



Products: R&S® SMATE200A, R&S® AFQ100A

Speeding up production test with the R&S® SMATE200A

Application Note

Due to today's worldwide highly competitive communications market, achieving shorter product design cycles, quicker response to customer requests and high-volume product runs at low costs is vital for manufacturers of wireless devices and components. These requirements inevitably lead to demands for improving the throughput of Automated Test Equipment (ATE) by increasing its speed.

This application note describes in detail how the special features of the R&S® SMATE200A can be used to optimize speed and throughput in an automated test environment.



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1 Overview

Due to today's worldwide highly competitive communications market, achieving shorter product design cycles, quicker response to customer requests and high-volume product runs at low costs is vital for manufacturers of wireless devices and components. These requirements inevitably lead to demands for improving the throughput of Automated Test Equipment (ATE) by increasing its speed.

The R&S® SMATE200A was conceived primarily to address high volume test requirements. It provides frequency and level setting times of typically less than 1 ms. In List Mode/Fast Hop Mode frequency and level pairs have previously been stored in a list, resulting in frequency and level setting times down to 300 µs. The Multi-Segment Waveform Mode enables high speed switching between various test signals in just a few microseconds.

This Application Note describes in detail how the special features of the R&S® SMATE200A can be used to optimize speed and throughput in an automated test environment.

Section 2 describes how to optimize remote control via SCPI commands. Section 3 introduces multi-segment waveforms, and section 4 RF List Mode. Section 5 explains how both features can be combined.

Note:

- Except for Fast Hop Mode, the functionality and features described in this Application Note can also be provided by the R&S® SMU200A and the R&S® SMJ100A. As a dedicated production solution the specifications regarding setting times are better for the R&S® SMATE200A. The R&S® SMA100A also offers List Mode, including Fast Hop Mode.
- The following abbreviations are used throughout this Application Note:
 - SMATE for the Vector Signal Generator R&S® SMATE200A
 - AFQ for the I/Q Modulation Generator R&S® AFQ100A
 - FSP for the R&S® FSP7

2 Optimizing SCPI programming

In an ATE environment the instruments involved in testing are normally controlled remotely using SCPI commands. This is the most easy and flexible way of setting up a device.

Sending, parsing and processing the commands result in time overheads. To keep this overhead for the SMATE as small as possible and thus to avoid that it becomes a considerable factor in the overall test time observe the following rules.

- Use the shortest possible command notation. For example, for setting the level instead of writing
`'SOURce:POWer:LEVel:IMMEDIATE:AMPLitude <value>'`
write
`'SOUR:POW:LEV:IMM:AMPL <value>'`.
Upper-case and lower-case notation serves to distinguish between the long and the short form (the instrument itself does not distinguish between upper-case and lower-case spelling).
Another possibility to save some microseconds is to leave out optional key words marked by square brackets in the manual:
`[SOURce:]POWer[:LEVel][:IMMEDIATE][:AMPLitude].`

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The command above can be shortened to just `'POW <value>'`.

- Send multiple commands in one command line if appropriate, for example when frequency and level both need to be changed. Several commands in one command line must be separated by a semicolon, for example `'FREQ <value>; POW <value>'`. The semicolon must be followed by a colon, if the next command belongs to a different command system. The colon marks the root of the command tree. Example: `'SOURce:FREQuency <value>; :OUTPut:STATe ON'`. The first command sets the RF frequency and belongs to the SOURce system. The second command switches the RF output on and is part of the OUTPut system. The command line can be abbreviated if successive commands have one or several levels in common. In this case the next command after the semicolon starts with the first differing level, omitting the colon. For instance, both commands in the line `'SOUR:FM:MODE NORM; :SOUR:FM:EXT:COUP DC'` belong to the SOURce system and the FM subsystem. So, the command line can be abbreviated to `'SOUR:FM:MODE NORM; EXT:COUP DC'` which saves some microseconds in parsing and processing the command line. For more information about the command tree structure and command syntax please refer to the instrument manual [1].
- For connecting the PC with the signal generator to be remote controlled, GPIB is preferable to LAN. GPIB is faster and better suited for fast transfer of simple SCPI commands, due to fewer overheads and significantly lower latency. (To transfer large amounts of data, LAN offers better performance because of its higher data transfer rate.)
- Switching off the GUI update with `'SYST:DISP:UPD OFF'` increases setting speed.
- Reduce the number of programming steps. For example reduce the number of times the signal generator changes states to the minimum. This is especially important for state transitions that take a long time, for example loading waveforms or resetting the instrument. If possible reset the signal generator once at the beginning of the programming sequence and then order the following tests in a way that only minimum changes are needed between two consecutive tests. Consider the following very simple example: ACLR and CCDF need to be measured each for three different waveforms. The less favourable approach is to loop through the waveforms twice, measuring ACLR the first time and CCDF the second time. This results in six time-consuming waveform loading operations. Even if the SMATE's Multi-Segment Waveform Mode is used, which extremely reduces waveform switchover time (see section 3) compared to loading the waveforms separately per SCPI commands, the second approach is preferable. This is, of course, looping through the waveforms once and measuring ACLR and CCDF consecutively for one waveform before changing to the other waveform. Only three generator state changes are needed now.
- Organize nested loops placing the fastest operation in the innermost loop and the slowest operation in the outermost loop. As to speed, this leads to the best overall result because the innermost and fastest operation is executed the most number of times. For example to test the performance of a DUT using different signals at several frequencies each, the waveform changes should be programed in the

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outer loop and the frequency changes in the inner loop. This results in the least number of time-consuming waveform changes and more simple and faster frequency changes.

However, for such a setup, a better meaning faster, alternative than programming nested loops of SCPI commands is using an externally triggered combination of Multi-Segment Waveform Mode and RF List Mode, see section 5.

- After sending a command to the signal generator, for instance to change frequency or waveform, the measurement on the DUT can not be started immediately because the signal generator needs some time to settle. Consequently it is common practice to insert a delay, i.e. a wait statement, into the controlling software. In most cases such delays are too long and thus have unnecessarily large negative impact on the system throughput. Instead of inserting delays the following can be done:
 - Use the operation complete command (**OPC?*).
**OPC?* returns a "1" to the controlling software after all previous commands have been executed and the instrument hardware has been set and has settled.
For time-consuming operations, for example loading a long ARB file you can avoid blocking the GPIB bus due to **OPC?* by polling the SETTING bit of the STATus:OPERation register with '*STATus:OPERation:CONDition?*' The SETTING bit is reset as soon as the new signal is settled.
 - To avoid long waiting times due to **OPC?*, group the commands into logical units and state one **OPC?* after a whole unit instead of after each command. For example changing frequency and level using the following command sequence:
FREQ <value>
POW <value>
**OPC?*
takes barely half the time of the following sequence:
FREQ <value>
**OPC?*
POW <value>
**OPC?*
 - Use trigger signals generated by the instrument when it is settled. For example, with RF List Mode the blank signal can be used to trigger the start of the next measurement. This signal marks the time the RF output of the signal generator is blanked while the signal generator settles to the new frequency and level. In the application example of section 5 the SMATE blank signal is fed into the EXT TRIG connector of the spectrum analyzer to trigger the next channel power measurement (see figure 9).

