

Application Note

MODULATION MEASUREMENT OPTIMIZER

Software tool for fast and repeatable optimization of signal analyzer RF front-end settings

Products:

- ▶ R&S®FSW
- ▶ R&S®FSV3000
- ▶ R&S®FSVA3000
- ▶ R&S®SMW200A

M. Breinbauer | 1EF111 | Version 3e | 11.2022

<https://www.rohde-schwarz.com/appnote/1EF111>

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1 Open-Source Acknowledgment (OSA)

The open-source acknowledgment document provides verbatim license texts of the open source software used for the Modulation Measurement Optimizer. See the OSA document in the *About* tab of the graphical user interface.

2 Terms and Conditions

See the Terms and Conditions document for using the Modulation Measurement Optimizer in the *About* tab of the graphical user interface.

3 Overview

The signal conditioning in the RF front-end of signal analyzers is crucial to achieve the best performance with respect to image-suppression, noise-floor, dynamic range and other RF-key parameters.

Precise signal levelling is especially important for complex measurements like Error-Vector-Magnitude (EVM). To minimize the measurement uncertainty from test system contributions over a wide range of different levels, the RF front-end needs to be adapted continuously according to the signal characteristics, signal power and frequency - ideally using an automatic levelling algorithm.

This document describes the approach of a waveform specific, on-site characterization of the analyzer: For each waveform and frequency of interest, the instrument is evaluated in a first step. With this additional data, a fast and repeatable auto-levelling can be performed during the actual measurement.

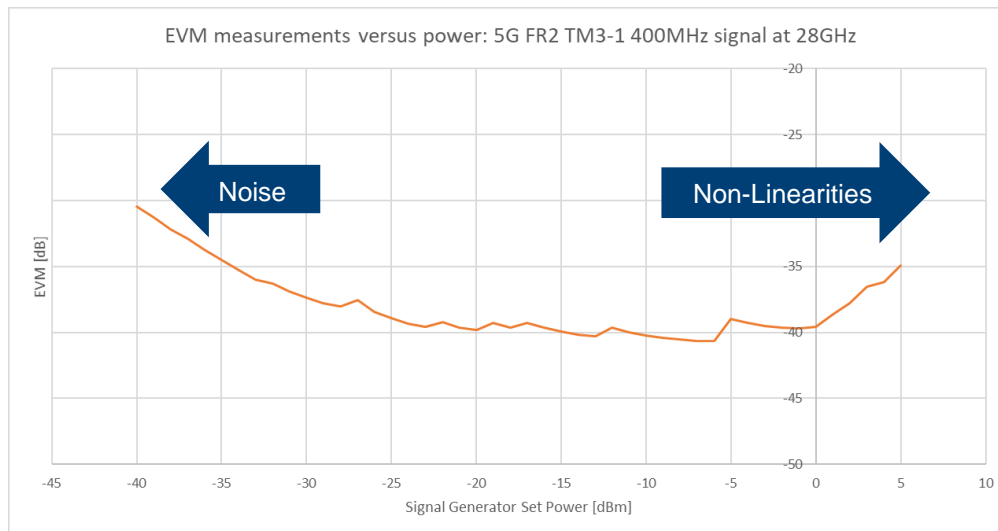
4 Introduction

4.1 Auto-Level Overview

The RF front-end of signal analyzers is highly adjustable to the current signal type and power level to achieve the optimal performance with respect to image-suppression, noise-floor, dynamic range and other RF-key parameters:



This is especially important for complex measurements like Error-Vector-Magnitude (EVM). Plotting EVM measurements for different input power levels typically results in a bathtub curve. This curve is dominated by noise on the one side and non-linearities on the other side:



To minimize the EVM measurement uncertainty from test system contributions over a wide range of power levels, the RF front-end needs to be adapted continuously - ideally using an automatic levelling algorithm.

There are several types of Auto-Level for different purposes:

- ▶ **Auto-Level in the Amplitude menu (SCPI command: ADJust:LEVel):**
General purpose auto-level making sure to avoid overload conditions. This approach is typically too conservative to provide optimum EVM values.
- ▶ **Auto-EVM in e.g. the 5G option (SCPI command: ADJust:EVM):**
Adjusts the amplitude settings to achieve the optimal EVM using the maximum dynamic range. This routine measures the signal several times at various levels to search for the best results. Often finds the optimum EVM but can take very long.
- ▶ **Waveform specific on-site characterization of the analyzer:**
For each waveform and frequency which is of interest, a characterization is executed by the user. Once these characterization values are available, a fast auto-levelling can be applied during productive usage.

This last approach will be evaluated further in this document.

4.2 Waveform Specific On-Site Characterization of the Signal Analyzer

This approach is ideal for environments where a predefined set of measurements is repeated many times. It splits the levelling task in two steps:

- ▶ A one-time characterization of the analyzer for a given signal and frequency of interest
- ▶ A speed-optimized and repeatable auto-levelling using the information gathered during characterization

For each waveform and frequency which should be evaluated, a one-time characterization of the signal analyzer is executed by the user. Once these characterization values are available, a fast auto-levelling can be applied during the normal test operation. This involves setting the pre-amplifier gain and the attenuation and using the IQ-analyzer mode to quickly find the optimum reference level.

The characterization according to this approach is implemented by the [Modulation Measurement Optimizer \(MMO\)](#) tool.

The exact values of the characterization parameters depend on the specific instrument, the frequency and the specific waveform properties.

5 Modulation Measurement Optimizer - Characterization Phase

5.1 Installing the MMO Tool

The MMO tool is available as single-file executable, which requires no installation. Copy the executable to a suitable directory.

When the MMO tool is opened the first time, the following directory structure is established next to the executable:

data	data	16/11/2022 09:55	File folder
characterizations	R&S_MMO.exe	20/10/2022 14:22	Application
config			
tmp			

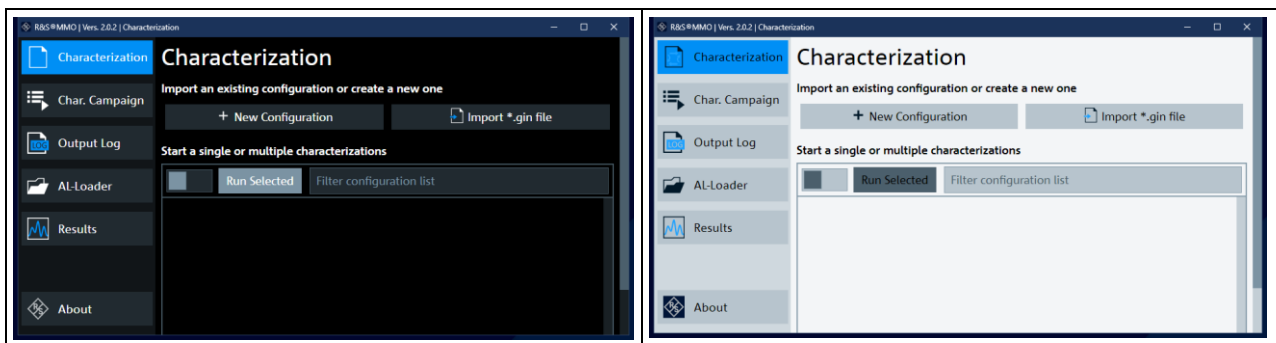
- ▶ **./data/characterizations:**
Each execution of a characterization will create a new subfolder with the result files in this directory.
- ▶ **./data/config:**
Each characterization configuration will be stored in a separate subfolder of this directory
- ▶ **./data/tmp:**
Used to store temporary files for the MMO-Loader and MMO-Campaign.
Also the `MMO_log.txt` file containing the Output-Log of the last execution is located here;

NOTICE

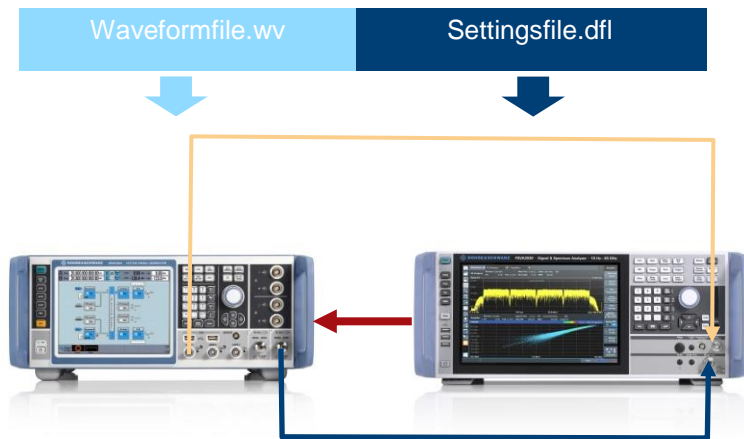
MMO uses the Chrome browser as GUI interface. It communicates with the connected instruments through VISA.

Make sure to have Chrome and a VISA installation on your PC.

The hot-key combination CTRL+ALT+d can be used to toggle between the dark and light design theme:



5.2 Characterization Setup



Red: 10MHz reference clock

Blue: RF signal

Orange: Trigger, User_1 of signal generator to Trigger_1 of signal analyzer

5.3 Running the Characterization

5.3.1 Overall process

Before the characterization can be started, some preparations are required.

The measurement needs to be set up *manually* in a way that, when executing `Run Single` on the instrument, a new stable and valid measurement is performed.

Especially make sure to take care about trigger and reference clock settings. It is recommended to set the unit for EVM results to "dB", as this typically provides higher accuracy when graphically evaluating the measurement traces (this is not possible in the R&S®FSW-K18 Amplifier Measurements option - the software will convert it automatically). The result unit can be adjusted in the analyzers menu item `MEAS CONFIG => Result config`.

