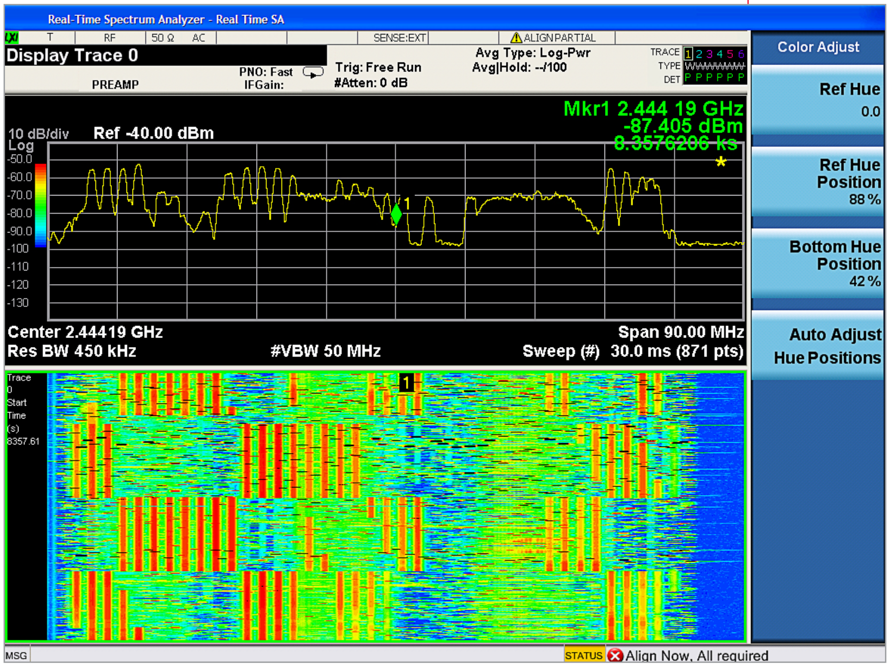
Keysight Technologies
Understanding and Applying Probability of Intercept in Real-time Spectrum Analysis

Application Note



Display Trace 0

RF 50 Ω AC
SENSE:EXT
ALIGNPARTIAL
PREAMP
PNO: Fast
IFGain:
Trig: Free Run
#Atten: 0 dB
Avg Type: Log-Pwr
Avg|Hold: --/100

Mkr1 2.444 19 GHz
-87.405 dBm
8.3576206 ks

10 dB/div Log Ref -40.00 dBm

Center 2.44419 GHz
Res BW 450 kHz
#VBW 50 MHz
Span 90.00 MHz
Sweep (#) 30.0 ms (871 pts)

Trace 0 Start Time (s) 8357.61

Ref Hue 0.0
Ref Hue Position 88 %
Bottom Hue Position 42 %

Align Now, All required

Introduction

As today's wireless signals become more complex, the process of analyzing and understanding those signals becomes more difficult. Examples include signals that have some combination of highly agile carrier frequencies, digital modulation, time-division multiplexing and burst shapes. In addition, more devices and systems are using the same frequency bands. As a result, it's becoming increasingly difficult to identify and characterize interference and signal errors, especially when they come from transient signals.

When chasing an elusive signal, several attributes are important: when it occurs, how long it lasts, where it occurs within the spectrum, and how large or small it is. Determining these attributes requires a signal analyzer capable of performing real-time spectrum analysis (RTSA), real-time data capture, or both. Real-time spectrum analysis is crucial for detecting, observing and identifying transient signals. Real-time data capture enables detailed post-processing analysis, including demodulation.

The first step is detecting the transient signal, and the main question in RTSA is, "Which signals can I see?" The key specification is probability of intercept (POI), which is actually a statistical property (see the sidebar on page 2). In the specifications for a signal analyzer, POI is often expressed as the minimum duration of a signal that can be observed with 100 percent probability—and accurately measured—if that signal is a specific amount above the instrument's noise floor. As an example, a Keysight Technologies, Inc. PXA X-Series signal analyzer equipped with 160-MHz analysis bandwidth and real-time spectrum analyzer capability (both are optional) can detect a signal as short as 5 µs 100 percent of the time. Another popular specification is POI, and this is 3.57 µs for the PXA and EXA. This means there is a 100-percent probability of detecting signals with durations as short as 3.57 µs while maintaining full amplitude accuracy. The required signal level relative to the noise floor depends on several of the variables to be discussed here.

Within a Keysight X-Series signal analyzer, six major factors determine the POI value and relative amplitude: sampling rate, time-record length (or FFT size), windowing function, window size, overlap processing, and noise floor. Because many of these have user-controllable parameters, the choices you make will affect the minimum achievable POI value. This application note describes the effect and interaction of the key factors—and this will help you understand the minimum POI value you can achieve in your application.

Chasing Dynamic or Transient Signals

In commercial or military settings, interference may be intentional or unintentional and the offending signal may be known or unknown. In either case, a fleeting or elusive interferer that occurs infrequently—an intermittent spurious emission—is the most difficult to see, capture and understand.[1]

Depending on the nature of the signals, the search may take place in either the time or frequency domain. The time domain is best for identifying when something occurs in both an absolute sense—at a specific time—and in a relative sense versus other events. It can also provide information about repetition. The required instrumentation must have a bandwidth wider than that of the signal-of-interest. Versatile triggering capabilities and deep signal-capture memory are also useful.

