Best Practices For Making The Most Accurate Radar Pulse Measurements

Application Note

- IEEE 1394 standard for pulse standard
- Reference level adjustment
- Hysteresis and hold-off setting
- SCPI for 10 consecutive pulses
- Tips to achieve accurate and consistent rise/fall time measurement
- Achieving extended DR measurements
- Maximizing your measurement speed

Introduction

RF and microwave power measurement is critical at every stage of the radar system lifecycle, helping to ensure the basic performance of the system is met. Today's test engineers are challenged to deliver comprehensive test results within the tightest schedule. Moreover, test coverage is not allowed to be compromised with the reduction in scheduled test time. These factors now force engineers to seek out equipment enabling the most coverage and providing the fastest measurement speed. The most cost-effective way of analyzing the output power from a radar system is with RF and microwave power meters and sensors.

As a long time manufacturer of power measurement tools for the aerospace and defense industry, Agilent has invaluable knowledge to share on making optimal radar measurements. This application note describes various tips to help test engineers make the fastest, most accurate radar pulse measurements. Specific topics to be covered include:

- an overview of IEEE standard 181-2011 as the standard used for pulse definitions;
- differences between 10%, 50%, 90% and 1%, 25%, 81% transition duration reference levels;
- how to achieve the most accurate and consistent rise/fall time measurements;
- how to capture an RF pulse with noisy spikes utilizing hysteresis and the hold-off setting;
- how to maximize equipment's dynamic range to make the most accurate pulse measurements;
- how to maximize pulse measurement speed; and
- advanced radar measurements with multi-pulse functions up to 10 consecutive pulses.

In addition, this application note will highlight a number of real-world scenarios that demonstrate the time savings and accuracy improvement achieved using Agilent power meters and sensors. Also included is a list of relevant literature and links to selection tables and other useful web tools.

IEEE Standard on Transitions, Pulses and Related Waveforms

The power envelope of a radar RF pulse can be analyzed using the IEEE standard 181-2011, "IEEE Standard for Transition, Pulses, and Related Waveforms." The standard refines and replaces the withdrawn standard IEEE STD-181-1977 and should be used in conjunction with IEEE STD-194-1977. IEEE standard 181-2011 defines approximately 100 terms (e.g., transition duration, state level, pulse amplitude, and waveform aberrations) and illustrates the algorithms used to compute their values.

Some commonly used terms in radar pulse measurements, and their associated definitions, are listed below. Note that some of the more commonly used terms (e.g., rise time, fall time and droop) have been deprecated and are listed in brackets.

Signal	Signal physical phenomenon that is a function of time. In this case, it is the power envelope of the radar signal.
Waveform	A representation of a signal (e.g., graph, plot, oscilloscope presentation, discrete time series, equations, or table of values). For this purpose, the waveform is the sampled representation of the measured power.
State	A particular level or, when applicable, a particular level and upper and lower limits that are referenced to or associated with that level.
Base State	The state of a waveform that possesses a level closest to zero.
Cycle	A portion of a periodic waveform with a duration of one period.
Duty Factor (Duty Cycle)	Unless otherwise specified, for a periodic pulse train, the duty factor is the ratio of the pulse duration to the waveform period.
Pulse Waveform	A waveform whose level departs from one state, attains another state, and ultimately returns to the original state.
Reference Level	A user-specified level that extends through all instants of the waveform epoch.
Percent Reference Level	A level that extends through all instants of the waveform epoch expressed as the percentage amplitude change between the states. Commonly used reference levels are 0%, 10%, 50%, 90% and 100%. Note that reference levels replace the deprecated mesial, proximal and distal terms of the withdrawn standard.
Peak	Pertaining to the greatest (least) value of the waveform.
Pulse Duration (Pulse Width)	The difference between the first and second transition occurrence instant.

IEEE Standard on Transitions, Pulses and Related Waveforms

Pulse Separation	The duration between the 50% reference level instant of the second transition of one pulse in a pulse train, and that of the first transition of the immediately following pulse in the same pulse train.
Tilt (Droop)	A distortion of a waveform state wherein the overall slope over the extent of the waveform state is essentially constant and other than zero. This distortion may be of either polarity. Note that the term "droop" is deprecated because it implies a negative slope and therefore, cannot be applied unambiguously to both positive and negative pulse waveforms.
Transition	The contiguous region of a waveform that connects, either directly or via intervening transients, two state occurrences that are consecutive in time but are the occurrences of different states.
Positive-Going Transition (Rising Edge)	A transition whose terminating state is more positive than its original state. The end points of the positive going transition are the last exit from the lower state boundary and the first entry to the upper state boundary.
Negative-Going Transition (Falling Edge)	A transition whose terminating state is more negative than its original state. The end points of the negative going transition are the last exit from the upper state boundary and the first entry to the lower state boundary.
Transition Occurrence	The first 50% reference level instant, unless otherwise specified, on the transition of a step-like waveform.
Transition Duration (Rise Time/Fall Time)	The difference between two reference level instants of the same transition. Unless otherwise specified, the two reference levels are the 10% and 90% reference levels. Note that rise time and fall time are deprecated and replaced by transition duration, positive or negative. Most modern instruments use icons to describe the measurements so it's safe to continue to use rise-time and fall-time informally. The most important thing is to have a common understanding of the phenomenon being measured.

