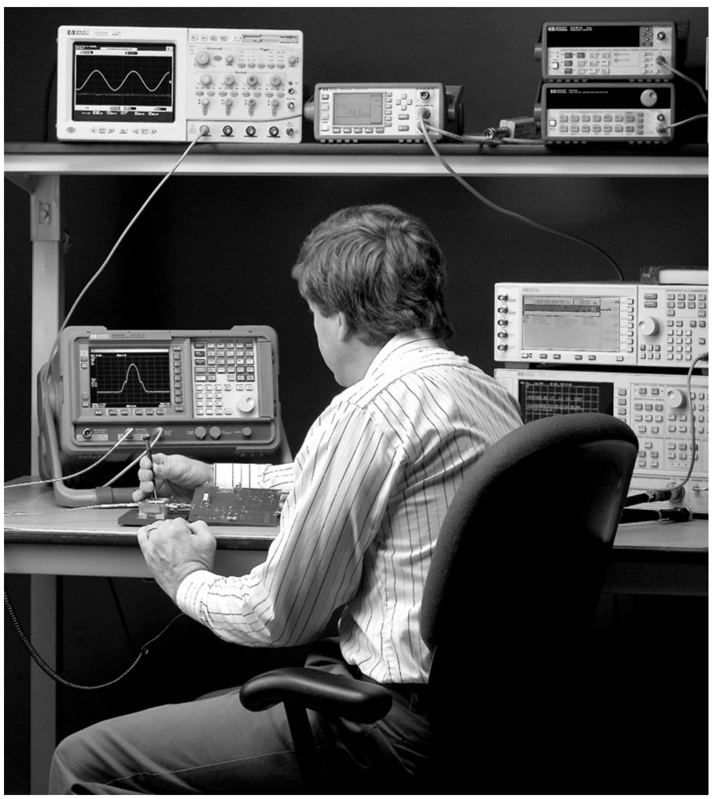
Agilent AN 1318

Optimizing Spectrum Analyzer Measurement Speed

Application Note



Agilent ESA-E Series

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Why speed matters

The measurement speed of your spectrum analyzer can significantly affect the time it takes you to complete a project. Consider the following examples:

- A manufacturing test engineer wants to optimize for speed to achieve the highest throughput on the assembly line. He has made all measurements, but waits for the results to move through the GPIB to the computer.

- A field technician needs to travel to a service location to make some measurements and adjustments, archive the results, and travel to the next job site. But the technician must wait 30 minutes to 2 hours for the spectrum analyzer to warm up to make calibrated measurements.

- R&D finally receives the new project prototypes back from Manufacturing. Tests reveal a problem with low-level harmonic and nonharmonic spurious signals. To find and examine these low-level spurs, a spectrum analyzer sweep time of 100 seconds or longer is needed, due to the narrow resolution bandwidth (RBW) filters required to drive the noise floor down.

Having speed where it matters most can help solve all three of these problems. For example, spectrum analyzers offering quick warm-ups, such as the Agilent Technologies ESA-E series (5 minutes), solve the problem of waiting a long time to use the analyzer. Fast warm-up is critical when a battery is supplying the operating power. Speed in other areas can reduce the delays described in the other two examples, as explained below.

How spectrum analyzers differ

In each of the examples above, data must be printed or displayed in a usable form as quickly as possible. But spectrum analyzers have to perform several steps to produce data in a usable form, and all spectrum analyzers are not created alike. Some provide fast display updates and others offer rapid GPIB updates. Knowing how quickly different analyzers perform these internal steps can help you understand the hold ups you may be experiencing now, and also help you choose the spectrum analyzer that best suits your needs.

What makes up spectrum analyzer speed?

One component of measurement speed is warm-up time, which has already been discussed. Once a spectrum analyzer is warmed up, speed is determined by the time required for measurement updates to the analyzer's display or to an external computer. Two elements make up measurement update time (see Figure 1):

- the time between sweeps, or "dead time," which consists of processing overhead and I/O traffic time; and

- measurement, or acquisition time; also called "sweep time."