Ideally this initial setup is parametrized for small power levels, as the MMO tool will start the power sweep at low power.

On the signal generator side the ARB arbitrary generator with a waveform file has to be used. Waveforms can be directly created from the generators real-time options by clicking *Generate Waveform*.

The *.dfl settings file for the signal analyzer and the waveform file for the signal generator have to be available on the PC which is used to run the characterization. The files can be easily copied over from the instruments by using the `Grab` buttons in the MMO graphical user interface (GUI) as detailed below. Alternatively, the setting file can be created and copied manually e.g. by using the `Save` button on the analyzer.

Additionally, the SCPI commands to read out the signal power and the value of the selected criteria (e.g. EVM) have to be specified. Please see some examples in chapter 5.3.4.

After setting all parameters like power-sweep start, sweep-stop and required frequencies, the characterization can be executed. The program does not modify the analyzer setup. It only adds an `IQ-Analyzer` (or `Spectrum`) window to perform the required additional measurements.

In a first step, the characterization is carried out. The gathered characterization values for the specific waveform and frequency are written into an `*.ini` file. This `*.ini` file is the main output of the characterization.

In an additional, optional step, the found characterization values can be directly applied in a power sweep to examine the achievable results. During the sweep the optimized settings are derived from the `*.ini` files for each power level.

Using signal analyzer setting files and signal generator waveform files allows to utilize the MMO tool with any type of measurement that creates measurement results whose value should be minimized, like EVM and ACLR (additional details for ACLR as measurement please see chapter 5.9. It is not dependent on any specific, standard-related option of the instruments.

Once the characterization and the optional power sweep is completed for all requested frequencies, the according `*.ini` files are available as primary characterization result. These can be used afterwards in productive mode for fast and precise levelling of the analyzer.

The parameters stored in the `*.ini` file can be used as input parameters for an external program which is executing the auto-levelling independent from the analyzer firmware.

Specific firmware versions and options are also able to process the calibration parameters and overwrite the internal nominal values.

The [Modulation Measurement Optimizer Loader](#) can be used for both approaches.

5.3.2 Characterization in Detail

The MMO tool searches for the optimal attenuation/reference-level settings for all preamplifier-settings (OFF, 15dB, 30dB) for the whole given power-range.

With these settings, the best results for the selected criteria - typically an EVM value - are expected.

The script does **not** apply any analyzers-settings in the measurement channel, except setting the frequency and attenuation/level. Therefore, the analyzer has to be preconfigured to a state, where the following SCPI commands are answered with a response containing valid data:

```
>> INIT:IMM; *OPC?
```

```
>> SCPI Criteria command e.g.: FETCh:BURSt:EVM:ALL:AVERage?
```

```
>> SCPI Power command e.g.: FETCh:BURSt:RMS?
```

The SCPI commands in the above example are suitable for a WLAN signal analyzed in the R&S® K91 WLAN option of the analyzer. Other examples can be found in the chapter 5.3.4.

If the queries reply an array of values, the **maximum** value in these arrays is used for further processing.

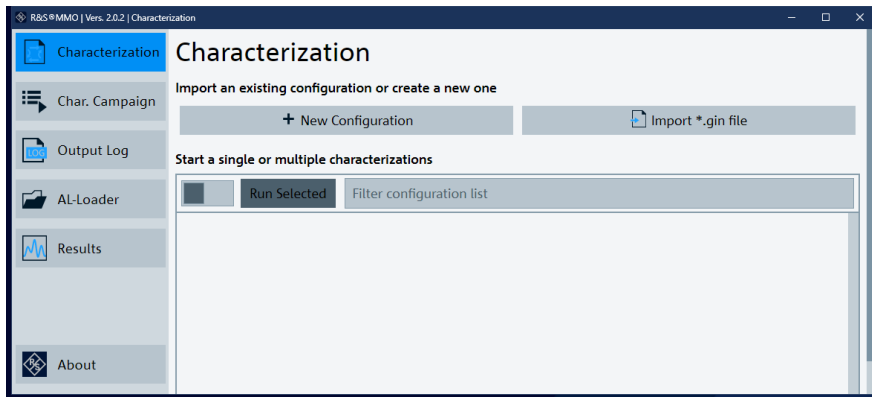
To speed-up the characterization, the optimization of attenuation and level is executed in an `IQ-Analyzer` channel named `Level`, which is automatically opened on the analyzer. The measurement time in this `IQ-Analyzer` channel can be set via a GUI entry. In case a spectrum-based measurement value like ACLR is used for optimization, the levelling is executed in a `Spectrum` channel as well.

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The pre-configuration of the analyzer for a specific signal type is achieved by loading a user-definable *.dfl settings-file into the analyzer. This *.dfl file has to match the user-selected waveform file which is loaded onto the signal generator.

Both files are automatically transferred from the PC to the instruments when starting the MMO characterization.

Start the program R&S_MMO.exe:



Main tabs:

- ▶ Characterization: Main tab to create and execute characterizations; configuration files from previous MMO executions can be imported by Import *.gin file
- ▶ Char. Campaign: Used to run a campaign characterizing several waveforms and frequencies; see chapter 7 for additional details
- ▶ Output Log: Provides logging information during execution
- ▶ AL-Loader: Used to apply the obtained characterization to optimize a measurement; see chapter 6 for additional details
- ▶ Results: Displays plots created by MMO during characterization
- ▶ About: Access to the *User Manual*, the *OSA documents* as well as the *Terms and Conditions* document

Click on Characterization, + New Configuration and expand the Advanced Settings:

The screenshot shows the 'R&S MMIO | Vers. 2.0.2 | Configuration' window. The 'Configuration' tab is active, showing a configuration named 'MMO.WLAN Example'. The interface is divided into several sections: 'Generator' (IP, P_{min}, P_{max}), 'Frequencies' (Center frequency, Offset), 'Generator Waveform' (File selection), 'Analyzer Configuration File', 'SCPI Analyzer-Query Measurement', 'SCPI Analyzer-Query Power', 'Advanced Settings' (SG Channel, IQ meas time, VISA timeout, checkboxes for Pause after setup, VISA logging, Preset generator, Suppress file upload, Calibrate generator attenuation, Invert RefClk), 'Additional signal generator SCPI', 'Additional signal analyzer SCPI', 'Run calibrated sweeps', 'Compare to standard autolevel', 'Use firmware functions', 'Use existing characterization *.ini file', 'Linearization threshold [dBm]', and 'Mode'. At the bottom are 'Back to list', 'Save', and 'Save & Run' buttons.

1: Name of the configuration; this name will also be used as subfolder-name in the `./data/config` directory

2: Copy an existing configuration; delete a configuration

3: Provide additional information to this configuration as a comment

4: IP-address or domain-name of signal analyzer and signal generator

5: Define the power-sweep range for the signal generator in dBm

6: Enter the frequencies to be measured; optionally provide frequency offsets between the center frequency of the signal generator and the center frequency used for the signal analyzer; see additional details below

7: Select the waveform file to be loaded into the generator.

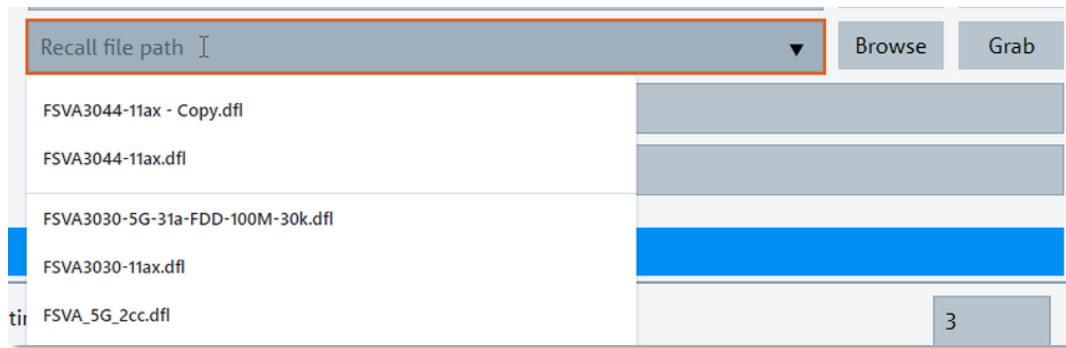
Use the **Browse** button to select the file in the file explorer.

User the **Grab** button to copy the currently loaded waveform of the signal generator ARB to the PC, keeping the name of the waveform as is on the generator.

The waveform is copied to the `./data/config` folder under the active configuration.

NOTICE

If the *Waveform* and *Configuration File* field are empty, a pop-up menu provides a list of *.dfl files found in the `./data/configurations` folder as well as a list of previously entered file names.



8: Select the settings-file to be applied on the analyzer.

Use the **Browse** button to select the file in the file explorer.

User the **Grab** button to create a setting file with the current settings of the signal analyzer and save it under the name which has to be provided in the **Configuration File** field before grabbing.

The settings-file is copied to the `./data/config` folder under the active configuration.

9: SCPI command to query the selected measurement value, typically EVM, from the analyzer. If the query replies an array of values, the maximum value of all entries in the array is used for further processing by default.

Alternatively, a single-digit index can be provided to select a specific entry of the array e.g.

`FETCH:BURSt:EVM:ALL:AVERAge?[1]` . Array indices are 0-based.

If the query contains "`? ACP`", the first value of the array is removed before the remaining maximum value in the array is used for further processing - unless a specific index is provided by the user.

