I Know I Need to Measure RF Power – Now What?

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Agenda: I Know I Need to Measure RF Power – Now What?

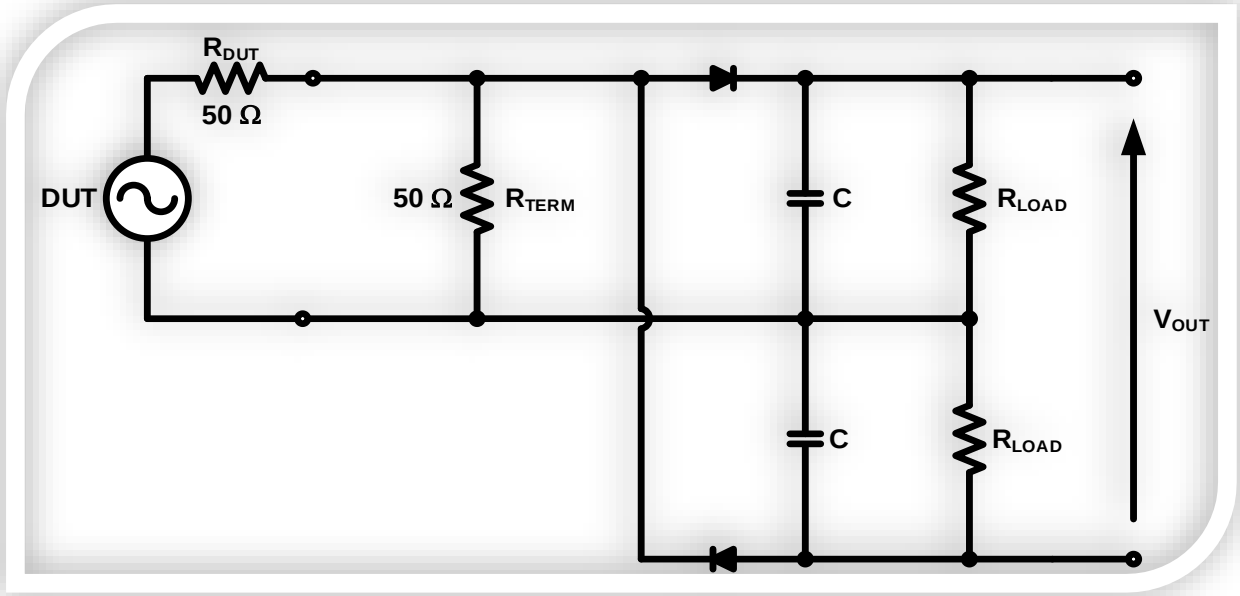
- Power sensor technology
- Type of power sensor and power measurement architecture
- Applications: Radar
- Applications: Communications
- Summary and Q&A

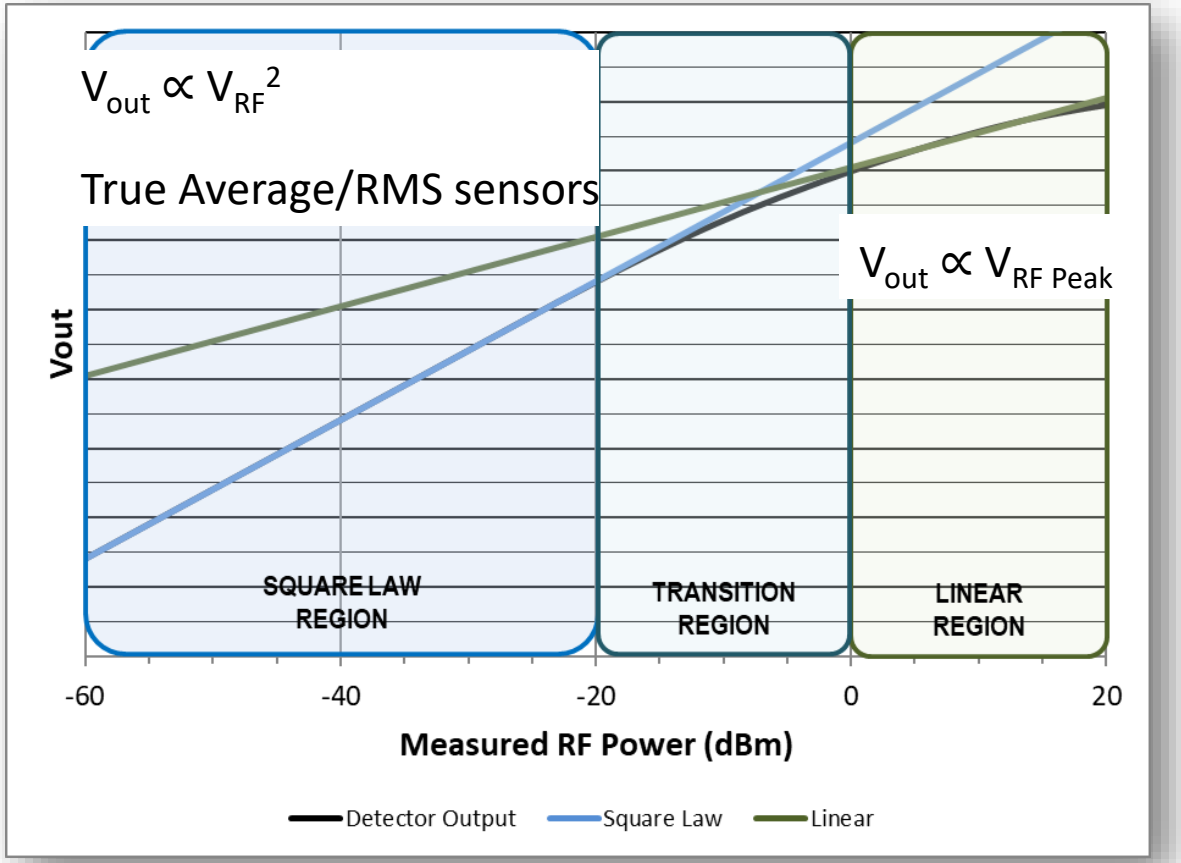
RF and Microwave Power Sensor Technology: Overview