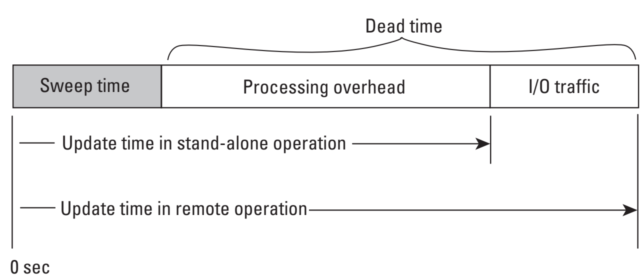

Figure 1. The components of measurement update time.

Processing overhead

Processing overhead is the time it takes the spectrum analyzer to perform its “housekeeping” tasks. These include formatting the acquired data for display, setting up for the next sweep, preparing the data for export to an external computer, and many others. Processing overhead increases with each task performed.

Currently, engineers want spectrum analyzers to provide more analysis on the acquired data, including markers, averaging, signal tracking, and adjacent channel power (ACP). Although these features add greatly to the convenience of the user, they also increase the processing overhead by as much as eight times, reducing spectrum analyzer speed.

I/O traffic time

At present, I/O traffic time (in remote control operation) is an insignificant part of the measurement update time, so improving computer and interface speeds will not noticeably affect measurement speed. However, as reductions in processing overhead are achieved, I/O traffic time may become an important factor.

Sweep time

RF and microwave spectrum analyzers can make full-span calibrated measurements with sweep times ranging from 5 milliseconds to several thousand seconds, and zero-span sweeps in microseconds. Sweep time is dependent on the resolution bandwidth (RBW) filter, frequency span, and the design of the spectrum analyzer.

For near-Gaussian-shaped analog RBW filters:

Sweep time = k(span)/RBW^2, where k = constant of proportionality.

Notice that when the RBW filter is reduced by a factor of 10, the sweep time goes up by a factor of 100 due to the squaring of the RBW filter value. Selecting the optimum RBW filter is clearly critical for fast measurements.

Modern spectrum analyzers employ various digital techniques to decrease sweep time. The most effective technique is the FFT (Fast Fourier Transform), used in place of swept analysis. The FFT calculates the spectrum using time samples of the signal. The use of fast analog-to-digital converters to sample the last intermediate frequency (IF) makes this possible. The FFT is used with digital RBW filters in the narrowest RBW settings (usually <1 kHz) to minimize sweep times.

Table 1 compares the sweep times of two analyzers: an Agilent 8566B Option 002 (turbo option) with analog RBW filters and an Agilent ESA-E series spectrum analyzer with digital RBW filters.

Table 1. Sweep time comparison (span = 10 kHz @ 1 GHz)

RBW	8566B Opt. 002 (analog filters)	ESA-E series (analog/digital filters)
1 kHz	300 milliseconds	275 milliseconds (analog)
10 Hz	300 seconds	4.025 seconds (FFT/digital)

In this example, the spectrum analyzer with digital RBW filters is up to 80 times faster when making the same measurement.

Choosing a resolution bandwidth filter
(optimizing for speed)

Consider the example of a manufacturing engineer who must verify the presence of two CW signals to prove that his device-under-test, a band-pass filter, passes the test specification. The first signal is at 1 GHz and is 20 dB lower than the second signal. The second signal is approximately 240 Hz higher in frequency. The key specifications the engineer must consider when choosing the RBW filter are width (usually specified at the –3 dB points) and selectivity (shape factor). RBW selectivity (see Figure 2) is the ratio of the filter width at –60 dB to the width at –3 dB. A sharper filter has a smaller selectivity.