The frequency domain is best for identifying what is happening within the spectrum. For example, a spectrum measurement separates a signal into all its frequency components and their respective magnitudes. This makes it possible to observe and understand the static and dynamic behavior of various signal types (e.g., continuous, burst, modulated, etc.). The instrumentation must reach sufficiently high frequencies, achieve adequate dynamic range, and include vector signal analysis if demodulation and detailed analysis are needed.

A real-time spectrum analyzer combines aspects of both approaches. For example, a real-time spectrogram presents frequency spectra versus time and uses color to indicate magnitude (Figure 1). To help visualize signal activity in highly dynamic environments, density displays show how signals change over time and reveal the presence of transient activity (Figure 2).

Understanding POI at a practical level

The word “probability” suggests a dependence on statistics that might be expressed as a percentage or parts per million. While that is a valid approach, those who use spectrum or signal analyzers to detect elusive signals want to know, “What is the shortest duration of an event that I can dependably observe?” That is a quantity best expressed in units of time.

With fast, wideband ADCs and speedy DSP engines, it becomes practical to process an entire frequency band. Power, spectral and logical criteria can then be established to identify events of interest, and these can be used to define the minimum qualities an event must satisfy to ensure detection. This also means a measurement can be configured such that it confirms—confidently—that no offending events have occurred at all.

For a qualitative discussion of POI and situations with probabilities that are much less than 100 percent, please see the application note *Measuring Keysight Signals and Dynamic Signal Environments,* publication number 5991-2119EN.

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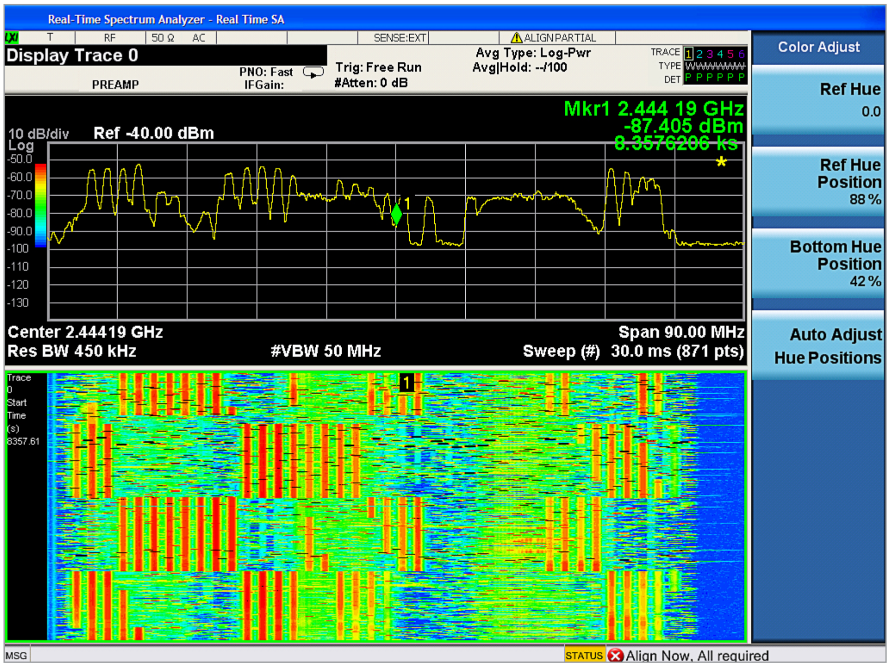
[1] *This note focuses on interfering signals rather than signal behavior (e.g., signals temporarily at the wrong frequencies) because the concepts and methods are similar, and because detecting interference is the more common goal.*



Real-Time Spectrum Analyzer - Real Time SA

Display Trace 0

PNO: Fast
IFGain:
PREAMP

Trig: Free Run
#Atten: 0 dB

Avg Type: Log-Pwr
Avg|Hold: --/100

Mkr1 2.444 19 GHz
-87.405 dBm
8.3576206 ks

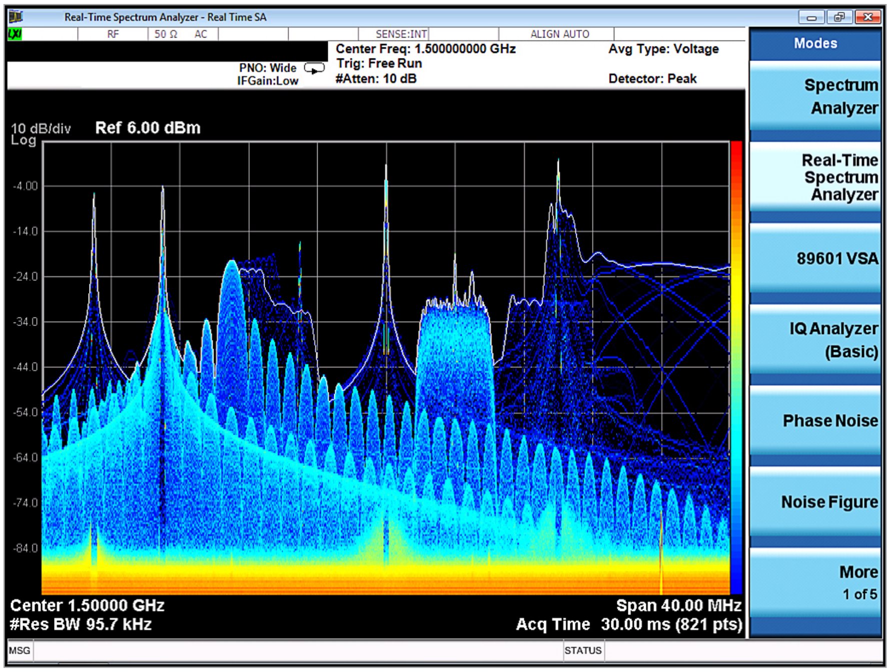
10 dB/div Ref -40.00 dBm

Center 2.44419 GHz
Res BW 450 kHz
#VBW 50 MHz
Span 90.00 MHz
Sweep (#) 30.0 ms (871 pts)

Trace 0 Start Time (s) 8357.61

Align Now, All required

Figure 1. A real-time spectrogram (bottom) provides information about time, frequency and amplitude. A single composite spectrum (top) includes a user-defined number of spectra presented in a traditional spectrum view.