Obtaining a common understanding of instrument performance specifications and providing common ground for parameter and performance comparisons, requires that standard definitions and algorithms for computation be well established prior to measurement. All Agilent peak and average power meters and sensors are referenced to these definitions and algorithms for measurement computation.

Differences Between 10%, 50%, 90% and 1%, 25%, 81% Transition Duration Reference Levels

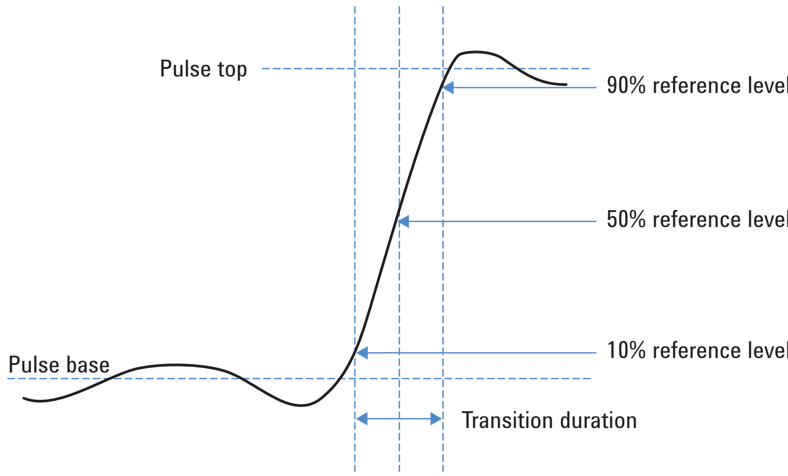


Figure 1. Single, positive-going transition and the illustration of 10%, 50% and 90% reference levels

The standard 10%, 50% and 90% reference levels are commonly used for power waveforms (Figure 1). However, most of the timing in a radar system (e.g., the time between control pulses) is derived in the voltage domain for the time between control pulses. Since power is proportional to the voltage squared, the 10%, 50% and 90% reference levels in the voltage domain must be scaled accordingly and this is mapped to 1%, 25% and 81% in the power waveform.

It is common to look at power waveforms with dB scaling. Here, the 1%, 25% and 81% reference levels are mapped to –20 dB, –6 dB and –0.9 dB relative to the state 100% reference power expressed in dBm. The 10%, 50% and 90% reference levels map to –10 dB, –3 dB and –0.5 dB relative to the 100% reference level expressed in dBm.

Therefore, the power in the pulse must be at least 20 dB above the instrument noise floor for it to accurately compute the 1% to 81% transition duration measurement. This ensures a consistent and accurate transition duration (rise/fall time) measurement.

The IEEE STD-181-2011 defines the algorithm used to determine the reference levels using the following process:

1. Generate a histogram from the waveform using a number of equally-spaced bins between the maximum and minimum values from the waveform.
2. Split the bi-modal distribution into two sub-histograms. Note that in Figure 2, only the top part of the histogram is shown.
3. The reference levels are determined by selecting the mean or mode of the sub-histograms.

Differences Between 10%, 50%, 90% and 1%, 25%, 81% Transition Duration Reference Levels

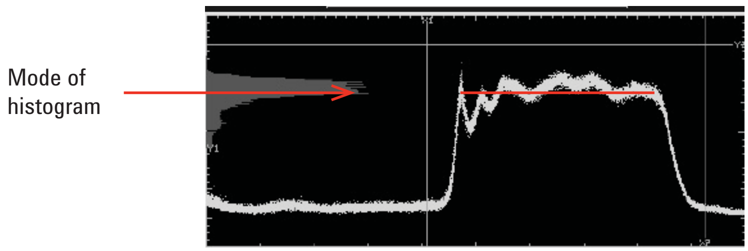


Figure 2. The IEEE STD-181-2011 defines the mode of histogram algorithm needed to determine the reference levels

This method can be flawed, however, such as in the case of Gaussian pulses like those in Distance Measurement Equipment (DME) signals. The histogram method is unable to determine an obvious upper level of the reference level, as the pulse smoothly transitions through the upper stages without a significant peak. As a consequence, the algorithm tends to select a reference level that is much lower than expected. In cases like this, an algorithm that recognizes and selects the peak of the waveform as the 100% reference level is much more suitable.

The Agilent P-Series power meters and U2020 X-Series peak and average USB power sensors utilize the mode of histogram algorithm to establish the 0% and 100% reference levels for accurate pulse parameter measurements (Figure 3). The default reference levels used for transition duration and pulse duration measurements are 10%, 50% and 90% of the pulse top. Both families of power meters also allow users to adjust the reference level to 1%, 25% and 81% (or any other values) for radar systems derived in the voltage domain.