Additionally, SMATE includes features that help improve throughput in an ATE environment, because they are less time-consuming than SCPI commands. This features, Multi-Segment Waveform Mode and RF List Mode, are especially advantageous if frequency, level and waveform states needed for testing are known in advance.

3 Multi-Segment Waveforms

In many cases testing requires multiple test signals, for example measuring the distortion of amplifiers, or checking all standards implemented in one single mobile radio chip.

Even with short signals, loading a waveform can take some seconds. The longer the waveform the more time the loading operation needs. So, changing between different signals by loading them separately can easily become a major bottle-neck for ATE throughput. To avoid this, the Multi-Segment Waveform Mode of the SMATE enables high speed operation by providing rapid switching between different test signals. A multi-segment waveform combines up to 100 completely independent waveforms with their own marker and clock settings in one single waveform file that is loaded in its entirety into the ARB memory. Switching between different waveform segments does not result in delays due to loading operations any more.

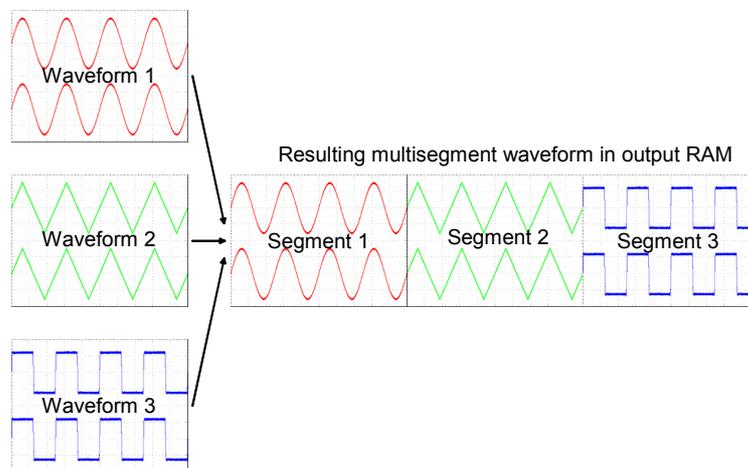


Fig. 1: Combination of waveforms to a multi-segment waveform

Create multi-segment waveforms in the “Multi-Segment...” menu (see figure 12) which is accessed via the “ARB...” main menu. After selecting the waveforms to form the different segments, adapt the “Clock” and “Level” settings as required.

The level of the single segments can be left “Unchanged”, meaning as originally defined. In which case the “Level” display only applies to the segment with the highest RMS value. Segments with lower levels will be output at a lower level than that displayed. To play back all segments with the same RMS value select the level mode “Equal RMS”.

The “Clock” mode can be set to “Unchanged” (each segment is played back with the sample rate originally defined), “Highest” (all segments are output at the highest available sample rate) or “User” (all segments are output at the sample rate specified in “User Clock”).

Although in principle the waveform segments can have different sample rates, some settings, for example externally triggering the transition between segments, require a common sample rate for all segments within the waveform. Resample different sample rates to one common sample rate by recalling the waveform setting file into the “Multi-Segment...” menu, changing the “Clock” setting from “Unchanged” to “Highest” or “User” and recalculating the multi-segment waveform.

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The segment currently being played back can be output once or continuously depending on the trigger settings. Switching between segments must be dedicatedly initiated per user interface, remote control or external trigger line. (The Multi-Segment Waveform Mode of the AFQ supports automatic sequencing of the waveform segments initiated by only one start trigger, see section “Multi-Segment Waveform Mode with the R&S® AFQ100A”).

For an automated test and production environment there are three typical applications for multi-segment waveforms:

- High speed switchovers
- Flexible dynamic switchovers (per remote control or via Fast Hop Mode)
- Switchovers without signal interruption

These applications are described below.

High speed switchovers

External hardware triggering results in very fast switchover between consecutive waveform segments. With each trigger event the current segment is stopped, and the next segment is output after a system imposed signal gap (see figure 2). After the last segment the next trigger event causes the first segment to be output again.

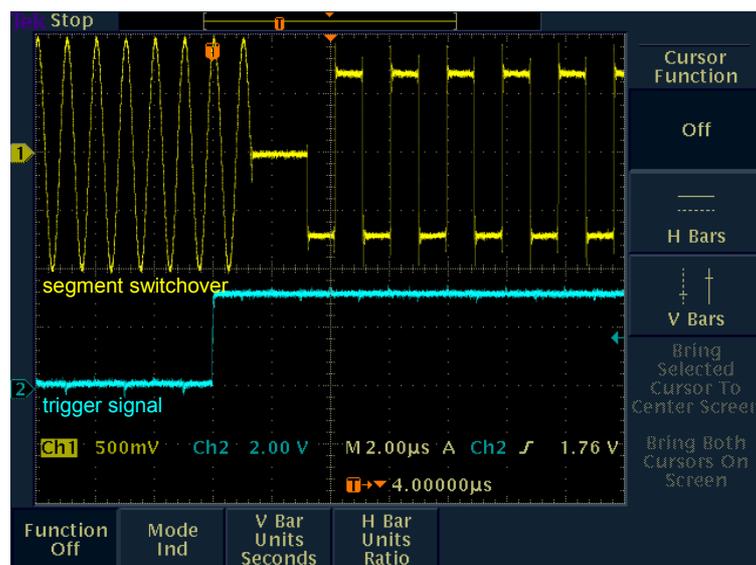


Fig. 2: Changeover between two segments of a multi-segment waveform

The necessary SMATE settings for this operating mode are:

Extended Trigger Mode = Next Segment

Trigger Mode = Auto

Trigger Source = External Trigger 1 or 2

The external trigger signal is fed into TRIGGER 1 or TRIGGER 2 (pin 26 or 27 of the Digital I/O interface on the SMATE rear panel).

This mode of operation requires a common sample rate for all waveform segments.

The gap between two successive segments, i.e. the time the device's output is blanked, depends on the segments' common sample rate. In the example in figure 2 with a sample rate of 100 MHz the gap is only 2.20 µs. A sample rate

Multi-Segment Waveforms

of 500 Hz however, results in a blank time of over 100 ms. For really high speed switchover choose a sample rate as high as possible.

The overall switching time consists of the blank time and an additional delay between trigger event and blank time. A worst case estimation for the overall switching time can be obtained with following formula:

$$\text{switching time} = 3.01 \mu\text{s} + 84/(\text{sample clock rate})$$

Flexible dynamic switchovers

It may be necessary to select the test signal depending on the outcome of the previous measurement. For this use case more flexibility is needed than just consecutively running through a predefined sequence of signals. This can be achieved by either switching per remote control or by using Fast Hop Mode¹.