Real-Time Spectrum Analyzer - Real Time SA

PNO: Wide
IFGain:Low

Center Freq: 1.500000000 GHz
Trig: Free Run
#Atten: 10 dB

Avg Type: Voltage
Detector: Peak

10 dB/div Ref 6.00 dBm

Center 1.50000 GHz
#Res BW 95.7 kHz
Span 40.00 MHz
Acq Time 30.00 ms (821 pts)

Figure 2. A real-time density display provides a detailed view of ongoing changes in the content of the spectral environment. As indicated in the color scale (right side of trace), warm colors indicate frequent occurrence and cool colors indicate infrequent occurrence.

Understanding RTSA

The phrase "real-time analysis" and the capabilities it implies mean different things to different people. Fortunately, though, a consistent core concept can be defined as follows: In a spectrum or signal analyzer with a digital intermediate frequency (IF) section, real-time operation is a state in which all signal samples are processed—continuously and gap-free—for some sort of measurement result or triggering operation. In most cases the measurement results are scalar—power or magnitude—as with traditional spectrum measurements.

Other ways to be gap-free

Various approaches satisfy parts of the "real-time" definition and provide essential types of real-time analysis for some applications. For example, vector signal analyzers use signal capture and post-processing to provide gap-free results for the length of the capture—which can be very long but not infinite—and can provide more complete analysis such as time domain and analog or digital demodulation. This type of operation will meet some user needs—and some definitions of real time—better than infinite-length spectrum-only analysis.

Some vector signal analyzers also use real-time signal magnitude processing (rather than spectrum processing) to implement an unlimited-length IF magnitude trigger that is better than FMT for some measurements and a good complement to others.

Catching signal activity without gaps

Achieving a wider real-time analysis bandwidth requires higher sampling and processing rates. Consequently, a given level of computational capability has a maximum bandwidth above which the signal-processing hardware cannot keep up with the sample stream (Figure 3).[1]

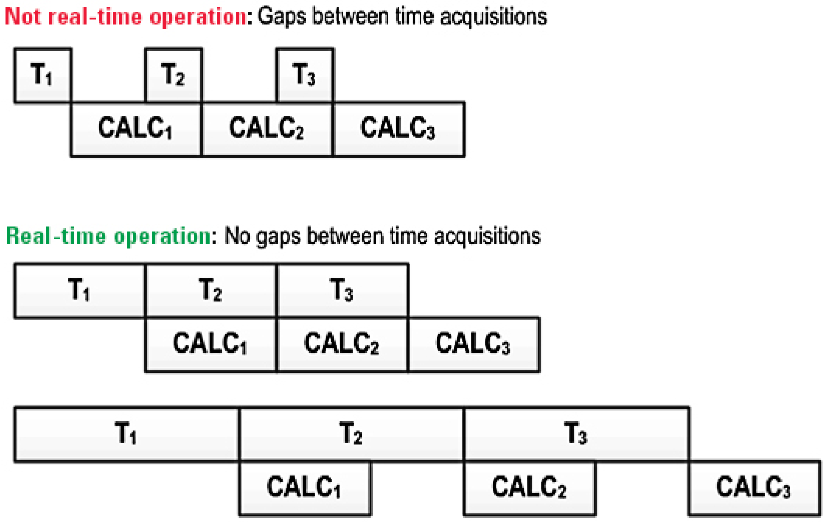


Figure 3. Real-time operation occurs when the calculation speed is fast enough to ensure gap-free analysis of sampled data. In this case each CALC includes computation of an FFT or a power spectrum as well as averaging, display updates, and so on.

In general, the stream of spectra from real-time processing can be used in one of two ways: The spectra can be combined into a composite spectrum display or successively compared to a limit mask to implement frequency-mask triggering.

From the preceding, a real-time RF analyzer may be summarized as having five key attributes: gap-free analysis, high-speed measurements, consistent measurement speed, advanced composite displays and frequency-mask triggering (FMT).

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[1] *A closely related term is real-time bandwidth (RTBW), which is the widest measurement span in which the analyzer can sustain real-time operation.*

Presenting real-time results

All of this happens at an amazingly fast rate. For example, the Keysight real-time PXA can produce nearly 300,000 spectra per second but most of us can see only 30 per second. Therefore, to take advantage of real-time results, each display update needs to combine and represent about 10,000 results in a useful way.

In this situation, the most informative displays are created by compiling statistics and displaying how often a particular measurement value occurs (e.g., specific amplitude at specific frequency). This histogram of measurement results is a spectrum measurement enhanced to show frequency of occurrence and can be considered a backward-looking version of probability.