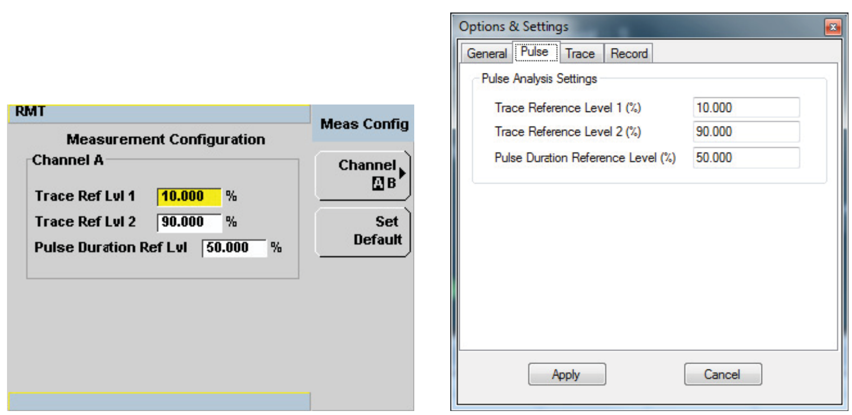


Figure 3. User-configurable rise or fall time, and pulse duration reference level setting in a P-Series power meter (left-most image) and in the N1918A option 100 or 200 Power Analyzer software for use with the U2020 X-Series (right-most image)

Achieving the Most Accurate, Consistent Transition Duration (Rise and Fall Time) Measurements

Power meter users will sometimes get different transition duration measurements with different scale settings. The question then becomes: Which reading is accurate? Engineers facing this problem are encouraged to read this section of the application note to understand more about this scenario.

As an example, consider a positive transition duration (rise time) measurement made using an Agilent U2021XA X-Series USB peak and average power sensor and ESG signal source. When set to a different time scale, the power sensor reports different positive transition duration measurements, as shown in Table 1.

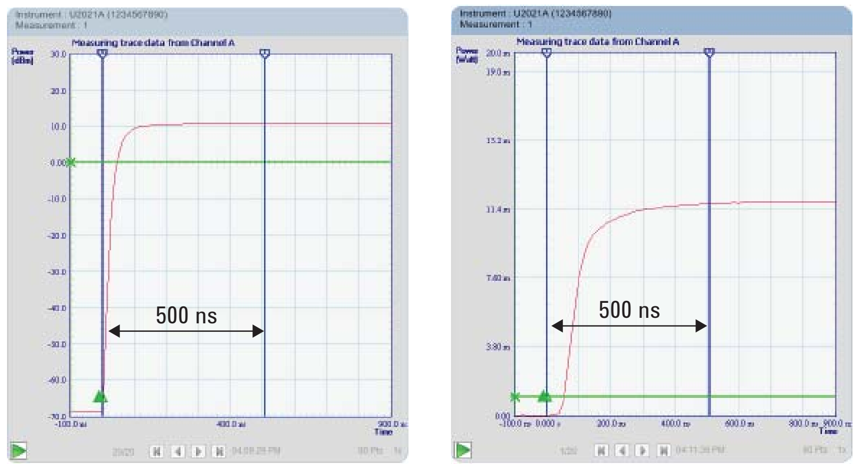
Table 1. Rise time varies with different time-scale settings

	Trace start	Trace end	Time scale	Positive transition duration (rise time)	Remarks
A	–100 ns	200 ns	30 ns/div	80.6 ns	Pulse top is not captured
B	–100 ns	300 ns	40 ns/div	99 ns	Pulse top is not captured
C	–100 ns	400 ns	50 ns/div	114 ns	Pulse top is not captured
D	–100 ns	500 ns	60 ns/div	120 ns	Rise time stabilizes
E	–100 ns	900 ns	100 ns/div	121 ns	Rise time stabilizes
F	–100 ns	1100 ns	120 ns/div	122 ns	Rise time stabilizes
G	–100 ns	1900 ns	200 ns/div	122 ns	Rise time stabilizes
H	–100 ns	2900 ns	300 ns/div	122 ns	Rise time stabilizes
I	–100 ns	4900 ns	500 ns/div	112 ns	Rise time degrades

Why does this happen? It is due to the fact that the ESG takes about 500 ns to get from –3 dB to its pulse top, as shown in Figure 4b. This behavior can be easily observed by changing the power sensor unit from dB to watt. According to Table 1, the positive transition duration measurement starts to stabilize when the time-scale setting reaches 60 ns/div. This allows the power sensor to capture the entire rising edge up to its pulse top at 500 ns (trace-end setting is at 500 ns). As long as the time-scale setting is long enough for the power sensor to capture the pulse top level, the power sensor is able to provide consistent rise-time measurements. However, if the time scale is set to too long, the resolution worsens and the accuracy starts to degrade again (refer to row I, Table 1).

