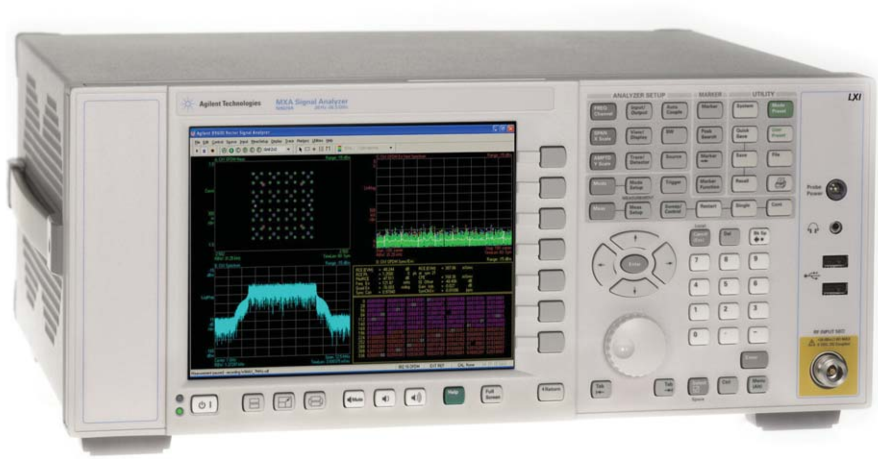
Maximizing Measurement Speed with Agilent's X-Series Signal Analyzers

Application Note 1583



Introduction and Overview

The Agilent X-Series (MXA, EXA) signal analyzers are a new generation of midrange analyzers designed for extremely fast measurements over RF and microwave frequencies. This flexible signal analyzer is capable of traditional spectrum analysis as well as advanced signal analysis of numerous digital communication standards including W-CDMA, HSDPA/HSUPA and WiMAX-OFDMA (WiMAX mobile). Several key features that improve the measurement speed include a full digital IF subsystem, a fast switching local oscillator (LO), a high data rate sampler and an optimized preselector. Additional speed improvements have also been achieved when using these analyzers in remote operation with the addition of USB2.0 and 100 Base-T connectivity and LO frequency list sweep mode.

This application note introduces several innovations that are used to improve the measurement speeds of the X-Series signal analyzers. This note also discusses how these features should be properly applied to the measurements in order to further optimize the measurement speed of the instrument. This application note is divided into two sections. The first section covers how to optimize the measurement speed using the front panel. The second section covers techniques to improve measurement speed via remote operation over the I/O connections.

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Front Panel Operation

The Agilent X-Series have the most advanced user interface in the industry with all measurement features and functions intuitively grouped and accessible from the front panel. The analyzer provides open access to the Windows® XP Professional operating system and allows seamless switching between spectrum analysis and numerous measurement applications. Using the front panel interface, the analyzers can be configured to operate with a 1 msec sweep time over a 200 MHz span. This section of the application note discusses how to enhance the measurement speed using front panel settings under a variety of test conditions.

Multiple simultaneous detection and trace display

The detection modes and display of data are similar in function to many traditional spectrum analyzers that use digital displays of measured data. Proper selection of detector type coupled to the available trace display may greatly improve the overall speed and flexibility of a measurement. Traditional spectrum analyzers are often limited to a single detector type for all measurement traces. Changing the detection mode requires the operator to manually select the detector type and re-sweep the instrument. The X-Series greatly simplifies this process by providing a unique detector type for each measurement trace and up to six measurement traces can be simultaneously displayed with one measurement sweep.

The detection mode or detection type is a data processing function that is used to select which data point is to be displayed from a larger set of measurements. The measured data is grouped into what is often referred to as frequency “bins” or “buckets” where the size of the bin is related to the total frequency span and number of trace points. More trace points result in smaller frequency bins and a closer representation of an analog signal display. Less trace points result in larger frequency bins and a higher number of data points processed in the selected detection scheme [1]. How the data in the frequency bin is processed is directly related to the type of detector. The X-Series has a variety of selectable detectors including normal, average, sample, peak and negative peak. There are several application notes that explain the function and technical details of these individual detector types [1, 2, 3].