Sensor Technology	Characteristics	Application
Thermal • Heating effect • Thermistor, thermocouple	✓ Highest accuracy ✓ Average power measurement independent of waveform type X Low sensitivity/dynamic range X Influenced by ambient temperature X Not suitable for instantaneous or pulse measurements	Calibration
Diode Detector • AC to DC conversion • True Average and Peak	✓ True average measurement independent of waveform type ✓ Fast rise time, wide video bandwidth ✓ Peak power measurement ✓ Narrow pulse measurement - Non-linear, but can be corrected	Radar Communications EMC Others
Receiver • Downconversion to IF and detected or sampled (e.g. spectrum analyzer)	✓ May permit I/Q data download ✓ Frequency selective X Frequency selective – not enough BW for wideband signals	Communications (with measurement bandwidth limitations) and where I/Q data required.
RF Sampling • Direct digitization at RF	✓ OK for low frequency signal X Limited dynamic range for high freq. X Expensive for high frequency	

More information available at: https://boonton.com/resource-library/principles-of-power-measurement-guide

RF and Microwave Power Sensor Technology: Diode Sensors





- Sensor's diode (or diode pair) detects the RF power
- Diode performs an AC to DC conversion
- The relationship of the DC voltage to the power measured depends on the diode region of operation

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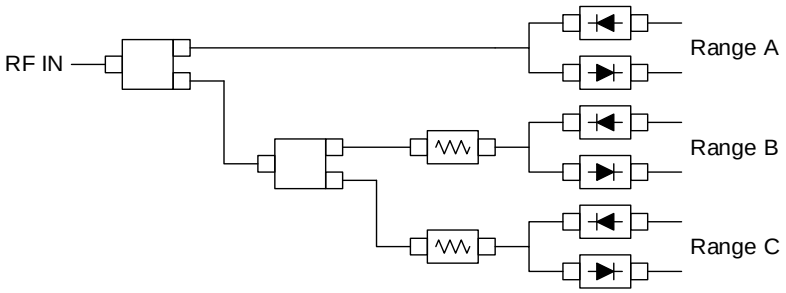
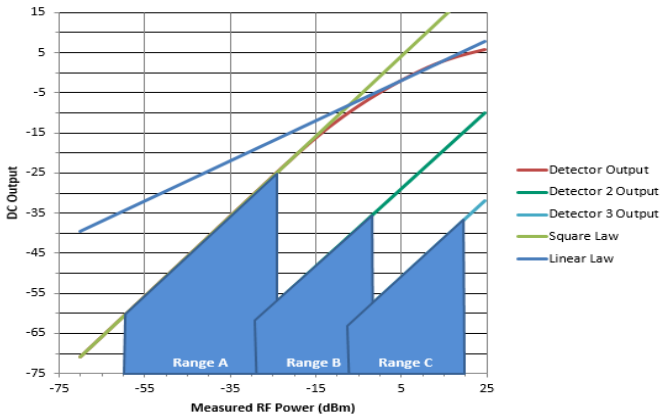
Types of Power Sensor

True Average Power Sensor

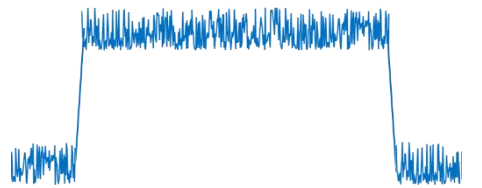
- Overlapping multiple paths to ensure operation in square law region
  - -60 to +20 dBm
- Modulation Independent





Peak Power Sensor

- Fast real-time sample rate and linearization
  - 100 MSa/s
  - -60 to +20 dBm
- Instantaneous and average values
- Random Interleaved Sampling (RIS)
  - 10 GSa/s ⇨ 100 ps resolution
- Wide video bandwidth to track RF envelope fluctuation



