▸ Application Note

Advanced Radar Testing with the RSA6100A Series Real-Time Spectrum Analyzer

Testing advanced radars often demands exceptional performance from measurement equipment. The RSA6100A Series sets a new industry standard for advanced radar testing, delivering performance and innovative features that greatly simplify diagnostic troubleshooting and production test. Covering the popular radar bands through 14 GHz, the RSA6100A leads the industry with up to 110 MHz of instantaneous IF bandwidth and a minimum of 73 dB of dynamic range. Combining this raw hardware performance with innovative features like live DPX displays and Pulse Measurement Suite makes the RSA6100A an excellent choice for testing advanced radars. In this application note we explore the performance and features of the RSA6100A Series of Real-Time Spectrum Analyzers (RTSA) as applied to advanced radar testing.

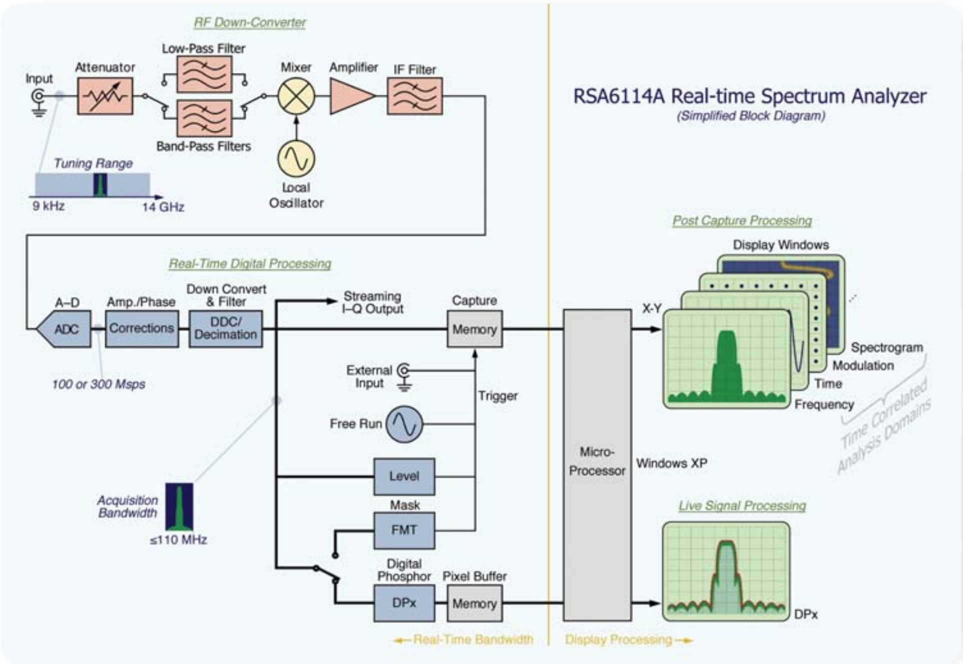
Tektronix
Enabling Innovation

Introduction

In the Tektronix 'Radar Pulse Measurements with the Real-Time Spectrum Analyzer' application note, basic radar concepts along with the RTSA's special capabilities and Pulse Measurement Suite were introduced.

With the introduction of the RSA6100A Series of Real-Time Spectrum Analyzers, a host of new capabilities are now available to address a wider range of applications.

In this application note, we look at the performance of the RSA6100A Series and its application to advanced radar measurements.



▶ **Figure 1.** *The simplified block diagram of the RSA6114A Real-Time Spectrum Analyzer with Digital Phosphor technology (DPX) illustrates the real-time architecture.*

The RSA6100A's Performance

The RSA6100A Real-Time Spectrum Analyzer offers solutions to historically difficult radar, Electronic Warfare (EW) and ELectronic INTelligence (ELINT) problems, expanding the measurement envelope in bandwidth, frequency, dynamic range and display processing for a single instrument. Let's examine the RSA6100A's unique capabilities…

Frequency Range

The signal path of the RSA6114A begins with an analog RF down-converter. Using multiple conversions, the RF down-converter is similar to many spectrum analyzers with the notable exception of its wide IF bandwidth.

The down-converter tunes over a frequency range from 9 kHz to 14 GHz, covering many of the popular radar bands.

Wide Bandwidth

The RSA6100A combines a 40 MHz (standard) or 110 MHz (Option 110) capture bandwidth with high dynamic range. This bandwidth requires a change in the RF portion of the instrument architecture from conventional spectrum analyzers. Previous instruments have used swept Yttrium-Iron-Garnet (YIG) filters as pre-selectors for image and spurious control above approximately 3 GHz. YIG filters, though, are limited in bandwidth, contain significant tuning hysteresis and have group delay variability, making it difficult to achieve repeatable results over multiple measurements. When wide-band captures are needed, conventional instruments require that the YIG filter be bypassed, with a resultant reduction in spurious-free dynamic range. For these reasons, the RSA6100As use a series of switched band-pass filters for image and spurious control above 8 GHz, achieving both high spurious-free dynamic range and wide bandwidth simultaneously.

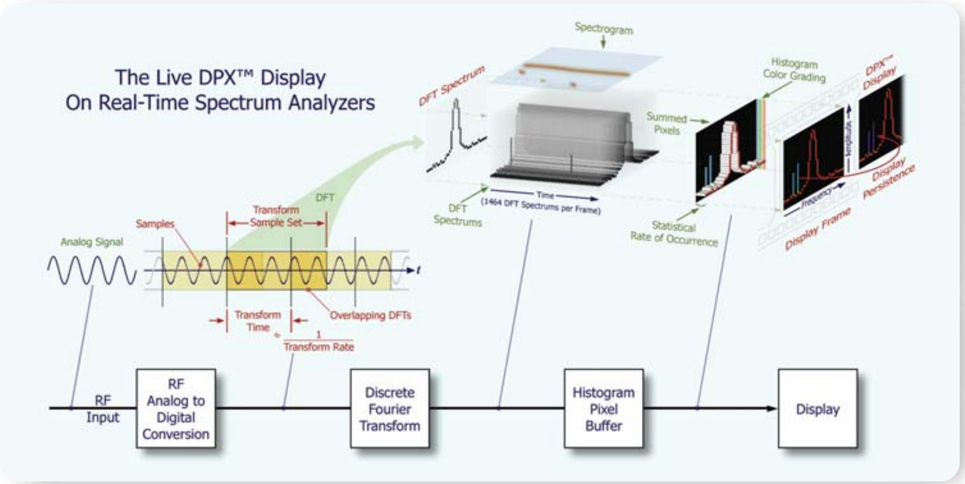
The DPX Display

The RSA6100A's unique live DPX spectrum display is of particular interest to the advanced radar engineer. The RSA6100A Series of Real-Time Spectrum Analyzers can process more than 48,000 spectrum measurements per second, assuring reliable intercept of short duration events, like narrow radar pulses.

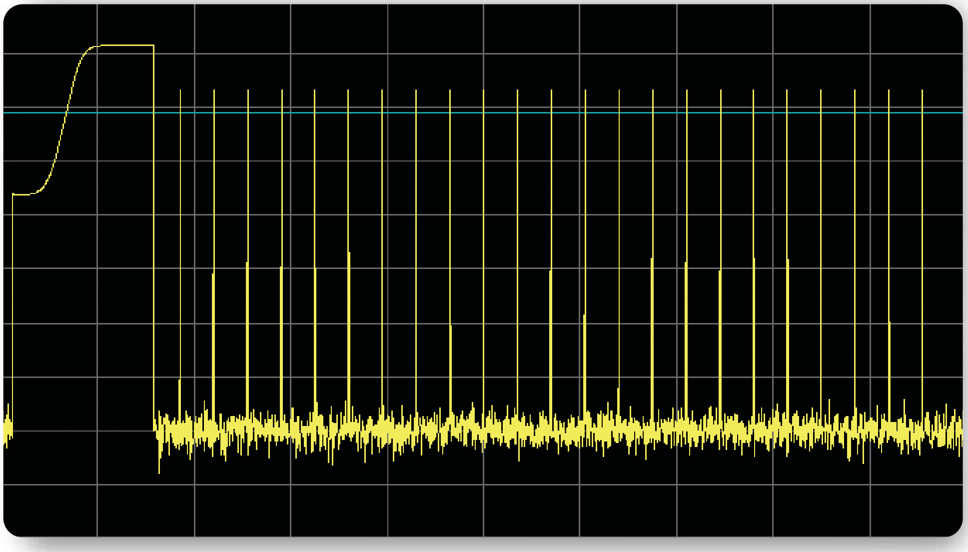
The DPX spectral processing rate is much faster than the human eye can perceive. To view live signals it must be slowed down without losing information. The DPX display processor compresses the 48,000 spectrums/s measurement rate to approximately 33 screen updates per second. To do so without losing information, the DPX processor creates a color-graded display by compiling a pixel histogram made up of the many spectrum samples that comprise each display frame. The energy found in each pixel location of the display is accumulated over the hundreds of spectrum measurements taken during each display frame. The color and intensity of each pixel in the display is based on the number of times that energy is found at each pixel location during a display frame. This reduces the spectrum update rate to approximately 33 frames per second without losing any of the spectral information.