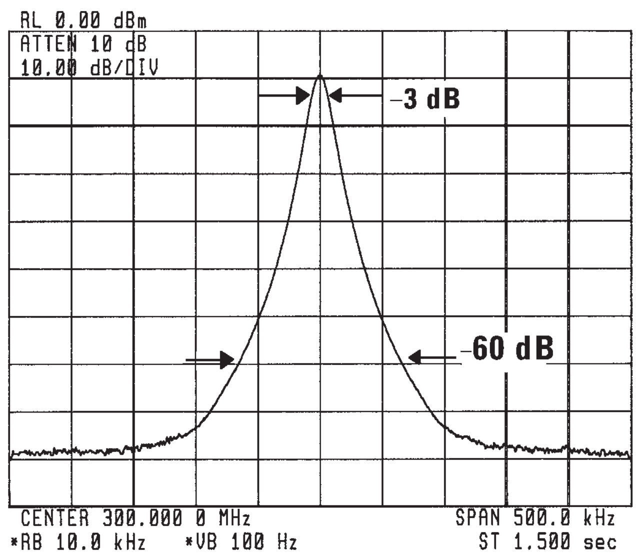

Figure 2. RBW selectivity is the ratio of the width at –60 dB to the width at –3 dB.

Figure 3 shows the output of the band-pass filter using a 300 Hz analog RBW filter. Only the largest signal can be identified due to the width of the selected filter. The RBW filter must be at least as narrow as the two signals are close together to resolve the signals.

Figure 4 shows the band-pass filter output using a 100 Hz analog RBW filter. Although the selected RBW filter is narrow enough to resolve a signal 240 Hz away from another signal, the 15:1 selectivity of the analog RBW filter is too large. The smaller 1 GHz signal still cannot be viewed, as it is hidden below the skirt of the larger signal. Therefore, an even narrower RBW filter is needed.

Figure 5 shows how the 30 Hz RBW filter will resolve the two signals with at least the 10 dB margin needed, although with a penalty in sweep time. In this example, it will take 16.7 seconds to make the measurement.

Figures 6 and 7 show the same measurement using a digital RBW filter with <5:1 selectivity. The <5:1 selectivity allows the manufacturing engineer to use the 100 Hz RBW filter and still clearly identify the smaller 1 GHz signal. A spectrum analyzer with digital RBW filters allows you to make measurements in 400 ms, or more than 40 times faster, eliminating a potential manufacturing bottleneck. This is one example of how to improve sweep time, but it doesn't address the more important issue of throughput, which must also take into account processing overhead.