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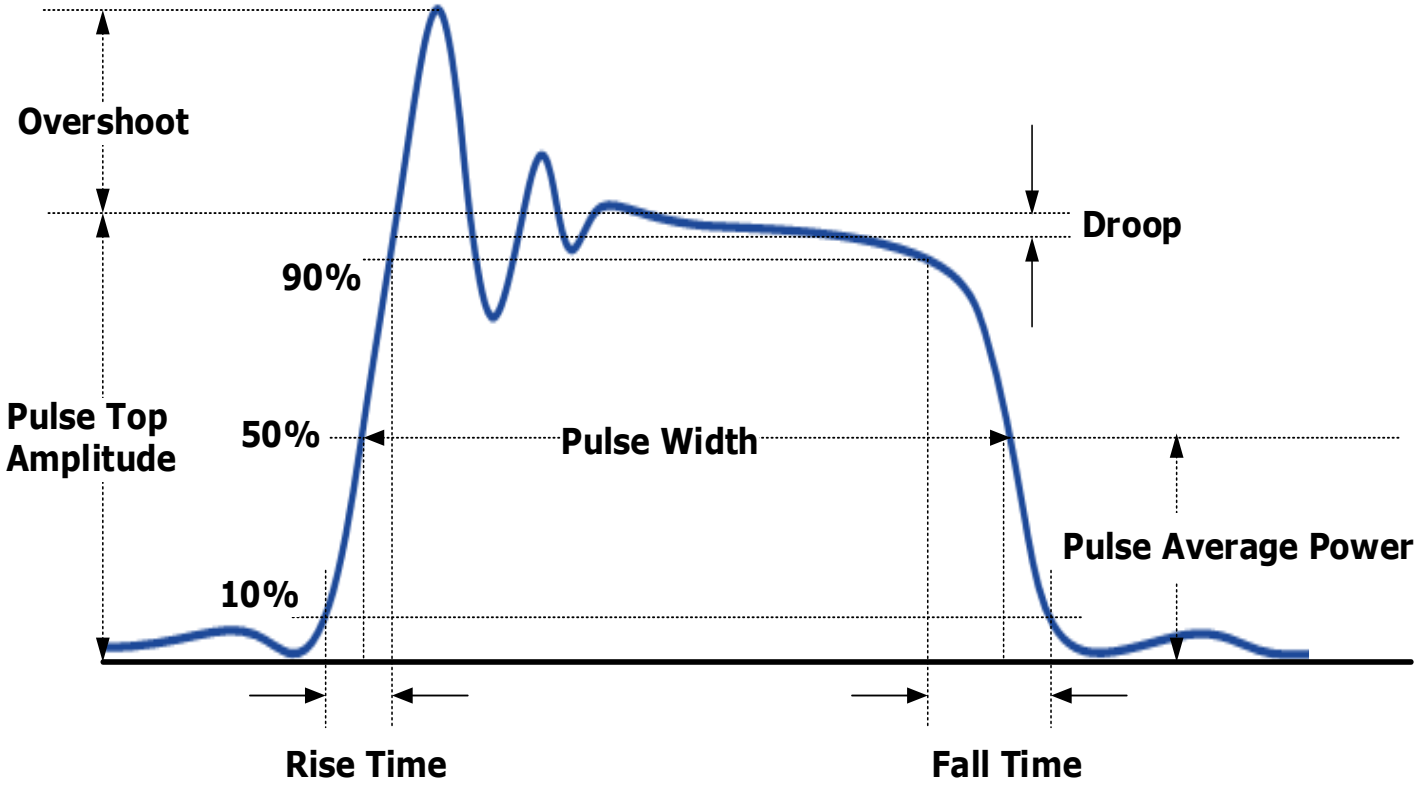
Radar Pulse Measurement: Definitions



Parameters of interest for pulsed or burst signals.

16 Automatic Pulse Measurements:

- Rise time
- Fall time
- Pulse width
- Off time
- Period
- Pulse repetition frequency
- Duty cycle
- Pulse peak
- Pulse overshoot
- Pulse average
- Waveform average
- Top level power
- Droop
- Bottom level power
- Edge delay
- Skew

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Radar: significance of sensor rise time choice

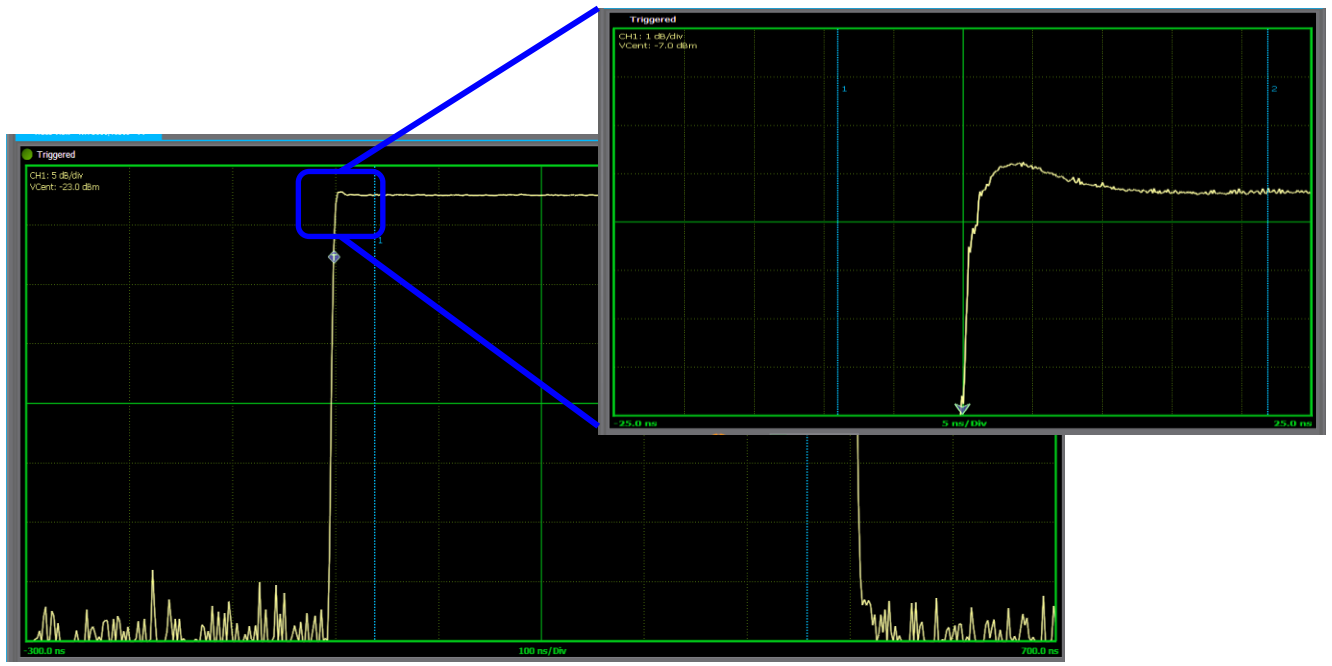
Param	CH1
Width	47.531 ns
Rise	4.1971 ns
Fall	5.9043 ns