Adjustable, phosphor-like persistence of each display frame then allows very short events to remain on the display long enough to be seen by the human eye. More information on this revolutionary technology can be found in other DPX spectrum display application notes available from Tektronix.

To illustrate the improved visualization of DPX spectrum technology, an intermittent pulse (see Figure 3), is used. During turn-on, the pulse generator emits an unusual carrier transient prior to producing pulses.

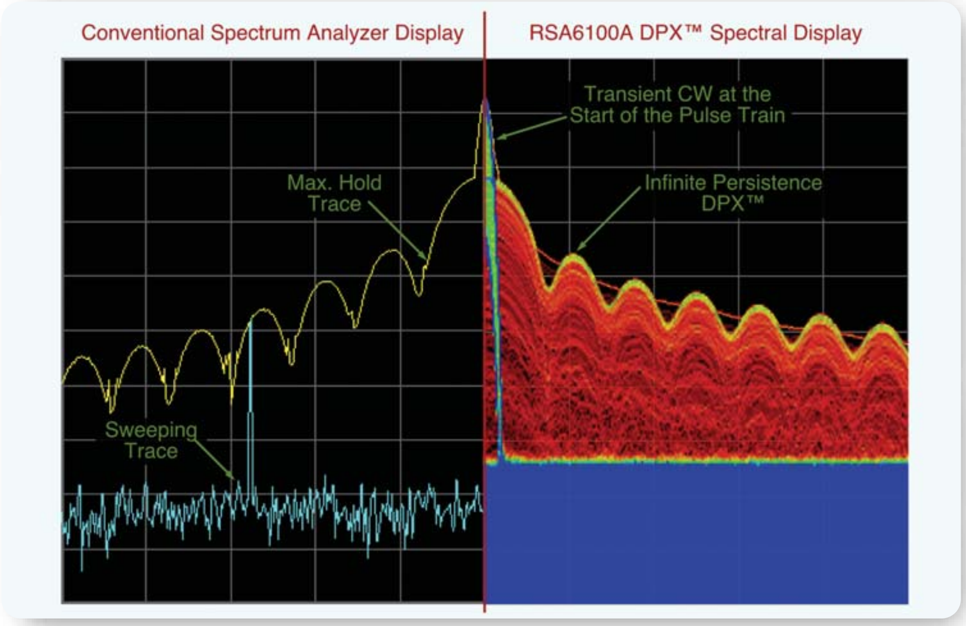


▶ **Figure 2.** *The simplified DPX diagram shows how the 48,000 spectrum/second processing rate is reduced using a pixel histogram and variable persistence display.*



▶ **Figure 3.** *Time domain view of intermittent pulse train with a turn-on transient.*

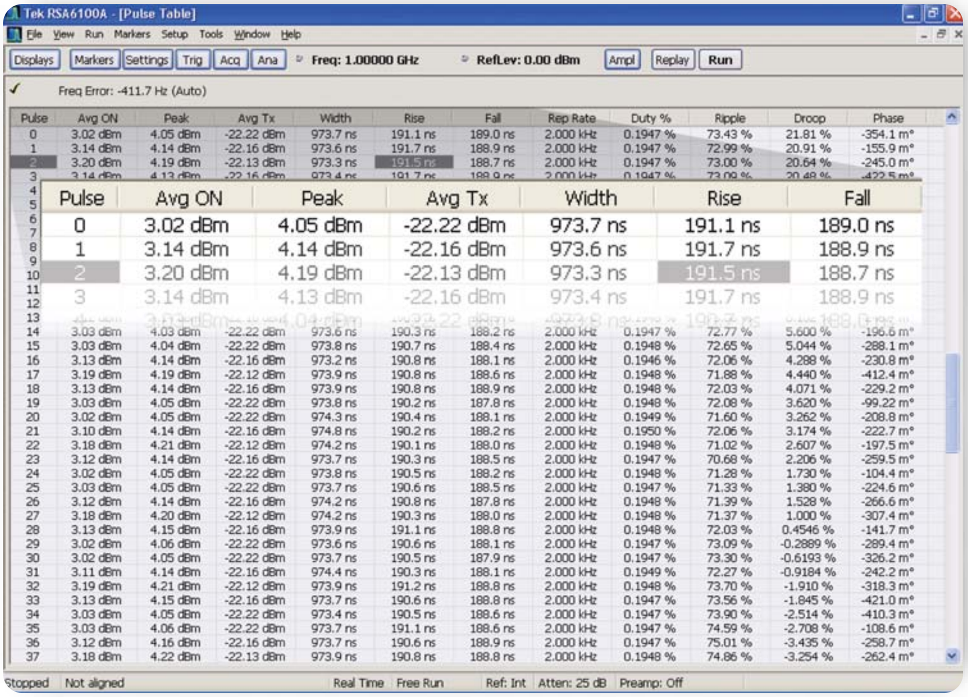
A comparison of a swept tuned spectrum analyzer display to the RSA6100A with DPX spectrum capability helps to illustrate the difference between the two instruments. Figure 4 presents a composite view of the two instruments. Several seconds were required to allow the swept analyzer to build up a max-hold trace that shows the sin(X)/X nature of the pulsed signal. The DPX display shows this characteristic immediately and is color-graded, such that infrequent events are shown in red, and more frequent events (such as the noise floor) are seen in blue. The green of the turn-on transient in the center of the screen indicates that it is present for a longer period of time than the rest of the pulse train. The swept analyzer is able to capture the turn-on transient signal in max-hold, but is unable to indicate how often it occurs.



▶ **Figure 4.** *A live DPX spectrum easily reveals detail like a frequently occurring turn-on transient, seen in green at the center of the screen. Conventional spectrum analyzers can only show the peak amplitude in a monochrome trace.*

Troubleshooting Radars

Advanced radar systems can encounter complex problems that are difficult to troubleshoot. Advances in Field Programmable Gate Arrays (FPGAs), Digital-to-Analog (D/A) and Analog-to-Digital (ADC) converters have advanced in performance such that yesterday's analog-based, triple-conversion systems are