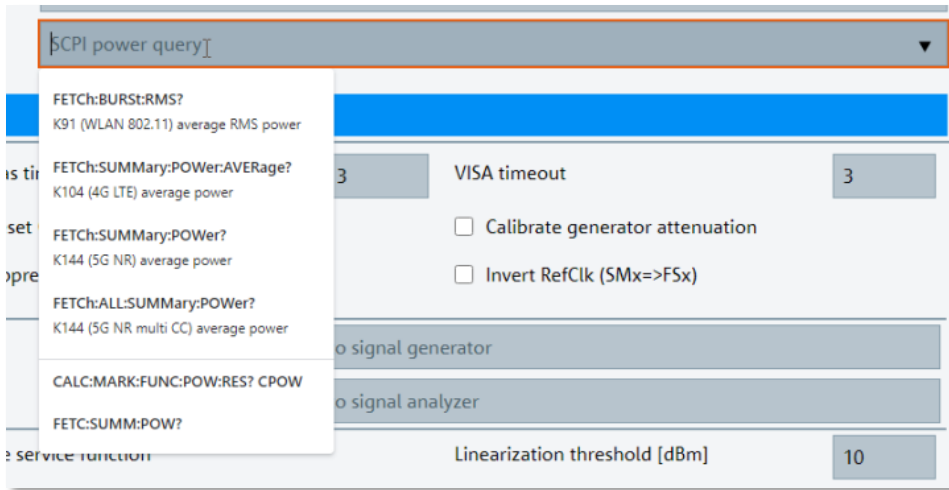
10: SCPI command to query the measured power value from the analyzer. If the query replies an array of values, the maximum value of all entries in the array is used for further processing by default.

Alternatively, a single-digit index can be provided to select a specific entry of the array e.g.

`FETCH:BURSt:RMS?[2]` . Array indices are 0-based.

NOTICE

If the *SCPI Query* entry fields are empty, a pop-up menu provides a list of predefined SCPI commands as well as a list of previously entered commands.



11: Advanced Settings – general

- ▶ SG Channel: Select the channel 1 or 2 on the generator
- ▶ IQ meas. time: Measurement time applied for the levelling in IQ-analyzer mode
- ▶ VISA timeout: Set the standard timeout applied for the communication with the instruments
- ▶ Pause after setup: pause after the setup of the instruments is completed to check or apply some manual adjustments; pauses before characterization and calibrated sweep
- ▶ Preset Generator: Choose if an initial reset of the signal generator should be applied
- ▶ Calibrate generator attenuation: Choose if the attenuator settings of the signal generator should be characterized in addition to the analyzer settings (see more details in chapter 5.7)
- ▶ VISA logging: activate the logging of the VISA/SCPI commands to the logging window
- ▶ Suppress file upload: if selected, *.dfl and *.wv files are expected to be available on the instruments already and will not be uploaded; e.g. useful if used via a slow remote connection
- ▶ Invert RefClk: use the 10MHz reference clock of the signal generator instead of the clock of the signal-analyzer as reference

12: Advanced Settings – Additional SCPI commands

Semicolon separated list of SCPI commands, which should be sent to the instruments additionally after the setup is completed; executed right before the "Pause after setup" halting point.

NOTICE

To send a SCPI command to the automatically opened level-window of the analyzer, enter "LEVEL;" into the field followed by the instructions; all instruction before "LEVEL;" are sent to the measure window, all instructions after "LEVEL;" are sent to the level window; e.g.:

Additional signal analyzer SCPI

:SENS:SWE:TIME 0.0101;LEVEL; LAY:ADD:WIND? '1',RIGH,FREQ

13: Advanced Settings – Calibrated Sweep settings

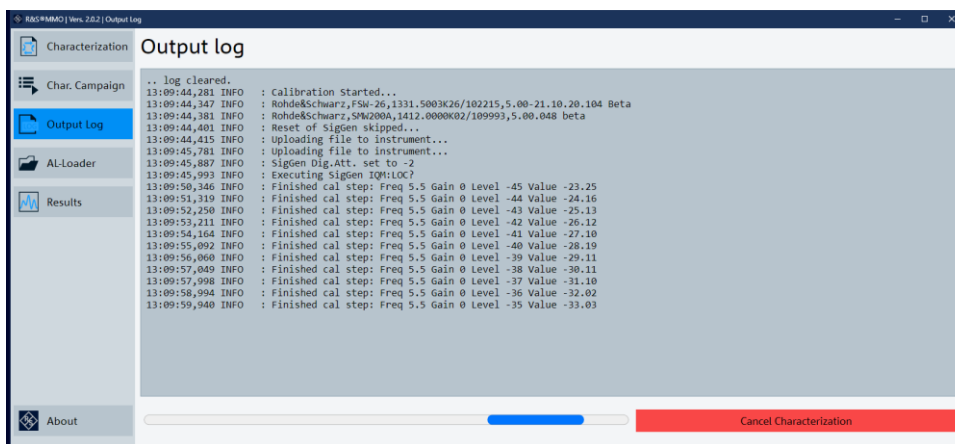
- ▶ Run Calibrated sweeps: Optionally execute power sweeps for all chosen frequencies and apply the characterization values obtained during the characterization step for auto-levelling.
- ▶ Use firmware function: if this flag is set, the auto level function of the analyzer firmware is updated with the previously found characterization data. Make sure your firmware does support this mode. If not, the auto-levelling is directly controlled by the MMO tool, independent of the analyzer firmware.
- ▶ Linearization threshold: Define from which dBm level upwards the RF-linearization of the generator is used
- ▶ Compare with standard AL: Additionally, measure EVM using the default auto-levelling during the calibrated sweep; for comparison with the MMO results
- ▶ Use existing characterization *.ini file: if this flag is set, no new characterization is executed; if no *.ini file to use for the calibrated sweep is provided in the according field, a pop-up window is shown which allows to select the name of an already existing *.ini file.
- ▶ *.ini to use: provide the path to an *.ini file, which should be used if Use existing *.ini cal file is selected; if no file is provided here, a pop-up window will ask for input; this is especially useful if characterizations are executed with the campaign manager;

14: Mode: Only for internal use; keep empty or apply "0"

15: Save the configuration

16: Save the configuration and directly start the characterization

During the characterization, the current test status can be observed in the logging window:

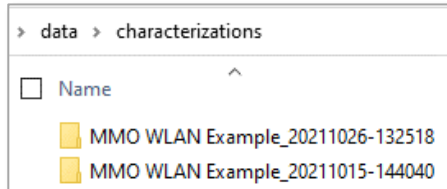


The logging information is additionally stored in the file `MMO_log.txt`, which can be found in the `./data/tmp` subdirectory.

5.3.3 Characterization Results

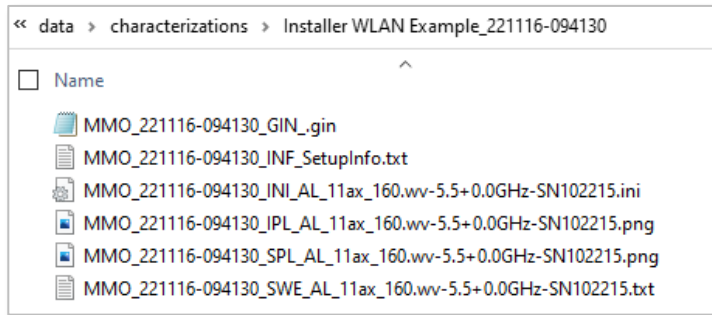
A running characterization or calibrated-sweep can be aborted by clicking `Cancel Characterization`.

For each executed characterization, a new subfolder is created in the `./data/characterizations` directory:



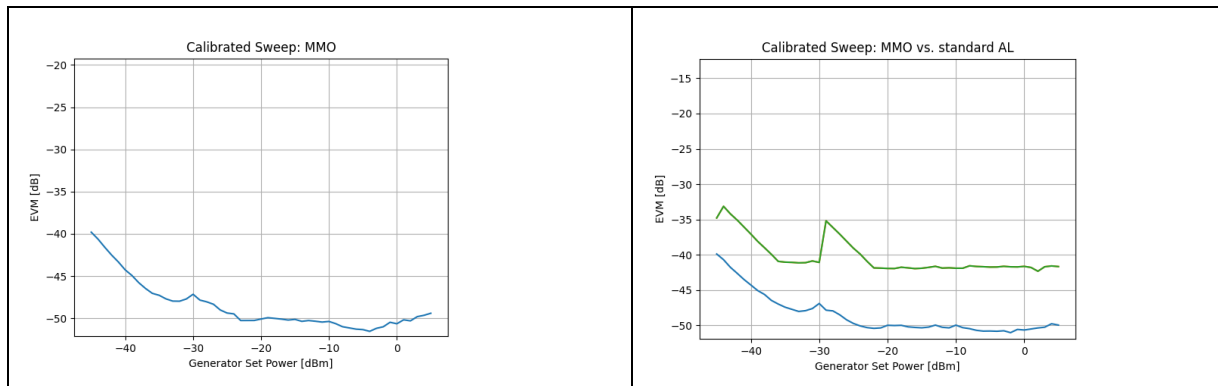
The name of the subfolder consists of the name of the used configuration plus a timestamp. A file explorer window is opened automatically in this new directory.