Fast rise times are needed to track the most demanding pulse waveforms

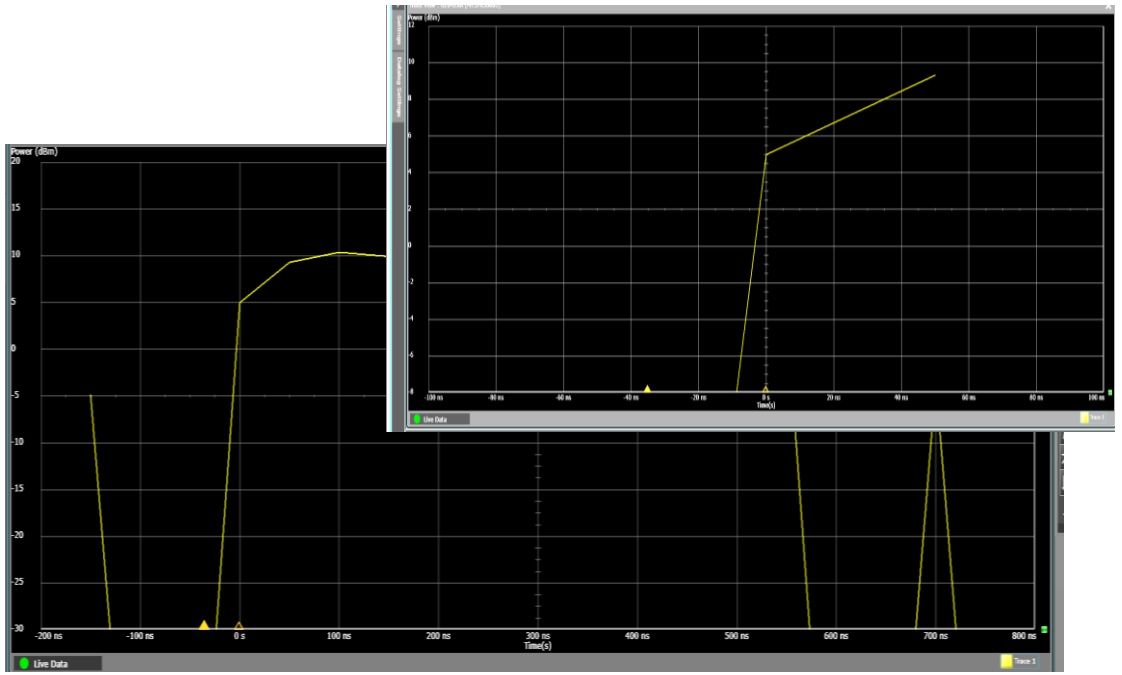
RTP5000 peak power sensors: rise time as fast as 3 ns.

Radar: Significance of sample rate

- Real time sample rate: determines resolution for single sweep captures
- Effective sample rate: uses RIS and determines resolution on repetitive signals



- **100 ns/div**
- **Zoom to 5 ns/div**
- **With 10 GSa/s see fine detail**
- **100 ps resolution**



- **100 ns/div**
- **Zoom to 20 ns/div**
- **With 20 MSa/s no more detail**
- **Limit is 50 ns resolution**