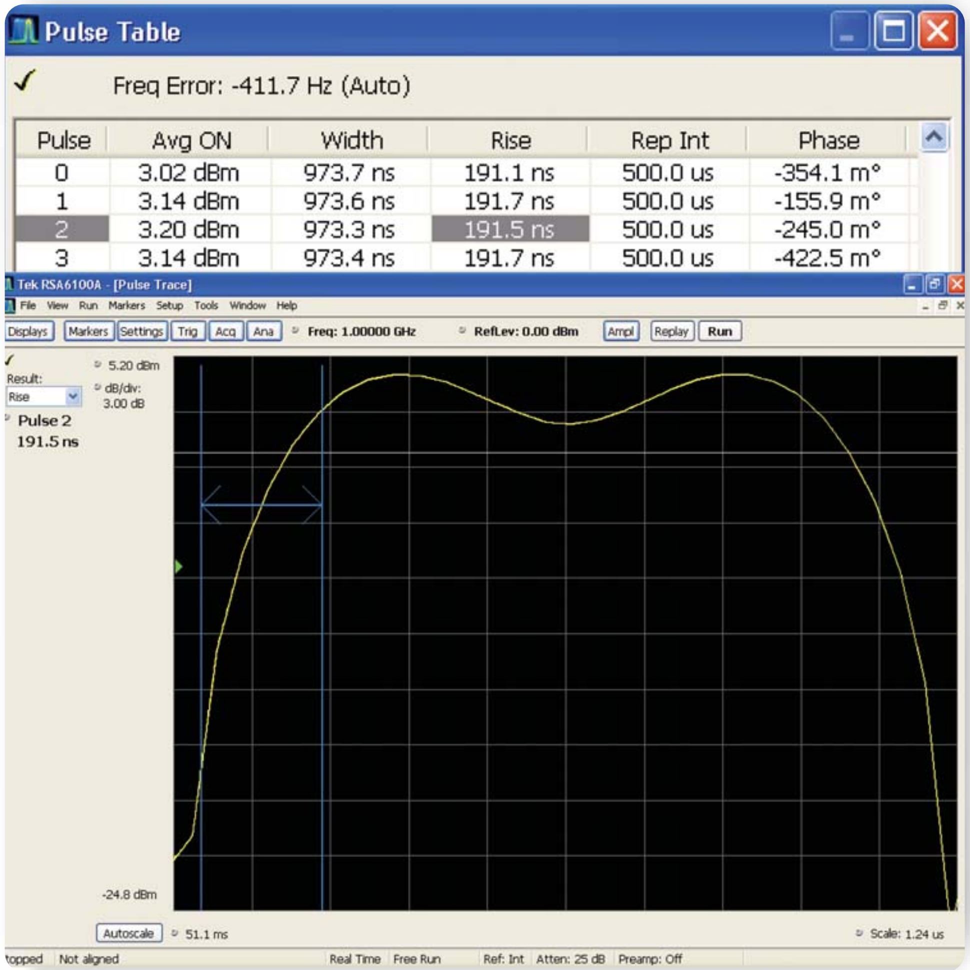
Pulse	Avg ON	Peak	Avg Tx	Width	Rise	Fall	Rep Rate	Duty %	Ripple	Droop	Phase
0	3.02 dBm	4.05 dBm	-22.22 dBm	973.7 ns	191.1 ns	189.0 ns	2.000 kHz	0.1947 %	73.43 %	21.81 %	-354.1 m°
1	3.14 dBm	4.14 dBm	-22.16 dBm	973.6 ns	191.7 ns	188.9 ns	2.000 kHz	0.1947 %	72.99 %	20.91 %	-155.9 m°
2	3.20 dBm	4.19 dBm	-22.13 dBm	973.3 ns	191.5 ns	188.7 ns	2.000 kHz	0.1947 %	73.00 %	20.64 %	-245.0 m°
3	3.14 dBm	4.13 dBm	-22.16 dBm	973.4 ns	191.7 ns	188.9 ns	2.000 kHz	0.1947 %	73.09 %	20.48 %	-422.5 m°
14	3.03 dBm	4.03 dBm	-22.22 dBm	973.6 ns	190.3 ns	188.2 ns	2.000 kHz	0.1947 %	72.77 %	5.600 %	-196.6 m°
15	3.03 dBm	4.04 dBm	-22.22 dBm	973.8 ns	190.7 ns	188.4 ns	2.000 kHz	0.1948 %	72.65 %	5.044 %	-288.1 m°
16	3.13 dBm	4.14 dBm	-22.16 dBm	973.2 ns	190.8 ns	188.1 ns	2.000 kHz	0.1946 %	72.06 %	4.288 %	-230.8 m°
17	3.19 dBm	4.19 dBm	-22.12 dBm	973.9 ns	190.8 ns	188.6 ns	2.000 kHz	0.1948 %	71.88 %	4.440 %	-412.4 m°
18	3.13 dBm	4.14 dBm	-22.16 dBm	973.9 ns	190.8 ns	188.9 ns	2.000 kHz	0.1948 %	72.03 %	4.071 %	-229.2 m°
19	3.03 dBm	4.05 dBm	-22.22 dBm	973.8 ns	190.2 ns	187.8 ns	2.000 kHz	0.1948 %	72.08 %	3.620 %	-99.22 m°
20	3.02 dBm	4.05 dBm	-22.22 dBm	974.3 ns	190.4 ns	188.1 ns	2.000 kHz	0.1949 %	71.60 %	3.262 %	-208.8 m°
21	3.10 dBm	4.14 dBm	-22.16 dBm	974.8 ns	190.2 ns	188.2 ns	2.000 kHz	0.1950 %	72.06 %	3.174 %	-222.7 m°
22	3.18 dBm	4.21 dBm	-22.12 dBm	974.2 ns	190.1 ns	188.0 ns	2.000 kHz	0.1948 %	71.02 %	2.607 %	-197.5 m°
23	3.12 dBm	4.14 dBm	-22.16 dBm	973.7 ns	190.3 ns	188.5 ns	2.000 kHz	0.1947 %	70.68 %	2.206 %	-259.5 m°
24	3.02 dBm	4.05 dBm	-22.22 dBm	973.8 ns	190.5 ns	188.2 ns	2.000 kHz	0.1948 %	71.28 %	1.730 %	-104.4 m°
25	3.03 dBm	4.05 dBm	-22.22 dBm	973.7 ns	190.6 ns	188.5 ns	2.000 kHz	0.1947 %	71.33 %	1.380 %	-224.6 m°
26	3.12 dBm	4.14 dBm	-22.16 dBm	974.2 ns	190.8 ns	187.8 ns	2.000 kHz	0.1948 %	71.39 %	1.528 %	-266.6 m°
27	3.18 dBm	4.20 dBm	-22.12 dBm	974.2 ns	190.3 ns	188.0 ns	2.000 kHz	0.1948 %	71.37 %	1.000 %	-307.4 m°
28	3.13 dBm	4.15 dBm	-22.16 dBm	973.9 ns	191.1 ns	188.8 ns	2.000 kHz	0.1948 %	72.03 %	0.4546 %	-141.7 m°
29	3.02 dBm	4.06 dBm	-22.22 dBm	973.6 ns	190.6 ns	188.1 ns	2.000 kHz	0.1947 %	73.09 %	-0.2889 %	-289.4 m°
30	3.02 dBm	4.05 dBm	-22.22 dBm	973.7 ns	190.5 ns	187.9 ns	2.000 kHz	0.1947 %	73.30 %	-0.6193 %	-326.2 m°
31	3.11 dBm	4.14 dBm	-22.16 dBm	974.4 ns	190.3 ns	188.1 ns	2.000 kHz	0.1949 %	72.27 %	-0.9184 %	-242.2 m°
32	3.19 dBm	4.21 dBm	-22.12 dBm	973.9 ns	191.2 ns	188.8 ns	2.000 kHz	0.1948 %	73.70 %	-1.910 %	-318.3 m°
33	3.13 dBm	4.15 dBm	-22.16 dBm	973.7 ns	190.6 ns	188.8 ns	2.000 kHz	0.1947 %	73.56 %	-1.845 %	-421.0 m°
34	3.03 dBm	4.05 dBm	-22.22 dBm	973.4 ns	190.5 ns	188.6 ns	2.000 kHz	0.1947 %	73.90 %	-2.514 %	-410.3 m°
35	3.03 dBm	4.06 dBm	-22.22 dBm	973.7 ns	191.1 ns	188.6 ns	2.000 kHz	0.1947 %	74.59 %	-2.708 %	-108.6 m°
36	3.12 dBm	4.16 dBm	-22.16 dBm	973.7 ns	190.6 ns	188.9 ns	2.000 kHz	0.1947 %	75.01 %	-3.435 %	-258.7 m°
37	3.18 dBm	4.22 dBm	-22.13 dBm	973.9 ns	190.8 ns	188.8 ns	2.000 kHz	0.1948 %	74.86 %	-3.254 %	-262.4 m°

▶ **Figure 5.** *The Pulse Table provides a summary of pulse characteristics for each pulse in a captured pulse train.*

being replaced with radars that contain digitally implemented filtering, modulation, signal processing and up-conversion to IF. These digital signal paths have reduced the number of test points available, so that the designer must get the most information possible from each point in the system. Let's look at how the RTSA's performance can aid in the diagnosis of complex radar issues…

Pulse Characterization

Determining basic radar operating parameters is greatly simplified with the automated Pulse Measurement Suite available in the RSA6100A Series. To illustrate basic characterization, a pulse train has been captured and a selection of measurements enabled for automatic analysis. The selected measurements are shown in the Pulse Table (Figure 5). The Pulse Table numbers each pulse encountered and puts all of the selected measurements for each pulse in a single row. In Figure 5, a few of the measurements displayed in the table are 'zoomed' for better view-ability in this application note. This view of the measurements can be used to get an overview of all of the signal characteristics to quickly discover large differences between pulses that occur over the analysis period.



▶ **Figure 6.** *Rise time of pulse number two using Pulse Trace view can be seen. The selected pulse for Trace View is highlighted in the Pulse Table.*

Pulse Trace

The Pulse Trace display is used for detailed examination of any pulse present in the pulse results table. Any measurement on a selected pulse can be examined in the Pulse View, and the user can automatically scale the measurement to zoom in on the detail. In Figure 6, the Pulse Table and Pulse Trace views are shown, with the rise time of pulse number two shown in detail.

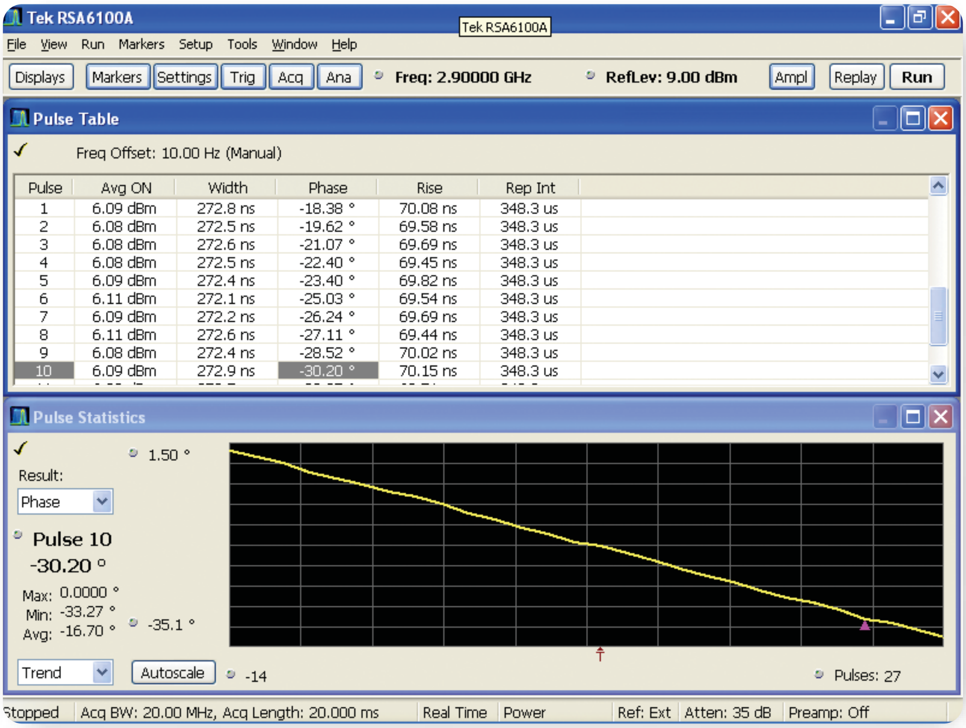
Pulse Statistics

The Pulse Statistics display performs a combined analysis on a series of pulses, offering either a measurement trend view or an FFT of measurement results. The pulse measurement trend graphs a measurement result for each pulse, versus its pulse number, automatically eliminating the variable dead time between pulses. This enables easy inspection of the trend of a measurement over time. Figure 7 shows the pulse-to-pulse phase variation over a series of 27 pulses.