As shown earlier in Figure 3, these displays are coded using color or trace intensity, and a persistence function can be added to focus attention on more recent events as older data fades away. Trace data such as the most recent single display update, or an average, can also be overlaid as a trace similar to a traditional spectrum measurement.

This approach allows you to see and focus on infrequent events or transients, then separate them from other signal behavior. By changing persistence and color-weighting values or schemes, specific activity can be highlighted. The real-time PXA further enhances these capabilities by providing complete trace-marker capabilities with persistence displays.[1]

Comparing RTSA to other methods

With RTSA, "gap-free" is the key idea. This is the primary difference from swept spectrum analysis and FFT-based signal analysis.

In traditional swept spectrum analysis, the local oscillator sweeps the frequency range of interest with a fixed resolution bandwidth (RBW). As shown in Figure 4, the analyzer misses anything and everything that happens outside that moving viewport.

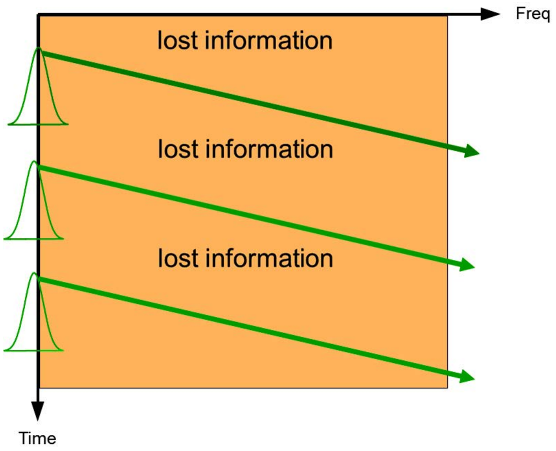

Figure 4. A swept analyzer misses data when events occur away from the instantaneous LO frequency and thus outside the RBW.

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[1] *The RTSA option can be added to new or existing Keysight PXA and MXA X-Series signal analyzers.*

In FFT-based signal analysis, processing speed or calculation time is the limiting factor. As shown in Figure 5, the analyzer gathers a complete block of time-domain samples and then computes the frequency-domain spectrum. If the instrument is not equipped with high-speed processing, there will be gaps between each block of time-domain data and the instrument will miss any events that occur in the gaps.

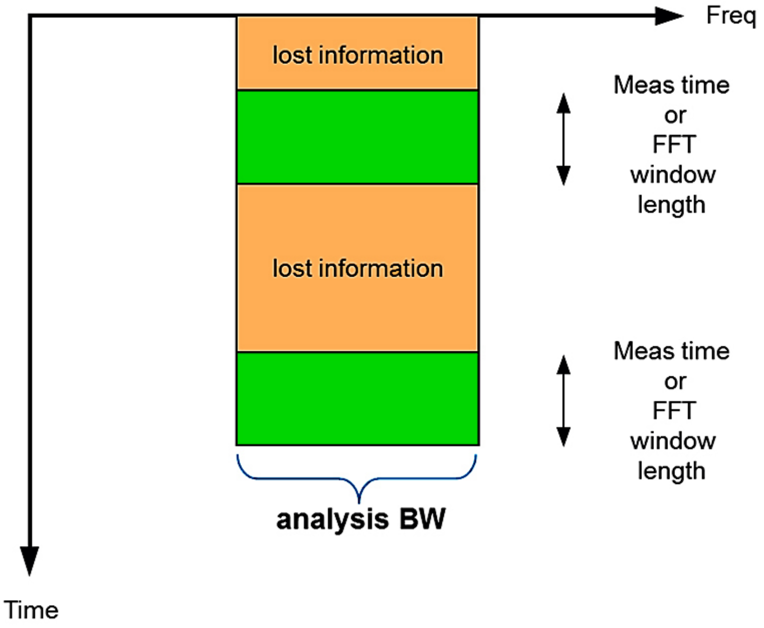

Figure 5. An FFT-based analyzer misses events that occur between blocks of sampled time data.

The net result: these methods provide a good view of stable or continuous signals. However, activity that occurs in the gaps may be seen at random or missed altogether.

Getting Started: FFT Basics

At its core, real-time spectrum analysis is a high-powered variation of FFT-based spectrum analysis. The core of FFT-based processing relies on the same attributes that ultimately determine POI: sampling rate, time-record length (or FFT size), windowing function, window size, overlap processing, and noise floor. Signal processing proceeds as follows:

– An analog-to-digital converter (ADC) samples the incoming signal and the sampling rate determines the maximum frequency span that can be analyzed.

– ADC samples are gathered in a memory buffer sometimes called a time record. In the PXA, this buffer always contains 1,024 samples. Some analyzers provide user-selectable time-record size, usually in powers of two: 32, 64, 128... 1,024, 2,048, and beyond.

  – If zooming is being used, data is translated to the desired center frequency and decimated to the user-selected measurement span. The decimated data is used to fill the time record.

  – The length of the time record is inversely proportional to the sampling rate. For example, a 100 MHz sampling rate and a 1,024-point time record equals a 1 μs time record. The slower the sample rate, the longer the time record (assuming a fixed number of points).

– An amplitude-weighting or "window" function is applied to the time record to compensate for possible discontinuities at the beginning or end of the sample block. Attenuating the samples at the beginning and end of the record removes these discontinuities and their undesirable spectral effects.

  – The best choice of window function depends on the type of signal, and the shape of the window in the time domain affects amplitude accuracy and frequency selectivity in the frequency domain (more on this in the next section).