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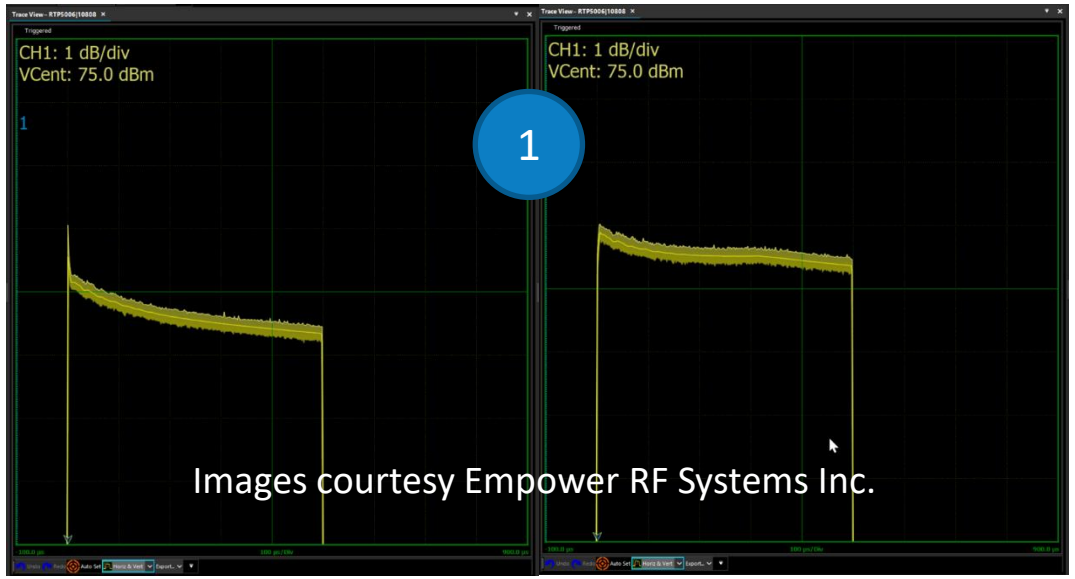
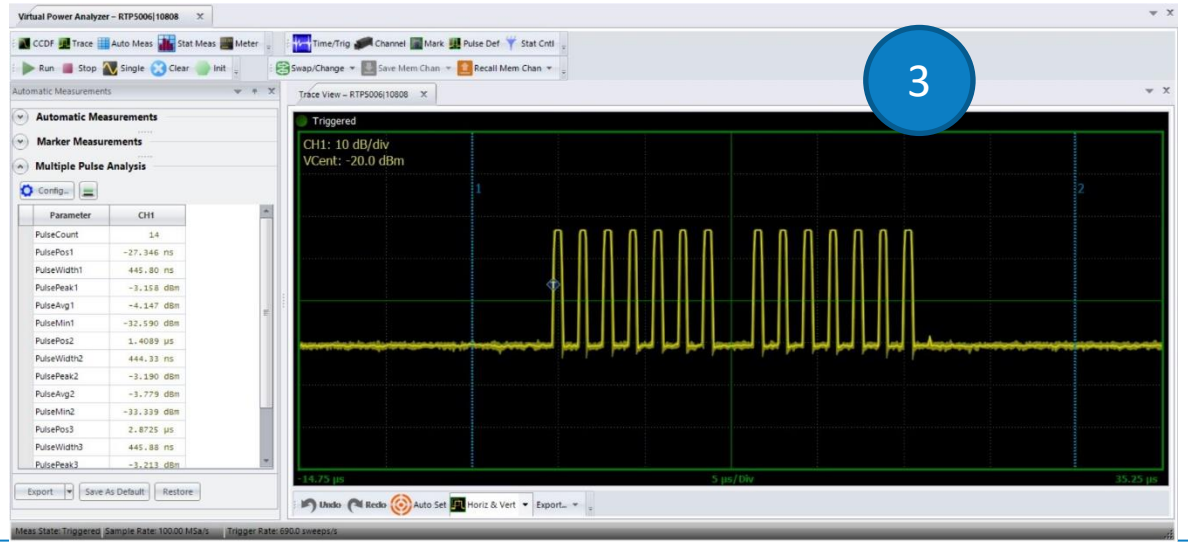
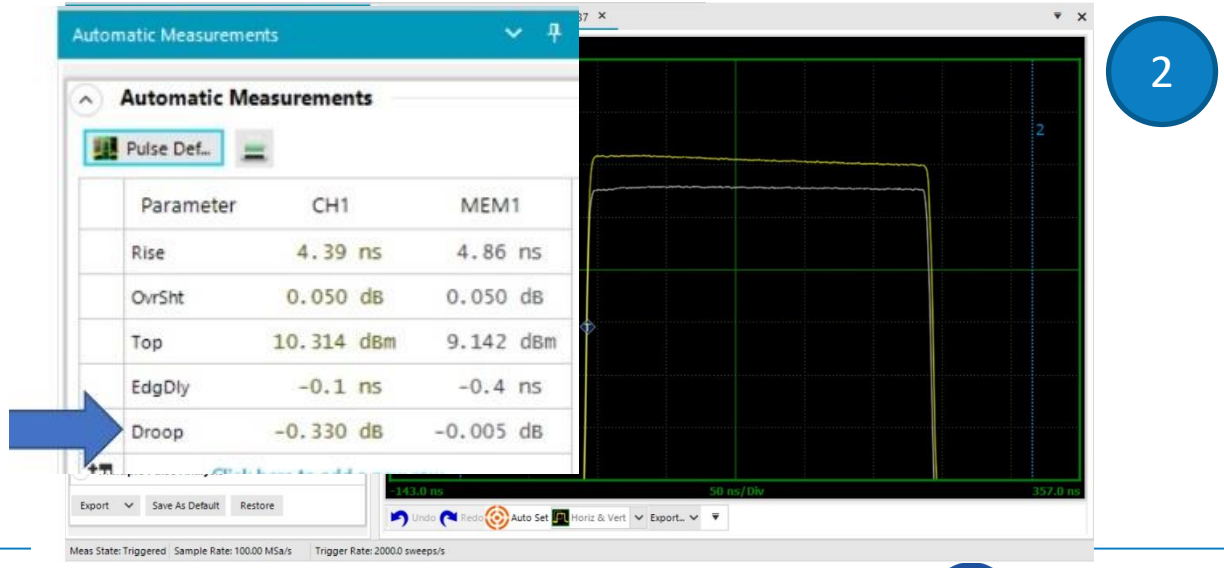
Pulse Measurement Examples

