Speeding up Spectrum Analyzer Measurements

Application Note

Products:

- R&S®FPS
- R&S®FSW
- R&S®FSV
- R&S®SGT100A
- R&S®SMW200A
- R&S®SMBV100A

Test time is a critical parameter when it comes to evaluating the cost of test.

This application note describes typical spectrum analyzer measurements in production environments and discusses different approaches to speed them up.

Application Note

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ROHDE&SCHWARZ

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1 Introduction

This application note focuses on measurement speed, especially for RF tests involving signal and spectrum analyzers.

Test time is a critical parameter. In some applications more than in others, but generally, there is no argument against a faster measurement, as long as it provides the same result. There are of course plenty of arguments for faster measurements, cost of test being the most important one.

Depending on who you talk to, various numbers are being discussed when it comes to quantifying cost of test. In RF testing, 100 ms in test time reduction can save several million US dollars per year.

Test time is at first given by the amount of tests specified for a certain product. This application note does not focus on reducing the number of tests, since this approach requires in depth knowledge of device under test (DUT).

Test time reduction for a given amount of tests has limitations as well: a production test environment must make sure that all produced parts are equal to within a certain tolerance. This imposes the requirement of repeatability on test instruments. A good repeatability ensures that the test results from two identical DUTs are equal to within a given value.

Repeatability imposes a natural limit in test time reduction. As a consequence, test time numbers do not make sense without specifying the corresponding repeatability.

2 Measurement Scenarios

2.1 Production Scenarios

The production test team typically selects a subset of the characterization tests based on the detailed knowledge of critical parameters to guarantee that all parts fulfill a given specification. Product and test engineers must interact closely to define the optimum test coverage.

A main contributor for the total cost of the production test is the achievable test throughput or the test cost per second. Equipment that is more expensive may lead to significantly lower test time and thus lower cost of test. In addition, aspects like stability over time, calibration intervals, accuracy, and MTBF (down times) strongly affect the total cost. Finally, the index time of the available handlers has to be carefully considered to optimize the overall solution.

As each second of test time directly adds to the production cost of the DUT, test time directly influences the margin and therefore your profit.

So in short, the target is to cut down the test plan to an acceptable minimum. Once the test plan is defined, the remaining tests are optimized in order to reach the shortest test time possible.

As an example, let us look into testing a power amplifier for mobile devices (PA). RF measurements are typically performed on a number of frequencies (often 3 per band), different power levels and if applicable with different test signals (i.e. different standards like LTE and WCDMA).

The most important boundary condition for the production test is repeatability. So almost anything that saves test time may be considered as long as repeatability stays within the given limit. A typical measure is shortening the test signal. In this case the signal is no longer a standard signal (e.g. LTE), but it can still be used for certain measurements, e.g. ACLR measurements.

Absolute accuracy on a production test system is usually reached through golden samples and correlation with the known values of these golden samples. These golden samples, are also used to verify a production tester's performance on a regular basis, e.g. once a day.

2.2 Design Verification Scenarios

The test approach for design verification tests (DVT) is somewhat different from production test. Instead of testing as many DUTs as possible in a given time, only a few samples are tested very extensively. The test coverage is by far larger than in production and results are typically tested not only versus frequency, power, and waveform, but also versus any parameter that might affect the test results. These typically include temperature, load match, and specific configuration parameters of the DUT, e.g. supply voltage.

During design verification, the design engineers have to verify that the product fulfills all required specification under all applicable boundary conditions. In addition, the worst-case conditions have to be identified.

Characterization test must be performed over a larger number of samples and over several production lots to obtain statistically valid data. Ideally, the production test capabilities are established in parallel with the product development and in close cooperation between test and product engineers. This includes design-for-test concepts where testing needs are taken into account from the very beginning of the development cycle.

DVT also requires a test system to be highly accurate, since there are no reference test results, which could be used for focused calibration or correction.

3 Speeding up Measurements

3.1 General Considerations

Before addressing specific measurements, we will address general considerations for best practice on remote control in this section.

Synchronization

In remote control, it is important to use single sweep mode. Single sweep mode performs a single measurement only, whereas in continuous mode the instrument is continuously measuring and updating results. In single sweep mode, it is essential to make sure that the current measurement has finished and results are valid. This process (making sure the previous action, e.g. the measurement, was completed) is called synchronization. In order to synchronize a result query to the end of a measurement, the command `*WAI` is recommended. Metacode for such a query with synchronization looks like the following sequence:

```
ActivateSingleSweep        (INIT:CONT OFF)
TransmitSettings()         'Send all measurement settings
MakeMeasurementAndSync     (INIT:IMM;*WAI)
QueryResult                (CALC:MARK:Y?)
```

For more information on how the different synchronization methods work in detail, the application note 1EF62 is recommended.

Result Displays

Another general hint for remote control is to switch off the displays of the instruments. Switching off the display saves processing time, since there is no processing power needed for the display and its update. The advantage of the display update off mode compared to the display update on mode can be a factor of 4 or even higher. Note that even instruments without a physical display (like the R&S FPS) may perform the display update computation, since they can feed external displays.

The default configuration of all R&S instruments is display update off. When in remote control mode, the display can be switched on or off using a softkey on the instrument or the following command:

```
SYST:DISP:UPD OFF | ON
```

Physical Connection of Instruments

The physical connection between the control PC and the instruments can make a significant difference. The GPIB bus used to be an industry standard with a low latency time. Since the GPIB bus is more than 30 years old, it can no longer compete with modern LAN connections, especially when it comes to transmission throughput. However, LAN connections are not primarily designed for instrument control so a few rules can make the difference between a fast and a slow connection.

Protocol: A protocol is basically something like a language, so it defines the rules on how commands are physically transferred. The standard protocol for LAN connections is still VXI-11, even though newer protocols are much faster. If your instrument supports the so called HiSLIP (High Speed LAN Instrumentation Protocol) protocol, choose HiSLIP. Both protocols, VXI-11 and HiSLIP are easy to use and emulate most features of the GPIB bus.

If you know exactly on how to set up so called socket connections, you might even go for raw socket connections, since they are slightly faster than HiSLIP. As a drawback, raw socket connections lack all the comfort features, such as timeouts, attributes that come with VXI-11 or HiSLIP.

Physical Architecture: Decisions on the physical architecture of your remote control network are straight forward. Make sure you are using the highest standard supported by PC and instrument (e.g. Gigabit components for cables and switches instead of Megabit components). In addition, avoid all traffic on the network that is not needed for instrument control, i.e. have only PC and the required instruments connected to the network switch.

Data Reduction: When it comes to transferring large amounts of data, such as I/Q data, make sure you are using a binary format instead of ASCII format. This easily speeds up data transfer by more than a factor of five, since one pair of I/Q data corresponds to 8 bytes in binary transfer mode, but more than 40 bytes in ASCII mode. In addition, most instruments provide commands to extract only the required samples instead of the full capture buffer. The metacode below explicitly sets binary transfer mode and queries only a subset of all available I/Q samples, here samples 100 to 299, i.e. 200 samples starting from sample 100, instead of the full capture buffer:

```
FORM REAL,32

TRAC:IQ:DATA:MEM? 100,200
```

In order to minimize the amount of data, it is also essential, to reduce the sampling rate to the acceptable minimum. All resampling is handled in real-time internally on dedicated hardware, so it does not affect the measurement time. All measurement personalities within the instrument firmware calculate results (e.g. an EVM value) using optimized signal processing algorithms. As a result, data transfer from a measurement personality can be reduced to a few values instead of large amounts of unprocessed I/Q data.