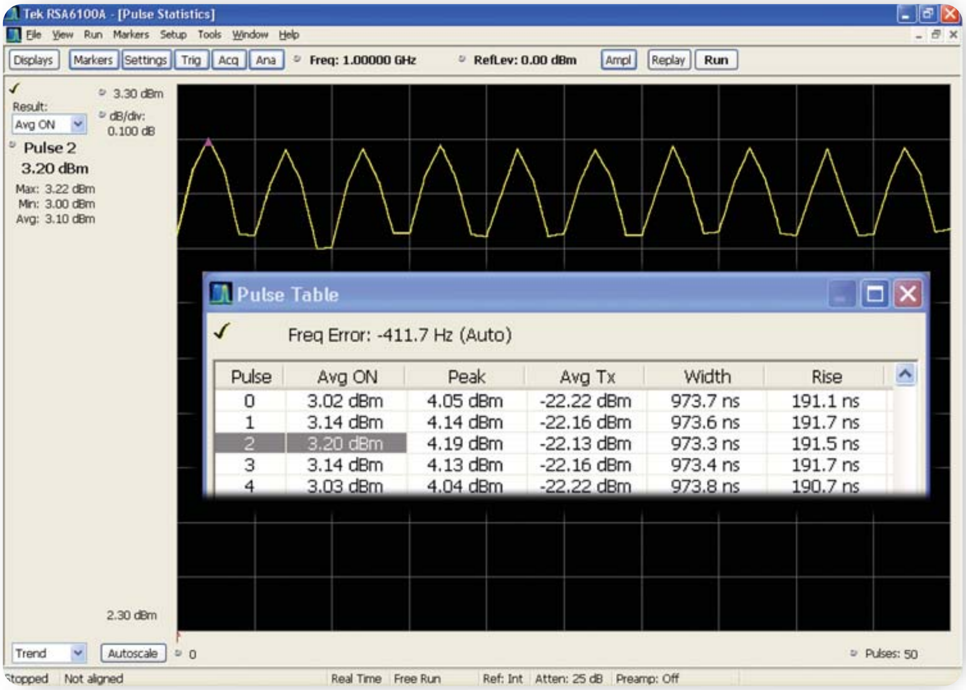
Troubleshooting with Trend and FFT

Unintentional phase or amplitude modulation of radar pulses can be a problem. For example, insufficiently filtered aircraft power supplies converting 400 Hz AC to a high voltage DC power source can modulate the microwave power amplifier used to transmit radar pulses, resulting in pulse-amplitude variations that occur at the rate of the AC power source.

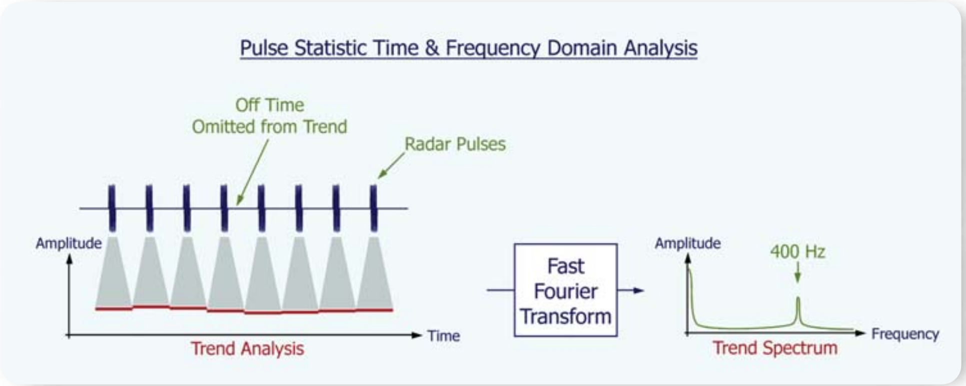
Quickly isolating a power supply modulation problem from a myriad of other possibilities can be difficult. With a typical swept tuned spectrum analyzer it would be necessary to try to discern a low level of narrow-band modulation on a broadband pulse in the frequency domain. Using the Pulse Statistics view in the RSA6100A can make discerning 400 Hz modulation on a pulse spectrum many MHz wide a simple problem.



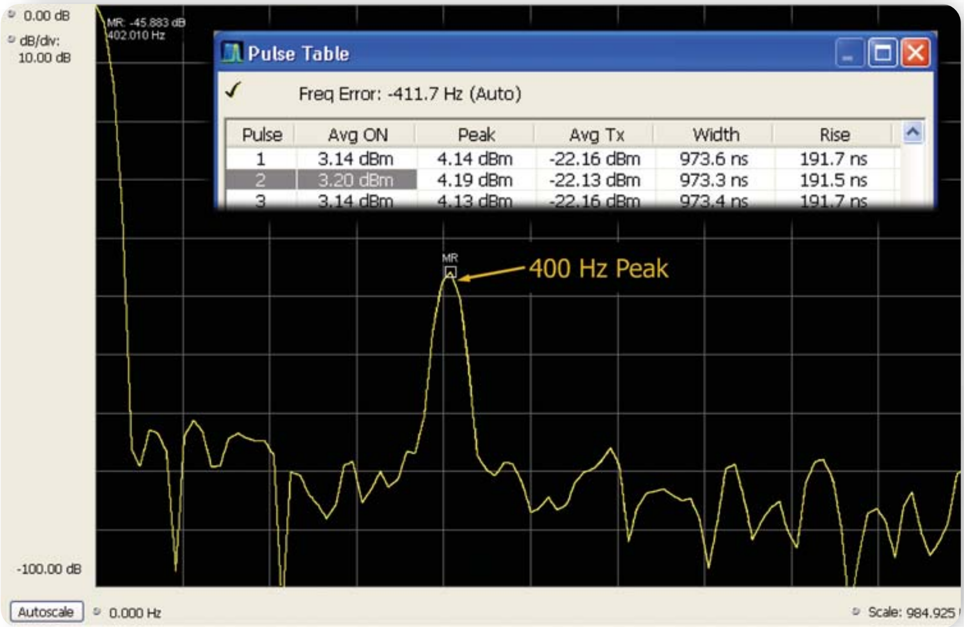
▶ **Figure 7.** *In this pulse-to-pulse phase difference measurement, a constant decreasing phase error is found in the transmitted signal, possibly indicating an unlocked local oscillator.*



▶ **Figure 8.** *The pulse statistics of a set of pulses clearly show an amplitude modulation of the pulse's power level.*



▶ **Figure 9.** *Trend analysis and FFT of trend results.*



▶ **Figure 10.** *Using the frquency transform function on the pulse statistic data, a 400 Hz amplitude modulation from the power supply is easily seen.*

In Figure 8, a trend of Average On Power measurements has been created and scaled to show small variations in the pulse-to-pulse amplitude. In this instance, the variations are very small, about 0.2 dB peak-to-peak, and might even go unnoticed unless they were plotted as a trend. As seen in Figure 8, the amplitude variations are periodic in nature. We can see there is a dominant frequency to the variations, but as yet cannot tell the rate at which they occur.

Conversion of trend data into the frequency domain (Figure 9, 10) allows easy viewing of the nature of the modulation and hence key information about its source. The spectral view can show if the modulation is at a single frequency or contains several frequencies.

The RSA6100A performs a Fast Fourier Transform to the trend of measurement results, providing a spectral view of the amplitude trend data that clearly shows a 400 Hz modulation (Figure 10).