In certain applications it is useful to examine the test signal using multiple detection modes. In the case of spectrum monitoring, examining the peak, negative peak and average levels of the signal can provide information about the occupied energy and interference within the band. For this example, the peak measurement can also use a Max Hold function to store the largest signal levels across the frequency. Figure 1 shows a measurement of a noise-like digitally modulated signal using the signal analyzer configured with three different detector types. For this measurement, all three detection modes are simultaneously operating during a single measurement sweep. Each detection type is coupled to one of six independent measurement traces available on the display.

The number of measurement points for the signal analyzer's trace can range from 1 to 20,001. Fortunately, increasing or decreasing the number of trace points has only a minor effect on the total sweep time for the instrument. For example, if the X-Series is configured to have a 1 msec sweep time using the default number of 1001 trace points, then changing the number of trace points to 20,001 will only increase the analyzer's sweep time by an additional 0.33 msec. It will be shown later in this application note that increasing the number of trace points may have a greater affect on the time required to transfer the trace data over the I/O.

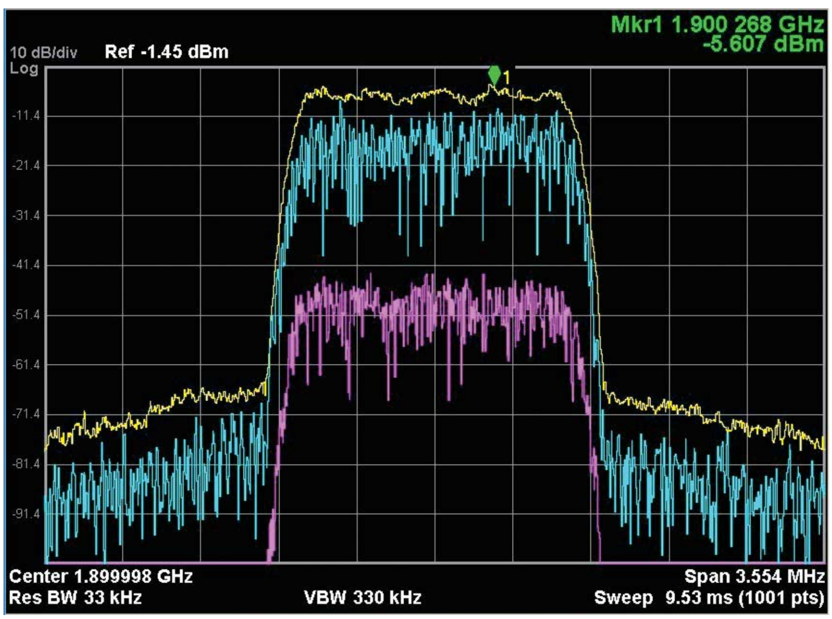

Figure 1. MXA display of a digitally modulated signal using three different detector types: peak, average and negative peak

Swept digital and FFT filtering

With any spectrum or signal analyzer, trade-offs exist between measurement sweep time, filter bandwidth and frequency span. Generally, for a specified frequency span, wide RBW and/or VBW filters result in faster sweep times while narrow filters result in longer times. Modern spectrum analyzers typically use some level of digital signal processing in the IF section in order to improve the analyzer's sweep time over a variety of instrument configurations.

The X-Series uses a full digital IF section which achieves fast measurement speed with high accuracy using selectable digital resolution bandwidth (RBW) filtering and fast Fourier transform (FFT) processing. When using digitally implemented RBW filters, the sampled IF data is convolved with the filter's response resulting in a measurement similar to that achieved when sweeping a traditional analog filter. Additionally, the digital RBW filters implemented in the X-Series have dynamic characteristics that are very predictable, stable and repeatable and therefore can be swept at a faster rate as compared to their analog counterparts [4].