Avoid Firmware Interrupts: Each single command that reaches the instrument causes an interrupt to the measurement firmware and starts a process to "digest" the remote control command. The number of these interrupts can be significantly reduced if consecutive commands are packaged and transferred in one single string.

So instead of sending "`INIT:IMM;*WAI`" and "`CALC:MARK:Y?`" to start a measurement, synchronize, and query the marker value, transmit "`INIT:IMM;*WAI;:CALC:MARK:Y?`" in a single string. A semicolon separates commands. Note that a colon is required for all but the first command. The colon forces the command parser to restart its search at the beginning of the command tree. The colon can be omitted if a command shares the same command tree with its predecessor. The following examples are equivalent and make use of 3 commands, two of them with identical command trees:

Example 1 uses colons and the full command tree for each command.

```
:SENS:SWE:TIME 1ms;:SENS:SWE:POIN 2001;:BAND:VID 100kHz
```

Example 2 uses colons only where necessary and abbreviates the command tree where possible.

```
SENS:SWE:TIME 1ms;POIN 2001;:BAND:VID 100kHz
```

Use Instruments in Parallel

Most test setups consist of more than one measurement instrument. Let us assume a PA test setup consisting of a spectrum analyzer, a signal generator, and a source measurement unit SMU, i.e. DC supply with current measurement capabilities.

The easy approach now is to set up each instrument individually and sequentially, i.e. configure DC voltage first, then set frequency, power level, and waveform on the generator, and finally tune the analyzer's frequency and reference level. This process can easily take 10 ms. A faster approach is to parallelize these three processes, since there is no interaction required. As a result, the configuration only takes as long as the longest process takes. The cost for this parallelization is a little bit of one-time programming effort.

Parallelization can also be used for measurements. A single measurement channel can only measure one signal at a time, but in the previous example we have a spectrum analyzer that performs RF measurements, and a DC supply that measures current flow into the DUT. These two measurements are independent and can therefore be parallelized.

Fig. 3-1 and Fig. 3-2 compare sequential and parallel configuration and measurement using exemplary durations. In the example below, a total test time reduction of more than 50% can be realized by using parallelization.

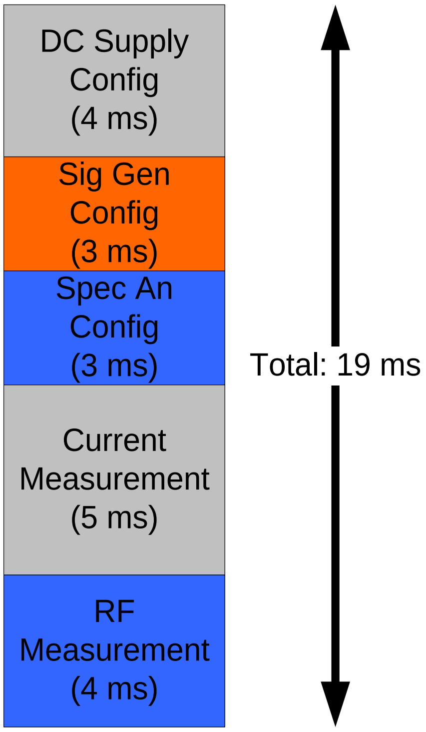

Fig. 3-1: Sequential configuration and measurement. No additional effort required to synchronize. Long total duration.

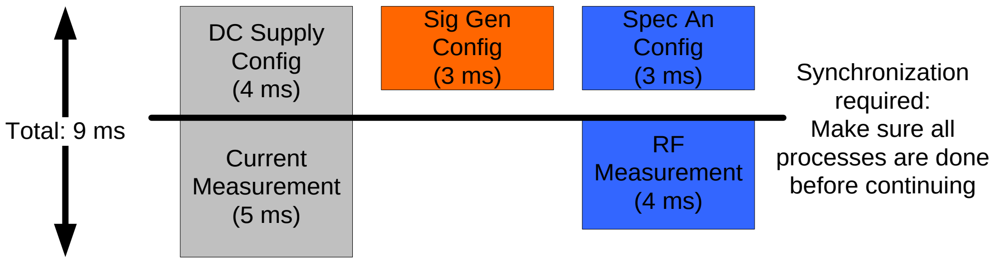

Fig. 3-2: Parallel configuration, all configurations are parallelized. Parallelization of measurements where applicable. Synchronization of configuration processes required before measurement start. Test time saving >50%

3.2 Spectral Measurements

Typical spectral measurements are harmonics and ACLR measurements. Moreover, modern spectrum analyzer can perform power measurements faster than a power sensor. Therefore, it makes sense to perform power measurements (e.g. the initial power servoing) on the spectrum analyzer. For all these measurements we typically need to do some sort of averaging, in order to obtain the required repeatability.

FFT and Sweep Mode on Spectrum Analyzers

Modern signal and spectrum analyzers provide the traditional sweep mode, as well as a so called FFT mode. In sweep mode, the LO is swept over the desired input frequency span. In FFT mode, the instrument captures multiple FFTs and concatenates them until the selected frequency span is covered. Clearly, the number of captures depends on the capture width, i.e. bandwidth of the instrument.

In sweep mode, the minimum sweep time is proportional to $\frac{SPAN}{RBW^2}$, whereas in FFT mode, the computing time is proportional to $\ln\left(\frac{SPAN}{RBW}\right) \cdot \frac{SPAN}{RBW}$. Therefore, the FFT mode shows a significant speed advantage for large span - RBW ratios.

Modern instruments decide on their own whether FFT or Sweep mode is faster, based on the selected span and RBW. This mode is called Auto. The display will show either "Auto Sweep" or "Auto FFT", depending on what the instrument is currently using.

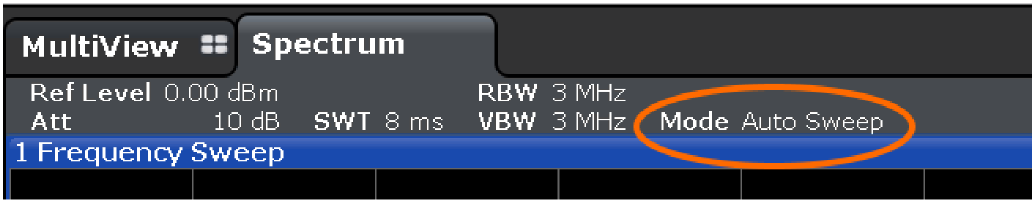

Fig. 3-3: Instrument title bar with "Auto Sweep" mode indication

As a general rule of thumb, the default sweep mode Auto is the ideal choice, as long as the sweep time setting has not been changed manually.

As soon as you increase the sweep time manually, e.g. to average a measurement using the RMS detector (see also next section), Auto mode may no longer be the fastest mode.

