Accurate RF Power Measurements of Second and Third Generation Wireless Communication Signals

Steve Reyes
Marketing Manager
Giga-tronics Instrument Division

Giga-tronics

Accurate RF Power Measurements

- Accurate power control critical for optimum coverage
  - Higher power for greater distance and improved voice quality
  - Lower power for longer battery life
  - Verify maximum power output conforms to regulatory restrictions
- Previous trade-off between speed and accuracy in production
  - New diode sensor technology provides speed with accuracy

Microwave Power

- Power is defined as work (available energy) over a period of time
  - 1 Watt = 1 Joule per second
- Average power (rather than instantaneous) is primary concern and is found by integration:

$$\left(\frac{1}{T}\right)\int_{0}^{T} e\,i\,dt$$

Power Sensors

- **Thermal Sensors**
  - Thermocouples, Thermistors
  - Integrate power (heat) over time
- **Diode Sensors**
  - Rectify RF energy to dc voltage
  - Fast - capable of tracking rapid power changes
  - Measure peak modulated power when designed with proper video bandwidth

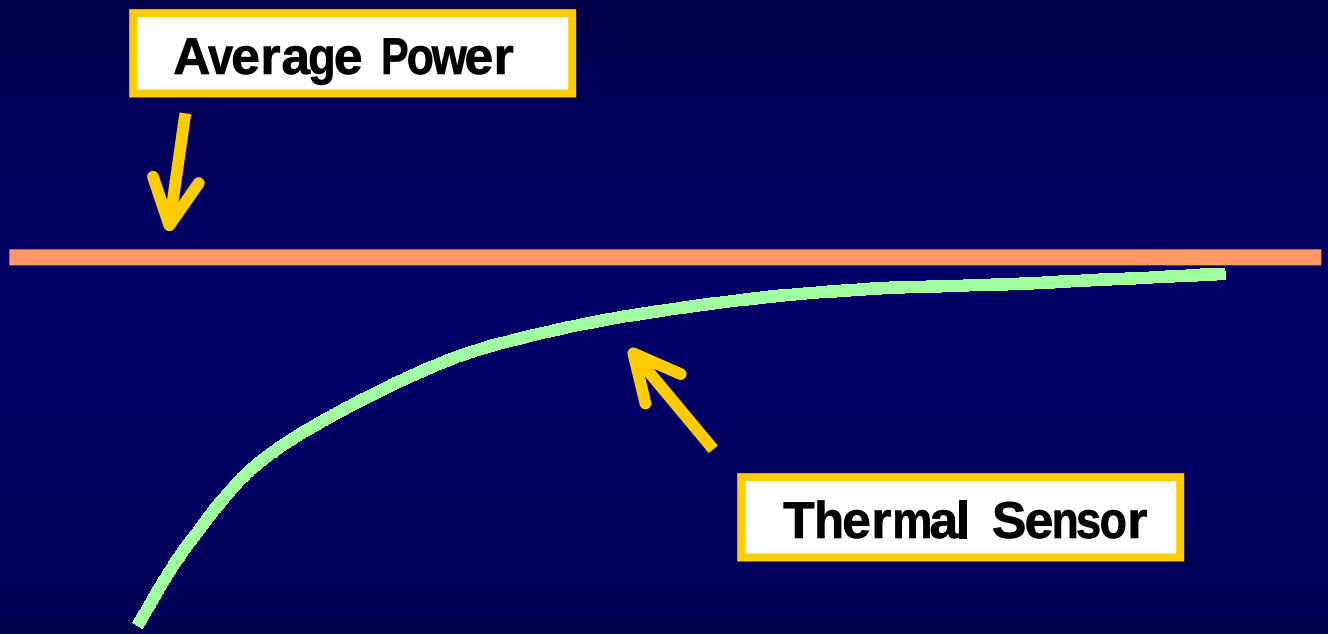
Power Measurement Accuracy

- Significant factors when considering measurement uncertainty:
  - Mismatch, sensor/source
  - Instrumentation linearity
  - Calibration factor uncertainty
  - Sensor power linearity
  - Calibrator uncertainty
  - Calibrator/sensor mismatch
  - Zero Error (last 15 dB of dynamic range)
  - Noise (last 15 dB of dynamic range)