Achieving the Most Accurate, Consistent Transition Duration (Rise and Fall Time) Measurements

Hence, in order to obtain an accurate and consistent positive transition duration measurement, the rule of thumb is to set the power meter time scale to zoom into the rising edge of the pulse and ensure that the power meter is capturing the pulse top level. The same principle can be applied to negative transition duration (fall time) measurements. Set the power meter time scale to zoom into the falling edge of the pulse and ensure that the start time of the trace is capturing the pulse top level before it starts to descend.



(a) Power sensor unit set to dBm

(b) Power sensor unit set to watt

Figure 4. Screenshots of the N1918A Option 100 Power Analysis Manager software with the U2021XA. By changing the power sensor unit from default dBm to watt, it is easy to observe that the ESG takes about 500 ns to get from –3 dB to its pulse top.

Capturing RF Pulses with Noisy Spikes Utilizing Hysteresis and Hold-Off Settings

An RF signal can be made up of a sequence of pulses. The pulses have leading rising edges and trailing falling edges. The power envelope of the RF signal is determined by its modulation type. Digital modulation such as OFDM and 64QAM can cause the signal envelope to be very spiky and noisy. A triggering base on trigger level alone will not work on this kind of signal because the noises within a pulse cross the trigger level multiple times and cause unstable trigger capture. Hysteresis and hold-off settings are important in this case to ensure stable capture of the noisy pulse envelope.

Trigger Hysteresis

To detect the edges of the pulse, a power meter uses the trigger level (or threshold) to detect whether the signal has crossed the threshold. However, RF power envelopes can be very noisy and the pulse may be heavily modulated, so the modulation envelope of the pulse may cross the trigger threshold multiple times. The hysteresis setting is used to validate the trigger.

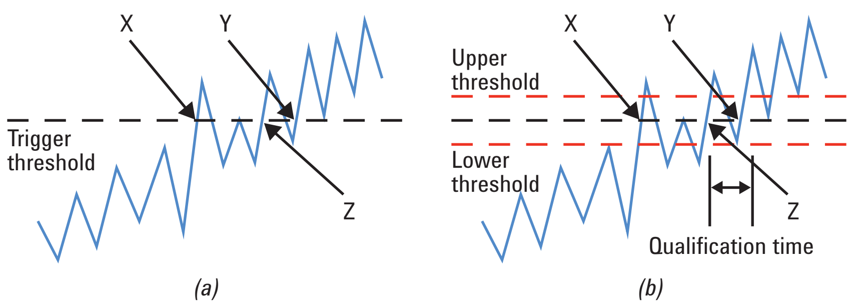


Figure 5. An RF signal with a leading edge masked by noisy spikes

Figure 5a shows a typical well behaved, but noisy, RF power signal with a leading rising edge masked by noisy spikes. The noise spike at point X exceeds the trigger threshold but immediately drops below the threshold. The first point at which the RF signal is completely above the trigger threshold is point Y. However, if noise were to be filtered out, the actual trigger point will be at point Z. To get a more accurate trigger, hysteresis is introduced. Instead of having just a single trigger threshold, two thresholds are provided, one on each side of the actual desired trigger threshold: an upper hysteresis threshold and a lower hysteresis threshold (Figure 5b).

For valid edge detection, the RF signal must rise above the upper hysteresis threshold and not fall below the lower hysteresis threshold within a certain time period (known as qualification time). The qualification time should be large enough to reject noise, but small enough to not reject genuine pulses. With this technique, point Z in Figure 5b is the first point at which the RF signal has risen above the upper hysteresis threshold and is not falling again below the lower hysteresis threshold within the qualification time. Therefore, the rising edge is detected as point Z, which is the accurate and desired trigger point.

Capturing RF Pulses with Noisy Spikes Utilizing Hysteresis and Hold-Off Settings

Trigger Hysteresis (continued)

The same principle applies to falling edge detection. The RF signal that falls below the lower hysteresis threshold must stay below the upper hysteresis threshold for a duration of the qualification time for a falling edge to be recognized. This method is well known and widely used in oscilloscopes and power meters.

Trigger Hold-Off

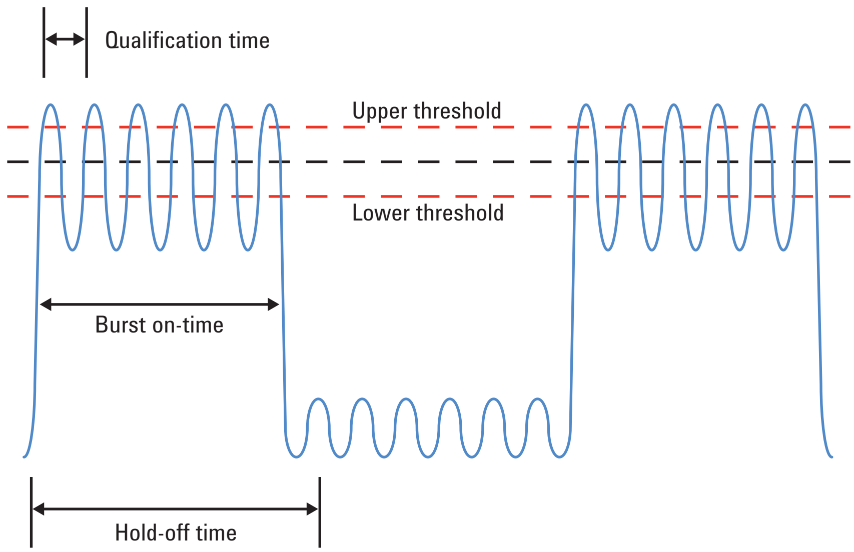


Figure 6. Trigger hold-off time should be slightly longer than the on-time of the OFDM signal for accurate and stable trigger capture

