Best Practices for Making the Most Accurate Radar Pulse Measurements

Agilent Technologies Inc

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Product Planner
November 2012
Agenda

• Standards and definitions
• How to:
  • Achieve accurate and consistent rise/fall time measurements
  • Capture RF signals with noisy spikes
  • Capture and measure small signal below -25dBm
  • Improve test time
Standards and Definitions
IEEE Standard 181-2011 for pulse definitions

Power Enveloped and RF pulse is governed by the IEEE standard 181-2011

Pulse characterization
Common questions from power meter and sensor users

**Question 1:** How to achieve accurate and consistent rise/fall time (transition duration) measurements?
Determining the right power reference level

Single positive-going transition and the illustration of 10%, 50% and 90% reference levels
Determining the right power reference level

**RF Domain**

<table>
<thead>
<tr>
<th>Reference Level - RF</th>
<th>Corresponding dB scaling</th>
</tr>
</thead>
<tbody>
<tr>
<td>10%</td>
<td>-10 dB</td>
</tr>
<tr>
<td>50%</td>
<td>-3 dB</td>
</tr>
<tr>
<td>90%</td>
<td>-0.5 dB</td>
</tr>
</tbody>
</table>

**Voltage Domain**

<table>
<thead>
<tr>
<th>Reference Level - voltage</th>
<th>Reference Level - RF</th>
<th>Corresponding dB scaling</th>
</tr>
</thead>
<tbody>
<tr>
<td>10%</td>
<td>1%</td>
<td>-20 dB</td>
</tr>
<tr>
<td>50%</td>
<td>25%</td>
<td>-6 dB</td>
</tr>
<tr>
<td>90%</td>
<td>81%</td>
<td>-0.9 dB</td>
</tr>
</tbody>
</table>
Determining the right power reference level

Mode of Histogram used in power meter and sensor to define the 100% reference level.

IEEE STD-181-2011 defines mode of histogram algorithm to determine the reference levels

Make sure you enter the right reference levels!

N1918A Power Analysis Manager software
# Case Study

## RF Out

<table>
<thead>
<tr>
<th>Trace start</th>
<th>Trace End</th>
<th>Time scale</th>
<th>Rise time</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>-100ns</td>
<td>200ns</td>
<td>30ns/div</td>
<td>80.6ns</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Pulse top is not captured</td>
</tr>
<tr>
<td>B</td>
<td>-100ns</td>
<td>300ns</td>
<td>40ns/div</td>
<td>99ns</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Pulse top is not captured</td>
</tr>
<tr>
<td>C</td>
<td>-100ns</td>
<td>400ns</td>
<td>50ns/div</td>
<td>114ns</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Rise time start to stabilize</td>
</tr>
<tr>
<td>D</td>
<td>-100ns</td>
<td>500ns</td>
<td>60ns/div</td>
<td>120ns</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Rise time stabilizes</td>
</tr>
<tr>
<td>E</td>
<td>-100ns</td>
<td>900ns</td>
<td>100ns/div</td>
<td>121ns</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Rise time stabilizes</td>
</tr>
<tr>
<td>F</td>
<td>-100ns</td>
<td>1100ns</td>
<td>120ns/div</td>
<td>122ns</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Rise time stabilizes</td>
</tr>
<tr>
<td>G</td>
<td>-100ns</td>
<td>1900ns</td>
<td>200ns/div</td>
<td>122ns</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Rise time stabilizes</td>
</tr>
<tr>
<td>H</td>
<td>-100ns</td>
<td>2900ns</td>
<td>300ns/div</td>
<td>122ns</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Rise time stabilizes</td>
</tr>
<tr>
<td>I</td>
<td>-100ns</td>
<td>4900ns</td>
<td>500ns/div</td>
<td>112ns</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Rise time degrades</td>
</tr>
</tbody>
</table>
Case Study - Continue

ESG takes about 500 ns to get from -3 dB to its pulse top!!

**Answer:**
- Set time scale to zoom into the rising edge
- Ensure that the time scale is long enough so that the pulse top level is captured.
Question 2:

How to capture RF pulse with noisy spikes?
How to capture RF pulse with noisy spikes?

Trigger Hysteresis

Trigger threshold is used to detect edges of pulse. Multiple triggers for noisy or highly modulated signals – unstable capture!

Two thresholds are provided between the desired trigger threshold. For valid trigger detection, signal must rise above the upper hysteresis threshold and not fall below the lower hysteresis threshold, within a certain time period. Z is the valid trigger!
How to capture RF pulse with noisy spikes?

Trigger Hold Off

- Hysteresis may cause this complete pulse to be missed.
- Qualification time can be reduced to detect the front edge of the pulse.
- But this resulted in 6 mall pulses to be detected.
- Trigger hold off is used to suppress trigger for a time period after the 1\textsuperscript{st} detection so that only one big pulse is detected.

