signal definition. Check the Allocation Matrix to identify unallocated cells. Unallocated cells will be displayed in white (see Figure 33).

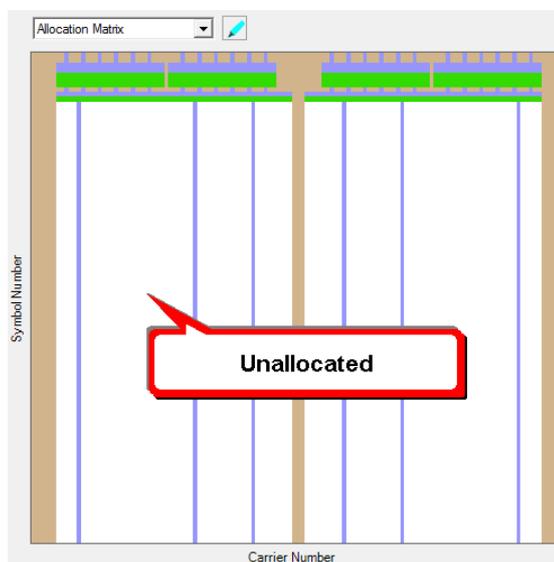


Figure 33: Display of unallocated cells in the allocation matrix.

When all fields have been allocated correctly, the allocation matrix should look as shown in Figure 34:



Figure 34: Display of the allocation matrix after all cells have been allocated.

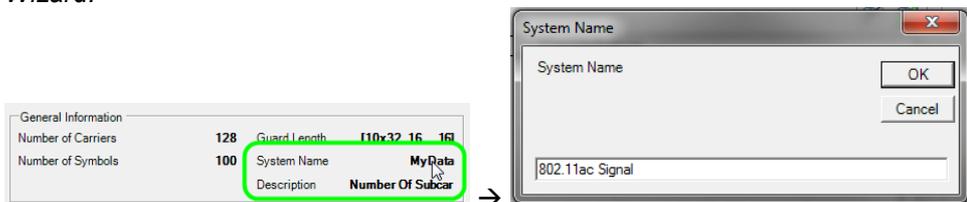
16. Store the configuration to a file and return to the R&S FS-K96 Software. The R&S Configuration File Wizard will ask to directly export the new configuration file to the R&S FS-K96 Software. The file may also be loaded later from within the R&S FS-K96 Software.

“Step 7 → <Store configuration file to the desired location>”

You can define a system name for your configuration by clicking on the "System Name" label in the "General Information" tab of the R&S FS-K96 Configuration File Wizard.



Hint



- Returning to the R&S FS-K96 Software window the analysis of the 802.11ac signal can be started. Press the refresh button once and select the desired result type. (e.g. EVM vs. Carrier and Constellation diagram as in Figure 35).

"REFRESH"