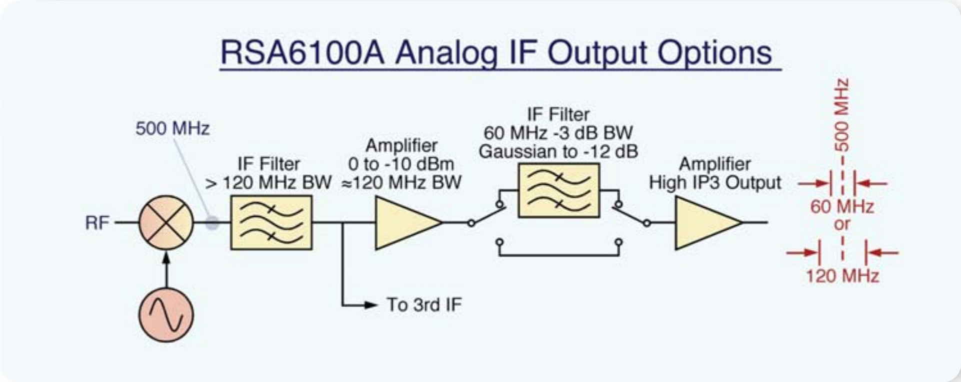
The ability of the RSA6100A's pulse measurement suite to convert time domain statisticalanalyses to the frequency domain provides a unique capability to discover and isolate problems from pulsed signals.

IF Output Measurements

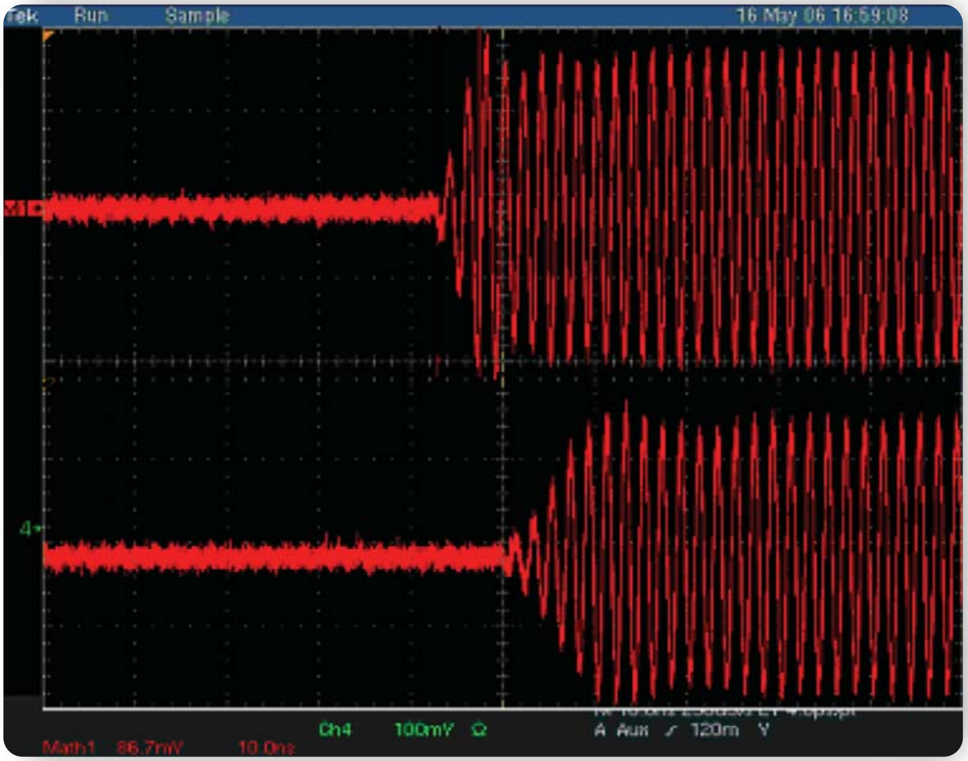
Using a spectrum analyzer as a band-limited downconvert-er to an oscilloscope has long been a popular technique for troubleshooting and making time domain measurements on pulses. Oscilloscopes offer the best triggering capabilities and timing resolution of any measurement tool. Today's oscilloscopes, with frequency ranges in excess of 10 GHz, could actually be used to view the RF pulse directly. However, such a broadband input suffers from an inherently low signal to noise ratio, and dynamic range is limited by the relatively low sensitivity of an oscilloscope's 8 bit digitizer. These limitations make the use of a spectrum analyzer as a band-limited downconverter an attractive option when using oscilloscopes for pulse measurements.

The RSA6100A Series offers an IF output port that is centered at 500 MHz and designed to work in conjunction with oscilloscopes and other equipment, such as external demodulators. The RSA6100A's tuning range to 14 GHz, 120 MHz IF bandwidth, selectable filters and integrated buffer amplifier greatly simplify the down-conversion process when using external IF analysis equipment.

The RSA6100A's IF output is uniquely oscilloscope friendly. The IF output contains an amplifier circuit that adjusts the output level to approximately 0 dBm (0.224 volts) for signal levels of -25 dBm at the first mixer of the RTSA. This eliminates the need for external signal conditioning amplifiers, reducing setup time, complexity and expense. The high output level provides a strong signal to the oscilloscope preventing any loss of dynamic range due to low IF levels.



▶ **Figure 11.** *The IF Output available on the RSA6100A at 500 MHz can be internally filtered to 60 MHz or left unfiltered at approximately 120 MHz wide.*



▶ **Figure 12.** *This composite view illustrates the difference between the 120 MHz BW IF and the selectable 60 MHz Gaussian filter. The 120 MHz filter (top) exhibits fast rise time, but overshoot characteristics are somewhat greater than the controlled Gaussian response (bottom).*

The IF output path (Figure 11) offers a selection of either the square-top filtered IF with 120 MHz of bandwidth or a Gaussian filter with 60 MHz of bandwidth. The filtered and unfiltered IFs enable control of the measurement's noise bandwidth, overshoot and pulse rise time. This can be useful for a wide variety of radar measurements.

This unique feature reduces the IF output noise power, while minimizing time domain overshoot and ringing of the IF. The Gaussian filter thus improves noise margins while introducing a controlled distortion to the pulse shape.

As the higher order lobes of the pulse spectrum are filtered away, the rise time of the pulse will be affected. Switching off the IF filter allows the engineer to quickly check the amount of rise time degradation associated with a filtered IF (Figure 12).

The IF output configuration of the RSA6100A (Figure 11) can be used simultaneously with Real-Time Spectrum Analyzer measurements. Precision timing measurements can be made with the oscilloscope while spectral and modulation measurements are simultaneously made with the real-time analyzer. This is an improvement over swept-tuned spectrum analyzers which require that the instrument be placed in zero-span when using the IF output.

IF output measurements using the oscilloscope can differ from the automated measurements made with the RSA6100A's internal pulse analysis. Differences in signal path characteristics and measurement methods between the Real-Time Spectrum Analyzer and the oscilloscope can affect pulse shape and rise time. For example, the bandwidth at the second IF of the instrument exceeds 120 MHz, leading to lower system rise times than are present after digital filtering and corrections have been applied when using the internal pulse measurement suite. Additionally, the IF output path is not corrected for amplitude flatness and phase variations. Flatness over the 3 dB bandwidth of the IF can be ±2 dB, and phase variations can be greater than 90 degrees over the 120 MHz bandwidth. By contrast, measurements made with the automated Pulse Measurement Suite are band-limited to 110 MHz, and amplitude and phase corrections have been made to minimize errors.

Measurement Considerations

Advanced radars are particularly challenging to characterize and test equipment performance can significantly affect measurement results. This section provides an overview of measurement considerations relative to instrument specifications necessary to achieve accurate results.