– To provide additional RBW flexibility in analyzers that use a fixed time-record size, the size of the window (in points) can be varied. In the PXA, the size can be set in powers of two: 32, 64, 128, 256, 512 or 1,024. This has almost the same net effect as a variable-sized time record.

– Signals that cover an entire time record will show accurate amplitude. For signals that do not span an entire time record, it is necessary to compensate for the effects of the window function: to increase the likelihood that some part of the signal will occur in the center of the time record, the time records are processed in an overlapped manner (Figure 6).

– An FFT is performed on successive blocks of samples, whether they are overlapped or concatenated. The number of lines of resolution in the frequency spectrum is directly related to the number of points in the time record. For example, a block of 1,024 points is transformed into an 821-bin or 831-line spectrum (assuming a Nyquist factor of 1.25, as in the PXA).

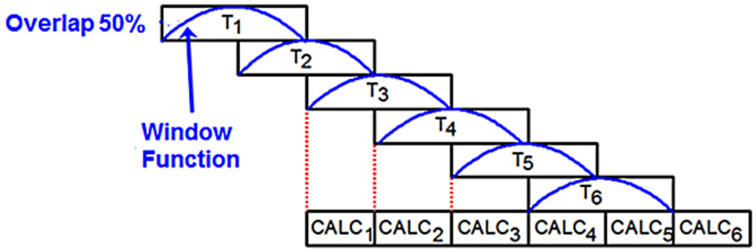

Figure 6. With overlap processing, successive time records contain a mix of existing and new samples—but the measured data remains gap-free.

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1. *The time per point is the inverse of the sampling rate, and the length of the time record is time/point times number of points. In this case 1 μs = [(1/108)*1024].*

After the time data has been transformed into the frequency domain, the display engine takes over. As an intermediate step, a frequency-mask trigger can be applied to the calculated spectra and further measurements and display processing will occur when the trigger criteria are met.

Dealing with windowing effects

Most analyzers provide a variety of user-selectable window functions. The best choice depends on four key factors: the nature of the signal itself in the time domain, the desired frequency selectivity, amplitude accuracy and dynamic range in the frequency-domain results. Table 1 provides a quick comparison of six common window functions.

Table 1. Each window function offers advantages and disadvantages.

Window function	Amplitude accuracy	Frequency selectivity	Dynamic range/ noise floor
Rectangular or Uniform	Excellent with on-bin signals, poor with off-bin	Excellent with on-bin signals, poor with off-bin	Excellent with on-bin signals, poor with off-bin
Blackman-Harris	Good	Good	Good
Flattop	Best	Fair	Good
Gaussian	Good	Good	Good
Hanning	Fair	Good	Fair
Kaiser	Good	Good	Good

One key point affects the resulting amplitude accuracy: whether or not the transformed signal falls on or between the discrete frequency bins (or lines) in the resulting spectrum. The flattop window is the most forgiving because it has a wider main lobe in the frequency domain and will show the correct amplitude, whether a signal is on- or off-bin. The rectangular window is the least forgiving because it does not compensate for discontinuities caused by off-bin signals; it has the narrowest shape (or highest Q) in the frequency domain for on-bin signals but has the greatest amplitude errors for off-bin signals.[1]

The width of the main lobes also affects frequency selectivity or resolution. That is why the flattop window provides excellent amplitude accuracy but fair frequency selectivity: it needs a wide main lobe to achieve its flat top. Many of the other window functions provide a good compromise between frequency selectivity and amplitude accuracy.

As a final point, it is also important to note the relationship between the number of window (or FFT) points and the noise floor. For any given window, fewer points mean a higher noise floor. The reason: because a narrower window function has less area under the curve in the time domain, the FFT result must be multiplied by a larger scale factor to provide a correct amplitude value in the frequency domain. From a mathematical perspective, a larger scale factor produces a higher noise floor. From an RF perspective, fewer points mean a wider bandwidth and therefore a wider equivalent noise bandwidth.

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1. *With its uniform weighting factor of one at all points, the rectangular or uniform shape is actually no window at all.*

Handling brief signals

Together, averaging and overlap processing account for complex signals that are longer in duration than either the time record or the window width. Overlap processing has another beneficial property: it ensures better amplitude accuracy for transient signals that are shorter than the time record length or narrower than the window width.

If a signal pulse has duration less than that of the time record and falls within the time record or window, its amplitude will be affected by the time-domain shape of the window function. The amplitude in the frequency domain will be displayed with less accuracy than would that of a CW signal. The accuracy is proportional to the sum of the coefficients of the window covered by the signal compared to the sum of all coefficients of the window.

To simplify the discussion, let us consider an on-bin signal, which is not affected by the frequency-domain "scalloping" caused by all but the flat top window. In the analyzer, we will assume a 200 MSa/s complex-valued sample rate, 1,024-point time record and 1,024-point Blackman-Harris window function.

To produce the same amplitude reading as that of a CW signal, the short-duration signal would have to span all 1,024 samples covered by the window. This equals a duration of 5.12 μs, which is simply the number of samples divided by the sample rate (1024/200*106).

Now let us assume the signal lasts one-quarter of this time and consider two cases. In one, the signal accidentally lines up with the center of the window; in the other, the signal occurs at the far-left edge of the window (Figure 7). Note that the amplitude of the example signal was constant during the pulse; the variation seen in Figure 7 is the caused by applying the window shape.