Problems arise when the pulsed signal is a burst of a digitally modulated signal like OFDM or 64QAM. In this case, the signal envelope crosses over the trigger thresholds throughout the on-time of the signal. Hysteresis for noise rejection, as shown in the waveform in Figure 6, could cause a whole burst to be missed because the signal always drops below the lower hysteresis threshold. Another technique of trigger hold-off is therefore used to prevent problems arising from multi-triggering by suppressing triggers for a time after the first detection. It is recommended that the trigger hold-off time be set for a duration longer than the signal burst time, as in Figure 6. With this setting, the power meter is able to capture complex, digitally modulated signals like OFDM pulses.

Capturing RF Pulses with Noisy Spikes Utilizing Hysteresis and Hold-Off Settings

Trigger Hold-Off (continued)

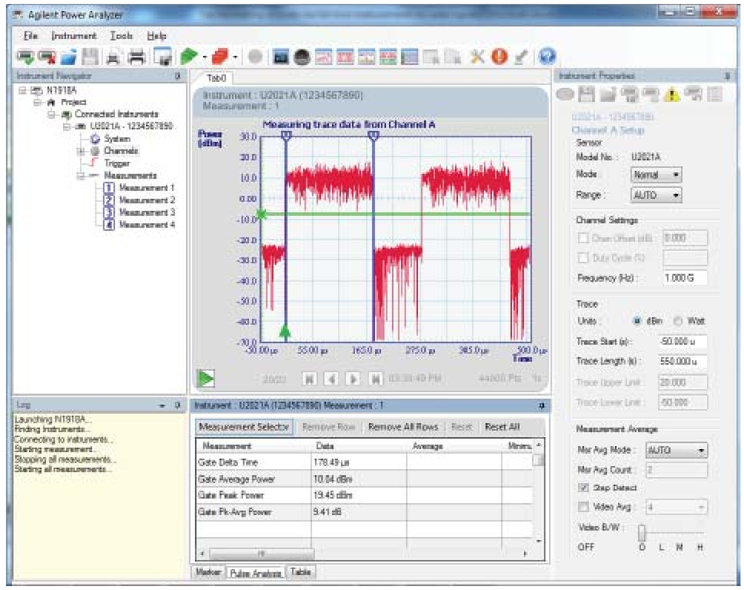


Figure 7. A WLAN 802.11b signal with burst length of 178 µs, captured with the U2021XA X-Series USB sensor and N1918A software with trigger hold-off set to 250 µs

Figure 7 shows an example of the capture of 20-MHz WLAN 802.11b signals, 64QAM, using the U2021XA X-Series USB sensor. The burst length is 178 µs, while the trigger hold-off is set to 250 µs to obtain a stable and accurate trigger.

In summary, with careful setup of trigger hysteresis and hold-off settings, the power meter is able to capture any signal even though it might be masked by noisy spikes.

Maximizing Equipment Dynamic Range to Make the Most Accurate Pulse Measurements

Typical peak and average power meters offer peak power dynamic range in the range of –35 to +20 dBm, a range generally sufficient to cover most radar application needs. With a noise floor of –35 dBm, the pulse top must be greater or equal to –15 dBm for the power meter to measure the rise time accurately. Recall that in the previous section, rise time is equal to the time difference from 1% to 81% of the pulse top, and 1% of the reference level corresponding to –20 dB down from the pulse top. This makes the effective transition duration (rise time or fall time) measurement range of the power meter shrink from 55 to 35 dB.

Techniques are available to maximize the peak power dynamic range of the power meter, including: external triggering, reducing the video bandwidth setting and increasing the video averaging. Each technique will be discussed in detail in the following section.

External Triggering

An external trigger enables accurate triggering of a small signal close to the signal noise floor. As an example, consider the Agilent U2020 X-Series power sensors (Figure 8). The internal trigger range is valid from –20 to +20 dBm. With an external trigger, for signals with an output power of –30 dBm, an external trigger signal is required from the signal source or the device-under-test (DUT) to trigger the power meter for measurement acquisition.