Risetime Measurement

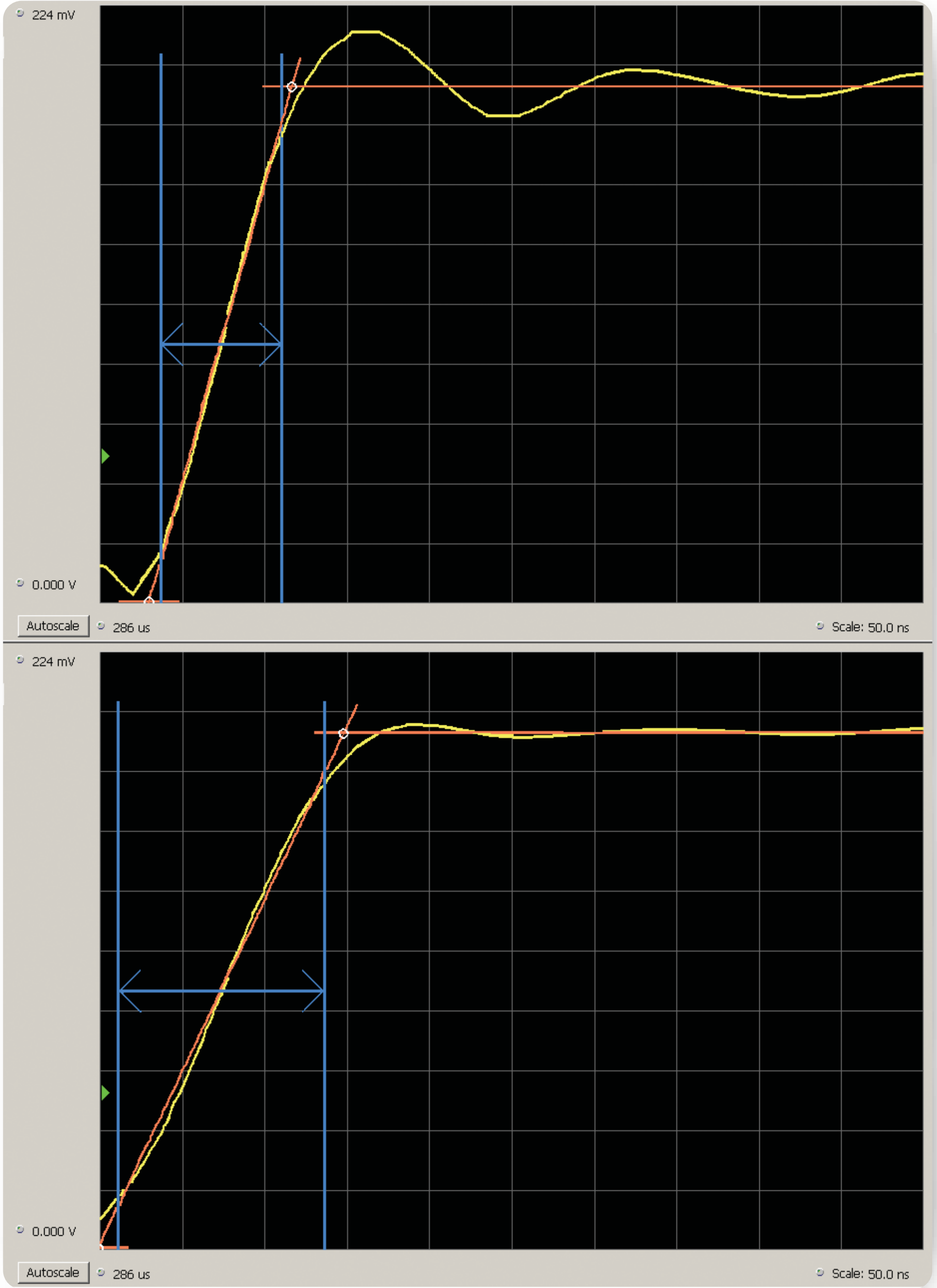
Short duration radar pulses require a wide signal bandwidth. An infinitely narrow impulse function requires infinite bandwidth. Hence, the narrower a pulse is, the wider the RF bandwidth must be, to avoid distortion of the pulse.

Wide bandwidth, however, increases the amount of noise power, adversely affecting sensitivity to small signals. For each application, one must consider the correct balance between measurement bandwidth, signal fidelity and noise performance.

To illustrate the effect of measurement bandwidth, examine the differences in rise time between a 110 MHz measurement bandwidth and one with 55 MHz (Figure 13). For this example, a pulse with less than 3 ns rise time was created, so that the system rise time of the RSA6100A could be seen. The resultant 7 ns measurement (top) is due primarily to the system rise time of the RSA6100A. However, some overshoot can be seen in this measurement, a result of the flattop band-pass filter used in the RTSA. Reducing the measurement bandwidth to 55 MHz with an internal, user-selected Gaussian filter (bottom) reduces the overshoot, but increases the pulse's measured rise-time.

The overshoot present in the 110 MHz measurement bandwidth is due to a combination of overshoot in both the pulse and the measurement-path. In this case, the measurement-path consists primarily of the filter in the RSA6100A's IF, combined with the digital filters used to correct for the amplitude and phase errors in the instrument. The combination of these filters produces very good amplitude flatness and phase linearity in the 110 MHz measurement bandwidth, but also results in pre-shoot and over-shoot ringing in the measurement. For this reason, a set of Gaussian filters can be applied to the measurement path to control pre-shoot and over-shoot.

Gaussian filters with up to 55 MHz bandwidth at the 3 dB point can be applied in the RSA6100A with option 110. When the Gaussian filter shape is combined with that of the IF and digital correction filters, a filter with 55 MHz of bandwidth is created, having a Gaussian response to approximately -12 dB. This combination of filters provides predictable phase and amplitude characteristics in the pass-band and more significant attenuation away from the pass-band.



▶ **Figure 13.** *The measured rise time of a pulse may vary depending on the filter type and bandwidth analyzer. Using the full 110 MHz bandwidth of the RSA6114A with option 110, an 7 ns rise time is measured versus an 12 ns rise time using a 55 MHz Gaussian filter bandwidth.*

Frequency Error Estimation

In order to accurately measure the characteristics of a pulse train, the frequency of the pulses must be known. In many cases, a system reference signal may be available that can be used to lock the reference of the RTSA to the DUT reference. In this case, the manually entered frequency error is zero, because the measurement tool and the DUT references are locked together.

When the pulse frequency is not precisely known, The RSA6100A Series uses three selectable methods of frequency error estimation to determine the difference between the center frequency of the RTSA and the pulse frequency. The method chosen depends upon the frequency and phase characteristics of the pulse, and is user-selected.

The frequency and phase characteristics of the pulses may be defined as:

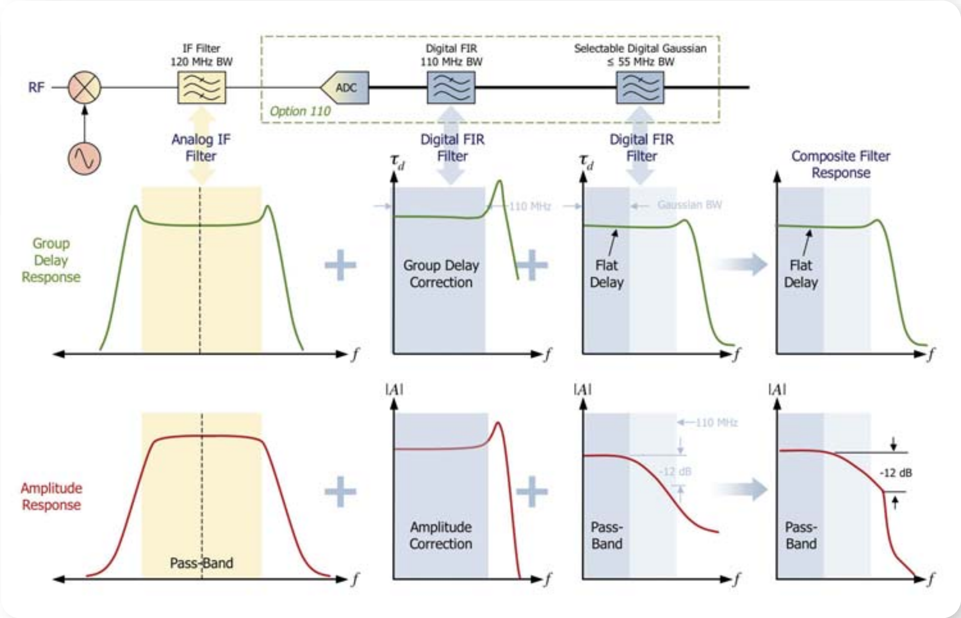
- Constant Phase
- Changing Phase
- Linear Frequency Chirp.

In each case, the phase of the pulses is estimated to determine a phase difference from the measurement frequency over time. This phase difference is used to estimate the frequency change or error between the pulse train and the instrument's center frequency.

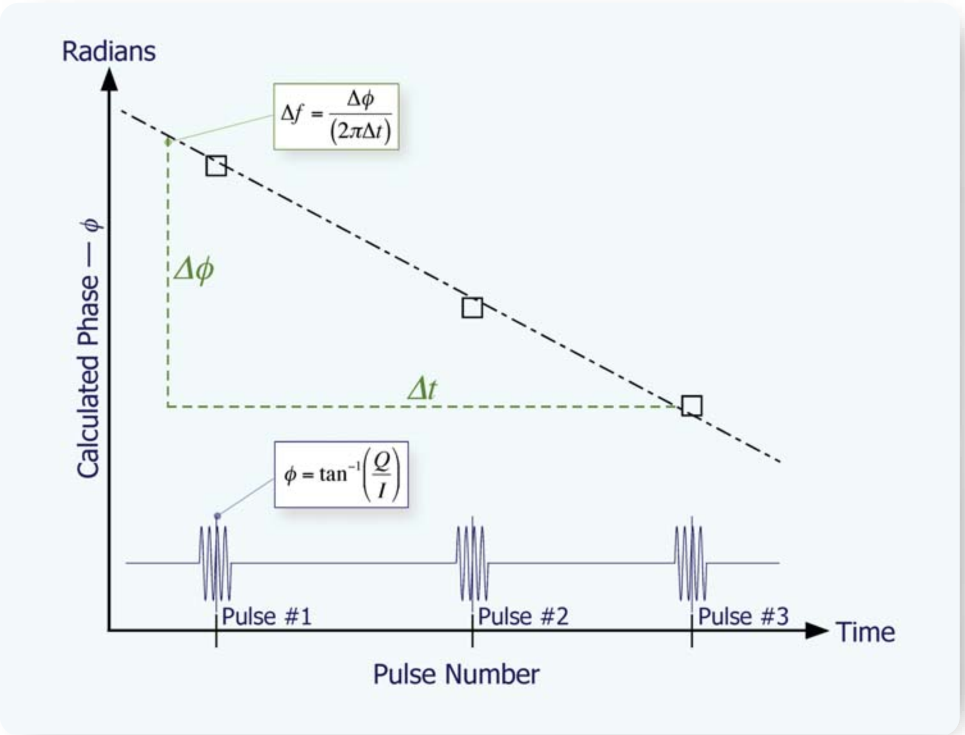
The frequency of a signal that has constant phase (such as can be made by pulse-modulating a CW signal) can be estimated by determining the phase of each pulse relative to the phase of the reference. The RSA6100A's signal processing algorithms use an I-Q representation of the signal to be measured. Phase is calculated from the I–Q waveform where:

$$Phase\ (\phi) = arctan\left(\frac{Q}{I}\right)$$

The calculated phase of each pulse is then used to calculate the slope of the phase difference vs. time, and the resultant frequency error relative to the analyzer frequency is obtained as shown in Figure 15. To minimize over-shoot and ringing effects caused by filtering when determining the phase of the pulse, I and Q samples are taken from the center 50% of each pulse.