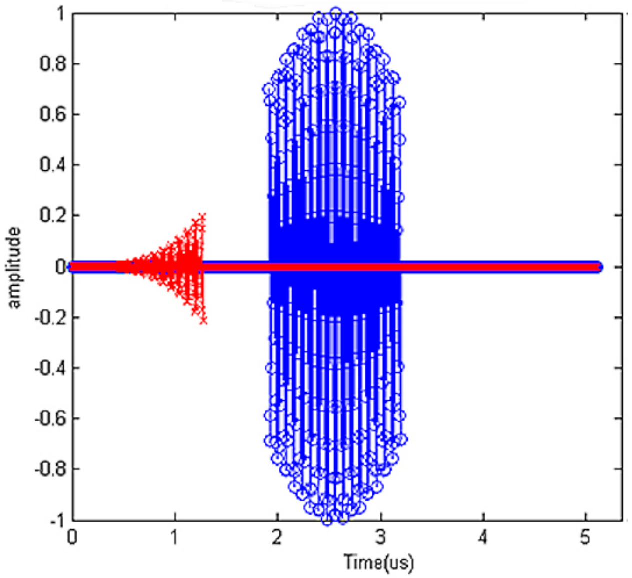

Figure 7. Both signals are one-fourth the duration of the time record and the amplitudes are affected by where they occur relative to the window shape.

The sum of the coefficients of the 256 points in the middle of the window equals 228.256, the sum of the 256 at the left edge comes to just 12.829, and the sum of all coefficients equals 367.000. As a result, the first signal will have a frequency-domain amplitude that is –4.125 dB lower than a CW signal expected (from 20*log (228.256/367)) and the other will appear to be –29.129 dB lower than a CW signal (from 20*log (12.829/367)).

Overlap processing compensates for this effect by computing an FFT using some of the samples from the previous time record and some from the current time record. This is possible if the FFT engine runs at a faster clock rate than the sample rate. The larger the difference between the two rates, the greater the possible amount of overlap. You might visualize the FFT processing as scrolling through the time samples, with the scrolling increment (in time) being proportional to the reciprocal of the overlap percentage.

In the PXA, the FFT engine runs at 300 MHz (fclk) and the maximum complex-valued sample rate is 200 MHz (fs). The formula for the maximum number of overlapped points (P) is as follows:[1]

$$P = \text{floor}\left\{1024 \; * \; \left[\left(f_{clk} - f_s\right) / f_{clk}\right]\right\}$$

Thus, when the PXA is running at its maximum sample rate, the maximum number of overlapped points is 341 (rounding down to the nearest integer). Conversely, the number of non-overlapped points is 1024 – P or 683. Table 2 shows the overlap values for a range of sample rates.

Table 2. At lower sample rates, the maximum amount of overlap increases.

FFT rate (MHz)	**Sample rate (MHz)**	**Overlap (points)**
300	200	341
300	150	512
300	100	682
300	50	853
300	25	938

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[1] Specific to the PXA, this assumes that the power-versus-time (PVT) display is turned off. When PVT is on, the overlap may be adjusted downward to ensure data consistency between the time and frequency domains.

Determining POI Values

With the preceding as our foundation, we can now determine the minimum achievable POI value at specific measurement spans and window sizes. In this case, working backwards from the range of answers can make this discussion easier to follow.

Table 3 shows POI values for the PXA at five spans and sample rates with the associated overlap values. Note how the narrower windows and faster sample rates produce a lower duration but introduce non-overlapped windows (non-starred values). As noted earlier, the PXA always uses a 1024-point FFT. Even though these are overlapped FFTs, some samples are multiplied by zero in the window function of the smaller windows. This results in areas with no non-zero values in time (i.e., “window gaps”).

Table 3. Within the analyzer, a combination of factors determines the minimum achievable POI value.

Span (MHz)	Sample rate (MHz)	Overlap (points)	Duration, 1024-pt window	Duration, 512-pt window	Duration, 256-pt window	Duration, 128-pt window	Duration, 64-pt window	Duration, 32-pt window
160	200	341	8.53 µs*	5.97 µs	4.69 µs	4.05 µs	3.73 µs	3.57 µs
120	150	512	10.23 µs*	6.82 µs*	5.11 µs	4.26 µs	3.83 µs	3.62 µs
80	100	682	13.65 µs*	8.53 µs*	5.97 µs	4.69 µs	4.05 µs	3.73 µs
40	50	853	23.88 µs*	13.6 µs*	8.52 µs*	5.96 µs	4.68 µs	4.04 µs
20	25	938	44.40 µs*	23.9 µs*	13.6 µs*	8.52 µs*	5.96 µs	4.68 µs

* = windows overlap

In the table, “Duration” is the minimum length of the signal of interest if it is to be detected with 100-percent probability and measured with the same amplitude accuracy as that of a CW signal. Here, the shortest possible signal duration—3.57 µs—occurs with a 160-MHz span (or analysis bandwidth) and a 32-point window function.

We use the following equation to calculate the duration value:

$$T_{min} = \left[\left(\text{window size} + \text{time record length} - 1\right) - P\right] / f_s$$

Because the PXA has a fixed time-record size of 1,024 samples, the equation becomes the following:

$$T_{min} = \left[\text{window size} + 1023 - P\right] / f_s$$

For the PXA, the minimum value of 3.57 µs is the result of the following:

$$T_{min} = \left[\left(32 + 1024 - 1\right) - 341\right] / \left(200 * 10^6\right) = \left[\left(1055 - 341\right)\right] /$$

$$\left(200 * 10^6\right) = \left[714\right] / \left(200 * 10^6\right) = 3.57\ \mu s$$

The key question: how did we arrive at the numerator formula? The determining factor is the minimum number of points needed to achieve full amplitude accuracy. That value is a function of the window size, the time record length, the maximum overlap value, and the resulting relative position of the windows in any two adjacent time records.