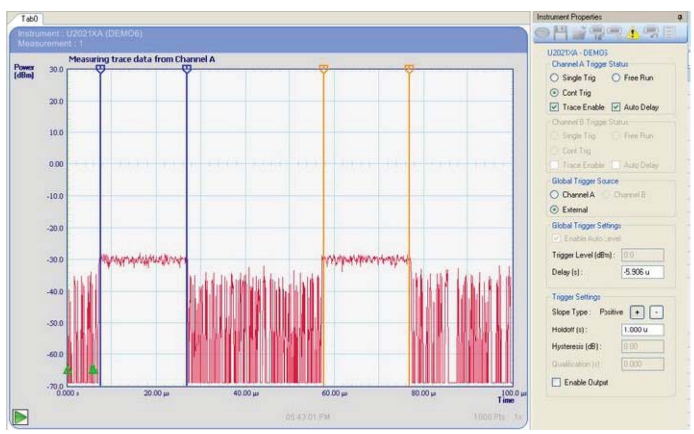
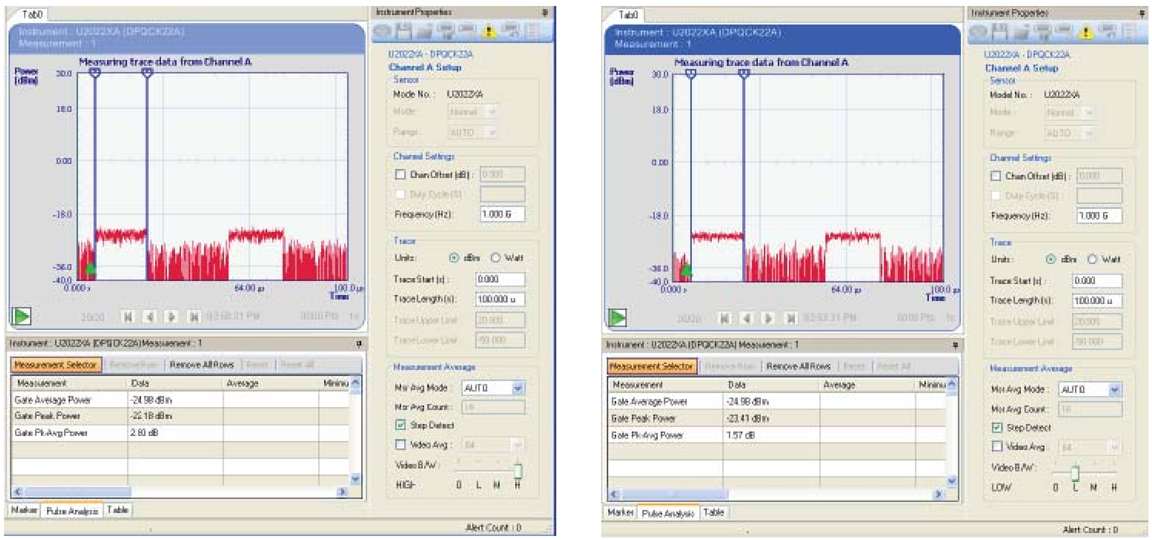


Figure 8. Stable signal captured at –30 dBm with external triggering

Maximizing Equipment Dynamic Range to Make the Most Accurate Pulse Measurements

Video Bandwidth

When the video bandwidth setting of a peak power meter is reduced, the peak-to-peak variations of the noise are reduced. This is due to the high-frequency spectrum of the RF signal, which dictates that the noise signals are removed, thereby leaving a smoother trace response.



(a) High (30 MHz) video bandwidth setting   *(b) Low (5 MHz) video bandwidth setting*

Figure 9. Comparison of different video bandwidths and their corresponding captured RF envelope

Figure 9 compares different video bandwidth settings (30 MHz and 5 MHz) and their corresponding captured RF envelope. The pulse power is set to –25 dBm, while external triggering is used to capture the signal. Note that the smaller the video bandwidth, the smaller the noise riding on the RF pulses. However, when the video bandwidth setting is reduced, the power meter system rise time increases, resulting in a larger minimum rise or fall time measurement.

Maximizing Equipment Dynamic Range to Make the Most Accurate Pulse Measurements

Video Averaging

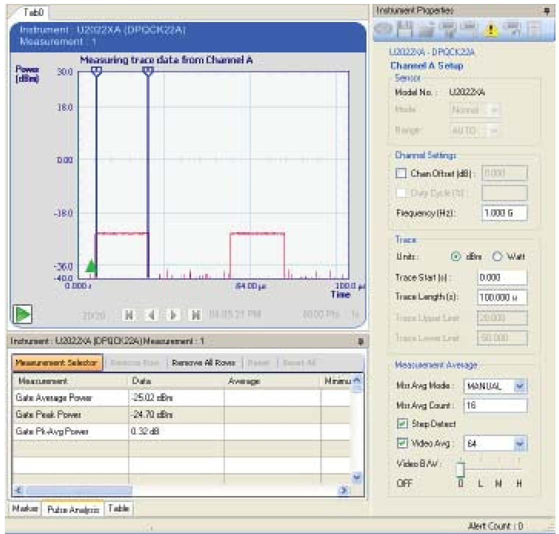


Figure 10. A clean trace is observed with a sufficient video average setting

The trace results in Figure 9b may still not be good enough and the signal quite noisy. The noise can further be eliminated by applying the video averaging setting. Figure 10 shows the same –25 dBm signal captured using a video averaging setting of 64. The noise has been removed and there is now a very clean signal. With the combination of external triggering, lowering the video bandwidth and applying sufficient video averaging, engineers can measure even down to lower than –25 dBm of the peak signal.