In sweep mode, an increasing sweep time slows down the sweep speed of the LO, thus enabling the analyzer to collect more data points per frequency range. The increased number of data points is averaged, but does not cause any significant computation overhead.

In FFT mode, an increasing sweep time also results in more data being captured. In opposite to sweep mode, the additional data in FFT mode results in more FFTs to be computed, i.e. a significant amount of additional computational load.

FFTs provide the advantage of a better averaging effect since there are more uncorrelated samples per trace point compared to the same scenario in sweep mode. As an example, let's take a setting with 10 trace points (any span). Let us select the sweep time as 20 time units. This results in a measurement time per trace point of 2 time units per trace point in sweep mode, so you can average over 2 time units. In FFT mode that covers the entire span with one FFT, the capture consists of 20 time units and the information of the 20 time units is available for each resulting trace point and thus allowing better averaging.

As a consequence, the instrument may switch from "Auto FFT" to "Auto Sweep" if you're increasing the sweep time beyond a certain limit. This switch over minimizes the measurement time for a given sweep time, however it may not align with your intention to smoothen the trace as fast as possible.

Here is why: as an example, we will look at a 10 MHz span with a 100 kHz RBW. The sweep mode selected by the instrument is FFT, and the minimum sweep time is approx. 42 µs, resulting in 7 ms of measurement time. Increasing the sweep time to 2 ms (along with RMS detector to get a good averaging result), will change the sweep type to Sweep. Note that in Sweep mode the selected sweep time corresponds roughly to the measurement time. However, the swept trace with 2 ms does not show significant averaging. When the instrument is forced back into FFT mode (see Fig. 3-4), the sweep time is still 2 ms, but the measurement time is approx. 18 ms (computational effort for FFTs). Fig. 3-5 shows clearly the advantage of the FFT mode - the trace is a lot smoother. Even if the sweep time in Sweep mode is increased to 18 ms (the measurement time of the FFT mode for 2 ms of sweep time), the FFT trace is still a lot smoother.

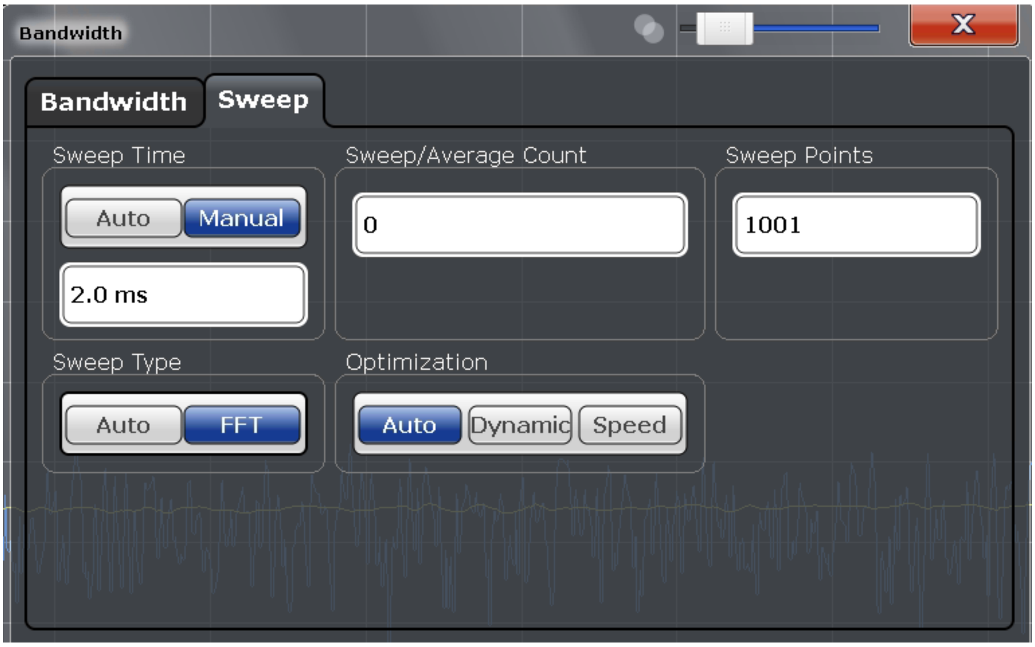

Fig. 3-4: Sweep configuration dialog of the R&S FSW and R&S FPS. Sweep type as well as optimization may be selected.

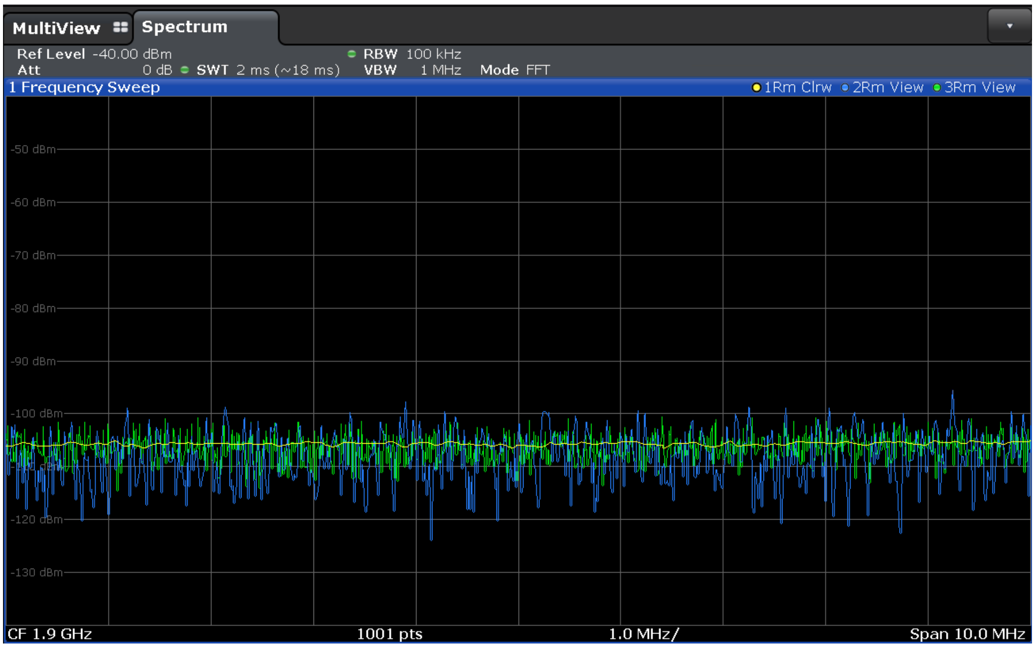

Fig. 3-5: Comparison of a 2 ms sweep with RMS detector in FFT mode (yellow) and Sweep mode (blue). The Sweep mode measurement was repeated with 18 ms sweep time (green).

So in summary, when manually adjusting the sweep time, make sure the Auto mode is still appropriate or change manually into FFT mode.