Several files are stored in this subfolder while the characterization is executed:



For each frequency point:

- ▶ An *.ini file containing the actual MMO characterization values; *this is the main result of the characterization which is required for later use*
- ▶ A *.png file with the EVM traces obtained during characterization (for reference only)
- ▶ If `Run Calibrated Sweeps` was selected:
 - A *.txt file containing the applied settings and achieved results for the measurement value (typ. EVM) over the selected power-range.
 - A *.png file visualizing the EVM vs. Power trace using MMO; extracted from the *.txt file; if also `Compare to standard Autolevel` was chosen, additionally the EVM v. Power trace using the default auto-level algorithm is shown



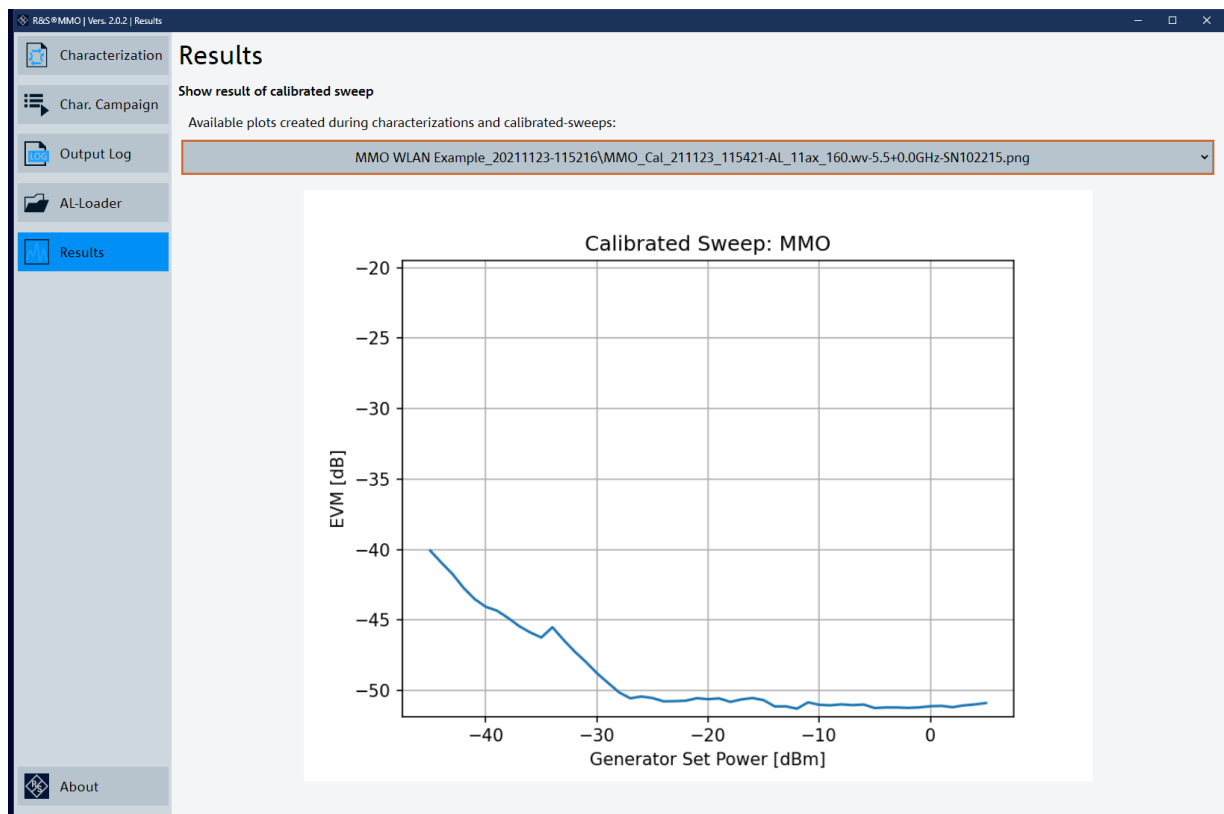
- If Calibrate generator attenuation was selected, a *.gni file is generated which contains the optimum attenuator settings for the generator for all power levels. Please see chapter 5.7 for further details.

Once per execution:

- The MMO...SetupInfo.txt file contains e.g. the serial numbers and firmware versions of the connected instruments.
- A copy of the configuration file (*.gin) which was used for this execution is stored for reference

All file names follow the naming convention MMO_time-stamp_fileType_optionalPart.xyz.

All *.png files which are available in the ./data/characterizations sub-folders can be selected and viewed in the *Results* tab:



5.3.4 Examples for Possible Applications

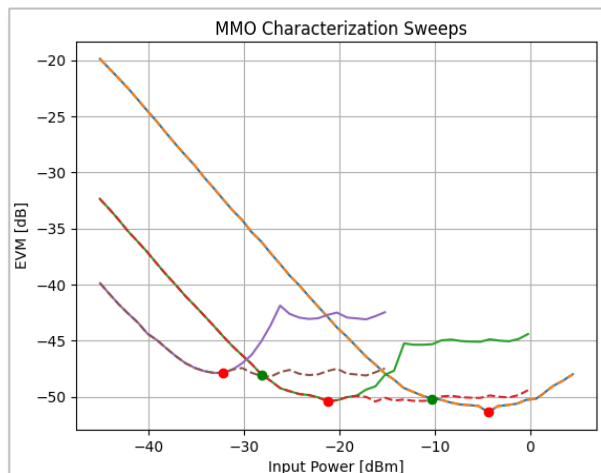
Analyzer applications and corresponding SCPI commands		
Application	SCPI Analyzer-Query Measurement (EVM)	SCPI Analyzer-Query Power
WLAN	FETCh:BURSt:EVM:ALL:AVERAge?	FETCh:BURSt:RMS?
5G	FETC:CC1:ISRC:FRAM:SUMM:EVM:ALL:AVER?	FETC:SUMM:POW?
5G multi-CC	FETC:ALL:SUMM:EVM:ALL?	FETC:ALL:SUMM:POW?
Amplifier	:FETC:MACC:REVM:CURR:RES?	:FETC:POW:OUTP:CURR:RES?

The MMO tool is not limited to the applications listed above. It can be used in combination with other analyzer options and in conjunction with the R&S®VSE software.
 Instead of EVM also e.g. the ACLR value can be used as a measurement value to optimize instead of EVM. See additional details in chapter 5.9.

5.4 Verifying the Characterization Results

A typical set of result files is discussed in the following:

- The *.png file contains the EVM plots for the different pre-amplifier settings obtained during characterization:



Solid lines: Pre-Amp OFF, Pre-Amp 15dB, Pre-Amp 30dB, optimized sweep to determine the minima of the traces

Dashed lines: additional measurements, optimized to determine the crossing points of the traces

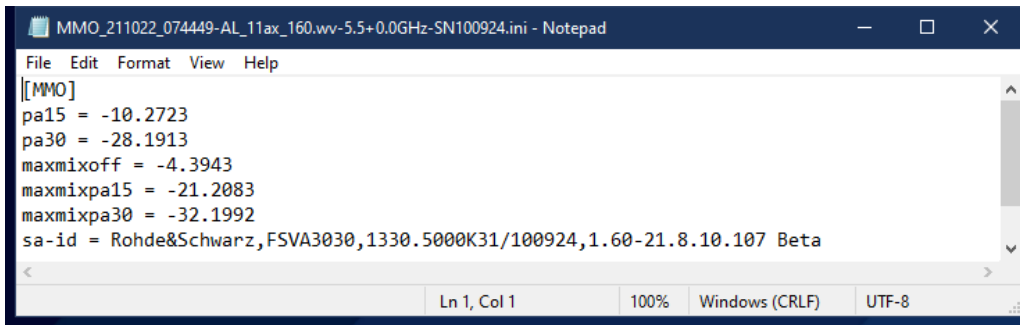
Green points: Pre-Amp-switching points

Red points: target levels for best performance

Make sure that the crossing points and minima of the traces look feasible. Otherwise, please adjust the power sweep range.

If the analyzer has a single-stage pre-amplifier, only 2 traces are shown accordingly.

The *.ini file contains the exact numbers for the PA-switching points and target levels:



```

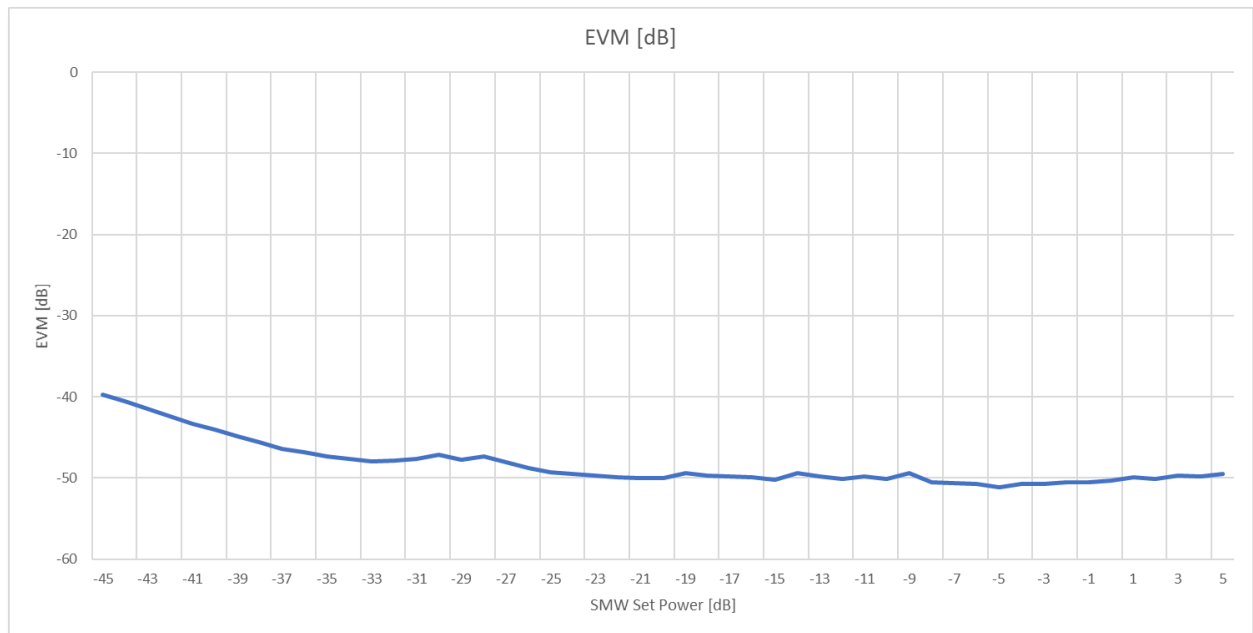
MMO_211022_074449-AL_11ax_160.wv-5.5+0.0GHz-SN100924.ini - Notepad
File Edit Format View Help
[MMO]
pa15 = -10.2723
pa30 = -28.1913
maxmixoff = -4.3943
maxmixpa15 = -21.2083
maxmixpa30 = -32.1992
sa-id = Rohde&Schwarz,FSVA3030,1330.5000K31/100924,1.60-21.8.10.107 Beta
Ln 1, Col 1 100% Windows (CRLF) UTF-8

```

The characterization is valid for the specific frequency and the specific waveform only. Also, variations over different instruments may occur. MMO characterization values can be reused for „similar“ waveforms and frequencies, if a certain increase in the residual EVM is accepted.