Maximizing Pulse Measurement Speed

Test time and accuracy are two critical requirements when characterizing radar components like a transmit/receive (TR) module. High-volume manufacturing and lower cost products place increasing demand on power measurement tools. This doesn't mean that the number of tests can be reduced to speed up test time. Instead, the engineer must find ways to reduce test time while maintaining the same test coverage—without compromising measurement accuracy and at a cost that is affordable. This section explains how to get the best measurement speed out of a power measurement tool.

Power Sensor Measurement Speed Settings

There are three possible measurement speed settings in most Agilent power meters and sensors: normal, double and fast. The speed setting is set using the SENSe:MRATe command. The default speed setting is normal.

Fast mode provides the fastest measurement speed possible, but it does have limitations. In this mode, averaging, limits and ratio/difference mathematic functions are disabled. In both normal and double mode, however, full instrument functionality is available.

The different measurement speeds of the three settings differ according to power sensors as tabulated in Table 2.

Table 2. Measurement speed of Agilent power sensors under different speed modes

	Measurement mode		
Power sensor	Normal	Double	Fast
8480 and N8480 Series	20 readings/s	40 readings/s	—
E-Series E4410 and E9300	20 readings/s	40 readings/s	Up to 400 readings/s
E-Series E9320 (Average mode)	20 readings/s	40 readings/s	Up to 400 readings/s
E-Series E9320 (Normal mode)	20 readings/s	40 readings/s	Up to 1,000 readings/s
P-Series wideband	20 readings/s	40 readings/s	Up to 1,500 readings/s
U2000 Series USB	20 readings/s	40 readings/s	Up to 110 readings/s
U2020 X-Series USB	20 readings/s	40 readings/s	Up to 3500 readings/s

Maximizing Pulse Measurement Speed

Buffer Mode Settings

In general, the maximum speed of a power meter is attained through the buffer mode setting. The power meter returns a measurement following receipt of a query. To obtain each and every measurement, users need to send a query command.

When taking a large amount of readings, say 1000, the user must send 1000 queries and read the results 1000 times. This method substantially lengthens test time due to the overhead of the programming and power meter operations. This overhead can be greatly reduced by accumulating measurements in the power meter's buffer before sending them all out in one read operation by the controller.

In this case, the command TRIG:COUNt is used to set the size of power meter's output buffer. The default setting for TRIG:COUNt is 1. For the fastest measurement speed, TRIG:COUNt must be set to return multiple measurements for each FETCh? command. For Agilent's U2020 X-Series sensors, the highest trigger count can be set to 100 under FAST mode. In this condition, the sensor will return 100 readings at once. Table 3 shows the results of a no buffer versus buffer count of 100.

Table 3. Measurement comparison between buffer mode and non-buffer mode with the U2021XA X-Series sensor

Measurement mode	Power sensor settings	Measurement speed	Pros	Cons
No buffer (TRIG:COUNt 1)	• U2021XA • power level: 5 dBm • measurement mode: fast (SENS:MRATe FAST) • trigger count: 1 (TRIG:COUNt 1)	500 readings/s	Accurate measurement, useful for measurement when querying one reading	Returns only one reading at a time, slower speed
Trigger count of 100 (TRIG:COUNt 100)	• U2021XA • power level: 5 dBm • measurement mode: fast (SENS:MRATe FAST) • trigger count: 100 (TRIG:COUNt 100)	3500 readings/s	Accurate measurements, returns multiple readings (up to 100 maximum) at once, fastest measurement speed	May cause less accurate measurement if measuring a low power signal

The buffer mode is useful if the user wants to retrieve multiple readings at once for the fastest measurement speed with the fast mode setting. However, in fast mode, as previously explained, there is no average count applied and it may produce less accurate measurements. If the user only needs to retrieve one measurement at a time, then the non-buffer mode is the best solution with the trade-off of measurement speed.

More tips on how to optimize a power meter and sensor measurement speed are available in Application Note 5990-8471EN, *Practices to Optimize Power Meter/Sensor Measurement Speed and Shorten Test Times*. In general, these tips can be applied to all Agilent power meters and sensors.

Advanced Radar Measurements with Multi-pulse Functions Up to 10 Consecutive Pulses

Some radar components are produced in high volume and therefore, require low test time and extensive testing to ensure they meet stringent specifications.

Measuring pulse transient performance, such as amplitude and pulse shape variation from pulse-to-pulse, requires a single-shot measurement capability from a power measurement tool. Successive pulses are captured and analyzed to determine if there is any performance deviation due to transient effect.

The multi-pulse capability of the Agilent U2020 X-Series USB peak and average power sensor and P-Series power meter and sensor enable accurate pulse parameter measurements of up to 10 consecutive pulses. This feature is especially useful in radar applications such as in TR module engineering characterization to ensure that the pulse changes in amplitude and pulse shape resulting from module start up or mode changes, power supply drift or temperature effects meet performance expectation. The other potential application is in WLAN tests where packet-to-packet power variation is analyzed for continuous repetitive WLAN bursts.