In addition, the FFT mode provides an optimization setting that can be set towards speed or towards dynamic range. In optimization Speed, the instrument does not perform automatic reference levelling and uses maximum FFT bandwidth. Dynamic mode on the other hand focuses on reaching maximum dynamic range at the cost of measurement speed. Smaller FFT widths for example allow for smaller analog filters, minimizing inherent intermodulation. The default Auto setting is a trade-off between speed and dynamic range. For DUTs coming close to the instrument's specifications (e.g. for intermodulation), the Dynamic Range setting is ideal, whereas for other DUTs, Auto or Speed are the recommended settings.

ACLR Measurements (Trace Average vs. Detectors)

The traditional method of averaging on a spectrum analyzer was using a small video filter (VBW) and using trace averaging. Both methods work well, however there is a faster way of doing the averaging.

Spectrum analyzers use so called detectors. A detector combines multiple measurement points into a single trace point. The trace, i.e. the graph that is displayed, consists of a fixed number of points, e.g. 1001. Depending on the measurement setup, especially the sweep time setting, the analyzer acquires a lot more measurement points. If the analyzer provides an averaging detector that averages power levels, this detector along with a higher sweep time has a significant speed advantage over trace averaging or VBW averaging. The required detector is called RMS detector on all R&S analyzers. RMS stands for Root Mean Square, since the squares of the sampled voltage values are averaged.

The RMS detector provides speed advantages, as all necessary data is collected during one sweep, i.e. there is no need to tune the spectrum analyzer back to start frequency, once the stop frequency is reached.

If you want to achieve the equivalent of two trace averages with RMS detector, the sweep time should be set to two times the original sweep time.

The results in Table 3-1 show a WCDMA uplink ACLR measurement on an R&S FPS (see Fig. 3-6). They clearly show a significant speed advantage (up to a factor of almost 3) for the RMS detector method at comparable or even better repeatability results.

Comparison of Trace Averaging and RMS Detector							
Sweep Time		Measurement Time		Std. Dev. TX Channel		Std. Dev. Lower 1 Adj.	
RMS	TRC AVG	RMS	TRC AVG	RMS	TRC AVG	RMS	TRC AVG
1 ms	2 x 0.5 ms	6.3 ms	9.4 ms	0.087 dB	0.099 dB	0.159 dB	0.169 dB
2.5 ms	5 x 0.5 ms	9.8 ms	22.1 ms	0.065 dB	0.065 dB	0.093 dB	0.101 dB
5 ms	10 x 0.5 ms	15.7 ms	43.5 ms	0.043 dB	0.050 dB	0.060 dB	0.071 dB

Table 3-1: Comparison of different averaging methods: RMS detector is faster than trace averaging.

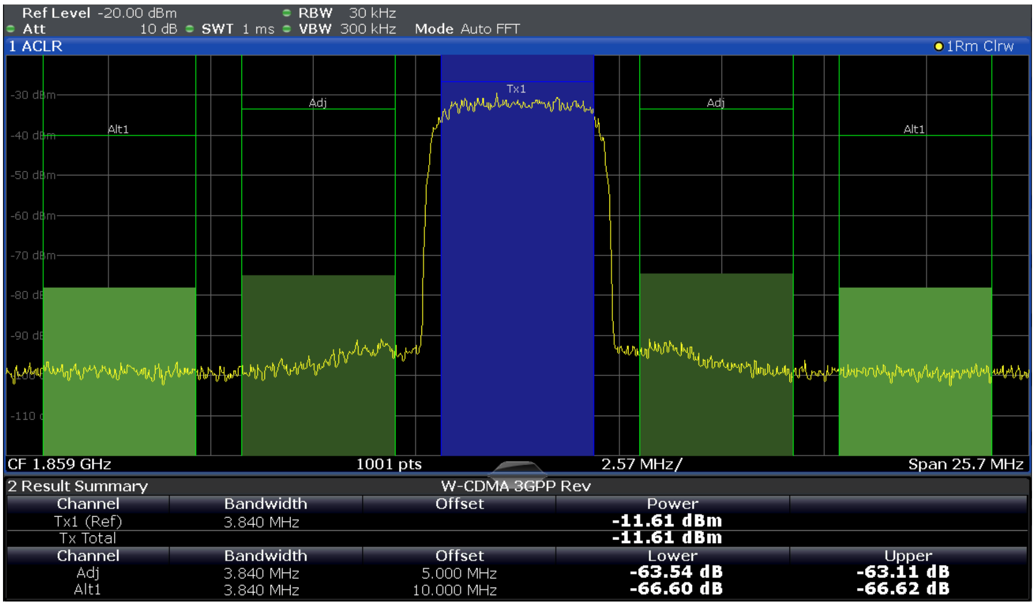

Fig. 3-6:Test scenario for results in Table 3-1

Power Measurements

Power measurements result in a single value: the total power within a certain bandwidth, averaged over a certain amount of time.

Modern spectrum analyzers have time domain power measurement functionality that is a fast alternative to a power sensor, if the absolute accuracy of a power sensor is not needed or transferred to the analyzer by a reference measurement.

For a power measurement, the spectrum analyzer does not only use the averaging effect of the RMS detector, but averages the entire time domain trace into a single value. By adjusting the sweep time, the total averaging interval is configured. The resolution bandwidth setting (RBW) determines the bandwidth for the power measurement. Spectrum analyzers use Gaussian filters as RBW filters as defaults, but can be configured to other filter types as well. A channel filter for example allows a power measurement on a clearly defined channel only, similar to the channel power measurements in the frequency domain.

So if your absolute accuracy requirements are met by the spectrum analyzer, e.g. because you're correlating to a golden sample, the spectrum analyzer provides a fast and highly repeatable method to measure power.

Signal and spectrum analyzers in general often provide a power measurement along with e.g. demodulation measurements, such as e.g. in the WiFi or LTE personalities. These power measurements come along free (no additional test time needed), however the test time of a demodulation measurement is at least an order of magnitude higher than a pure power measurement.

So in a scenario where only the power measurement result is needed, e.g. when servoing the output power of a PA, the time domain power functionality might be the fastest way for the power measurement. In other scenarios with e.g. demodulation measurements going on, the power measurement result coming along with the demodulation results can be used.

Finally, if the absolute accuracy of a power sensors is required and cannot be transferred to the spectrum analyzer, keep in mind that the power sensor measurement can often be parallelized with the spectrum analyzer measurement (see section 3.1) to save test time.