Fine frequency resolution in spectrum measurements often requires very narrow RBW filters. Depending on the frequency span and required frequency resolution, it may be beneficial to substitute the swept digital RBW filter for FFT filter processing. FFT processing can result in narrow RBW filters with the greatest speed advantage over narrow frequency spans and RBW requirements. The FFT processing is typically the fastest when the instrument's frequency span is less than or equal to the full analysis bandwidth of the digital IF section. For this case only a single FFT is required. The MXA uses an analysis bandwidth of up to 25 MHz (the EXA utilizes 10 MHz analysis bandwidth). For frequency spans larger than this analysis bandwidth, the analyzer must retune the center frequency and process another set of sampled data. For wide frequency spans that are several times larger than the analysis bandwidth, multiple FFT processing may result in longer sweep times than achievable with swept digital filtering. Fortunately, the X-Series can be configured to automatically switch between swept digital and FFT filtering for the fastest sweep time.

When using the front panel of the X-Series, the analyzer can be configured to automatically choose the appropriate filter type by selecting SWEEP menu, Sweep Setup, Swp Type Rules and Best Speed. It is worth noting that for frequency spans less than the analysis bandwidth, multiple FFT processing can also be used to improve the dynamic range of the instrument at the expense of slightly longer sweep times. For this case, the user can select the FFT span from the SWEEP menu, Sweep Setup, FFT Width. Additional information on FFT processing can be found in either the MXA or EXA user manual and other Agilent application notes [3, 4].

Digital RBW filters, both swept and FFT, also provide a low-cost alternative for implementing a much larger range of selectable filter bandwidths to further optimize sweep speed by allowing the user to select just the right amount of filtering required for the measurement. The X-Series has 160 different RBW filters selectable from 1 Hz to 3 MHz in 10 percent steps and 4, 5, 6 and 8 MHz.

Repeatability and averaging

Repeatability in a measurement is the amount of variation observed using the same instrument, under the same test conditions and over a small period of time. This is not to be confused with accuracy, which is the closeness of the measurement to the true value. Repeatability is often affected by noise within the measurement. Averaging several measurements can greatly improve the repeatability even when only a few measurements are used in the average. In a traditional spectrum analyzer, trace averaging is often used to improve the repeatability of the measurements. Trace averaging requires the analyzer to sweep multiple times and then combines the effects of multiple trace sweeps using a weighted averaging function. Sweeping the analyzer multiple times can greatly increase the total time necessary to make a measurement. To optimize the speed of the measurement, the X-Series signal analyzers have an average detector type that allows highly repeatable measurements to be obtained with a *ten-fold speed improvement in the total measurement time as compared to traditional trace averaging using sample detection.*

The X-Series utilizes a full digital IF section that samples the IF at a 90 Ms/s rate. Depending on the analyzer's sweep time, this high-speed sampler can provide a large set of data to be averaged within each frequency bucket. In this case, only a single measurement sweep is required to achieve the same repeatability that can be achieved using multiple trace averaging. The amount of averaging is determined by the sweep time setting, which can be manually adjusted for the required repeatability. The average detector type is especially useful in the higher frequency ranges of the analyzer, namely greater than 3 GHz, where the tuning time for the preselector is the dominant driver for the overall sweep time. As a comparison between the two techniques, Figure 2 shows two EXA measurement traces, one using trace averaging shown on the left and the other using average detection on the right. The left trace using 10 trace averages shows a larger variability in the noise level as compared to the right trace using average detection. For this case, the left trace would require additional trace averaging and more time to achieve the same repeatability as a measurement using average detection. The measurement using trace averaging required a total of 5 seconds over 10 trace averages. The measurement using average detection required only one 500 msec sweep.