- **Switchover per remote control**

Use the SCPI command
`'SOUR:BB:ARB:WSEG:NEXT 'segment'`
to switch to the desired segment, achieving transition times of typically less than 1.2 ms for segments with the same sample rate. This switching time applies for high enough sample rates, for instance 5 MHz. For lower sample rates or for segments having different sample rates the changeover time increases.

The necessary instrument settings are:

Extended Trigger Mode = Next Segment

Trigger Mode = Auto

Trigger Source = Internal

- **Fast Hop Mode**

Faster switching is possible using either Fast Hop Mode or Fast Hop Direct. In both cases, the next waveform segment to be played back is determined by external control signals supplied on the serial FHOP bus of the Digital I/O interface at the rear of the instrument.

The only difference between Fast Hop and Fast Hop Direct is:

In Fast Hop Direct the changeover between old and new segment takes place immediately after data transmission on the FHOP bus ends. In Fast Hop Mode an additional external trigger signal is needed to initiate changeover after data transmission on the FHOP bus ends.

The segment switching times are the same as with external triggering. It will take at worst ($3.01 \mu\text{s} + 84/(\text{sample clock rate})$) until the new segment is output after data transmission ends in Fast Hop Direct or after an external trigger occurs in Fast Hop Mode. But additional time is needed for transmission on the FHOP bus before changeover starts.

The FHOP bus not only controls multi-segment waveform changeover but also step transition in RF List Mode, so that RF List Mode and Multi-Segment Waveform Mode can be combined easily and flexibly. Figure 3 shows the input control signals on the serial FHOP bus.

¹ The SMATE Fast Hop functionality for multi-segment waveform switchover will be available in Q2 2007. At the moment the Fast Hop Mode is only available for RF lists.

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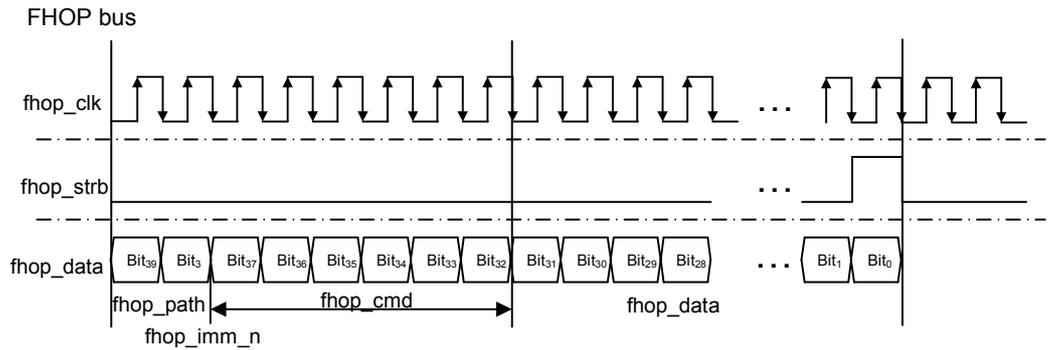


Fig. 3: FHOP bus of the Digital I/O interface

The maximum clock rate for the FHOP bus is 30 MHz.

A valid data sequence on the bus consists of 40 bits. Transmission starts with the most significant bit (MSB) and ends with the least significant bit (LSB) which is marked by a strobe. The meaning of the particular bits of the data line is shown in the table below.

Data bit name (bit number)	Function
path (39)	Selects RF path and/or BB path: 0 = RF path A and/or BB path A; 1 = RF path B and/or BB path B;
imm_n (38)	Selects Fast Hop Mode: 0 = Fast Hop Direct (the selected settings are performed at once after data transfer of a complete sequence (40 bits) without additional triggering) 1 = Fast Hop (the selected settings are performed after an instrument trigger)
cmd (37 to 32)	Selects function for Fast Hop Mode. There are three operation modes: <ol style="list-style-type: none"> 1. Multi-Segment Waveform Mode only The address (data signal) is only used for the Multi-Segment Waveform Mode Bit 32 must be set to 0 Bit 33 must be set to 1 (= Multi-Segment Waveform Mode) Bit 37 to 34 must be set to 0 (= reserved for future extensions) 2. List Mode only The address (data signal) is only used for List Mode Bit 32 must be set to 1 (= List Mode) Bit 33 must be set to 0 Bit 37 to 34 must be set to 0 (= reserved for future extensions) 3. List Mode and Multi-Segment Waveform Mode The address (data signal) is used for List Mode and Multi-Segment Waveform Mode Bit 32 must be set to 1 (= List Mode) Bit 33 must be set to 1 (= Multi-Segment Waveform Mode) Bit 37 to 34 must be set to 0 (= reserved for future extensions)
data (31 to 0)	Data bits Determine the waveform segment index to be processed in Multi-Segment Waveform Mode and/or the list index (frequency/level setting) to be processed for List Mode <ol style="list-style-type: none"> 1. Multi-Segment Waveform Mode only Bit 0 to 31 determine the segment index (Multi-Segment Waveform Mode)

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	<p>2. List Mode only Bit 0 to 31 determine the RF list index (frequency/level pair)</p> <p>3. List Mode and Multi-Segment Waveform Mode Bit 0 to 15 determine the RF list index (frequency/level pair) Bit 16 to 31 determine the segment index (Multi-Segment Waveform Mode)</p>
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Table 1: Function of data bits of FHOP bus

Examples:

The bit sequence 0100-0010-0000-0000-0000-0000-0000-0000-1010 (Bit₃₉ ... Bit₀) on the data line selects segment index 10 for Multi-Segment Waveform Mode on baseband path A in Fast Hop Mode. That is, the changeover to the waveform segment associated with index 10 is performed after the next trigger event.

The bit sequence 0000-0011-0000-0000-0001-0010-0000-0000-0111-1101 (Bit₃₉ ... Bit₀) selects Multi-Segment Waveform Mode together with List Mode on path A in Fast Hop Direct. Once the transmission of the 40 bits is completed, waveform segment 18 and list step 125 will be selected.

Switchovers without signal interruption

Set “Extended Trigger Mode” to “Next Segment Seamless” if no signal interruptions shall occur when switching between segments, for example for testing receivers. (This mode is only available for segments with the same sample rate.)

This causes the new segment to be output after a complete output (wrap around) of the current segment, the length of which consequently determines the necessary switching time.

Switchover can be done by external trigger signal (as shown in figure 4) or via remote control.