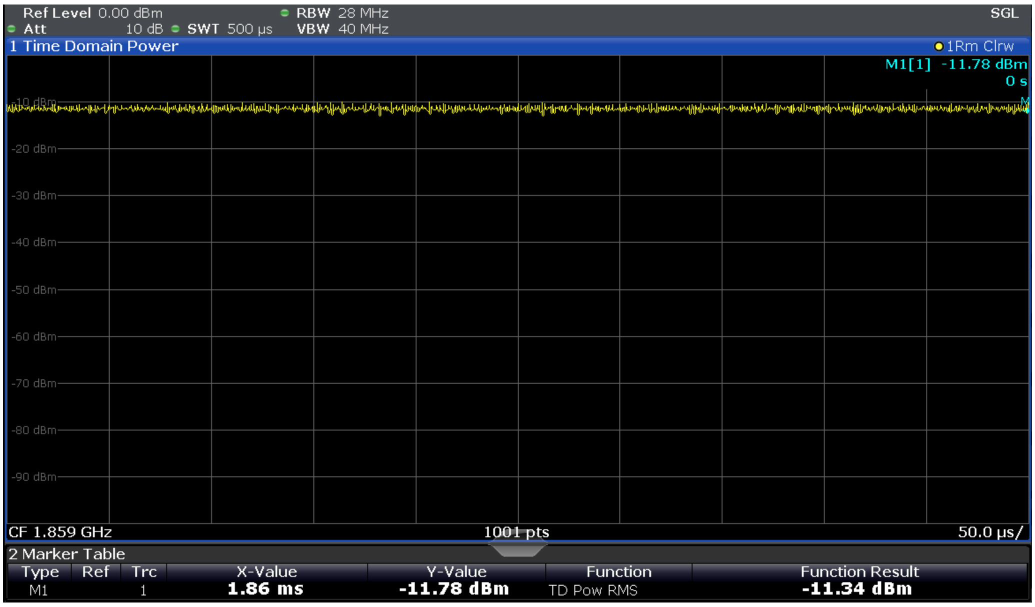

Fig. 3-7:Zero span measurement of a WCDMA signal with activated time domain power function

Zero Span Power Measurements		
Sweep Time	**Measurement Time**	**Std. Dev. Result**
50 µs	1.1 ms	0.0056 dB
100 µs	1.3 ms	0.0032 dB
500 µs	2.2 ms	0.0015 dB
1 ms	3.3 ms	0.0010 dB

3.3 Using Trigger Events

All of the above numbers, i.e. repeatability and measurement time, apply to an instrument in Free Run mode, i.e. it starts at an arbitrary point of a given signal and lasts for a given sweep time. In Free Run mode, repeatability compares measurements of different portions of the signal, since each measurement starts at a different point in the signal. As a result, the repeatability for a given sweep time is by far lower in free run mode compared to triggered mode. To reach comparable standard deviation (repeatability) in free run mode, significantly more averaging, i.e. sweep time, must be applied.

In a production setup, the test system engineer generally has full control over the signal generation, be it a signal generator or the DUT itself. Therefore, we can make sure that consecutive measurements use the same signal, i.e. start at the same point in time of the signal.

The external trigger functionality of a spectrum analyzer accomplishes exactly this requirement. However, there are often concerns in using external triggers for speed optimized applications, especially when users are not aware of methods to shorten or adapt the period between two consecutive trigger events.

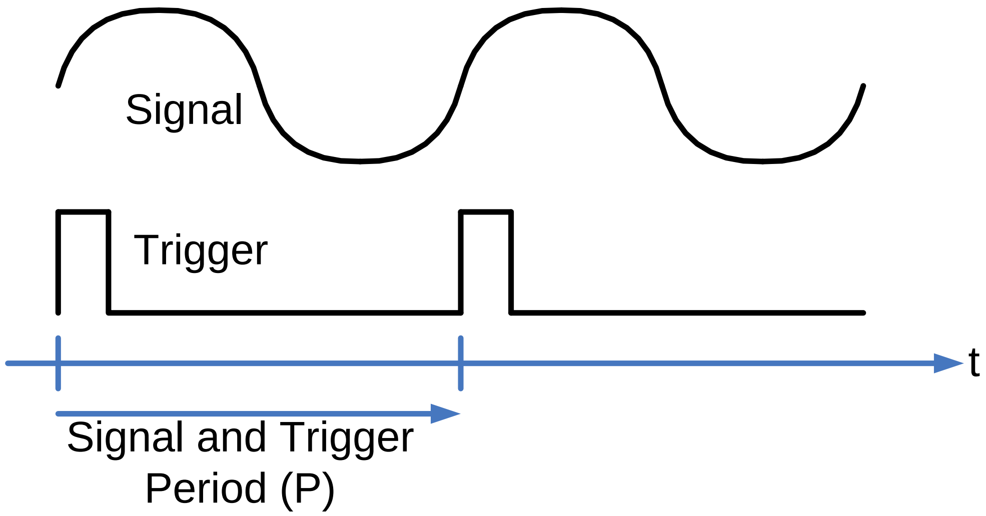

Fig. 3-8: Signal and trigger with static period

In a static scenario, as shown in Fig. 3-8, a trigger occurs for every period P. So given the case that a measurement lasts significantly shorter than P, waiting for the next trigger wastes an enormous amount of time.

There are two approaches to avoid waiting for the next trigger.

1. Shorten the signal to match the measurement time
2. Dynamically shorten the period so that e.g. the spectrum analyzer determines the start of the next signal / trigger period

We will focus on method 2, as the static approach in method 1 cannot handle measurements with different duration, e.g. a full standard consistent demodulation and an ACLR measurement. Method 2 requires two trigger lines between the signal generator and the spectrum analyzer as shown in Fig. 3-9.

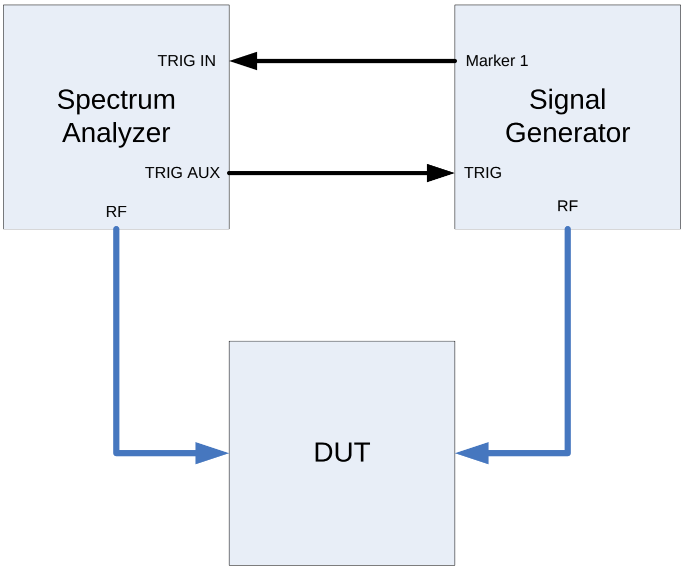

Fig. 3-9: General setup with a spectrum analyzer signaling "Trigger Armed" and a signal generator triggering the spectrum analyzer with its marker signal

The R&S FPS as well as the R&S FSW provide so called trigger output ports. A number of instrument states can be signaled on this port, e.g. "Trigger Armed" or "Device Triggered". For this application we will use "Trigger Armed" to signal the generator to start the next waveform segment. "Trigger Armed" is signaled if the spectrum analyzer is ready to start the next measurement and is configured to external trigger. So as soon as the spectrum analyzer signals "Trigger Armed" it is ready to receive the next trigger. This signal is ideal to restart the current waveform on the signal generator.

Fig. 3-10 is a timing graph showing the adaptive signal duration concept for different measurement durations. So no matter if a measurement takes 1 or 5 ms, there is no dead time with instruments waiting for the next trigger event. The reaction time of R&S signal generators between receiving the signal "Trigger Armed" and restarting the waveform is about 2 µs (see Fig. 3-11), so it can be neglected.