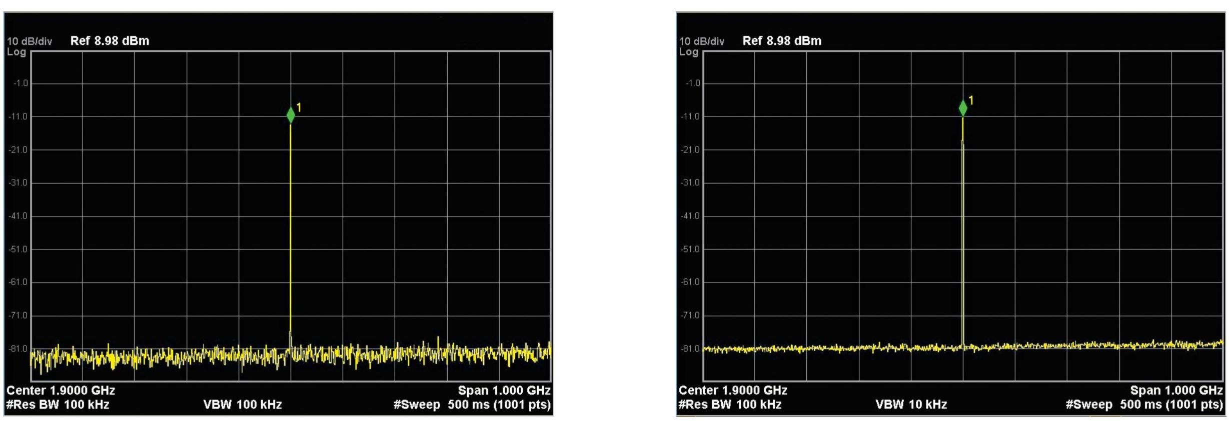

Figure 2. Repeatability comparison using trace averaging and average detection

Preselector tuning

Modern signal analyzers often use preselectors when measuring signals at the microwave frequencies. The preselector is a tunable bandpass filter that filters out unwanted LO harmonics and image responses from the measurements. For wideband measurements, the preselector will track the center frequency during the measurement sweep. Wideband tuning of the preselector may be one of the limitations in optimizing the sweep time of the analyzer. The preselector operates using a resonant-tuned YIG (yttrium-iron-garnet) sphere controlled by a magnetic field. A tuning current applied to coupling loops is used to alter the magnetic field resulting in a shift of the resonant frequency of the sphere. Large frequency ranges require large changes in the applied current that may limit the sweep speed of the analyzer. There are cases where proper selection of the frequency span will improve the sweep time by limiting the tuning requirements of the preselector.

The preselector filter in the X-Series has a bandwidth between 40 MHz to 80 MHz depending on the frequency of operation. With proper selection of the frequency span, the tuning time for the preselector can be optimized for speed. At microwave frequencies greater than 3 GHz, the X-Series will achieve the fastest sweep times using frequency spans of 5 MHz or less. In this case, the frequency span is within the passband of the preselector and no tuning is required after the initial filter setup. For frequency spans between 5 MHz and 200 MHz, the sweep time only increases by 5 percent as the tuning current requirements are minimized over this frequency range. For frequency spans beyond 200 MHz, large current changes required to tune the preselector may limit the sweep time in the instrument.

Another unique feature that improves measurement time occurs during “preselector centering” of the analyzer. Due to temperature changes, aging and nonlinearities within the YIG material, it is sometimes necessary to retune the center of the preselector in order to achieve the highest amplitude accuracy. Traditionally, users were required to input a CW signal into the spectrum analyzer and execute a preselector tuning operation to achieve the analyzer’s specified amplitude accuracy. This process was time consuming especially if broadband measurements were required. The X-Series includes an internal broadband noise generator and a specialized algorithm that results in easy and rapid preselector centering [5].

Auto align

Periodically the X-Series signal analyzer will perform an automatic alignment of the RF, IF and ADC subsystems in order to achieve the highest absolute amplitude accuracy. Full alignment of all subsystems occurs every 24 hours or with a 3 degree Celsius change in temperature. A more limited alignment of the RF subsystem occurs every 15 minutes or with a 1.5 degree Celsius change. Depending on which subsystems are aligned, the procedure can take between 3 to 18 seconds. It is under the discretion of the user to disable the auto alignment feature to guarantee uninterrupted measurement sweeps with a possible reduction in amplitude accuracy. Fortunately, the X-Series can also be placed in “alert” mode, which will inform the user that an alignment is necessary. In alert mode, no alignments will be performed until the user executes an alignment command from the front panel or instrument I/O.

Remote Operation

The X-Series signal analyzers have built-in capability to network with personal computers, printers and software programs over a variety of I/O interfaces. The fast frequency tuning, rapid data acquisition and high-speed I/O connectivity allows the MXA to provide rapid signal analysis and data transfer over a wide variety of measurement conditions. This section of the application note focuses on techniques that can be used to improve the measurement speed and data transfer rates when operating remotely.