The *.ini file is used later-on to configure the auto-levelling routines during productive usage.

If Run calibrated sweeps was selected, a third file (*.txt) with the applied settings and achieved measurement values (typ. EVM) is created for each chosen frequency. Plotting the data of these files visualizes the achievable results versus signal power:



5.5 Using the Frequencies Offset Field

If this field is left empty, it has no effect on the measurement results.

If a frequency-offset between generator and analyzer is required, values have to be provided here. One offset is required for each frequency given in the frequency list. This offset is added to the frequency of the *signal-analyzer*. The center frequency of the signal-generator is not affected.

A typical use case is a base-band offset of +100MHz which is applied at the signal generator to reduce the carrier-leakage.

Frequencies	0.65	GHz	100	MHz
	1.8	GHz	100	MHz
	2.4	GHz	100	MHz
Center frequency		GHz	Offset	MHz

In this example, the following center frequencies are set during characterization:

Applied Center Frequencies		
	Signal Generator	Signal Analyzer
Characterization 1	0.65 GHz	0.75 GHz
Characterization 2	1.80 GHz	1.90 GHz
...

This feature is also usable in 5G multi-carrier measurements to compensate different definitions of center-frequency between signal generator and analyzer. See the next chapter for additional details.

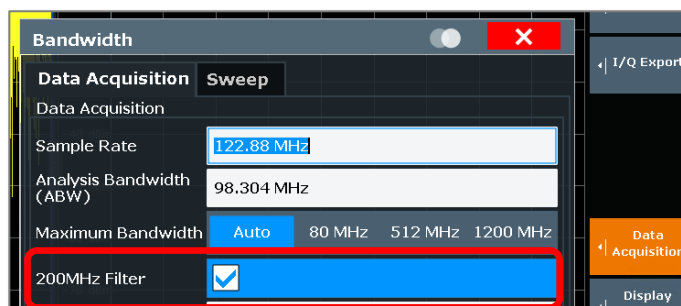
5.6 MMO in Combination with the 5G Option

5.6.1 Signal Analyzers with 200 MHz Bandpass Filter

Some R&S®FSW Signal Analyzers are - if optioned with R&S®FSW-B160, R&S®FSW-B320 or R&S®FSW-B512 - equipped with a separately switchable 200 MHz bandpass filter in front of the A/D converter. The 5G option is automatically using this filter for signal conditioning if applicable. To achieve a correct levelling in the *Level* window, this filter has to be activated in this window as well. MMO is doing this automatically if possible. This is indicated by the following logging output:

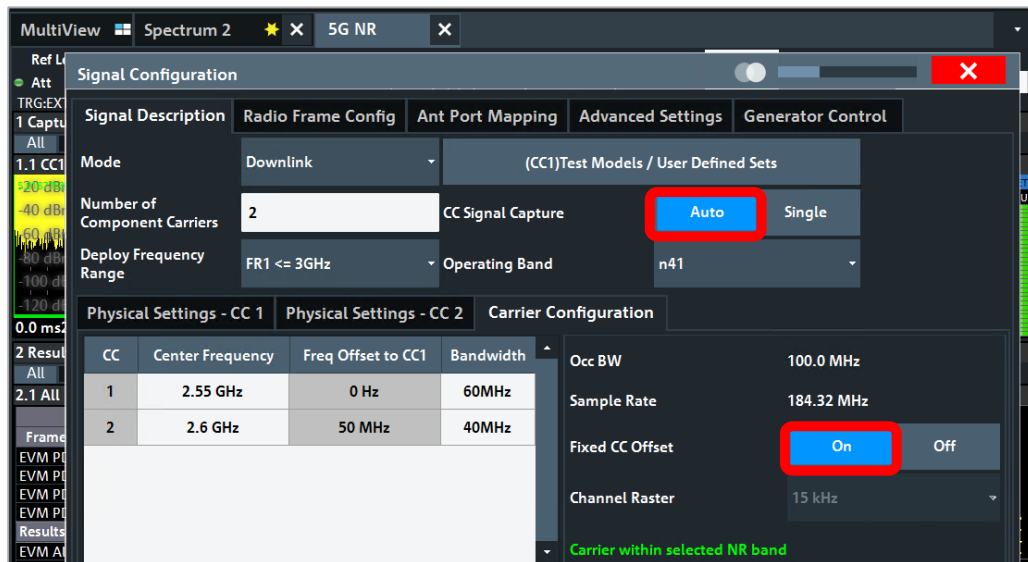
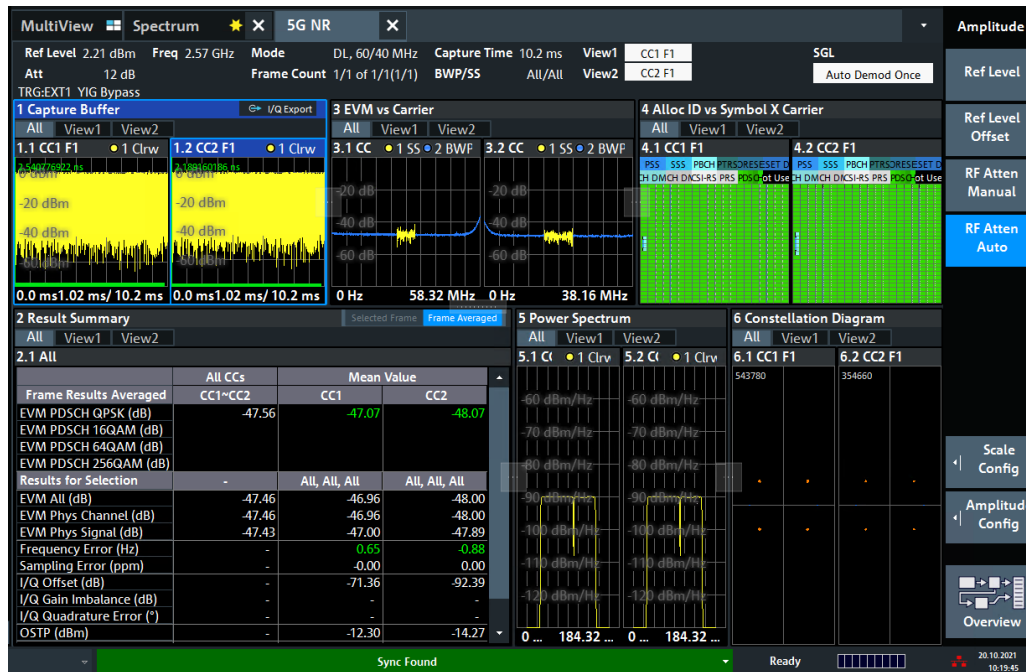
```
09:39:34,158 INFO : Uploading file to instrument...
09:39:36,653 WARNING: 200MHz was filter activated in Level Window (IQ analyzer) based on analysis bandwidth used in 5G option!
09:39:36,677 WARNING: Please deactivate (:TRAC:IQ:WFIL 0) if not requested!
09:39:36,722 INFO : Uploading file to instrument...
```

The setting can be confirmed in the *Level* window under "Data Acquisition":



5.6.2 MMO with 5G Component Carrier Signals

To enable the MMO tool to control the center frequency of all component carriers via a single `FREQ:CENT` command, only the `CC Signal Capture mode AUTO` and `Fixed CC Offset` set to `ON` is supported:



The SCPI command `FREQ:CENT` does set the center frequency of CC1 on the analyzer side in this mode. On the generator it sets the output center frequency.

To make sure, that the center frequency of CC1 of the generated signal is identical to the frequency set at the analyzer for CC1, the parameter `Δf to Output` has to be set to "0" for CC1 on the generator before creating the waveform.