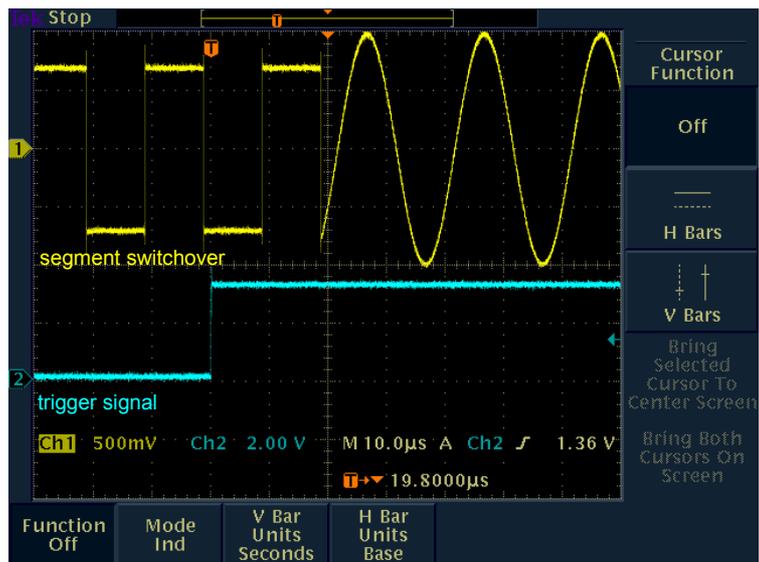


Fig. 4: Seamless changeover between two segments of a multi-segment waveform

Multi-Segment Waveforms

Multi-Segment Waveform Mode with the R&S® AFQ100A

The AFQ is an I/Q modulation generator designed to support development and production tests for a variety of rapidly evolving digital standards. It offers large memory, large bandwidth, outstanding signal quality and variable digital and analog outputs to directly operate the DUT.

The Multi-Segment Waveform Mode of the AFQ offers some advantages compared to the SMATE:

Instead of 100 different waveform segments the AFQ supports up to 2048 different segments. Furthermore, sample rates can go up to 300 MHz (100 MHz with the SMATE) and I/Q bandwidths up to 100 MHz (40 MHz with the SMATE).

Figure 5 shows another important advantage of the AFQ for very time-critical applications. The changeover between two segments of the same multi-segment waveform played back at the same ARB clock rate in the SMATE and in the AFQ is shown.

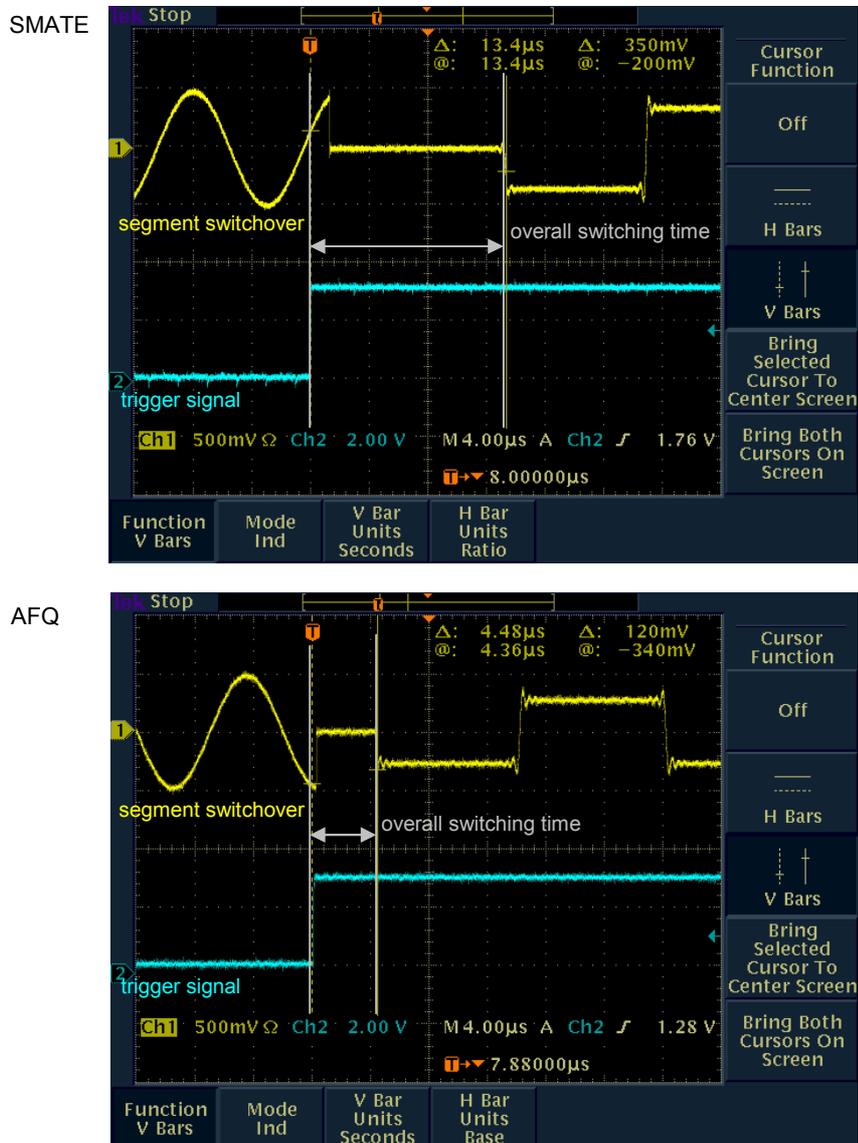


Fig. 5: Comparison of segment changeover between SMATE and AFQ with a sample rate of 5 MHz

Multi-Segment Waveforms

In evidence, the blank time between old and new segment after an external trigger event is much shorter with the AFQ than with the SMATE. Furthermore, the delay between trigger and blank time is also shorter with an AFQ.

The higher the segments' sample rate the smaller the reduction of blank time with an AFQ compared to a SMATE. The segments shown in figure 5 have a sample rate of 5 MHz. With a sample rate of 100 MHz the blank time of the two instruments barely differs. But the delay between trigger event and blank time is independent of the sample rate, so the overall transition time between segments is still shorter with the AFQ even with very high sample rates.

A worst case estimation for the AFQ overall switching time can be given with:

$$\text{switching time} = 2.68 \mu\text{s} + 13/(\text{sample clock rate})$$

As with the SMATE, changeover between segments can be triggered by an external trigger signal (incrementing the segments' indices automatically or using the FHOP bus²) or by remote control. The external trigger signal is fed in via the "NEXT" connector on the rear of the instrument. If needed, the AFQ allows seamless changeover between segments. With segment trigger mode set to "Continuous Seamless" a trigger event switches to the next segment only after finishing the current one.

Unlike the SMATE, the AFQ has no Fast Hop Direct, so segment transition in Fast Hop Mode always requires an external trigger signal. The AFQ is a pure baseband source, so Fast Hop Mode only controls multi-segment waveform changeover. Hence, although the timing diagram is the same (see figure 3), the meaning of the 40 data bits is slightly different compared to the SMATE.

Data bit name (bit number)	Function
Bit 39 to 10	Bits must be set to 0
data (9 to 0)	Data bits Determine the segment index to be processed for multi-segment waveforms

Table 2: Function of data bits of FHOP bus for AFQ

Data and control signals are fed in at the BERT BNC connectors at the rear of the instrument

BERT CLOCK: fhop_clk
BERT DATA: fhop_data
BERT DATA ENABLE: fhop_strb

Additionally to this FHOP Serial Mode, the AFQ also offers FHOP Parallel Mode. Here, a signal is fed in parallel as binary digit via the BERT BNC connectors and loaded as segment index at the occurrence of a trigger event.