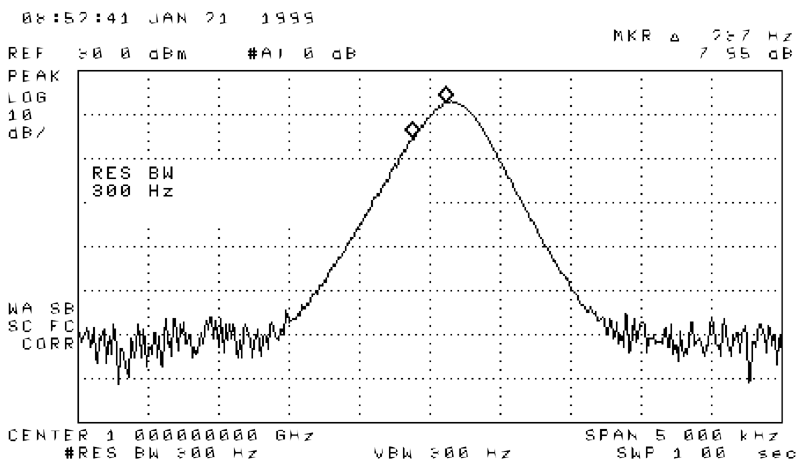

Figure 3. 300 Hz analog RBW filter

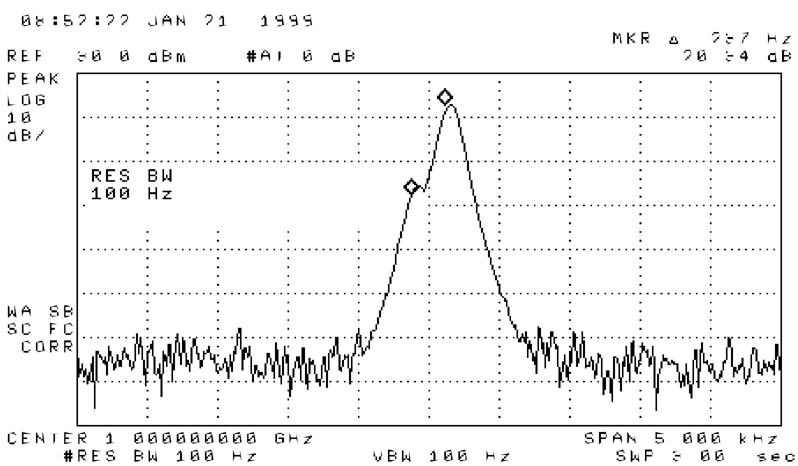

Figure 4. 100 Hz analog RBW filter

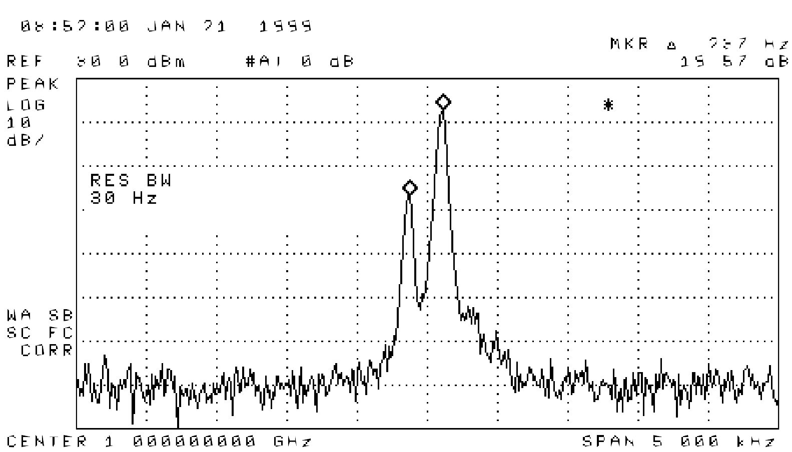

Figure 5. 30 Hz analog RBW filter

Note: Figures 3, 4, and 5 were obtained using an Agilent 8594E with optional narrow analog RBW filters.

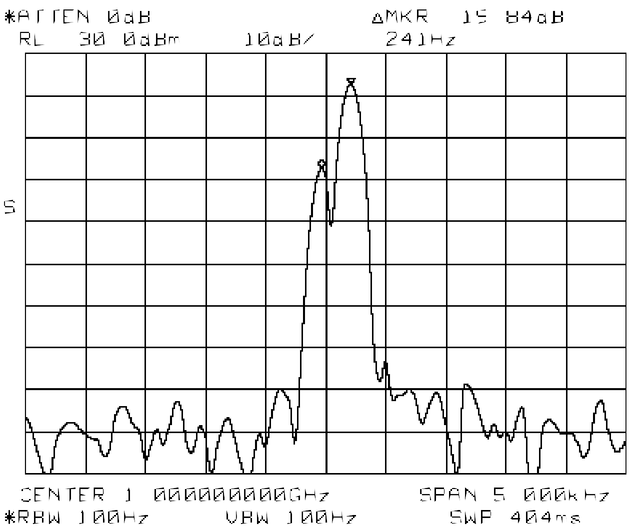

Figure 6. 100 Hz digital RBW filter

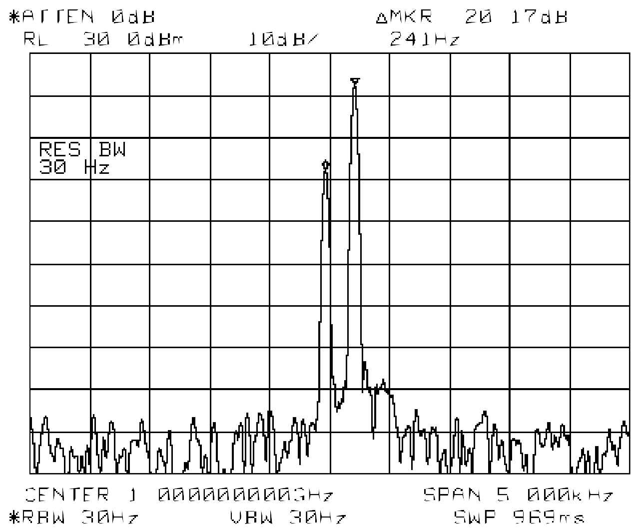

Figure 7. 30 Hz digital RBW filter

Note: Figures 6 and 7 were obtained using an Agilent 8563E with optional narrow digital RBW filters.