In this case the frequencies at the analyzer and generator, which are set by the SCPI command `FREQ:CENT`, do line up nicely. Please see the next figure:

Signal Configuration

Signal Description

Radio Frame Config

Ant Port Mapping

Advanced Settings

Generator Control

Mode

Downlink

(CC1)Test Models / User Defined Sets

Number of Component Carriers

2

CC Signal Capture

Auto

Single

Deploy Frequency Range

FR1 <= 3GHz

Operating Band

n41

Physical Settings - CC 1

Physical Settings - CC 2

Carrier Configuration

CC	Center Frequency	Freq Offset to CC1	Bandwidth
1	2.55 GHz	0 Hz	60MHz
2	2.6 GHz	50 MHz	40MHz

Occ BW

100.0 MHz

Sample Rate

184.32 MHz

Fixed CC Offset

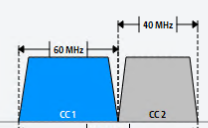
On

Off

Channel Raster

15 kHz

Carrier within selected NR band



10.102.72.193 Meiner (SMW200A-102830-MARTIN-B.0) - VNC Viewer

Frequency

2.550 000 000 000 GHz

RF On

Ext Ref

Lev DigAtt

Mod On

PEP

-7.99 dBm

Level

-20.00 dBm

5G New Radio A: Node Settings

Scheduling Manual

Carriers

TxBW Cell 0

LTE-CRS Coexistence Cell 0

SS/PBCH Cell 0

PRS Cell 0

Dummy RES Cell 0

Carrier Mapping

Number of Carriers

2

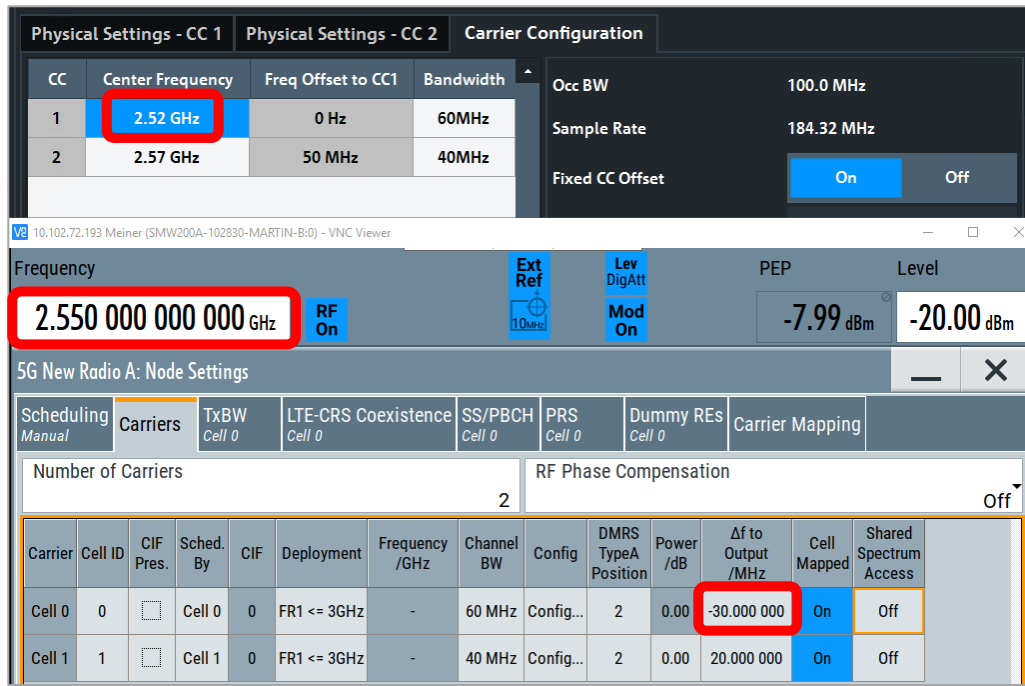
RF Phase Compensation

Off

Carrier	Cell ID	CIF Pres.	Sched. By	CIF	Deployment	Frequency /GHz	Channel BW	Config	DMRS TypeA Position	Power /dB	Δf to Output /MHz	Cell Mapped	Shared Spectrum Access
Cell 0	0	<input type="checkbox"/>	Cell 0	0	FR1 <= 3GHz	-	60 MHz	Config...	2	0.00	0.000 000	On	Off
Cell 1	1	<input type="checkbox"/>	Cell 1	0	FR1 <= 3GHz	-	40 MHz	Config...	2	0.00	50.000 000	On	Off

If the parameter Δf to Output has been set to a value not equal to 0, this value has to be compensated with a corresponding frequency offset in the Frequencies-Offset field of MMO:

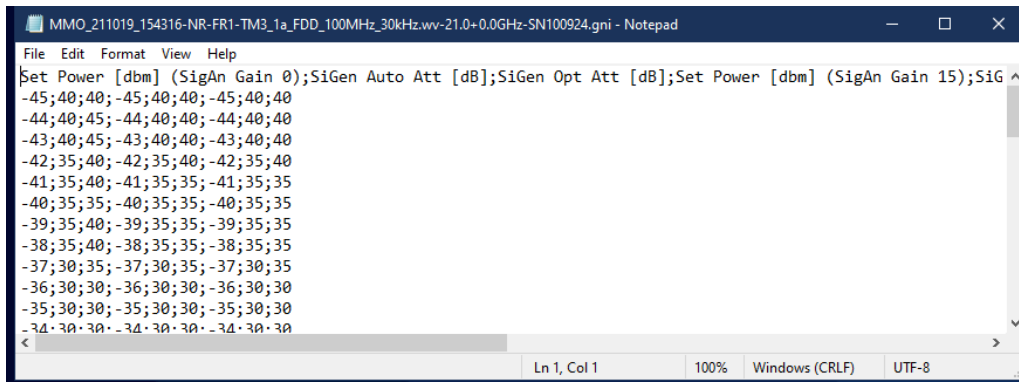
Frequencies	2.55	GHz	-30	MHz
Center frequency		GHz	Offset	MHz



As the MMO tool only runs with waveform files, a waveform has to be created out of the generators 5G application. The settings in this waveform with respect to the frequency of CC1 have to be known.

5.7 Using the Signal Generator Attenuation Characterization

Especially at frequencies above 20GHz, the resulting EVM traces can show an unexpected zigzagging. If this is the case, the optional `Calibrate generator attenuation` might be able to reduce this effect. If this flag is set, an additional step is executed during the characterization. The attenuator setting of the generator is optimized for each power level with respect to best EVM performance. The best attenuator values are stored in the *.gni file.

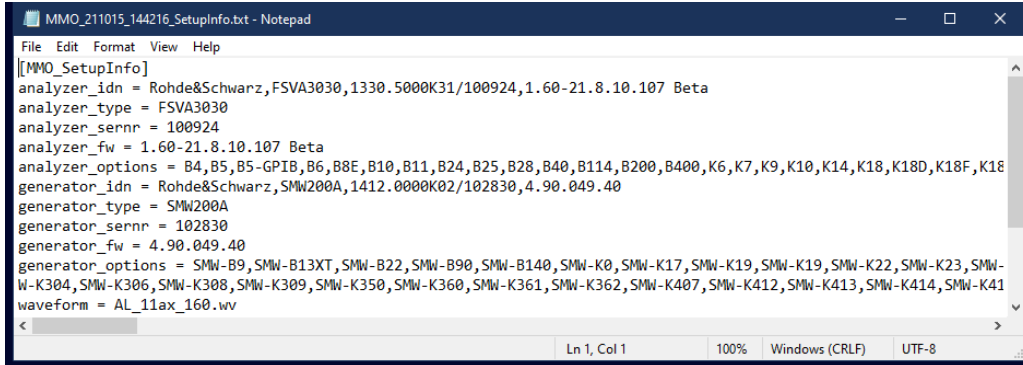


The attenuator values from this file are then used during the calibrated sweep to achieve a flatter EVM versus power trace.

This generator characterization is only used to reduce the effect of the attenuator switching in the generator during the residual EVM vs. Power sweep, which is executed in the MMO calibrated sweep. The additional generator characterization considerably increases the characterization time. These values are not used in the firmware functions of the analyzer or the MMO-Loader tool, as these only apply optimizations of the signal analyzer.

5.8 The MMO_SetupInfo File

For each MMO characterization, one `MMO_TimeStamp_INF_SetupInfo.txt` file is generated in the result folder:



```

[MMO_SetupInfo]
analyzer_idn = Rohde&Schwarz,FSVA3030,1330.5000K31/100924,1.60-21.8.10.107 Beta
analyzer_type = FSVA3030
analyzer_sernr = 100924
analyzer_fw = 1.60-21.8.10.107 Beta
analyzer_options = B4,B5,B5-GPIB,B6,B8E,B10,B11,B24,B25,B28,B40,B114,B200,B400,K6,K7,K9,K10,K14,K18,K18D,K18F,K18
generator_idn = Rohde&Schwarz,SMW200A,1412.0000K02/102830,4.90.049.40
generator_type = SMW200A
generator_sernr = 102830
generator_fw = 4.90.049.40
generator_options = SMW-B9,SMW-B13XT,SMW-B22,SMW-B90,SMW-B140,SMW-K0,SMW-K17,SMW-K19,SMW-K19,SMW-K22,SMW-K23,SMW-
W-K304,SMW-K306,SMW-K308,SMW-K309,SMW-K350,SMW-K360,SMW-K361,SMW-K362,SMW-K407,SMW-K412,SMW-K413,SMW-K414,SMW-K41
waveform = AL_11ax_160.wv
  
```

This file contains information about the hardware which was used for the specific test execution and also other details of the test. This file is for documentation only.

5.9 Using ACLR Instead of EVM as Parameter

As mentioned already, MMO can use every parameter - with an optimal value at its minimum - as a criterion for optimization. Instead of the typical EVM value, this can be e.g. the Adjacent Channel Leakage Ratio (ACLR).

The SCPI query (e.g.: `CALC:MARK:FUNC:POW:RES? ACP`) to read out the ACLR value, does not return a single value, but an array of values.

If a query replies an array of values, the **maximum** value of all array elements is used for further processing in MMO by default. Alternatively a specific index can be provided by the user in square brackets (e.g. `CALC:MARK:FUNC:POW:RES? ACP[2]`) to select a specific entry of the replied array.

The ACLR query also includes the channel power itself, this needs special handling inside the MMO code. If no specific array-index is provided by the user and the query command contains the string `' ? ACP '`, the first value of the returned array is automatically removed (this is the channel power), before processing the maximum value of the remaining elements as usual.

This handling of the ACP result array does not need any interaction of the user. But depending of the exact setup, some points have to be considered:

5.9.1 Using ACLR of a Standard Option e.g. 5G

The ACLR measurement is typically executed in the swept-spectrum mode of the analyzer. This involves very different hardware configurations compared to the IQ mode, which is used e.g. to calculate EVM values. Therefore, fast levelling in an IQ-window might not provide the correct optimal settings for the RF front-end in spectrum mode.