BERT DATA ENABLE: bit 0 (LSB)
BERT RESTART: bit 1
BERT DATA: bit 2
BERT CLOCK: bit 3 (MSB)

Up to 16 segments can be addressed in this case.

² The AFQ FHOP Mode is available from firmware version 2.04.176 and baseboard version ≥ 5

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As an advantage compared to FHOP Serial, in Parallel Mode transmission time on the bus does not add to the switching time. The disadvantage is the reduced number of segments that can be addressed.

The AFQ supports all multi-segment waveform operating modes of the SMATE. Additionally, it also supports automatic sequencing of the waveform segments initiated by only one start trigger. The trigger signal starts the first segment. After playing back the first segment once, the second segment is started automatically and without any signal interruption. After playing the second segment back once the third segment is started and so on. This loop can be output either once or continuously depending on the settings.

The following figure shows the settings that need to be made in the AFQ "Trigger..." menu for externally triggering a continuous automatic loop through the waveform segments.

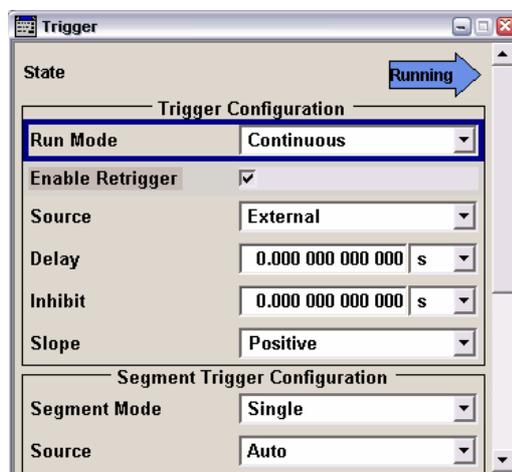


Fig. 6: AFQ "Trigger..." menu for automatic segment sequencing

Multi-segment waveforms for the AFQ can be created with the external PC software WinIQSIM2. The ARB menu of WinIQSIM2 is the same as for the SMATE, so the user will be familiar with it.

After creating a waveform it can be transferred to the AFQ via GPIB, LAN or USB. To upconvert the signal from baseband to RF, connect the I and Q outputs at the front panel of the AFQ to the I IN A and Q IN A (or I IN B and Q IN B) at the rear panel of the SMATE and switch "Internal Baseband I/Q In" to "Analog Wideband I/Q In". This can be done in the "I/Q Mod" block of the corresponding RF path.

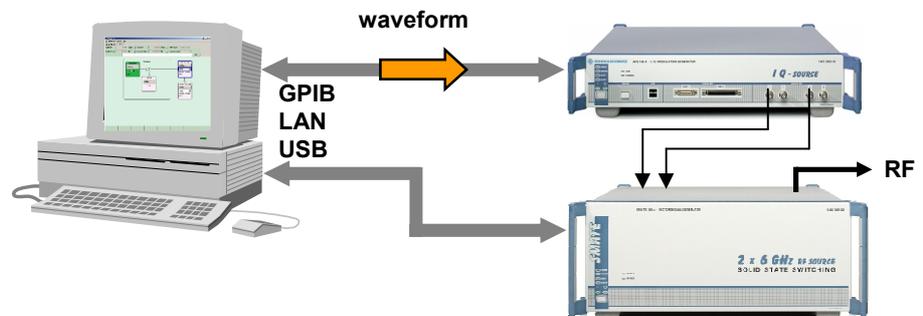


Fig. 7: Uploading a WinIQSIM2 waveform to the SMATE via the AFQ

4 List Mode

For fast switching between multiple frequencies and/or power levels, List Mode offers frequency and level setting times of typically only 300 μ s.

In List Mode up to 10,000 freely selectable frequency and level pairs, whose values can cover the whole range of the instrument, are stored in a list. A dwell time between the different points can be specified. When processing the list for the first time it needs to be learned by calculating necessary hardware settings. These calculations are done either by pressing the “Learn List Mode Data” button or in the initial cycle through the list. The data determined during the learning process is stored along with the list and available whenever the list is used again. Recalculation is necessary each time the list or the corresponding hardware settings are modified.

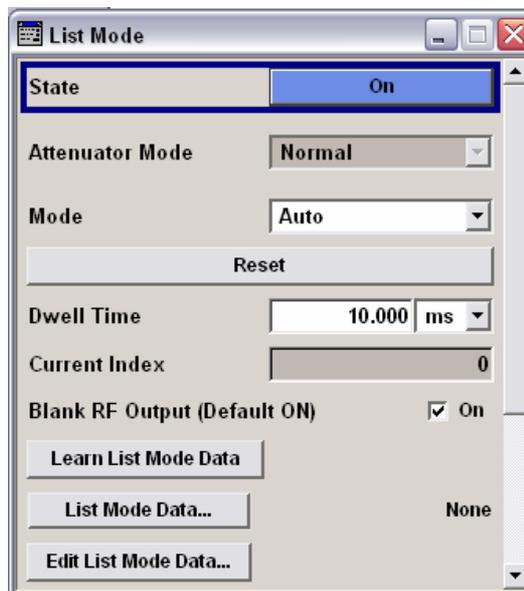


Fig. 8: List Mode menu

If external triggering is used the trigger signal is input at the rear of the instrument. For path A use pin INST TRIG A on the Digital I/O interface, for path B pin INST TRIG B on the AUX/IO interface.

The following modes are available:

- **Auto**
The list loops from the beginning to the end with automatic restart at the first list entry. The duration of a list step is determined by the specified dwell time.
- **Single**
The list is run through once from the beginning to the end. Start the cycle either by remote control or via the user interface by pressing “Execute Single”. The given dwell time determines the duration of one list step.
- **Extern Single**
As with mode “Single” but started by an external trigger.
- **Step**
This mode provides step-by-step processing of the list by setting the “Current Index” in the user interface. As no SCPI command is available for changing the list index this mode is of no use in an automated test environment.

Application example

- **Extern Step**

Step-by-step cycle through the list using an external trigger signal where each trigger event starts a single step. The time between two list steps is determined by the time between two trigger events. The given dwell time is ignored.

For more flexibility than a consecutive scroll through the list can provide (for example if the next frequency and level setting depends on the result of the current measurement), use Fast Hop Mode or Fast Hop Direct.

- **Fast Hop**

This mode enables hopping from one freely selectable frequency/level pair, i.e. list index, to the next. The new list index is determined by external control signals supplied on the serial FHOP bus of the Digital I/O interface at the instrument's rear panel. The actual changeover between old and new list step is initiated by an external trigger signal. The duration of one list step is determined by the time between two trigger events.

- **Fast Hop Direct**

As Fast Hop Mode, except that changeover to frequency and level associated with the selected index is started immediately after data transmission ends whereas in Fast Hop Mode external triggering is needed.

Figure 3 shows the timing diagram on the FHOP bus and Table 1 explains the function of the data bits.

5 Application example

In many cases it may be required to switch waveform along with frequency and level. Frequency, level and waveform can be set independently of each other per remote control. This is extremely time-consuming, especially if many changes are needed for each DUT. So, the better way is to combine Multi-Segment Waveform Mode with List Mode.