▶ **Figure 14.** *The combination of the Gaussian measurement filter and the flat, steep roll-off system response of the RSA6100A RF/IF and DSP filters in a controlled response that is Gaussian in shape to -12 dB.*



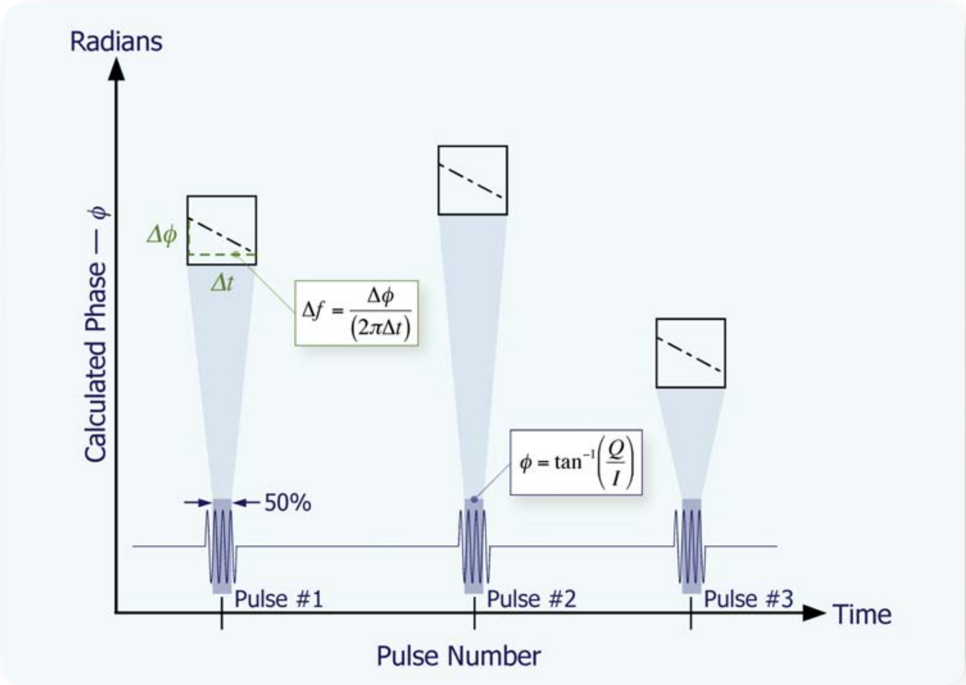
▶ **Figure 15.** *Estimating frequency error for signals with constant frequency and constant phase. Phase of each pulse is calculated at the center point of each pulse, and the slope of the line over multiple pulses determines frequency offset.*

For signals described as constant frequency with changing phase, (such as can be created by turning an oscillator on and off) there is no simple phase relationship between pulses. That is, while the frequency of each pulse is the same, the phase of each pulse may vary. Here it becomes necessary to determine the frequency of each pulse. Determining the phase slope of each pulse relative to the measurement frequency allows us to calculate the frequency error of each pulse. The center 50% of each pulse's on-time is used for this calculation. The resulting frequency values for all pulses in the analysis period are then averaged together to determine frequency error from the measurement frequency.

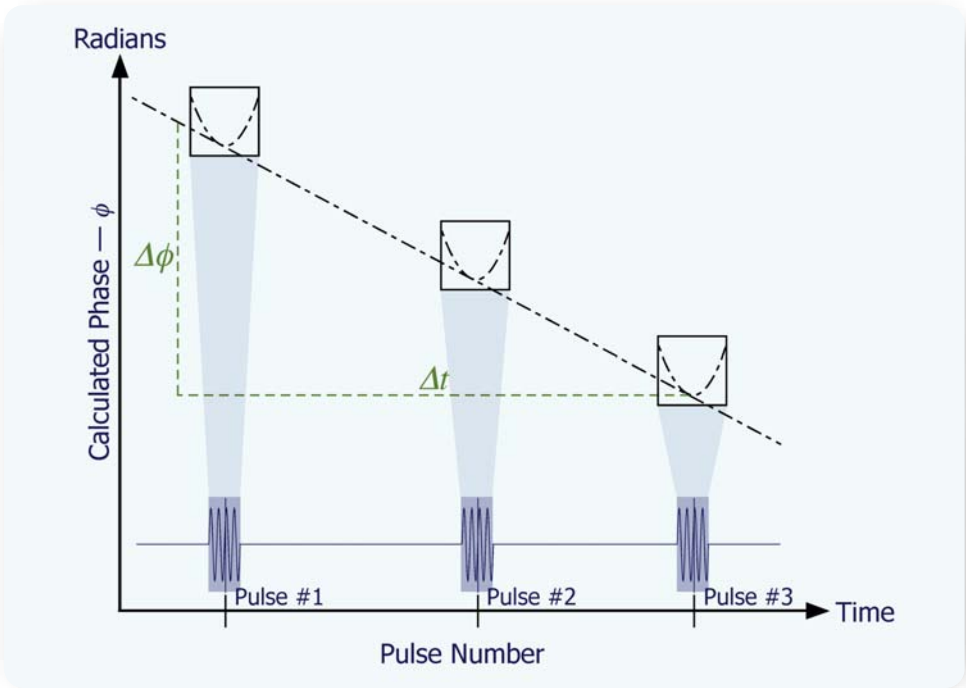
For signals that contain a repeating linear Frequency Modulated (FM) chirp, the phase will be seen to be changing in a parabolic fashion over the pulse On-time. In this case, the frequency error estimate is obtained by fitting a line tangent to each of the parabolic phase calculations, as shown in figure 17.

Pulse-to-Pulse Phase Measurement

Pulse-to-pulse phase measurements are frequently an important metric for advanced radar systems. Along with the need



▶ **Figure 16.** *Frequency error of a changing phase signal is the average of the frequency errors of all pulses in the analysis period.*

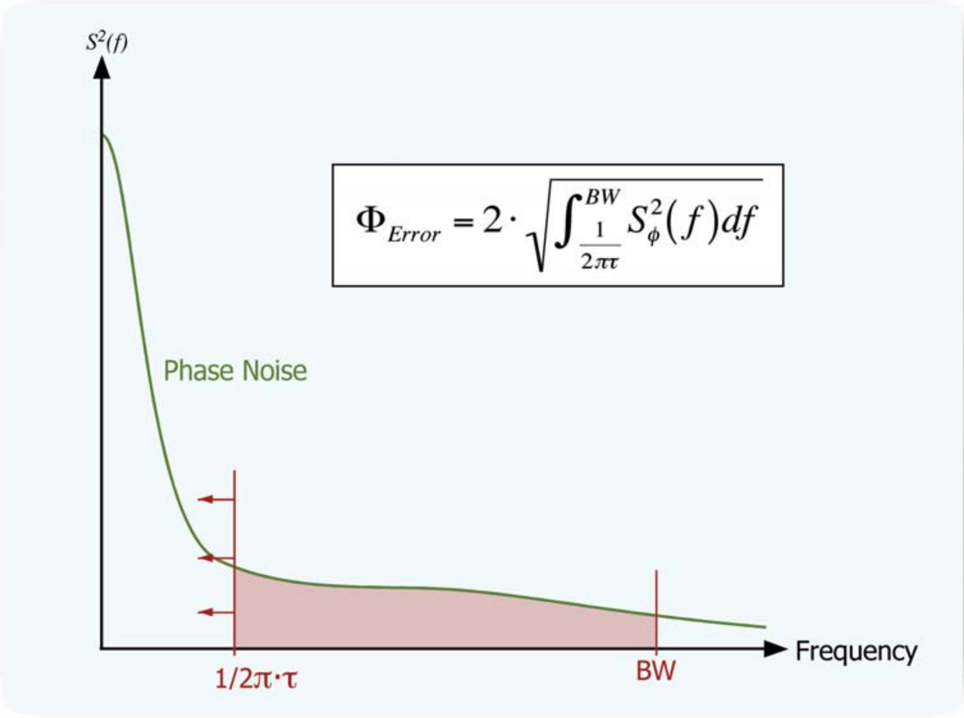


▶ **Figure 17.** *Linear FM Chirp Frequncy Estimation.*

to accurately measure the pulse frequency (described above), pulse-to-pulse phase measurement accuracy is dependent on four principle factors:

- Phase Noise
- Total Measurement time
- Pulse Edge Definition & Measurement Point
- Signal to Noise Ratio

Phase noise from both the signal under test and the measurement instrument can affect measurement accuracy. The amount of uncertainty created by phase noise is determined by total measurement time. For example, a measurement time of 1 ms will result in the integrated phase noise limit of integration beginning at approximately a 1 kHz offset from the carrier and extending out to the measurement bandwidth.