Figure 11 shows 10 consecutive pulses captured using the Agilent X-Series U2021XA power sensor. Users can make use of the IVI driver or SCPI commands to retrieve detailed pulse parameter measurements from any of these 10 consecutive pulses. The SCPI commands needed to retrieve the pulse parameters are shown in Table 4.

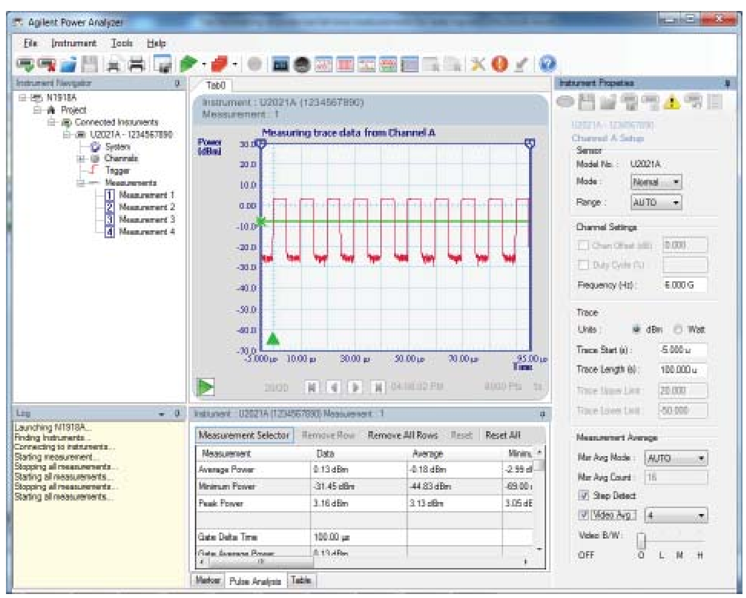


Figure 11. Ten consecutive pulses captured using the Agilent U2021XA power sensor

Advanced Radar Measurements with Multi-pulse Functions Up to 10 Consecutive Pulses

Table 4. SCPI commands to retrieve pulse parameters of up to 10 consecutive pulses

Pulse parameter	SCPI command
Duty cycle	TRAC:MEAS:PULS[1-10]:DCYC?
Pulse duration	TRAC:MEAS:PULS[1-10]:DUR?
Pulse period	TRAC:MEAS:PULS[1-10]:PER?
Pulse separation	TRAC:MEAS:PULS[1-10]:SEP?
Negative transition duration (fall time)	TRAC:MEAS:TRAN[1-10]:NEG:DUR?
Occurrence of a negative transition relative to trigger instant	TRAC:MEAS:TRAN[1-10]:NEG:OCC?
Positive transition duration (rise time)	TRAC:MEAS:TRAN[1-10]:POS:DUR?
Occurrence of a positive transition relative to trigger instant	TRAC:MEAS:TRAN[1-10]:POS:OCC?

Conclusion

Accurate and fast radar pulse measurements are a critical aspect of radar component design and manufacturing. As radar components become increasingly advanced and therefore, complex, time-to-market cycles and test times are reduced to meet stringent market demand and intense competitive pressure. Knowing how to optimize power measurement tools will give the engineer an edge in completing tests faster, with more accuracy and more efficiently. Use of appropriate instrumentation, such as Agilent's U2020 X-Series USB peak and average power sensors and P-Series power meters and sensors, can play a key role in enabling test engineers to make faster, more accurate and more comprehensive pulse parameters and pulse power measurements.

Additional Information

More information about Agilent power meters and sensors is available on the web at **www.agilent.com/find/powermeters**. Also, please refer to the following publications.

Related Agilent Literature

Publication title	Pub number
Agilent U2020 X-Series USB Peak and Average Power Sensors, Data Sheet	5991-0310EN
Agilent Power Meters and Sensors, Selection Guide	5989-7837EN
Agilent N1918A Power Analysis Manager, Data Sheet	5989-6612EN
Agilent N1911A/N1912A P-Series Power Meters and N1921A/N1922A Wideband Power Sensors, Data Sheet	5989-2471EN
P-Series Power Meteres and P-Series Wideband Power Sensors, Configuration Guide	5989-1252EN
P-Series Power Meters and P-Series Wideband Power Sensors, Technical Overview	5989-1049EN
Agilent E4416A/E4417A EPM-P Series Power Metersand E-Series E9320 Peak and Average Power Sensors, Data Sheet	5980-1469E
Agilent N1913A/N1914A EPM Series Power Meters, E-Series and 8480 Series Power Sensors, Data Sheet	5990-4019EN
Agilent U2000 Series USB Power Sensors, Data Sheet	5989-6278EN
Agilent Radar Measurement, Application Note	5989-7575EN
Perfecting Pulsed RF Radar Measurements, White Paper	5989-7323EN

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