The FHOP bus provides the most flexibility. RF list index and waveform segment index can be selected freely and independently of each other. The disadvantage is the time it takes to transmit the information about the next indices over the bus. This time adds to the switching time. The FHOP bus needs to be controlled, too, which leads to some further programming effort.

Therefore, if frequency, level and waveform states and transition order are initially known it is advisable to automatically step through waveform segments and RF list simultaneously using an external signal to trigger switchover. The multi-segment waveform settings needed for this purpose are those described in "High speed switchovers" on page 7. For the RF list use "Extern Step" mode. One waveform segment corresponds to one frequency/level pair of the RF list. That means that both lists need to be the same length.

Frequency and level setting time in List Mode is typically 300 μ s whereas the complete changeover time between two waveform segments is less than 15 μ s for high segment sample rates, such as 5 MHz. Consequently, when the new frequency/level pair is settled the ARB already outputs the new waveform segment.

That means the SMATE allows frequency, level and waveform switching in typically only 300 μ s.

The following example shows how to combine Multi-Segment Waveform Mode and List Mode to measure the channel power of various CDMA based digital cellular phone standards.

Application example

Prior to the test, an adequate waveform must be created for each standard. These single waveforms are combined in one multi-segment waveform. As transition between segments is to be triggered by an external signal the segments need to have a common clock rate. Therefore, when creating the multi-segment waveform “Highest” is selected as Clock mode. “Equal RMS” is selected as Level mode. The frequency and level values that correspond to the waveform segments are stored in an RF list.

Figure 9 shows the measurement setup.

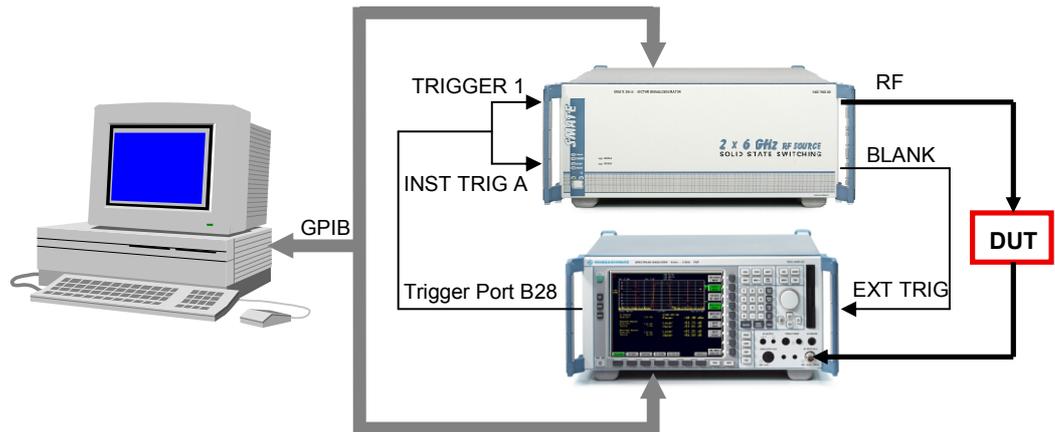


Fig. 9: Combination of Multi-Segment Waveform Mode and RF List Mode

The spectrum analyzer used for this example is a R&S® FSP7 with trigger port installed (B28).

To minimise the overall measurement time use the “List Mode” (SENSe:LIST subsystem) of the spectrum analyzer. Power is measured at a predefined list of frequency points with an individual set of reference levels, attenuator settings, bandwidth settings and measurement times. The measurement is always performed in time domain (span = 0 Hz). Beside from level measurements over frequency the FSP List Mode also supports quick channel and adjacent channel power measurements in time domain (Fast ACP). The FSP provides filters that are precisely tailored for this purpose.

For programming “List Mode” on the analyzer two commands are necessary:

1. `'SENSe:LIST:POWer:SET <PEAK meas>,<RMS meas>,<AVG meas>,<trigger mode>,<trigger slope>,<trigger offset>,<gate length>'`:

This command defines the constant settings for the list during multiple power measurements. The parameters `<PEAK meas>`, `<RMS meas>` and `<AVG meas>` define which measurements are to be performed at the same time at one frequency point. 'ON' activates the corresponding measurement, 'OFF' deactivates it. Accordingly, the FSP outputs one, two or three results per frequency point.

2. `'SENSe:LIST:POWer? <analyzer freq>,<ref level>,<rf att>,<el att>,<filter type>,<rbw>,<vbw>,<meas time>,<trigger level>,...'`:

This command specifies the individual settings for each list point (frequency, reference level, attenuation, electronic attenuation, filter type, resolution and video bandwidth, measurement time and trigger level) and queries the result. The length of the resulting list is dependent on the number of points and the number of measurements (peak, rms, avg) per point.

Application example

Two parameters are particularly important for our purpose:

- *<filter type>*: There are three possible filter types:
 - NORMal: This is the normal, gaussian shaped filter. It is used for level measurements over frequency and can also be used for GSM/EDGE channel power measurements in time domain.
 - CFILter: This is a special steep-edged filter used for Fast ACP measurements. It ensures band-limiting of a transmission channel in time domain.
 - RRC: The Root Raised Cosine filter is used for channel power measurements for some mobile radio standards
- *<meas time>*: Our goal is to maximize throughput reducing the overall test time. Nevertheless, the measurement time should not be too short, otherwise accuracy and repeatability are sacrificed.

For more information about the analyzer's List Mode and channel power measurements please see [5], [6] and [8].

To obtain valid measurements it is essential the wanted signal is present at the RF input of the analyzer when a measurement is started. However, no time should be wasted with delays added in the controlling software which in most cases are only guess work and inevitably too long. The best solution is to use the signal generator's blank signal to trigger a measurement. The blank signal marks the time when the RF output is blanked while the signal generator settles to the new frequency and level. (The SMATE's ARB already outputs the new waveform segment when the new RF list step is settled). The blank signal is output at pin 39 of the SMATE's AUX I/O interface. It's polarity can be set to either positive or negative. If positive is selected (default), the signal is high during the setting time. In which case the signal's negative slope is used to trigger the analyzer.

When the spectrum analyzer has finished the current channel power measurement and has settled to its next list point, the signal generator needs to be triggered to switch to the next waveform segment and to the corresponding RF list step. For this purpose the FSP's trigger port is used. It supplies a signal that indicates the instrument's readiness to collect measured data. This signal is reset on detection of the next trigger signal meant to start a new measurement [5]. The trigger port signal is fed into TRIGGER 1 (pin 26 of the Digital I/O interface at the rear panel of the SMATE) for waveform segment switchover and at the same time into INST TRIG A (pin 32 of the Digital I/O interface) for hopping to the next frequency/level pair.

When the signal generator has settled again, the blank signal initiates the next channel power measurement at the analyzer and so on. After the last measurement the analyzer returns the measurement results to the controlling PC.