**Answer:**

*Modulated signals with noisy spikes can be captures with careful setup of trigger hysteresis and hold off settings.*
Question 3:
How do I capture and measure low output power (-25dBm and below)
Case Study

ESG –25 dBm, 1 GHz
RF Out

U2021XA USB Peak Sensor
Internal Triggering Spec -
-20 dBm to +20 dBm

Unstable triggering
due to signals are
close to the noise
ground
External Triggering

External trigger will enable accurate trigger of small signal close to the signal noise floor.
Video Bandwidth

Example:

-25dBm pulse signal captured using U2021XA USB Peak Power Sensor

VBW = High (30MHz)  
VBW = Low (5MHz)

With low VBW, high frequency spectrum of the RF signal that constitutes the noise signals are removed, therefore leaving a smoother trace response.
Video Averaging
Further eliminate noise by applying video averaging.

Answer: You can measure lower peak power level with the combination of external triggering, lower down the VBW, and apply sufficient video averaging.
Question 4: How do I improve my test time?
Choose the Right Speed Settings

Measurement speed of Agilent power sensors in different speed modes

<table>
<thead>
<tr>
<th>Power Sensor</th>
<th>Normal</th>
<th>Double</th>
<th>Fast</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Measurement mode</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Normal</td>
<td>Double</td>
<td>Fast</td>
</tr>
<tr>
<td></td>
<td>Most accurate</td>
<td>Accurate</td>
<td>Faster speed, less accurate when measure low power</td>
</tr>
<tr>
<td></td>
<td>Full Instrument functionality</td>
<td>Full Instrument functionality</td>
<td>Avg, limits and ratio/diff math functions are disabled</td>
</tr>
<tr>
<td>8480 and N8480 series</td>
<td>20 readings/s</td>
<td>40 readings/s</td>
<td>--</td>
</tr>
<tr>
<td>E-Series E4410 and E9300</td>
<td>20 readings/s</td>
<td>40 readings/s</td>
<td>Up to 400 readings/s</td>
</tr>
<tr>
<td>E-Series E9320 (Average mode)</td>
<td>20 readings/s</td>
<td>40 readings/s</td>
<td>Up to 400 readings/s</td>
</tr>
<tr>
<td>E-Series E9320 (Normal mode)</td>
<td>20 readings/s</td>
<td>40 readings/s</td>
<td>Up to 1,000 readings/s</td>
</tr>
<tr>
<td>P-Series wideband</td>
<td>20 readings/s</td>
<td>40 readings/s</td>
<td>Up to 1,500 readings/s</td>
</tr>
<tr>
<td>U2000 Series USB</td>
<td>20 readings/s</td>
<td>40 readings/s</td>
<td>Up to 110 readings/s</td>
</tr>
<tr>
<td>U2020 X-Series USB</td>
<td>20 readings/s</td>
<td>40 readings/s</td>
<td>Up to 3500 readings/s</td>
</tr>
</tbody>
</table>
Utilizing Buffer Mode

**Normal Operation:**

Normal operation – To obtain one measurement, send one query and one read command

For 1000 measurements, send 1000 queries and 1000 read commands

Long test time! Due to large overhead of operations

**Buffer mode:**

Accumulate measurements in power meter’s buffer before retrieving all the measurements in one read operations

Reduce overhead and FASTER TEST TIME!
**Buffer Mode Settings**

Example: Agilent U2020 X-Series sensors, the highest trigger count can be set is 100 under FAST mode. In this condition, the sensor will return 100 readings at one time.

<table>
<thead>
<tr>
<th>Measurement Mode</th>
<th>Power Sensor settings</th>
<th>Measurement speed</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>No buffer (TRIG:COUNt 1)</td>
<td>U2021XA</td>
<td>200 readings/s</td>
<td>Accurate measurement. Useful for measurement when querying one reading</td>
<td>Returns only one reading at a time. Slower speed.</td>
</tr>
<tr>
<td></td>
<td>Power level: 5dBm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Measurement mode: Fast (SENS:MRATe FAST)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Trigger count: 1 (TRIG:COUNt 1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trigger count of 100 (TRIG:COUNt 100)</td>
<td>U2021XA</td>
<td>3500 readings/s</td>
<td>Accurate measurements. Returns multiple readings (up to 100 maximum) at once. Fastest measurement speed.</td>
<td>May cause less accurate measurement if measure low power signal.</td>
</tr>
<tr>
<td></td>
<td>Power level: 5dBm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Measurement mode: Fast (SENS:MRATe FAST)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Trigger count: 100 (TRIG:COUNt 100)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Multi-pulse function (up to 10 consecutive pulses)