I/O selection

The X-Series has a variety of connectivity methods, including: 100 Base-T (high-speed Ethernet), USB 2.0 and GPIB interfaces. The choice of I/O can greatly impact the speed of data transfer over the selected interface. Traditionally most programmers used SCPI commands over the GPIB, as this was the only available option on most of the older spectrum analyzers. Much faster data transfers are possible when using either the USB 2.0 or 100 Base-T.

The USB 2.0 interface is faster than 100 Base-T but the USB cable length is typically limited to 5 meters unless a cable repeater is used. If instrument control over a LAN is required then the 100 Base-T is the preferred option. Keep in mind that connecting the X-Series to the company's enterprise LAN may actually decrease the I/O speed if there is excessive traffic on the LAN. For this case, it would be better to configure a private LAN for analyzer control and data acquisition.

Programming the frequency in a loop

This section of the application note is less about the speed of the X-Series signal analyzers and more about the proper way to configure the program flow of the control software. Understanding and planning which measurement and setup functions take the longest time to execute, the executing speed of the control and acquisition software can greatly be improved with simple reconfiguring of the program looping. As shown in the previous section, there are speed advantages to transferring the data without retuning the center frequency of the analyzer. If several spectrum measurements are required over different states in the device-under-test (DUT), it would benefit the overall speed of the test to determine longest time between analyzer control and device control. In this way the outer programming loops can be configured with the slower operations and the inner loops could contain the faster operations.

For example, Figure 3 shows two simplified flow diagrams for measuring the peak marker values over several voltage conditions and operating frequencies. For this example, assume that the time to change the voltage setting of the DUT is faster than the center frequency tuning of the analyzer. The flow diagram on the left shows the slower measurement process, as the center frequency of the analyzer requires MxN tuning operations. For this example, it is beneficial to reorder the looping functions to place the analyzer tuning in the outer loop. The flow diagram on the right side of Figure 3 shows the faster measurement process requiring that the analyzer need only N tuning operations.