1. Radar TX overshoot & droop reduction
   - Enables higher P_{AV} and greater radar range
2. Automated pulse measurements
   - Droop is one of 16
3. Multi-pulse burst analysis
   - E.g. secondary surveillance radar

- RTP5000 series sensor family
  - Frequency to 40 GHz, rise time as low as 3 ns
  - Sample rate 100 MS/s cont., 10 GS/s effective
  - 100,000 measurements/second (Max, Min, Average)







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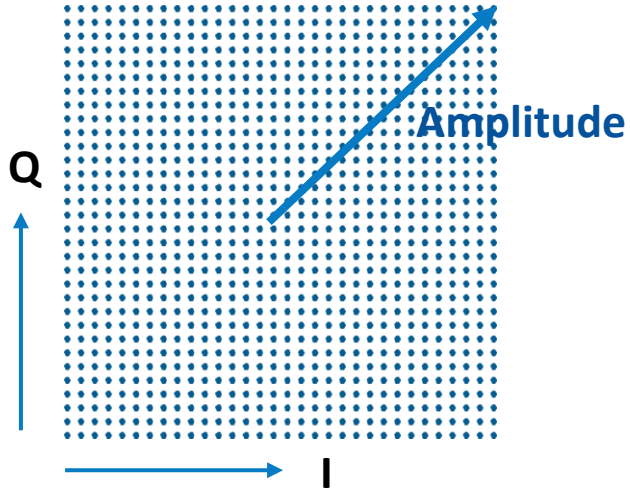
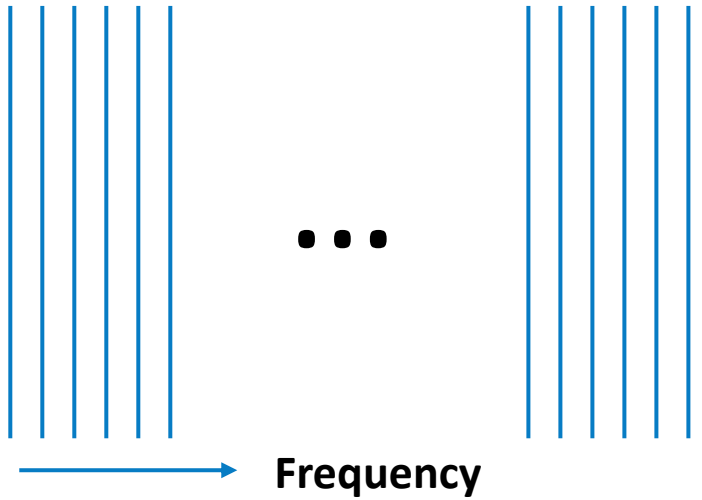
Communication Applications: Nature of Signals