<table>
<thead>
<tr>
<th>Pulse parameter</th>
<th>SCPI command</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duty cycle</td>
<td>TRAC:MEAS:PULS[1-10]:DCYC?</td>
</tr>
<tr>
<td>Pulse duration</td>
<td>TRAC:MEAS:PULS[1-10]:DUR?</td>
</tr>
<tr>
<td>Pulse period</td>
<td>TRAC:MEAS:PULS[1-10]:PER?</td>
</tr>
<tr>
<td>Pulse separation</td>
<td>TRAC:MEAS:PULS[1-10]:SEP?</td>
</tr>
<tr>
<td>Negative transition duration (fall time)</td>
<td>TRAC:MEAS:TRAN[1-10]:NEG:DUR?</td>
</tr>
</tbody>
</table>

TR module testing
- characterize pulse changes (amplitude/pulse shape)

WLAN test
- Analyzer packet-to-packet power variation for continuous WLAN bursts
Built-in Radar and Wireless Presets

- RADAR
- DME
- GSM
- EDGE
- LTE
- WLAN
- WCDMA
- CDMA
- WiMAX

and many more....
RECAP

**Question 1:** How to achieve accurate and consistent rise/fall time?
A: By applying the right reference levels and zooming in on the rising/falling edge of the signal to capture the entire pulse top

**Question 2:** How to capture RF pulse with noisy spikes?
A: By utilizing the trigger hysteresis and hold-off features

**Question 3:** How do I capture and measure low output power (-25dBm and below)
A: Apply external triggering, lower down video bandwidth and increase video averaging

**Question 4:** How do I improve my test time?
A: Use fast and buffer mode, make use of multi pulse function and built-in presets
Agilent Power Meter Series
Agilent Power Meters and Sensors for RF and microwave measurements

USB Peak Sensors
Peak, Average (<30MHz VBW)
Low cost peak measurement solution
>3500 rdgs/sec

EPM-P
- Peak & Average (<5MHz VBW)
- Wireless Com (GSM, EDGE, WCDMA, Bluetooth, etc)
- Radar Pulse Tr > 13ns

EPM
- Average Power
- R&D & Mfg (Std Rack Size)
- Military & ATE Systems

Handheld Power Meter
- Average Power
- Handheld solutions

USB Sensors
- Average Power
- Low Cost Solution
- I&M market, R&D & Mfg

Peak Power Analyzer
- Peak, Average, CCDF (<150MHz VBW)
- Pulse Measurement
- Radar Pulse Tr < 5ns

P-Series LXI
- Peak, Average, CCDF (<30MHz VBW)
- Wireless Networking (WLAN, WiMAX, MIMO)
- Radar Pulse Tr > 200ns
- Compact, modular, faceless
- For A&D ATE/ CASS

NEW!!!
June '12

Price

Performance
Introducing the new **U2020 X-Series**

**World’s fastest** USB power sensors with peak and average power measurement capability of a bench power meter

- Internal zeroing and calibration eliminates external calibration needs
- Works with any PC and many Agilent instruments
- 30MHz VBW, 80MSa/s, 3500 rdg/s, wide 50dB peak dynamic range
- USB allows remote measurements beyond typical cable length
- Built-in external trigger in and trigger out / video out / recording out ports

Agilent Technologies
Introducing the new **U2020 X-Series** - continue

**Key Specifications**

- **Frequency range:**
  - U2021XA - 50MHz – 18GHz (N-type)
  - U2022XA - 50MHz – 40GHz (2.4mm)

- **Power range:**
  - Average power: -35 to +20dBm
  - Peak power: -30 to +20dBm

- **Video bandwidth:** >=30MHz (switchable to lower BW for wider power range)

- **Sampling rate:** 80 Msamples/second

- **Measurement speed:** 3500 rdgs/s

- **Accuracy:** <±4.5% (±0.2dB)

- **Trigger in/out:** Built in with recorder/video out

- **System rise/fall time:** <= 13ns

- **Zeroing and Calibration:** Internal

- **Minimum pulse width:** 50 ns

- **Maximum pulse repetition rate:** 10MHz

- **Linearity:** <1%

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**Bundled Software for easy set-up of complex measurements**

- Wide peak power dynamic range for most accurate complex pulse analysis
- Fastest sampling time and speed for high trace resolution and reduce overall test time
- Clean and simple setup without need of external modules. Built-in trigger in/out for synchronization with external event. Video out for alternate analysis with an Oscilloscope.
- True plug and play capability without the hassle of removing for external calibration
Mobile Selection Guide Apps is HERE!!!
For more information…

On this topic:  
www.agilent.com/find/rfpowertips

On Agilent Power Meter/Sensor:  
www.agilent.com/find/powermeters

On new U2020 X-Series USB peak & average power sensor  
www.agilent.com/find/usbpeaksensor
Thank you for your time!