Due to this fact, ACLR as parameter is only supported for ACLR measurements set up in a spectrum channel. Please see the next chapter.

5.9.2 Using ACLR in a Spectrum Channel

When using the ACLR measurement in a normal spectrum channel, e.g. the following SCPI commands are used to read the required values:

SCPI Analyzer-Query Measurement	CALC:MARK:FUNC:POW:RES? ACP
SCPI Analyzer-Query Power	CALC:MARK:FUNC:POW:RES? CPOW

By default, the maximum value of the replied ACLR-array is used after removing the first element (TX power). Optionally an index can be added in square brackets to select a specific entry of the replied array of values:

SCPI Analyzer-Query Measurement	CALC:MARK:FUNC:POW:RES? ACP[1]
SCPI Analyzer-Query Power	CALC:MARK:FUNC:POW:RES? CPOW

The *Channel Power ACLR* measurement has to be set up correctly in the spectrum channel according to the applied signal. A *.dfl file has to be created in this status.

It might be needed to send the following SCPI command additionally to activate `clear-write` for the trace:

Additional signal analyzer SCPI	:DISP:WIND:SUBW:TRAC1:MODE WRIT
---------------------------------	---------------------------------

To get correct results for a sweep measurement, the levelling cannot be executed in the fast sweeping IQ window, but has to be done in a spectrum window as well. Optimizing ALRC in combination with MMO is therefore slow compared to an EVM-based MMO characterization. It is recommended to use noise-cancellation and the standard built-in auto-levelling for ACLR optimization.

6 Modulation Measurement Optimizer - Productive Phase

6.1 Autolevel - Loader

Once the MMO characterization is completed, the five key datapoints are stored in the *.ini file.

These *.ini files can be used to execute a fast and accurate auto-levelling on the analyzer, after a corresponding signal is applied at the right frequency with a random power level.

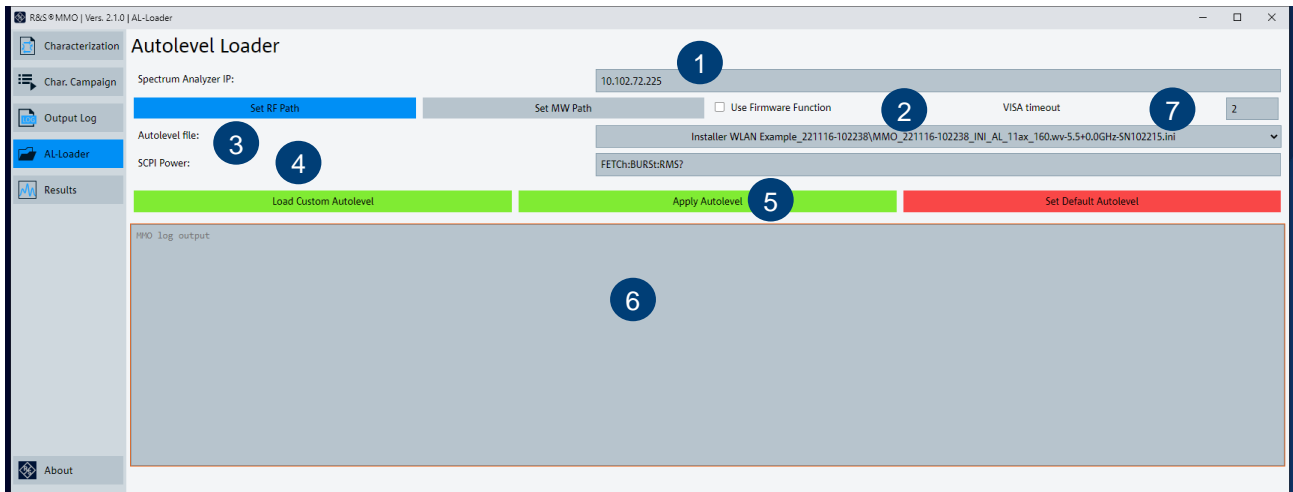
The MMO tool can execute this auto-levelling completely independent of the analyzer firmware. In this case the command to read the power value from the analyzer has to be provided in an equivalent way as for the characterization.

If the analyzer firmware supports MMO-based auto-levelling, the datapoints from an *.ini file can be used to parametrize the internal auto-level and the MMO based auto-levelling can be executed by the analyzer firmware independent from the MMO tool.

The *Use Firmware Function* flag determines, which approach is used.

Keep the flag un-checked as default to make sure, that the MMO tool can execute the MMO based auto-levelling independent from the specific analyzer firmware.

Switch to the AL-Loader tab of the MMO tool:



1: IP-address or domain name of the signal analyzer

2: Use Firmware Function:

- ▶ If not selected, the auto-levelling will be controlled directly by the MMO tool without using specific instrument firmware features. Use this as default setting.
- ▶ If the analyzer firmware supports MMO-based auto-levelling, the AL-Loader will upload the characterization values in the *.ini file to parametrize the firmware-based auto-levelling. The firmware can apply different characterization values in the RF- and the MW path, depending on the user's selection in the GUI.

3: Autolevel file: select the *.ini file which contains the characterization parameters to load

4: SCPI Power: command to query the measured power value (only needed if executed using firmware functions). If the query replies an array of values, the maximum value of all entries in the array is used for further processing by default. Alternatively, a single-digit index can be provided to select a specific entry of the array e.g. `FETCH:BURSt:RMS?[2]`. Array indices are 0-based.

5: Execute:

- ▶ Load Custom Autolevel: read the parameters from the selected *.ini file and activate the MMO based auto-levelling
- ▶ Apply Autolevel: Execute one auto-levelling - either default or MMO-based
- ▶ Set Default Autolevel: Deactivate the MMO based auto-levelling and activate the default auto-level of the analyzer firmware

6: Status output window

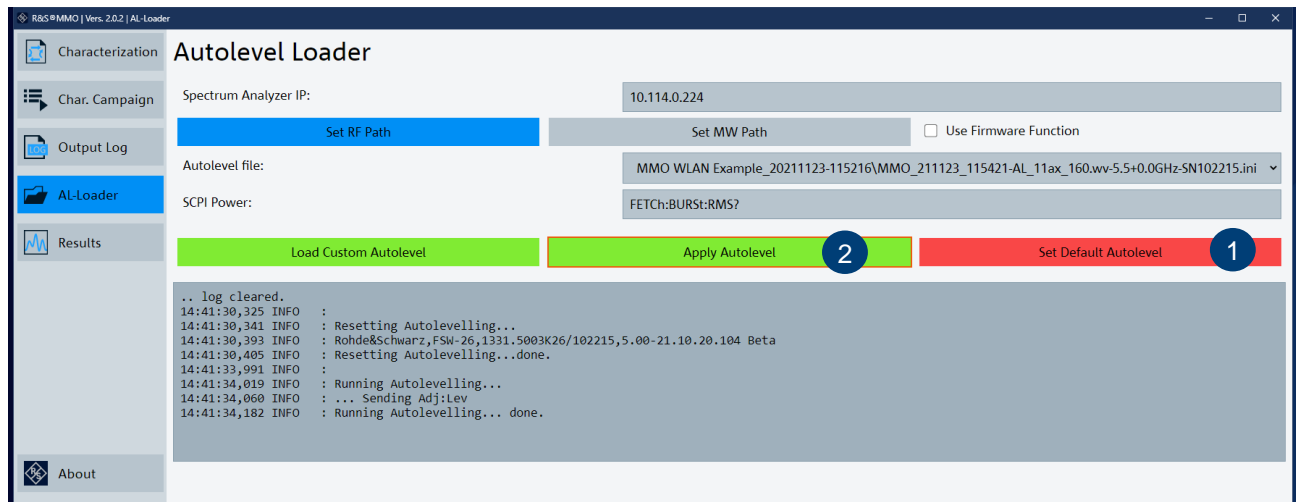
7: VISA timeout: default value is 2 seconds

6.2 Verifying the MMO Auto-Levelling

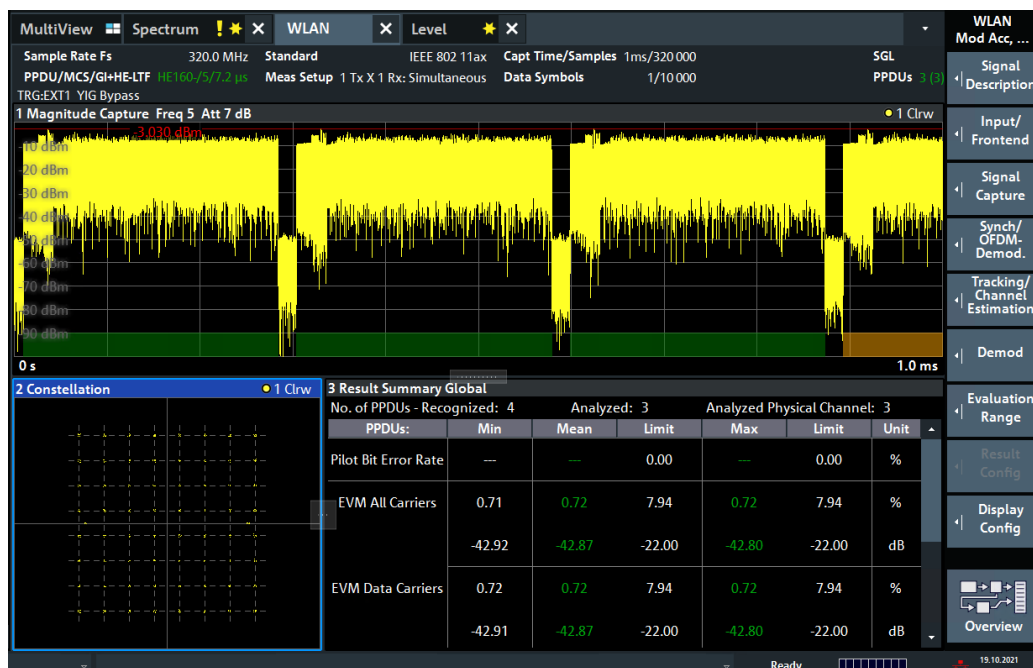
The following screenshots are taken from an example, where firmware functions are not supported by the analyzer firmware. Exactly the same applies for the case with available firmware functions.