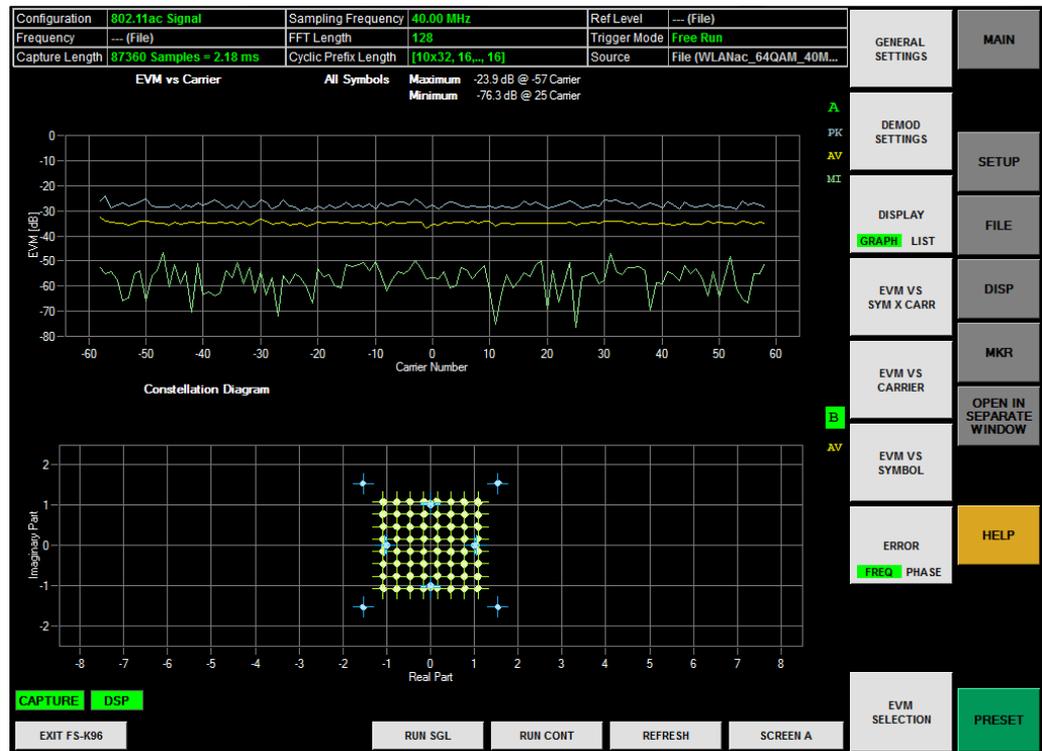


Figure 35: EVM vs. Carrier and Constellation diagram for the 40 MHz 64 QAM example file supplied with this application note.

4 Summary

802.11ac signals can already be measured using the currently available R&S FS-K96 Software. The dynamic generation of OFDM configurations with the R&S Configuration File Wizard allows one to react quickly on any upcoming changes in the 802.11ac standard.

The R&S FS-K96 Software offers a wide range of different graphical measurement results, which allow a detailed analysis of 802.11ac signals. The EVM versus symbol number versus carrier number, for example, offers a comfortable way to identify unwanted effects in the time-frequency domain. Many different graphical results can be monitored simultaneously by placing them into separate windows. Besides the graphical results, a table which holds the most important numerical measurement results at a glance is available.

The R&S FS-K96 Software not only offers the possibility to analyze 802.11ac signals but also to analyze 802.11a, 802.11g or 802.11n signals. Given that the device under test shall be backward compatible, one software can be used to test many different transmit modes.

These features make the R&S FS-K96 Software a very convenient choice for testing 802.11ac devices.

5 Literature

Reference Number	Author	Title
[1]	Lisa Ward (R&S)	1MA192 - 802.11ac Technology Introduction White Paper; Rohde & Schwarz GmbH & Co. KG
[2]	Robert Stacey (Intel)	Proposed TGac Draft Amendment; IEEE 802.11-10/1361r3

6 Additional Information

Please send any comments or suggestions about this application note to TM-Applications@rsd.rohde-schwarz.com.

6.1 Playback of a waveform file on an R&S Vector Signal Generator

The following step-by-step description will explain how to configure a Rohde & Schwarz generator to playback the provided 802.11ac example signal files.

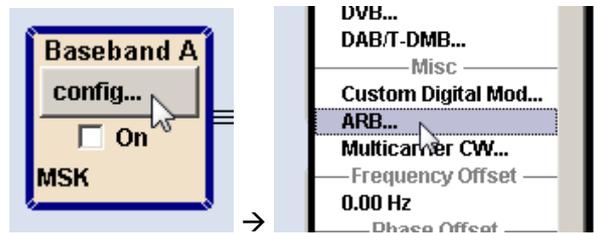
1. Depending on which connection type is to be used, either connect the signal generator and the spectrum analyzer via the RF ports, the analogue baseband ports or the digital baseband ports.
2. Preset the generator.

"PRESET"

3. Copy the file "**<Signal Generator Model>_802.11AC_64QAM_40MHz_ShortCP.wv**" supplied with this application note from the folder "**SIGNALS\<Signal Generator Model>**" to a USB stick and insert the USB stick into the signal generator. Make sure to use the signal file appropriate for your signal generator model (R&S SMBV or R&S SMU).

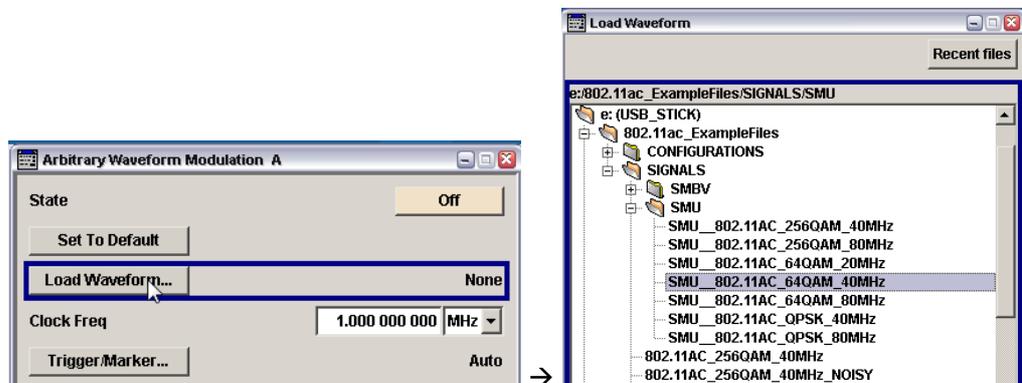
- Open the baseband dialog and select the ARB generator.