Modes of operation

In this section, we'll examine the two most common ways in which a spectrum analyzer is used: stand-alone operation and remote operation (controlled by an external computer). This will help you to better understand which component of speed (sweep time or processing overhead) is critical in making your measurements faster.

Stand-Alone operation

Stand-alone operation is typically used when the operator is either analyzing one or more signals, or adjusting a component to a specified value. In this manual operation mode, instantaneous response is desired. To achieve this instantaneous response, the update rate should be between 25 and 30 continuous measurements per second, or the refresh rate of the display. This minimizes any time delay between a manual adjustment and the updated spectrum analyzer display. The latest RF and microwave spectrum analyzers can achieve this flicker-free performance by minimizing processing overhead and sweep times. The Agilent 8566B with turbo option, now discontinued, has been the spectrum analyzer speed benchmark since its introduction in 1991, and will be used for comparison.

In stand-alone operation (no data transfer to a computer or printer), the following equation will yield measurement updates per second:

Measurement update rate = 1/(sweep time + time between sweeps)

Table 2 is a comparison of update rates for the Agilent 8566B and Agilent ESA-E series spectrum analyzers. While the processing overhead is greater for the newer analyzers, sweep times are faster because of recent advances, resulting in faster update rates.

Table 2. Measurement update rates (stand-alone operation)

Center frequency = 1GHz Frequency span = 300 MHz RBW filter = 3 MHz	**8566B Opt. 002 spectrum analyzer**	**ESA-E series spectrum analyzers**
Sweep time	20 ms	5 ms
Processing overhead	23 ms	30 ms
Measurement update rate	~23 updates/sec	~28 updates/sec

Remote Operation

Under computer control the spectrum analyzer performs most, if not all, of the processing that is required in stand-alone operation, plus data formatting for export. This added processing time slows down the update rate significantly. Spectrum analyzers offer amplitude data in different formats, trading off processing overhead for display scaling information. Choosing the format with the shortest processing overhead time can more than double your throughput.

All data is not created equal

The two formats a spectrum analyzer sends across the GPIB are machine units (M-units, in thousandths of a dBm) and display units (scaled to display setup). These amplitude values represent each point in the span of the measurement sweep. Amplitude points are 8, 16, 32, or 64 bits long, depending on the resolution specified. The number of frequency points in a sweep is 201, 401, 801, 1001, or more. The number of formatted bytes sent, which will affect the update rate, can be determined by the following equation:

Bytes sent = (bytes/point) x number of points

If display annotations are required, additional processing will be needed.

Which format should be used?

In ATE (automatic test equipment) environments, where speed is a priority, machine units (binary) produce the fastest results by minimizing processing overhead. Since the test conditions and instrument set-ups are known by the test software application, display scaling and instrument annotations are redundant. If GPIB speed is not an issue for your testing needs, display units (A-units in ASCII or binary) can be used.

Table 3 compares update rates with GPIB for the same two analyzers.

Table 3. ATE update rates

	8566B Opt. 002	**ESA-E series**
Machine units	15.1 updates/second	>19 updates/second
Display units (ASCII)	5.6 updates/second	7.2 updates/second

Conclusion

Whether you are installing a new, high-speed production line, making transmitter measurements in the field, or designing a new low-noise amplifier, the speed of your spectrum analyzer will greatly affect your productivity. With the speed that the latest generation of spectrum analyzers offers, spectrum analysis need never be a bottleneck in your testing process.

For additional information, see Agilent Application Note 150 (literature number 5952-0292).

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