Application example

The following table shows the SCPI commands for the entire procedure.

Device	Command	Remark
FSP	*RST	Reset. Sets the FSP to a defined state.
SMATE	*RST	Reset. Sets the SMATE to a defined state.
FSP	SYST:DISP:UPD off	Switches off the update of the FSP display to increase speed.
	INIT:CONT OFF	The trigger system is not initiated continuously but performs single measurements.
	SENS:LIST:POW:SET OFF,ON,OFF,EXT,neg,0,0	Defines the constant settings for the analyzer list [6]
SMATE	SYST:DISP:UPD OFF	Switches off the update of the SMATE GUI ³ to increase speed.
	SOUR:BB:ARB:WAV:SEL 'filename'	Selects the multi-segment waveform.
	SOUR:BB:ARB:TRIG:SOUR EXT	Sets the trigger source to external.
	SOUR:BB:ARB:STAT ON	Switches on the ARB => First waveform segment is output.
	OUTP ON	Switches on the RF output.
	SOUR:LIST:SEL 'filename'	Selects the RF list.
	SOUR:LIST:MODE STEP	Selects Step Mode for List Mode.
	SOUR:LIST:TRIG:SOUR EXT	Sets the trigger source to external.
	SOUR:LIST:LEARN	Learns the selected list. It is important that the ARB is already switched on when learning the list, otherwise the baseband settings will not be observed when switching on the list.
	OUTP:USER1:SOUR ABL	The Blank signal of path A is routed to USER 1 (pin 31 of the Digital I/O interface).
	SOUR:FREQ:MODE LIST	Switches on the RF list => First frequency/level pair is output.
FSP	SENS:LIST:POW? %list%	Configures the list of frequencies and corresponding settings and starts the sequence. %list% is the placeholder for the list.

Table 3: Command sequence

³ The SMATE has no built-in display, but the GUI can be seen by connecting to the instrument via Remote Desktop, or connecting an external monitor to the instrument.

Application example

The timing relation of the setup looks as follows:

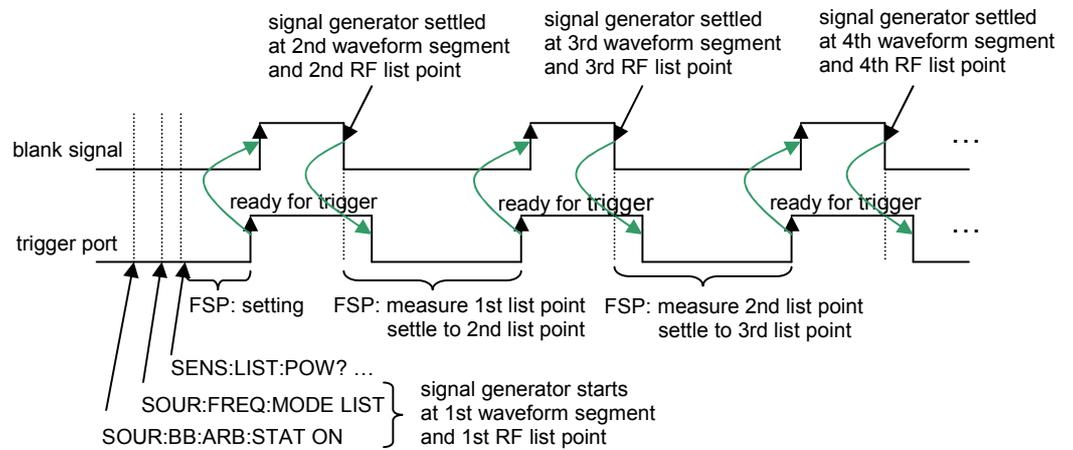


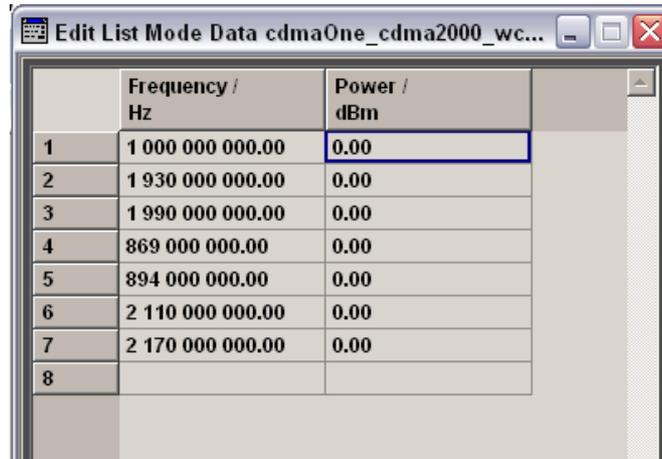
Fig. 10: Timing diagram

The automated channel power measurements are started with 'SENS:LIST:POW?'. The signal generator outputs the first waveform segment and the first frequency/level pair. After 'SENS:LIST:POW?' the FSP settles to the first point of its list. After settling, the trigger port outputs a signal indicating the analyzer's readiness for being triggered to start the first measurement. The positive slope of the trigger port initiates segment and frequency/level switchover at the signal generator. The negative slope of the blank signal indicates that the second waveform segment as well as the second frequency/level pair is settled, so the FSP can measure its first list point. That means the first waveform segment and the first frequency/level pair of the RF list just contain dummy data needed to activate the measurement mechanism. The first channel power measurement is done at the first analyzer list point and at the second generator segment/frequency and level setting.

In this example the channel power of downlink cdmaOne, CDMA2000® and WCDMA signals is measured at the band limits of the corresponding frequency bands. For cdmaOne the DL band 1930 MHz to 1990 MHz is used, so the first frequency to be measured is $f_1 = 1930$ MHz, the second is $f_2 = 1990$ MHz. For CDMA2000® the DL frequency band 869 MHz to 894 MHz is chosen, so $f_1 = 869$ MHz and $f_2 = 894$ MHz. For WCDMA $f_1 = 2110$ MHz and $f_2 = 2170$ MHz for the DL frequency band of 2110 MHz to 2170 MHz. The level for all measurements is set to 0 dBm.

The following figure shows the SMATE's RF list.