In order to use this configuration, the spectrum analyzer needs to be configured as follows:

- Single Sweep (`INIT:CONT OFF`)
- External Trigger (`TRIG:SOUR EXT`)
- Trigger 2 configured as Output (`OUTP:TRIG2:DIR OUTP`)
- Trigger Output configured as Type Trigger Armed (`OUTP:TRIG2:OTYP TARM`)

On the signal generator side, it is essential to generate the marker signal. It can either be integrated in the waveform (e.g. for bursted signals), or generated every time the waveform starts.

- Single or multiple repetitions on trigger (`BB:ARB:TRIG:SEQ SING | RETR`)
- Restart waveform on external trigger (`BB:ARB:TRIG:SOUR EXT`)

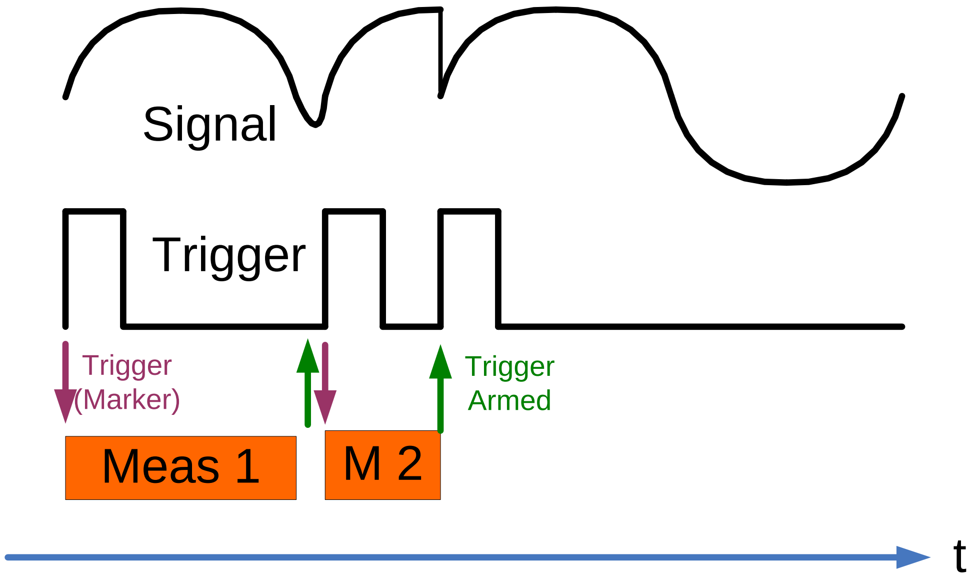

Fig. 3-10: Adaptive signal duration. The spectrum analyzer performs a longer measurement Meas 1 and a measurement with shorter duration M 2.

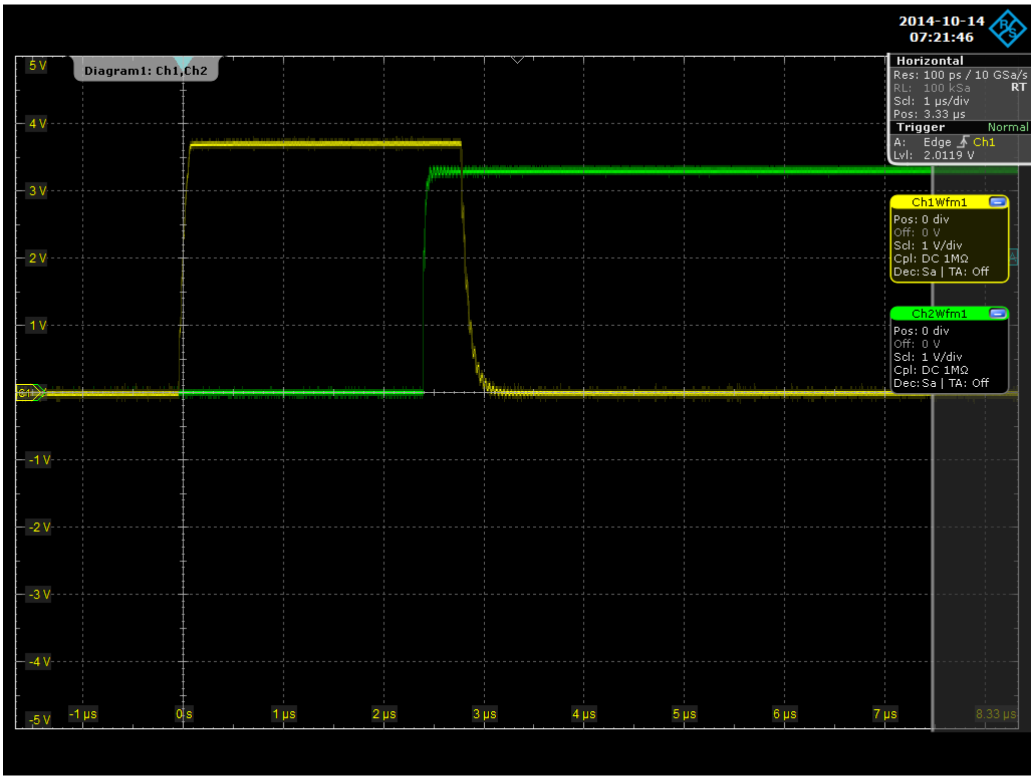

Fig. 3-11: "Trigger Armed" signal of the R&S FPS (yellow) and Marker 1 signal of an R&S SGT 100A (green) indicating the time needed by the generator to restart the waveform.

3.4 Demodulation and other I/Q-Data Based Measurements

As the variety of I/Q-data based measurements is even larger than the variety of cellular standards, this section focuses on general hints and recommendations that are valid for all I/Q based measurements, be it GSM, WCDMA, WLAN, or analog demodulation.

The general signal flow in all I/Q based applications is always identical (see Fig. 3-12).

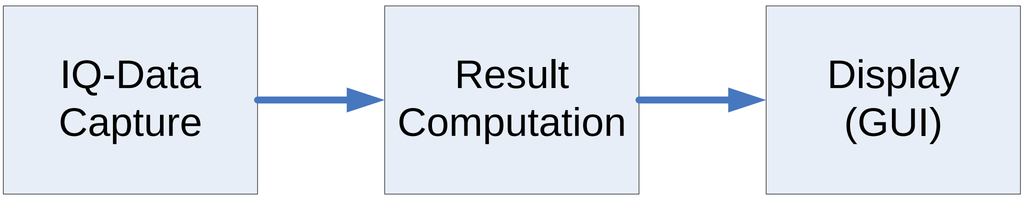

Fig. 3-12: Signal flow for I/Q-data based measurements, e.g. in GSM, WCDMA, or WLAN personalities.

Minimize Capture Length

Based on this diagram, savings in the first block, will affect all other blocks. Therefore, as a first measure, we will reduce the number of captured I/Q samples as much as possible. The number of samples results from the selected sampling rate (i.e. bandwidth) and the selected capture length (i.e. sweep time). While most standards need a fixed sampling rate for demodulation, the sweep time can often be reduced. For standards, such as LTE or WCDMA, the measurement personalities offer so called sub-frame or slot modes, i.e. demodulation is based only on a subsection (often 1/10) instead of the full frame (often 10 ms). In addition, many measurement personalities configure the default sweep times to make sure they are capturing a full contiguous frame even in free run mode, i.e. assuming a 10 ms frame, a 20 ms capture is required to account for the worst case (see Fig. 3-13). Again, in a controlled environment, such as production or verification environments, an external trigger signaling the beginning of a frame saves significant amount of time, since the sweep time can be reduced to one frame length.