Apply the waveform of interest with a random power level to the signal analyzer, e.g. -14dBm.

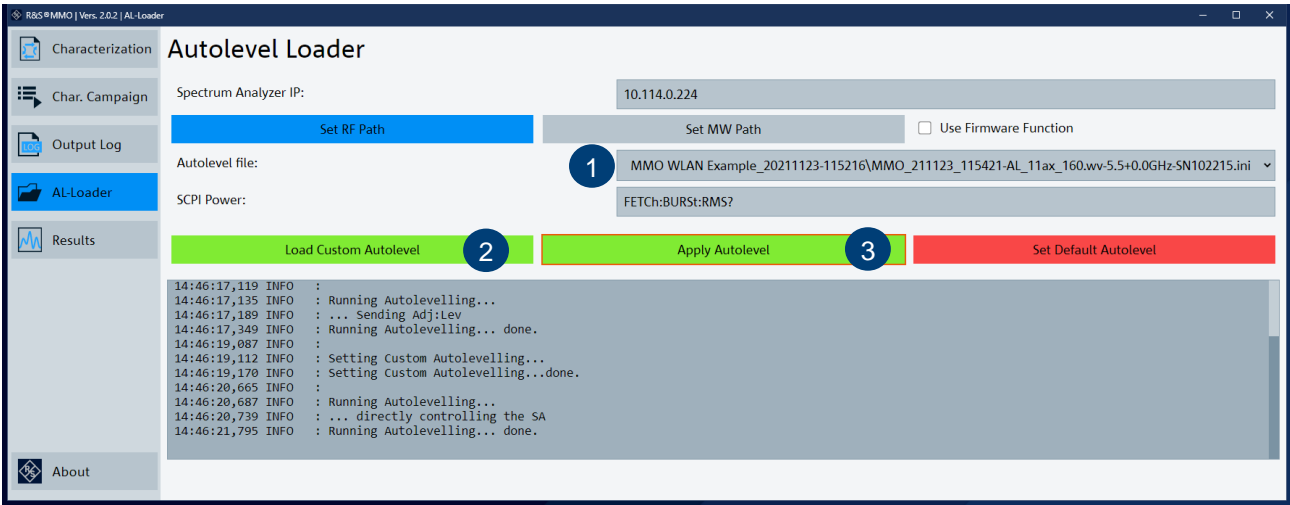
First execute the default, general auto-levelling:



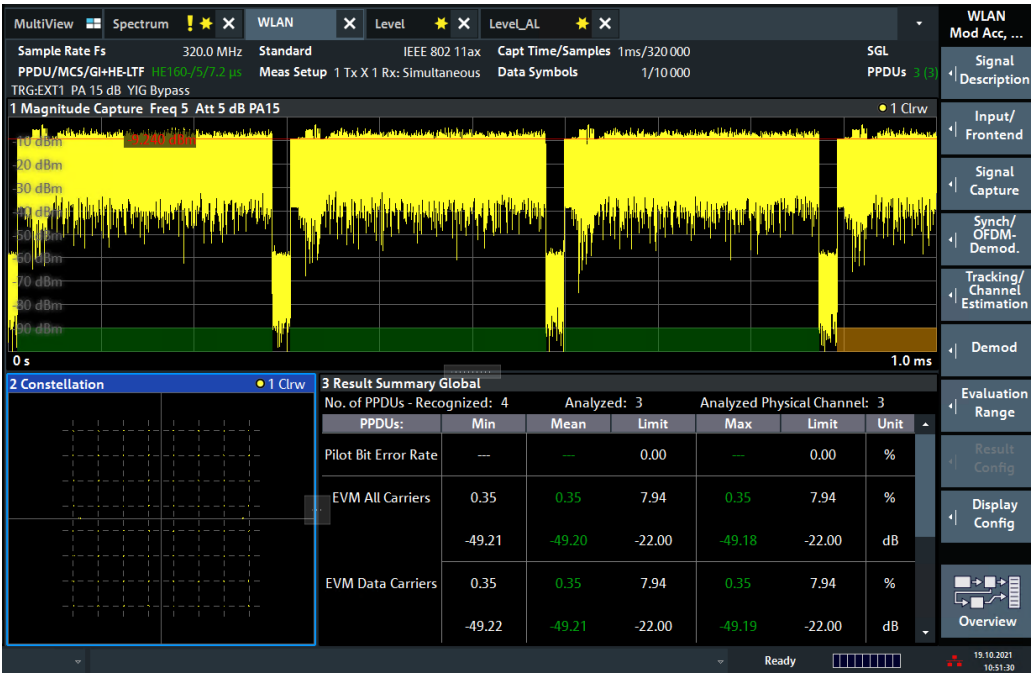
The result for the waveform used in this example should be similar to the following:



Next, load the optimized parameters found during the characterization by selecting the correct *.ini file, loading it, and running another auto-levelling:



Now the EVM value achieved with MMO-optimized auto-levelling is displayed:



7 MMO - Characterization Campaign

To MMO campaign manager helps to characterize a whole series of different waveforms and standards in one execution. It allows to step through a predefined list of MMO configurations and executes the characterizations one after the other:



The single characterizations have to be defined in an *Excel*-style csv-file, where one line represents one MMO configuration with all its parameters.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD		
1	MMO Campaign File:																															
2	fswip	smwip	waveform	pmin	pmax	sgchan	resetge	attcalge	freq	saconf	inisa	evruncals	evmscp	rmsscpi	iqswep	visatime	pausea	useserv	useexist	dpdonp	freqoffs	compar	modelfa	sascpi	sgscpi	visalogg	suppres	infilteo	refclkin			
3	10.102	10.102	AL_11a	-45	5	1	0	0	5.4	FSVA3\data\ca	1	FETCH	FETCH	3	3	0	0	0	20						0	0						
4	10.102	10.102	AL_11a	-45	5	1	0	0	5.5	FSVA3\data\ca	1	FETCH	FETCH	3	3	0	0	0	20						0	0						
5	10.102	10.102	AL_11a	-45	5	1	0	0	5.6	FSVA3\data\ca	1	FETCH	FETCH	3	3	0	0	0	20						0	0						
6																																

The first line needs to contain the string MMO Campaign File:

The columns must contain the parameters in the following order and with the following headers in line 2:

fswip, smwip, waveform, pmin, pmax, sgchannel, resetgenerator, attcalgenerator, freq, saconfigfile, inisavepath, runcalsweep, evmscpi, rmsscpi, iqsweep, visatimeout, pauseaftersetup, useservfunc, useexistini, dpdonpoint, freqoffset, compareal, modelflag, sascpi, sgscpi, visalogging, suppressupload, inifileto, refclkinvert

The content of one line corresponds to the content of one *.gin configuration file.

All result files are stored under the path provided in the inisavepath column.

8 Release Notes

Modified functionality

Version	Functions
2.1.0	All files created during one execution start with "MMO_TimeStamp_TYP_...", with TimeStamp being identical for all; timestamp format is YYYYMMDD-HHMMSS; the filetype is indicated by 3 letters being one of INF, INI, IPL, SWE, SPL, GNI
2.1.0	MMO_log.txt file moved from the "." to the ".\data\tmp" directory
2.1.0	An index can be provided optionally to the SCPI Analyzer Queries to request a specific index of array-type replies instead of automatically using the highest value in the array
2.1.0	ACLR as parameter: only supported in spectrum mode; the levelling for swept-spectrum mode measurements (SANALYZER) is done in spectrum mode now, which is slower but creates correct results
2.0.6	Result files are sorted according to the result folder timestamp, newest on top. Previously the listing was in reverse alphabetical order.
2.0.5	Initial Version

Improvements

Version	Improvements
2.1.0	Avoid Backend-Connection-Lost errors and generally improved time-out handling
2.1.0	Frequency added in the header of plots; mode flag added in *.ini file as comment
2.1.0	Availability of wv and dfl files is checked on input (highlighted red if not)
2.0.6	Fix of problem when using MMO in combination with the amplifier option of the analyzer.
2.0.6	Example configuration and result files are included.
2.0.6	Default values for Pmin (-45dBm) and Pmax (5dBm) are used if not entered by the user.
2.0.6	Entry for amplifier option added to the SCPI Analyzer-Query Power drop down list.
2.0.5	Initial Version

Known issues

Version	Known Issues
2.x	Pop-Up windows might show up behind the main GUI while MMO seems to be frozen.
2.x	MMO cannot be executed directly on an R&S®FSW, because the Internet Explorer is not supported by the Web-Framework.

9 Appendix

- A characterization is only valid for a specific frequency and a specific waveform/bandwidth on the specific instrument. The same characterization might be used for similar frequencies and waveforms, if a certain reduction in the optimization of the measurement is accepted.
- To allow the MMO tool to run all requested power sweeps, the setup must support stable and reproducible results over the whole range of power values.
- To speed up the characterization, make sure to optimize your measurement setup e.g. by using single-slot EVM measurements instead of full-frame EVM. This requires an external trigger for the analyzer that indicates the start of the frame.

10 Ordering Information

Designation	Type	Order No.
Signal and Spectrum Analyzer	R&S®FSW26	1331.5003.08
Signal and Spectrum Analyzer	R&S®FSVA3030	1330.5000.31
Vector Signal Generator	R&S®SMW200A	1412.0000.02

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