To illustrate, let us look at the two contrasting cases for adjacent time records in the PXA:

- Case 1: 1,024-point time record, 1,024-point window and zero overlap
- Case 2: 1,024-point time record, 1,024-point window and maximum overlap

In a 1,024-point time record with no overlap, the centers of the adjacent time records are 1,024 points apart.[1] The worst-case alignment between a signal and two adjacent windows occurs when the signal lands midway between the centers of the windows.

As noted earlier, a fleeting signal will register CW-like amplitude accuracy only if its duration spans the entire time record. For the consecutive non-overlapped time records, the signal must last for nearly two full records. In this case, the minimum duration is 1,024 + 1,023 or 2,047 samples. This is the minimum needed to ensure that one of the two windows receives 1,024 samples.

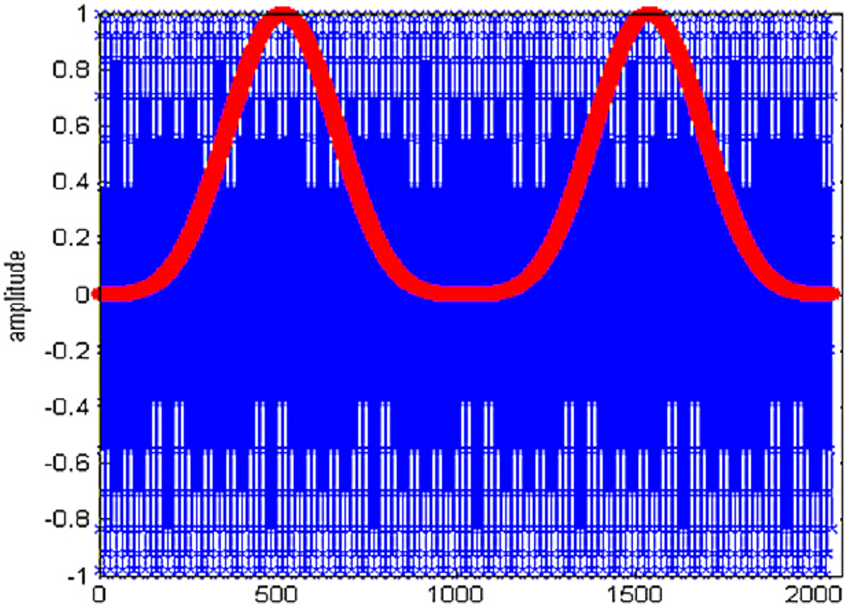

Figure 8. In this case the sampled signal spans two 1,024-point time records and fills at least one of the windows.

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[1] *In the PXA, this is the case for any selected window size because it will be centered at the midpoint of the 1,024-point time record.*

Next, let us consider the second case with a 1,024-point time record, a 1,024-point window and maximum overlap. Because the window centers are now 683 samples apart (1,024 – 341), the signal can last for 1,706 samples (2,047 – 341) and still ensure an accurate amplitude measurement.

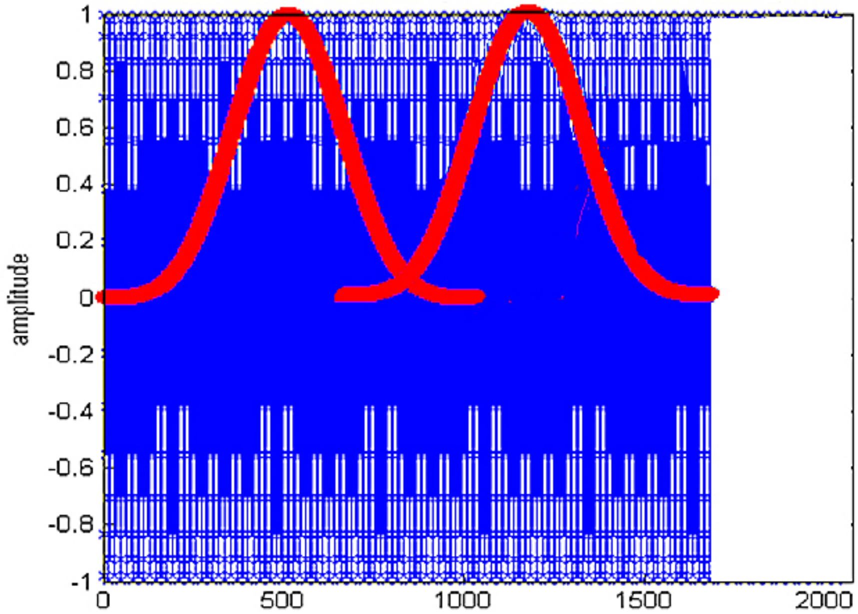

Figure 9. With maximum overlap, the sampled signal must last only 1,706 samples to ensure that at least one of the windows contains 1,024 samples.