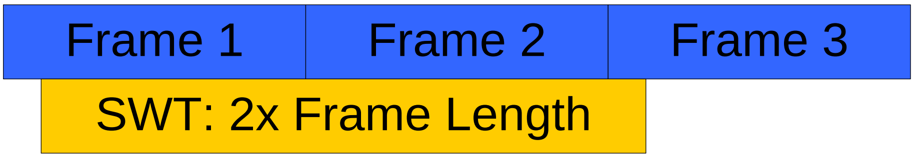

Fig. 3-13: Required sweep time setting is two times the frame length to guarantee at least one full frame

For some standards, such as most WiFi standards, even the signal itself can be adapted to reach shorter test times. With WiFi signals, test engineers typically have some degree of freedom to select e.g. the number of symbols per burst, or the idle time between two consecutive bursts. Looking only at the measurement time - the general rule is: the shorter the signal capture (in samples) the shorter the measurement time.

However - measurement time itself is only one side. Most results are worthless, if they are not stable across DUTs. Once it comes to balancing speed and repeatability, a general rule is no longer adequate. As an example, we will look at an 802.11ac signal. As discussed before, the number of symbols per burst can be set to "1" and we could look at only a single burst, but at the cost of a low repeatability. In an attempt to increase repeatability, a test engineer could either increase the number of symbols per burst, or the number of bursts in the capture buffer to average EVM. For the K91 measurement application on the R&S FPS, it proves ideal to set the number of symbols to 6 and from there on increase the number of bursts being analyzed until the desired repeatability is reached. The R&S FPS has a significant speed advantage when analyzing multiple bursts as it utilizes a multi core processor and multiple bursts can be analyzed in parallel.

Configure Required Results as Precise as Possible

Most measurement applications start up in a default state that is optimized for users operating the instrument in a lab. For example, the default sweep time allows measurements in free run mode. In addition, most default demodulation parameters are set to "Auto", allowing demodulation of all variants of a certain standard, e.g. different LTE resource block allocations.

However this comfortable approach is not the fastest one. Imagine that for an LTE signal, the application determines the resource block allocation setting first, before it can start the demodulation. Obviously this takes time.

So regarding the result computation block in Fig. 3-12, a first rule of thumb is:

Specify the signal as precise as possible.

In detail, this specification may consist of bandwidth setting, modulation type, and more standard specific settings.

In the same manner, the result configuration may affect the measurement time. In GSM for example, the application can come up with results of a spectral measurement along with the EVM setting, but additional measurements are equivalent to longer test time. Note that measurement personalities automatically deactivate measurements if the corresponding result display is removed. In addition, consider if certain signal enhancement functions, such as phase or frequency tracking are essential for your measurement. In general these functions can be turned on or off as needed. Make sure, you are using the minimum configuration the instrument or measurement application provides, so only the required parameters are calculated. On the R&S FPS, a GSM measurement may save more than a millisecond, if modulation spectrum parameters are disabled. Disabling results is equivalent with not configuring the respective result display.

So the second rule of thumb here is:

Activate only results and / or result displays which are needed.

As an example, we will look at a 20 MHz LTE (FDD) downlink signal, with 100 resource blocks allocated. By preconfiguring the resource block allocation, the modulation type, and switching off the subframe configuration detection (see Fig. 3-14), the application can be sped up easily by a factor of two.

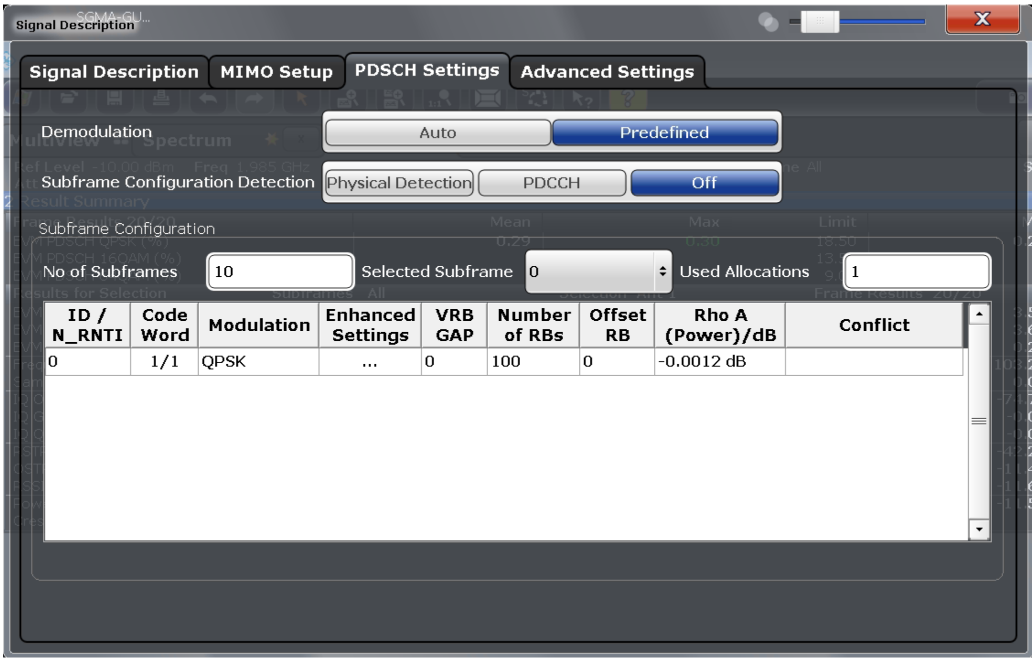

Fig. 3-14: Manual configuration of an LTE signal to speed up the demodulation

Deactivate Auto-Levelling

Many measurement applications provide an auto-levelling function. This function automatically adjusts reference level and input attenuation to the signal analyzer.

Levelling can make a significant difference to your measurement results - since bad levelling wastes dynamic range of the instrument.

Auto-levelling is perfect for manual measurements, since you don't have to care about the optimum level settings. The drawback of auto-levelling is its time consumption. In a production setup, all DUT levels are typically known, so there is no need to level for each DUT. Levelling once and remembering the settings saves precious test time.

Note that some applications such as the WiFi personality have auto-levelling activated as a default setting.

3.5 Switching Between Measurements

In a production environment, the variety of measurements is typically limited. Most measurements are typically spectrum analyzer based measurements. In a verification scenario, we can find demodulation measurements or advanced spectral measurements, such as phase noise or noise figure measurements, in addition to spectral measurements.

Switching between different measurements can take a significant amount of time. In this section, a "different measurement" does not only refer to measurements in different personalities - but it also includes measurements in the same personality, but using a totally different instrument configuration, such as e.g. a zero span measurement and an ACLR measurement.