"Baseband (A) → ARB..."



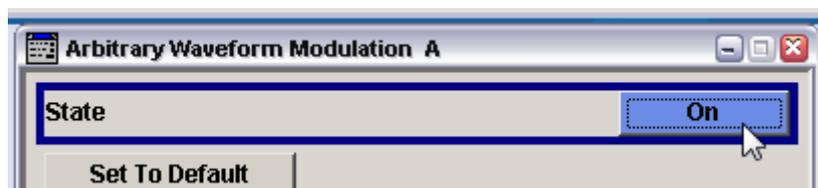
- Load the waveform file from the USB stick.

"Load Waveform... → <select file location of the example signal on the USB stick>"



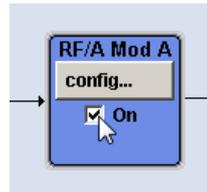
- Activate the ARB generator.

"State → On"



7. If an RF connection shall be used, the center frequency and the desired signal level must be configured and the RF output must be activated.

"FREQ → 1 GHz"
"LEVEL → -20 dBm"
"RF (A) Mod (A) → On"



After the signal generator has been configured successfully the example 802.11ac file will be transmitted repeatedly.

7 Ordering Information

Type	Order No.
R&S FS-K96 OFDM Vector Signal Analysis Software	1310.0202.06
R&S FS-K96PC OFDM Vector Signal Analysis Software	1310.0219.06
R&S FS-K96U Upgrade from R&S FS-K96 to R&S FS-K96PC	1310.0225.06
R&S FSW8 Signal and Spectrum Analyzer	1312.8000.08
R&S FSW13 Signal and Spectrum Analyzer	1312.8000.13
R&S FSW26 Signal and Spectrum Analyzer	1312.8000.26
R&S FSW-B28 I/Q Bandwidth Extension	1313.1645.02
R&S FSW-B40 I/Q Bandwidth Extension	1313.0861.02
R&S FSW-B80 I/Q Bandwidth Extension	1313.0878.02
R&S FSW-B160 I/Q Bandwidth Extension	<coming soon>
R&S FSQ3 Signal Analyzer	1155.5001.03
R&S FSQ8 Signal Analyzer	1155.5001.08
R&S FSQ26 Signal Analyzer	1155.5001.26
R&S FSQ40 Signal Analyzer	1155.5001.40
R&S FSQ-B72 I/Q Bandwidth Extension	1157.0336.12
R&S FSG8 Signal Analyzer	1309.0002.08
R&S FSG13 Signal Analyzer	1309.0002.13
R&S FSV3 Signal Analyzer	1307.9002K03
R&S FSV7 Signal Analyzer	1307.9002K07
R&S FSV13 Signal Analyzer	1307.9002K13
R&S FSV30 Signal Analyzer	1307.9002K30
R&S FSV40 Signal Analyzer	1307.9002K40
R&S FSV40 Signal Analyzer	1307.9002K39
R&S FSV-B70 40 MHz Analysis Bandwidth	1310.9645.02
R&S FSVR7 Signal Analyzer	1311.0006.07
R&S FSVR13 Signal Analyzer	1311.0006.13
R&S FSVR30 Signal Analyzer	1311.0006.30
R&S FSVR40 Signal Analyzer	1311.0006.40
R&S SMU200A Vector Signal Generator	1141.2005.02
R&S SMBV100A Vector Signal Generator	1407.6004.02

About Rohde & Schwarz

Rohde & Schwarz is an independent group of companies specializing in electronics. It is a leading supplier of solutions in the fields of test and measurement, broadcasting, radiomonitoring and radiolocation, as well as secure communications. Established more than 75 years ago, Rohde & Schwarz has a global presence and a dedicated service network in over 70 countries. Company headquarters are in Munich, Germany.

Environmental commitment

- Energy-efficient products
- Continuous improvement in environmental sustainability
- ISO 14001-certified environmental management system



Regional contact

Europe, Africa, Middle East

+49 89 4129 12345

customersupport@rohde-schwarz.com

North America

1-888-TEST-RSA (1-888-837-8772)

customer.support@rsa.rohde-schwarz.com

Latin America

+1-410-910-7988

customersupport.la@rohde-schwarz.com

Asia/Pacific

+65 65 13 04 88

customersupport.asia@rohde-schwarz.com

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Rohde & Schwarz GmbH & Co. KG

Mühlendorfstraße 15 | D - 81671 München

Phone + 49 89 4129 - 0 | Fax + 49 89 4129 - 13777

www.rohde-schwarz.com