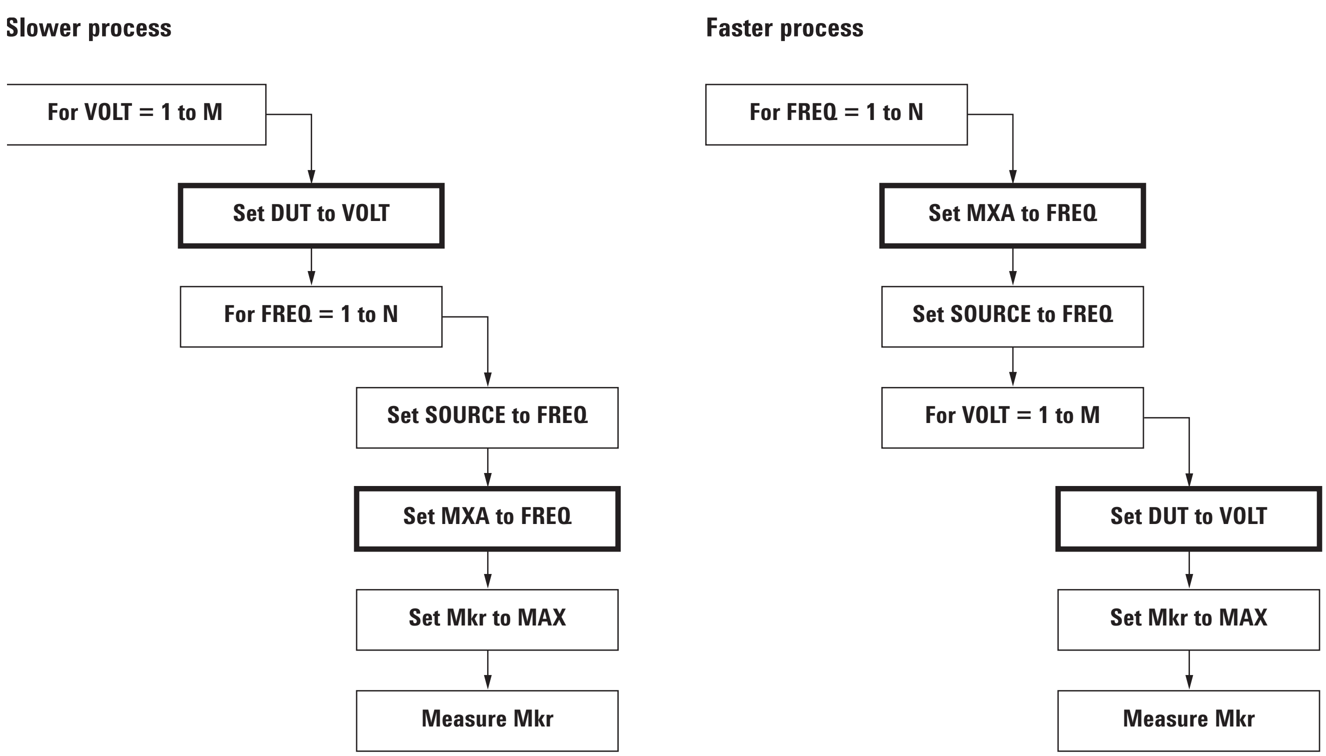

Figure 3. Programming flow diagrams showing two approaches to looping device and instrument control

Optimizing the number of trace points

As previously discussed in the "multiple simultaneous detection and trace display" section, the X-Series signal analyzers can be configured with a range of trace points from 1 to 20,001. Data transfer speeds over the I/O interface can be optimized if the selected number of trace points is set to the minimum number of points required for the measurement. For example, if the test requirement is for the measurement of the power in 72 equally spaced channels, then the X-Series should be configured to 72 trace points. In this case, the data transfer over the I/O will yield much faster results using 72 points than it would by leaving the instrument in the default setting of 1001.

Marker search

Traditionally, the marker search functions has been a time consuming operation and it was often more efficient to download the entire trace data and perform the search using an external PC. Fortunately, the X-Series marker peak search speed is less than 5 msec whether operated over the I/O or from the front panel. With the fast marker search capability it is now quicker to download only the marker value after the search is complete.

List sweep mode

The X-Series signal analyzers have an advanced local oscillator (LO) function that allows rapid frequency tuning called the list sweep mode. In this mode, the desired frequency list is preloaded using a set of programming commands. List sweep will result in a two times faster measurement speed when compared to the standard zero span tuning which is typically used for measuring the signal power in a specified bandwidth. A traditional spectrum analyzer that is controlled by a remote program would require a set of individual frequency commands to adjust the center frequency of the analyzer. This process often requires several hardware subsystems in the analyzer to enter a partial preset that can be very time consuming. Utilizing the list sweep mode in a X-Series, the complete frequency list is downloaded into memory and the LO and associated hardware are preloaded with the required states for the next frequency in the list. For example, when measuring the signal power in 124 GSM channels using a traditional zero span tuning sequence, the total measurement time is 1.5 seconds. Making the same measurement using the list sweep mode, the measurement time is cut almost in half, to 0.8 seconds.

Figure 4 shows a section of programming code that is used to configure the EXA for list sweep mode. For this example, the frequencies for the measurement are loaded into a portion of the analyzer's memory associated with the LO.

```
CAL:AUTO OFF
INST:SEL SA
INIT:CONT OFF
LIST:FREQ 890.2MHz,890.4MHz,890.6MHz,890.8MHz,891.0MHz,891.2MHz,891.4MHz,891.6MHz,891.8MHz,892.0MHz
LIST:ATT 10dB
LIST:BAND:RES:TYPE FLAT
LIST:BAND:RES 300kHz
LIST:BAND:VID 3MHz
LIST:SWE:TIME 600us
LIST:DET RMS
LIST:TRIG:SOURce IMM
:SENSe:SWEep:TYPE:AUTO:RULes SPEed
READ:LIST?
```