Traditionally, switching was not an issue, since each measurement had to be configured, before it would deliver results. Today, measurements can still be configured manually, the entire instrument state can be saved, or the instruments allow different configurations to be present on the instrument at the same time. The R&S FSW and R&S FPS introduce a so called channel concept. Each channel, represented by a tab in the measurement GUI (see Fig. 3-15) is directly accessible, either by touching the tab or by sending the corresponding remote control command (e.g. `INST:SEL SAN`, where `SAN` stands for spectrum analyzer).

Fig. 3-15: Different channels allow different measurement configurations to coexist on the instrument. Tabs allow for quick changes between measurements.

It is in general much faster to configure each measurement in a separate channel, instead of reconfiguring a single channel to the next measurement. This automatically leads to dramatically faster switching times between personalities, but it also offers new ways to configure the instrument.

Assume that a time domain power measurement (power servoing) and ACLR measurement are to be measured on the spectrum analyzer. Reconfiguring a single channel for these two measurements takes quite a few remote commands and some milliseconds. Setting up these two measurements in different channels speeds up the switching between both dramatically.

3.6 Considerations on the Vector Signal Generator

In production as well as design verification scenarios, there are three major settings on the generator side that change frequently: frequency, level, and waveform.

Whereas frequency can be set directly or by using a predefined list, today's generators offer new ways to change waveform and level.

Changing the Waveform

The range of waveforms for a certain test platform is in general limited to a few tens. A typical set for a mobile PA consists of maybe one WCDMA signal, 6-7 LTE waveforms, including different bandwidths, different resource block allocations, as well as TDD and FDD waveforms. In addition, other standards, such as TD-SCDMA, or GSM may be included. Typically, a waveform is loaded from hard disk into the generator's waveform RAM. As on any PC, hard disk access is slow. Rohde & Schwarz signal generators are able to handle multi-segment waveform files. Multi-segment waveform files consist of multiple single waveforms that are combined into a single file. The generator loads the file once (e.g. at test system boot up) from hard disk. Once the multi-segment file is in the RAM, the individual file (segment) can be quickly accessed without any hard disk operations. The R&S WinIQSIM2 software (available from the Rohde & Schwarz website free of charge) creates multi-segment waveform files using standard waveform-files as input (see Fig. 3-16).

With multi-segment waveform files, changing the waveform (i.e. segment of the multi-segment file) is easy: `BB:ARB:WSEG:NEXT n` instructs the generator to jump to segment `n`.

In order to achieve minimum switching time between segments, it is recommended to resample all waveforms to the same clock rate (i.e. common multiples sampling rate).

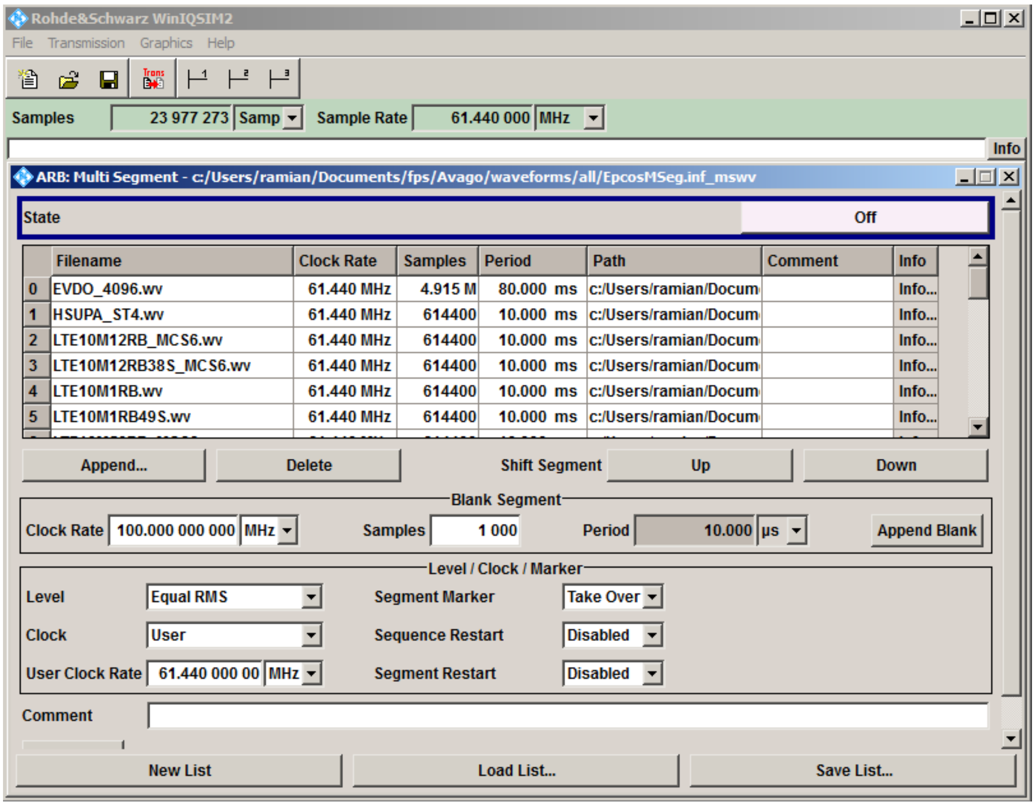

Fig. 3-16: WinIQSIM2 may be used to create multi-segment waveform files

To further reduce the switching time an external NEXT segment trigger signal can be applied to the vector signal generator. However, external triggers allow changes of the waveform only in the given order by increments of 1.

Fine-Adjusting Signal Level

In a typical test plan, there are multiple changes to the signal generator level. Coarse ones covering 10, 20 or more dB, but also small steps covering only fractions of a dB.

Especially for mobile PA testing, a large number of small level changes are needed. A test plan typically defines a measurement point by the DUT output level. Since the DUT is operated in its non-linear region, the corresponding input level, i.e. signal generator level, can be found only in an iterative approach, often called servoing. A typical servoing consists of 3-5 iterations steps, each changing the signal generator level by a few tenth of a dB or 2-3 dB at maximum.

Changing the signal generator level on the analog side involves settling times for the analog components. Since the generator replays waveforms, i.e. digital data, for most tests, vector signal generators provide a digital attenuation. Setting the digital attenuation to e.g. 3 dB corresponds to downscaling the I/Q-values by a factor of $\sqrt{2}$. Note that I and Q are amplitudes in Volts, rather than power levels, resulting in a factor of $\sqrt{2}$ instead of 2.

Digital attenuation may have a speed advantage of more than a factor of 10, compared to setting the analog level of a signal generator.

4 Conclusion

This application note discussed a variety of measures to improve measurement time. Some of them are significant and easy to use, even in everyday use, such as using the RMS detector for averaging. Others may require additional signals, e.g. external triggers, which may only make sense in production or verification scenarios.

In general it is important to keep in mind that measurement speed is a parameter that only makes sense to evaluate in the presence of a clear specification of the measurement and the desired repeatability.

Once it comes down to hunting the last milliseconds, an application note cannot cover all issues any more. There are a lot of dependencies and tradeoffs that need to be weighted for a certain scenario. At this point, please contact your local Rohde & Schwarz support team or application engineer.

About Rohde & Schwarz

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

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