The required signal duration in samples can be calculated using the following formula:

$$N = \left(\text{window size} + \text{time record length} - 1\right) - P$$

This is, of course, the numerator from the POI calculation. P is the maximum number of overlap points:

$$P = 1024 * \left[\left(f_{clk} - f_s\right) / f_{clk}\right]$$

Plugging in the values from our second case produces the following result:

$$N = \left(1{,}024 + 1{,}024 - 1\right) - 341 = \left(2{,}047\right) - \left(341\right) = 1{,}706$$

Coming full circle, dividing N by the sample rate (fs) provides the minimum duration of a signal that can be measured with CW-like amplitude accuracy.

$$T_{min} = 1{,}708 / 200 * 10^6 = 8.53\ \mu s$$

This value corresponds to the first value in the Duration column of Table 3. Thus, at a 200 MHz sample rate, 160 MHz analysis bandwidth, 1,024-point time record, 1,024-point window and maximum overlap (341 points) a signal as short as 8.53 μs in duration will always be measured with full amplitude accuracy. A signal as short as 5.12 μs may be measured accurately if it happens to be centered in the window function; however, the accuracy can be guaranteed only if it lasts 8.53 μs.

In some applications, amplitude accuracy may be less important than simply detecting a signal. Fortunately, it is possible to detect events of much shorter durations with 100-percent probability by operating an RTSA in a mode that no longer provides its specified amplitude accuracy.

For the PXA and its 200 MHz sampling rate, the theoretical minimum is 5 ns:

$$T_{\text{min}} = 1/\left(200\ *\ 10^{6}\right) = 5\text{ ns}\ \left(1024-\text{point time record and rectangular window}\right)$$

The actual attainable minimum value depends on factors such as sample rate (frequency span), window function, trigger level, noise level and the maximum amplitude of the signal of interest. The offset between analyzer noise level and input signal amplitude is the key determining factor: the greater the offset, the shorter the minimum detectable duration; the lower the offset (especially less than 20 dB), the greater the likelihood of noise interfering with the measurement.

Table 4 shows a range of minimum-duration values for 100-percent probability of detection in the PXA using a Blackman-Harris window. To highlight the differences, the table shows five example sample rates versus six different offset levels, which are actually signal-to-noise ratios or, more precisely, signal-to-mask ratios (due to possible effects of trigger settings and the selected window function).

Table 4. The calculated values for minimum signal length for 100-percent probability of detection are shown as a function of the offset between the input signal amplitude and the analyzer noise floor (PXA signal analyzer).

Sample rate (MHz)	Span (MHz)	Overlap (points)	Duration, 0 dB offset	Duration, 6 dB offset	Duration, 12 dB offset	Duration, 20 dB offset	Duration, 40 dB offset	Duration, 60 dB offset
200	160	341	8.53 µs	3.42 µs	2.44 µs	1.58 µs	0.325 µs	0.035 µs
150	120	512	10.23 µs	3.42 µs	2.12 µs	1.04 µs	0.120 µs	0.013 µs
100	80	682	13.65 µs	3.48 µs	1.76 µs	0.71 µs	0.080 µs	0.010 µs
50	40	853	23.88 µs	4.66 µs	2.22 µs	0.88 µs	0.100 µs	0.020 µs
25	20	938	44.36 µs	8.36 µs	4.00 µs	1.64 µs	0.240 µs	0.040 µs

To further enhance these measurements, the PXA can present time-domain data and a full 160-MHz spectrum in a multi-domain display. This is ideal for detection of very brief transient events.

Recapping and Revisiting the Main Objective

When chasing an elusive signal, several attributes are important: when it occurs, how long it lasts, where it occurs within the spectrum, and how large or small it is. Determining these attributes requires a signal analyzer capable of performing real-time spectrum analysis, real-time data capture or both.

Within the instrument, the interaction of six major factors determines the POI value: sampling rate, time-record length (or FFT size), windowing function, window size, overlap processing, and noise floor. As shown here, careful selection of these values can result in the ability to observe signals that last only a few microseconds. In practice, it is often possible to reliably detect signals that last just a few nanoseconds.

The types of real-time spectrum analysis measurements described here make it possible to simply observe the elusive signal—and that may be sufficient in many situations. In other cases, observing the signal is the first step towards a more detailed analysis. Once the signal behavior is understood, those attributes can be used to define a frequency-mask trigger that initiates either a specific measurement or a time capture.

If time capture is used, the captured block of samples can be analyzed repeatedly and nondestructively using different settings: span, center frequency, window function, overlap, and so on. With the capture/playback mode, it is possible to detect and accurately analyze bursts as brief as several samples because overlap can be set as high as 99.99 percent (effectively one sample) and time-gated spectrum can also be used. At the maximum sample rate of 200 MHz, this corresponds to a burst length of several tens of nanoseconds. In addition, amplitude data can be recovered for signals of very short duration by using smaller window sizes with maximum overlap. Finally, with the addition of the 89600 VSA software, the captured signal can be demodulated and further analyzed in great detail from a wide range of useful perspectives.

Related Information

Application note: *Measuring Agile Signals and Dynamic Signal Environments,* publication 5991-2119EN

Application note: *Real-time Analysis Techniques for Making Wireless Measurements,* publication 5991-2779EN

Application note: *Using Noise Floor Extension in the PXA Signal Analyzer,* publication 5990-5340EN

Technical overview: *Real-Time Spectrum Analyzer (RTSA),* publication 5991-1748EN

Brochure: *N9030A PXA X-Series Signal Analyzer,* publication 5990-3951EN

Brochure: *MXA X-Series Signal Analyzer N9020A,* publication 5989-5047EN

Flyer: *Upgrade Your X-Series Signal Analyzer Today,* publication 5991-2673EN myKeysight

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Published in USA, August 4, 2014
5991-4317EN
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