Figure 4. Programming example for the list sweep mode of operation

Display off

One of the most basic operations that can improve the measurement speed of a X-Series signal analyzer as well as most spectrum analyzers is to turn the instrument display off. Under remote operation, there is typically no need to operate the instrument with the display active. Disabling the display will make the instrument operate about 20 percent faster as the instrument does not have to update the display after every measurement acquisition. The SCPI command to disable the display is **:DISPlay:ENABle OFF**. The display can be turned back on at any time using the command **;DISPlay:ENABle ON**. As a measurement example, when measuring the fast ACP mode of a W-CDMA signal, the measurement and data transfer over the I/O is 20 percent faster with the display off as compared to the same measurement and transfer with the display on.

Binary and ASCII formats

Binary-formatted data transfers are much faster than ASCII transfers. There are three types of binary formats, INTEGER32, REAL32 and REAL64. The X-Series will provide the fastest transfer speed using either INTEGER32 or REAL32. Transferring measurement data using the REAL64 format will require twice the time as compared to the INTEGER32 and REAL32 formats. A software programmer will find that ASCII formats are typically simpler to program as compared to binary formats but the transfer speed using ASCII is five times slower than transfers using INTEGER32 and REAL32.

References

[1] Agilent Application Note 150, Spectrum Analysis Basics, Literature number 5952-0292, August 2006

[2] Agilent Application Note 1286-1, 8 Hints for Better Spectrum Analysis, Literature number 5965-7009E, July 2005

[3] Agilent Application Note 303, Spectrum Analyzer Measurements and Noise, Literature number 5966-4008E, February 2003

[4] Agilent Application Note, Swept and FFT Analysis, Literature number 5980-3081E, October 2004

[5] Agilent Application Note, Achieving Amplitude Accuracy in Microwave Spectrum Analyzers, Literature number 5989-4946EN, September 2006

Literature Resources

Agilent MXA Signal Analyzer
Agilent MXA Signal Analyzer, Brochure, Literature number: 5989-5047EN
Agilent MXA Signal Analyzer, Data Sheet, Literature number: 5989-4942EN
Agilent MXA Signal Analyzer Configuration Guide, Literature number: 5989-4943EN

Agilent EXA Signal Analyzer
Agilent EXA Signal Analyzer, Brochure, Literature number: 5989-6527EN
Agilent EXA Signal Analyzer, Data Sheet, Literature number: 5989-6529EN
Agilent EXA Signal Analyzer Configuration Guide, Literature number: 5989-6531EN

Agilent X-Series Signal Analyzers
Agilent X-Series Signal Analyzer (MXA/EXA), Demonstration Guide, Literature number: 5989-6126EN
Agilent X-Series Signal Analyzers (MXA/EXA) W-CDMA, HSDPA/HSUPA, Technical Overview, Literature number: 5989-5352EN
Agilent X-Series Signal Analyzers (MXA/EXA) 802.16 OFDMA, Technical Overview, Literature number: 5989-5353EN
Agilent X-Series Signal Analyzers (MXA/EXA) Phase Noise, Technical Overview, Literature number: 5989-5354EN
Agilent X-Series Signal Analyzers (MXA/EXA) GSM/EDGE, Technical Overview, Literature number: 5989-6532EN
Agilent X-Series Signal Analyzers (MXA/EXA) TD-SCDMA, Technical Overview, Literature number: 5989-6534EN
Agilent X-Series Signal Analyzers (MXA/EXA) Analog Demodulation, Technical Overview, Literature number: 5989-6535EN
Agilent X-Series Signal Analyzers (MXA/EXA) Noise Figure, Technical Overview, Literature number: 5989-6536EN
Using Agilent X-Series Signal Analyzers (MXA/EXA) for Measuring and Troubleshooting Digitally Modulated Signals, Application Note Literature number: 5989-4944EN
Using Agilent X-Series Signal Analyzers (MXA/EXA) Preselector Tuning for Amplitude Accuracy in Microwave Spectrum Analysis, Application Note Literature number: 5989-4946EN
Maximizing Measurement Speed with Agilent X-Series Signal Analyzers (MXA/EXA), Application Note, Literature number: 5989-4947EN

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