- Example Wi-Fi: m-QAM modulated OFDM sub-carriers



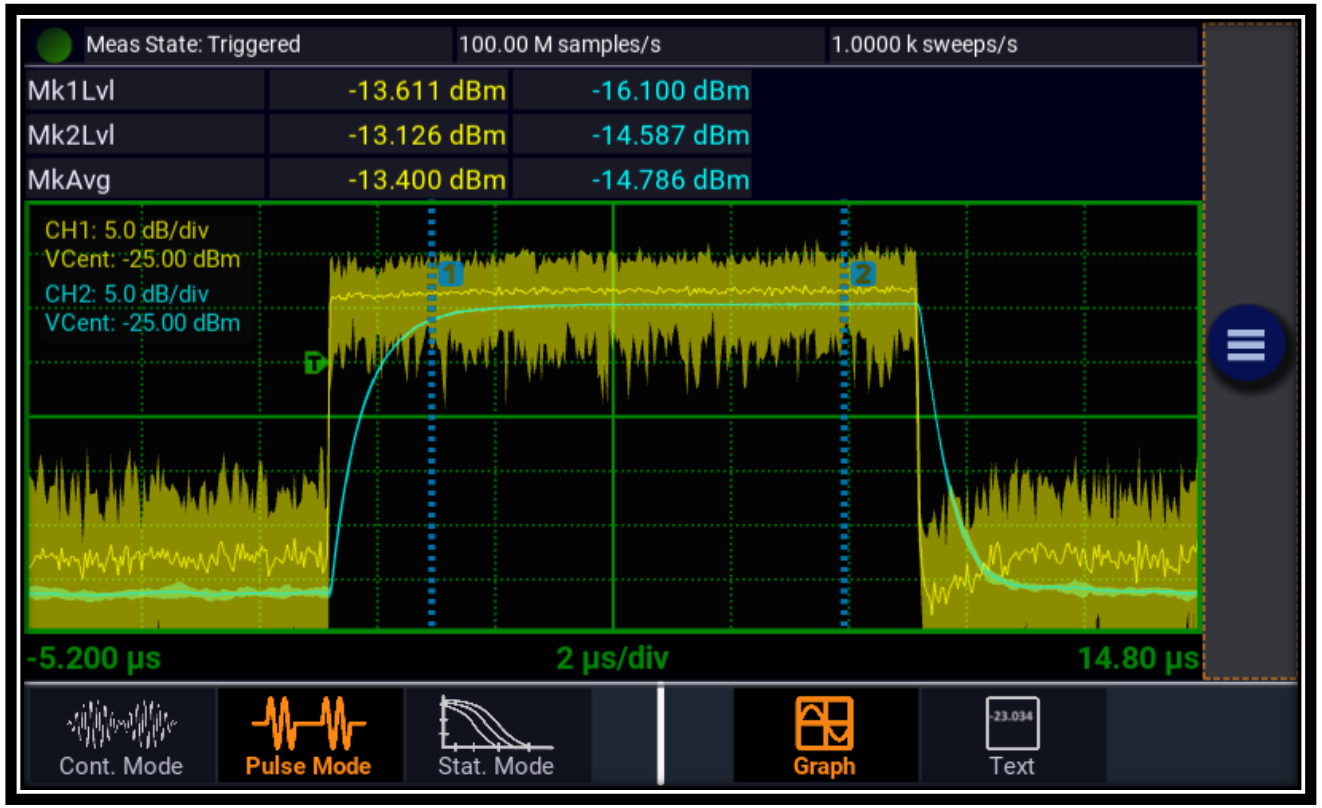
1024-QAM



Wi-Fi 6: 2x 1024 tones spaced at 78.125 kHz

- Channel bandwidth 160 MHz
- Wide variation in instantaneous signal amplitude ⇨ high peak to average power ratio (PAPR)
- Need to ensure amplifier non-linearities are not reducing peaks and hence causing symbol/bit errors

Communications Applications: Sensor Video Bandwidth

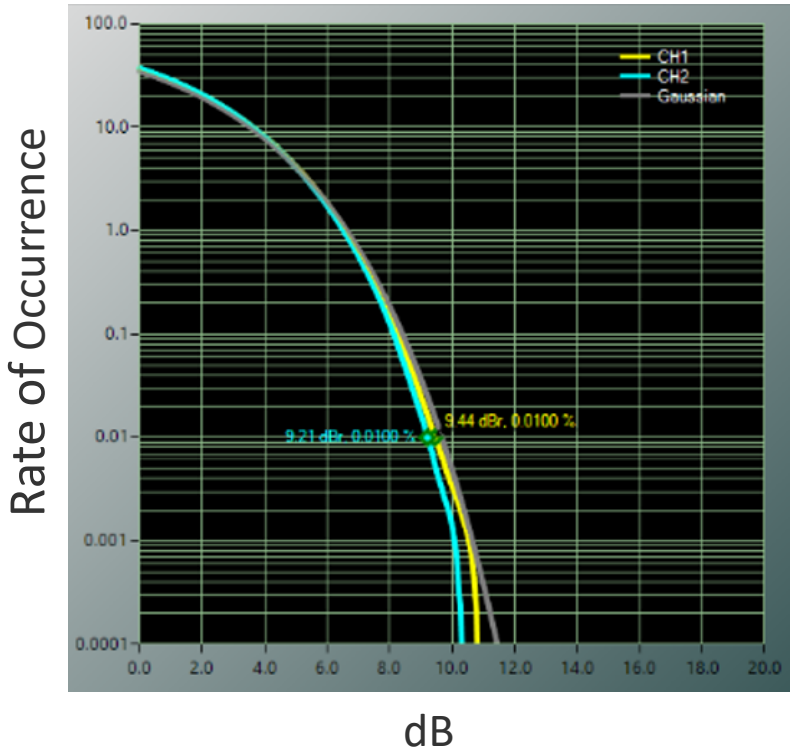


- Errors in envelope power, peak envelope power, and average power
- Using average power as a substitute can mask signal compression
- Wi-Fi 6 and 5G channel bandwidths: up to 160 MHz and 100 MHz
  - Boonton's RTP5000 peak power sensors feature VBW up to 195 MHz