▶ **Figure 18.** *As the pulse-to-pulse phase measurement time increases, the lower limit of phase noise integration decreases, in turn increasing the total phase error.*

Greater pulse-to-pulse measurement stability can be obtained by minimizing the time between the reference pulse and the measured pulse.

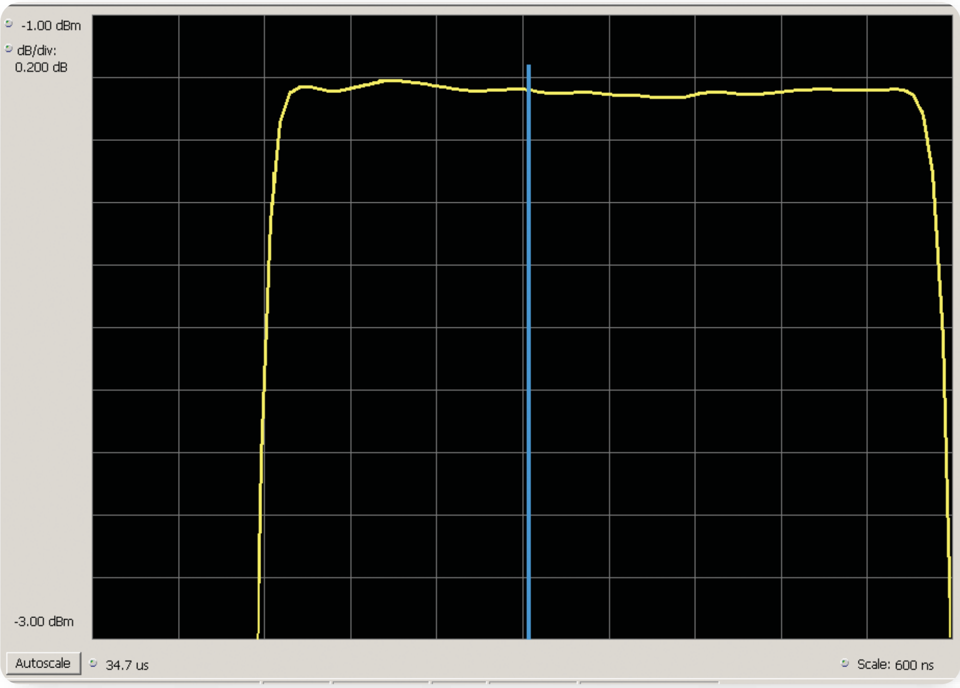
Another important factor in accurate phase measurements is the estimation of where the rising edge of the pulse actually begins and how long it takes for phase ringing to diminish. Pulse-to-pulse phase measurements of the RF carrier are made at a defined offset from the rising edge of the pulse. Poorly defined or poorly measured rising edges can cause inconsistent offsets from the reference pulse and degrade accuracy. The RSA6100A uses interpolation methods when measuring rising and falling edges to help minimize this uncertainty.

The RSA6100A allows the measurement point to be specified relative to the rising edge of the pulse. To account for ringing, Pulse-to-Pulse phase measurement accuracy is specified for any point greater than t = 10/(Measurement Bandwidth) from either the rising or falling edge of the pulse. For example, pulse-to-pulse phase measurements using a 55 MHz measurement filter are within specifications for measurement points greater than $10/(55\times10^6)$, or approximately 182 ns from the rising or falling edge of the pulse. A Pulse Trace view, illustrating placement of the phase measurement point, is seen in Figure 19.

Finally, Signal to Noise Ratio (SNR) is an important factor in accurate pulse-to-pulse measurements. The RSA6100A's typical pulse-to-pulse phase measurement uncertainty at 2 GHz with a 20 MHz bandwidth is 1.7° and 2.0° with a 110 MHz bandwidth. At 10 GHz the accuracy is 3.2° and 5.0° for the same 20 and 110 MHz bandwidths respectively. This increase in uncertainty is primarily due to the higher phase noise and noise level present in the analyzer at the higher frequency.

The level of performance offered by the RSA6100A is most useful for observing trends in the pulse-to-pulse phase, which can be helpful in troubleshooting hardware issues.

A high performance radar, with a fixed-frequency coherent down converter having extremely low phase noise, can often achieve well under one degree of phase variation with signal conditions similar to those specified for the RSA6100A. The RSA6100A's performance while outstanding may not be sufficient for precision Doppler measurements on some fixed-frequency radars.



▶ **Figure 19.** *The RSA6100A allows the user to specify the phase measurement point for pulse-to-pulse phase measurements, indicated by the blue line in the display.*

Conclusions

The RSA6100A expands the Tektronix line of Real-Time Spectrum Analyzers by providing outstanding instrument performance. The frequency coverage, bandwidth and dynamic range, combined with the DPX spectrum display place it at the forefront of the Real-Time Spectrum Analyzer product line.

The RSA6100A also features advanced measurement algorithms, a variety of user selectable filtering options and simultaneous IF output capability that address the key measurement challenges faced by today's radar professionals.

Appendix: Comparison of RTSAs for Pulse Measurement Applications

Many radar applications can be addressed with more economical real-time analyzers from Tektronix. The table below outlines the differences between the RSA3408A and the RSA6100A Series as an aid selecting the performance level required for your application.

	Models	
Specification	**RSA3300/3408A**	**RSA6106A/6114A**
Frequency Range	DC - 8 GHz	9 kHz - 6.2 / 14 GHz
Capture Bandwidth	36 MHz	40 MHz / 110 MHz[1]
Capture Memory	64 MB / 256 MB	256 MB / 1 GB
Maximum Input (CW)	+30 dBm (1W)	+30 dBm (1W)
Maximum Input (DC)	± 0.2 VDC	± 40 VDC
Maximum Input (Pulse)	+30 dBm (1W)	+48 dBm (75W)[2]
IF Output	standard	optional
IF Output Frequency	421 MHz	500 MHz
IF Analog Bandwidth	36 MHz	120 / 60 MHz[3]
IF Filter Shape	Square Top	Square Top / Guassian
System Rise Time	25 ns	25 ns / 10 ns[1]
Min. Pulse Duration	400 ns	150 ns / 50 ns[1]
Min. DPX™ Event Duration	—	24 µs

[1] Option 110
[2] Duty Cycle ≦0.01%, 1µs Pulse Width
[3] Selectable

▶ **Table 1.** *The Tektronix Real-Time Spectrum Analyzers offer a wide range of performance capabilities to fit the most demanding radar systems and the most modest budgets.*

The RSA3408A and RSA6100A both have automatic pulse measurement capability. Though their measurements are similar, there are a few important differences to be aware of.

The RSA6100A's Pulse Measurement Suite incorporates the flexibility to display dBm, Watts or Volts in a 50-Ohm system versus the RSA3408A vertical display of dBm. This display flexibility of the RSA6100A is convenient when system test requirements are written in power or voltage units.

To improve measurement accuracy and resolution, advanced interpolation algorithms are employed on the RSA6100A. This allows for the addition of pulse rise time measurements to the pulse measurement suite, and pulse-to-pulse phase measurement accuracy has been improved.

The following measurement summary table details the differences between the RSA3408A and RSA6100A Series pulse measurements capabilities.

	Models	
Automated Measurements	**RSA3300A/3400A**	**RSA6106A/6114A**
Pulse Amplitude	✓	✓
Pulse Peak Amplitude	✓	✓
Total Average Amplitude	—	✓
Pulse Top Ripple	✓	✓
Pulse Droop	✓	✓
Pulse Width	✓	✓
Pulse Repetition Rate	—	✓
Pulse Repetition Interval	✓	✓
Pulse Duty Cycle	✓	✓
Pulse-Pulse Phase	✓	✓
Pulse Ripple	✓	✓
Pulse Trend	✓	✓
FFT of Trend Results	—	✓
Pulse Rise Time	—	✓
Pulse Fall Time	—	✓
On/Off Ratio	✓	—
Channel Power	✓	✓
Occupied Bandwidth	✓	—
Emission Bandwidth	✓	—
DPX™ Spectrum	—	✓

▶ **Table 2.** *Built-in measurement capabilities for a variety radar pulse characteristics is available on the RSA3300A series, RSA3408A and RSA6100A Series RTSAs.*

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