Application example

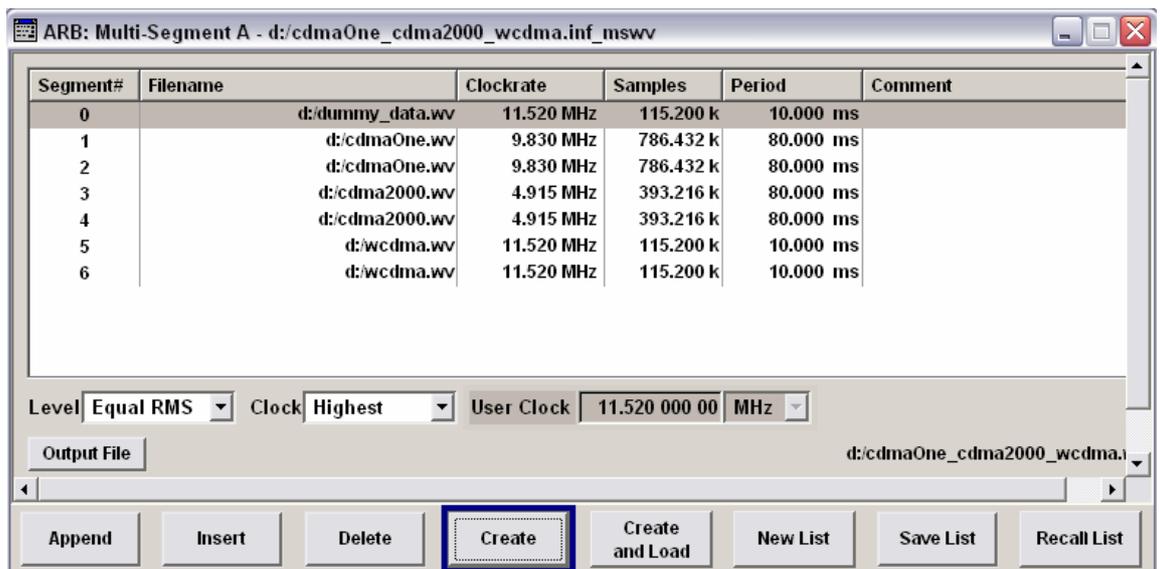


	Frequency / Hz	Power / dBm
1	1 000 000 000.00	0.00
2	1 930 000 000.00	0.00
3	1 990 000 000.00	0.00
4	869 000 000.00	0.00
5	894 000 000.00	0.00
6	2 110 000 000.00	0.00
7	2 170 000 000.00	0.00
8		

Fig. 11: SMATE RF list

Note that the first entry of the list is a dummy frequency/level pair needed to activate the automated measurement mechanism (see above).

The following figure shows the multi-segment waveform corresponding to the RF list.



Segment#	Filename	Clockrate	Samples	Period	Comment
0	d:/dummy_data.wv	11.520 MHz	115.200 k	10.000 ms	
1	d:/cdmaOne.wv	9.830 MHz	786.432 k	80.000 ms	
2	d:/cdmaOne.wv	9.830 MHz	786.432 k	80.000 ms	
3	d:/cdma2000.wv	4.915 MHz	393.216 k	80.000 ms	
4	d:/cdma2000.wv	4.915 MHz	393.216 k	80.000 ms	
5	d:/wcdma.wv	11.520 MHz	115.200 k	10.000 ms	
6	d:/wcdma.wv	11.520 MHz	115.200 k	10.000 ms	

Level: Equal RMS | Clock: Highest | User Clock: 11.520 000 00 MHz

Output File: d:/cdmaOne_cdma2000_wcdma.i

Buttons: Append, Insert, Delete, **Create**, Create and Load, New List, Save List, Recall List

Fig. 12: SMATE Multi-Segment Waveform Mode

The first entry of the multi-segment waveform is also a dummy waveform. Because RF list step and waveform segment are switched simultaneously the multi-segment waveform contains the same cdmaOne, CDMA2000® and WCDMA segments twice. This does not result in additional testing time because frequency/level setting in List Mode takes longer than waveform segment switchover.

Summary

Accordingly, the %list% placeholder for the 'SENS:LIST:POW?' command in table 3 is:

```
1930MHz,12dBm,20dB,Off,CFIL,1.2288MHz,10MHz,2.5ms,0,  
1990MHz,12dBm,20dB,Off,CFIL,1.2288MHz,10MHz,2.5ms,0,  
869MHz,12dBm,20dB,Off,CFIL,1.2288MHz,10MHz,2.5ms,0,  
894MHz,12dBm,20dB,Off,CFIL,1.2288MHz,10MHz,2.5ms,0,  
2110MHz,12dBm,20dB,Off,RRC,3.84MHz,10MHz,2.0ms,0,  
2170MHz,12dBm,20dB,Off,RRC,3.84MHz,10MHz,2.0ms,0
```

Without the instrument resets (*RST) the overall sequence of table 3 takes 395 ms in average, 88 ms for the FSP and 307 ms for the SMATE.

The six channel power measurements, which are initiated by just the last command line of table 3 in average take only 66 ms.

6 Summary

The key requirement for an automated test and production environment is increasing throughput to keep costs down and accelerate time to market.

Beside of optimizing the software controlling the test runs, choosing the right equipment is a very crucial factor.

Both, the R&S® SMATE200A and the R&S® AFQ100A are best suited to fulfil these requirements:

The SMATE offers very high setting speed and some special features that help to further increase switching times:

- Multi-segment waveforms enable rapid alternation between different test signals in a few microseconds.
- RF List Mode and Fast Hop Mode were designed for very fast and flexible switching between multiple frequencies and/or power levels.

Combining Multi-Segment Waveform Mode and RF List Mode, the SMATE provides simultaneous switching of waveform, frequency and level in typically only 300 µs.

The baseband I/Q generator AFQ also offers Multi-Segment Waveform Mode which provides switching times even faster than the SMATE.

7 Literature

- [1] R&S® SMATE200A Operating Manual
- [2] R&S® SMATE200A Specifications
- [3] R&S® AFQ100A Operating Manual
- [4] R&S® AFQ100A Specifications
- [5] R&S® FSP3/7/13/30/31/40 Operating Manual Volume 1
- [6] R&S® FSP3/7/13/30/31/40 Operating Manual Volume 2
- [7] Simulation Software R&S® WinIQSIM2™ Specifications
- [8] Application Note 1MA65: “Fast and Accurate Test of Mobile Phone Boards”
- [9] Application Note 1EF41: “Measurement of Adjacent Channel Leakage Power on 3GPP W-CDMA Signals with the FSP”

8 Additional Information

This Application Note is updated from time to time. Please visit the website www.rohde-schwarz.com/appnotes/1GP63 in order to download the newest version.

9 Ordering information

R&S® SMATE200A	Vector Signal Generator	1400.7005.02
R&S® SMATE-B103	RF path A 100 kHz to 3 GHz	1401.1000.02
R&S® SMATE-B106	RF path A 100 kHz to 6 GHz	1401.1200.02
R&S® SMATE-B203	RF path B 100 kHz to 3 GHz	1401.1400.02
R&S® SMATE-B206	RF path B 100 kHz to 6 GHz	1401.1600.02
R&S® SMATE-B9	ARB with 128 Msamples	1404.7500.02
R&S® SMATE-B10	ARB with 64 Msamples	1401.2707.02
R&S® SMATE-B11	ARB with 16 Msamples	1401.2807.02
R&S® SMATE-B13	Baseband Main Module	1401.2907.02
R&S® AFQ100A	I/Q Modulation Generator	1401.3003.02
R&S® AFQ-B10	ARB with 256 Msamples	1401.5106.02
R&S® AFQ-B11	ARB with 1Gsamples	1401.5206.02
R&S® FSP	Spectrum Analyzer	
R&S® FSP7	9 kHz to 7 GHz	1164.4391.07
R&S® FSP-B28	Trigger Port	1162.9915.02

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