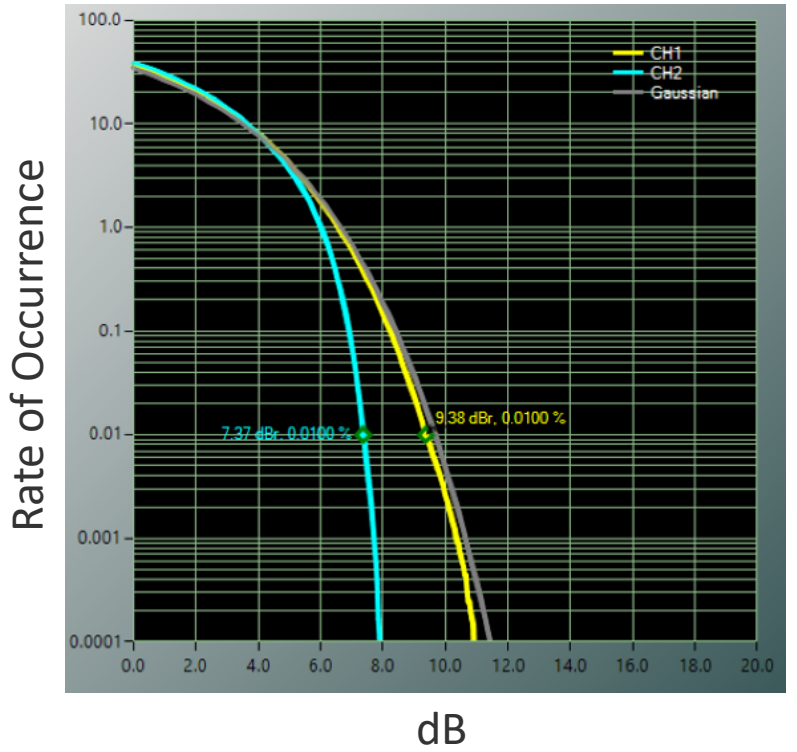
Communications Applications: CCDF and PAPR

- Complementary Cumulative Distribution Function (CCDF):
  - Statistical depiction that shows how frequently a specific PAPR (Crest Factor) will occur

✓ **Linear**



× **Non-Linear**



Average Input Power = -11.9 dBm		
Input PAPR = 9.4 dB	Output PAPR = 9.2 dB	Delta PAPR = -0.2 dB
Pin = -11.9 dBm	Pout = 2.5 dBm	Gain = 14.4 dB

Average Input Power = -7.1 dBm		
Input PAPR = 9.4 dB	Output PAPR = 7.4 dB	Delta PAPR = -2.0 dB
Pin = -7.1 dBm	Pout = 7.1 dBm	Gain = 14.2 dB

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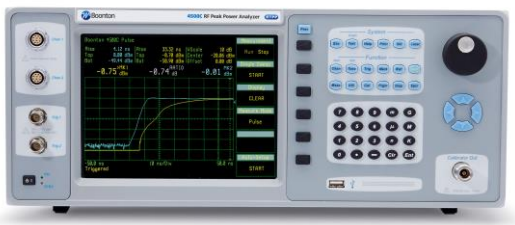
Summary: 10 Questions

Question	If Yes	If No
1. What frequency is my signal?	Choose sensor covering frequency range	
2. What level is my signal?	Choose sensor with dynamic range to match	
3. Does my signal have modulation?	Consider question 4	CW or true average sensor
4. Do I only want to measure average power?	Choose a true average power sensor	Consider questions 5 thru 10
5. Do I want to profile a pulse in time domain?	Chose peak power sensor (T_r < signal T_r)	
6. What time resolution is required?	Choose appropriate effective sample rate	
7. Do I need automated pulse measurements?	Choose from 16 measurements	
8. Is my signal a burst of pulses?	Consider multi-pulse measurements	
9. Am I concerned about PAPR?	Need sensor VBW > channel BW	
10. Do I want to see a specific % occurrence of PAPR?	Consider CCDF capability	

CW Power Measurement



Peak Power Analyzer

USB Peak and True Average Power Sensors

Thank You!

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Please visit our booth #1619 to see Boonton power measurement solutions and other great products from Boonton, Noisecom, and Holzworth.

Boonton Portfolio

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Markets

- Commercial comms
- Military/Aerospace
- Avionics
- R&D and Scientific
- ATE, Production Test

Applications

- RF components and amps
- Medical devices
- Radar systems
- WiFi & LTE
- Military communications
- EMI/EMC

Products

- RF Power Meters
- USB Power Sensors
- Modulation Analyzers
- Audio Analyzers
- RF Signal Generators
- RF Noise Generators

RF Signal Generation

RF Noise Generation

Peak and Wideband Power Measurement

Average/RMS Power Measurement

Modulation and Audio Analysis

CW Power Measurement

Wireless Telecom Group Test & Measurement Business Unit Overview

	Markets	Applications	Products
Boonton	• Commercial comms • Military/Aerospace • Avionics • R&D and Scientific • ATE, Production Test	• RF components and amps • Medical devices • Radar systems • WiFi & LTE • Military communications • EMI/EMC	• RF Power Meters • USB Power Sensors • Modulation Analyzers • Audio Analyzers • RF Signal Generators • RF Noise Generators
Noisecom	• Commercial comms • Satellite comms • Military/Aerospace • R&D and Scientific	• Signal integrity • Jamming • Noise Figure Measurement • Receiver calibration • Carrier-to-Noise	• Noise Generators • Noise Standards • Calibrated Sources • Noise Modules • Chips and Diodes • Jitter and PSRR analysis
Holzworth	• Quantum Computing • Commercial comms • Satellite comms • Military/Aerospace • R&D and Scientific	• Qubit Manipulation • Absolute Phase Noise Analysis • Additive Phase Noise Analysis • LO Generation	• RF Synthesizers • Synthesizer Modules • Phase Noise Analyzers • Amplifiers • Phase Detectors • Phase Shifters • Frequency Dividers