Power Measurements

- CW measurements
  - Constant amplitude signal
- Modulated measurements
  - FM
  - AM
  - Pulse; peak or average
- Digital communication signals

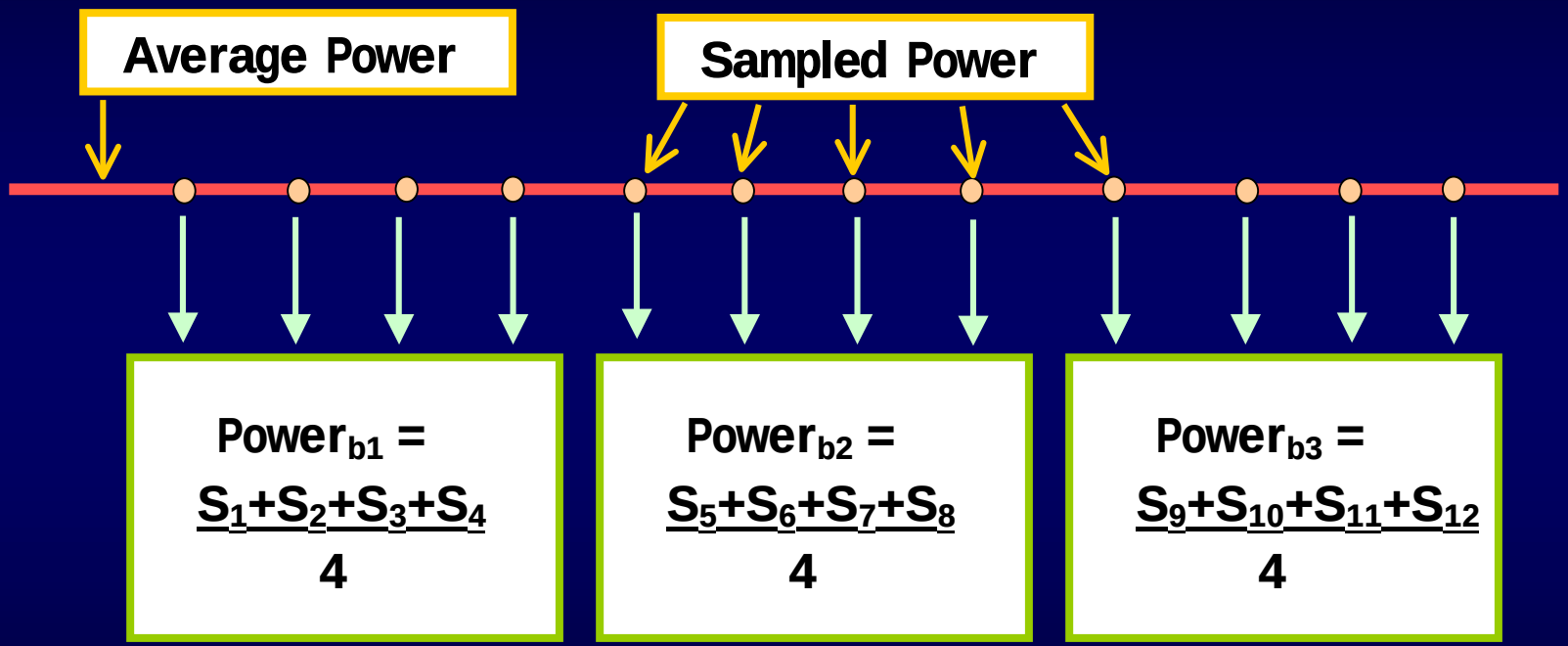
Measuring CW Power Using Thermal Sensors



- Thermal Sensors rise to the level of the average power through integration

Giga-tronics

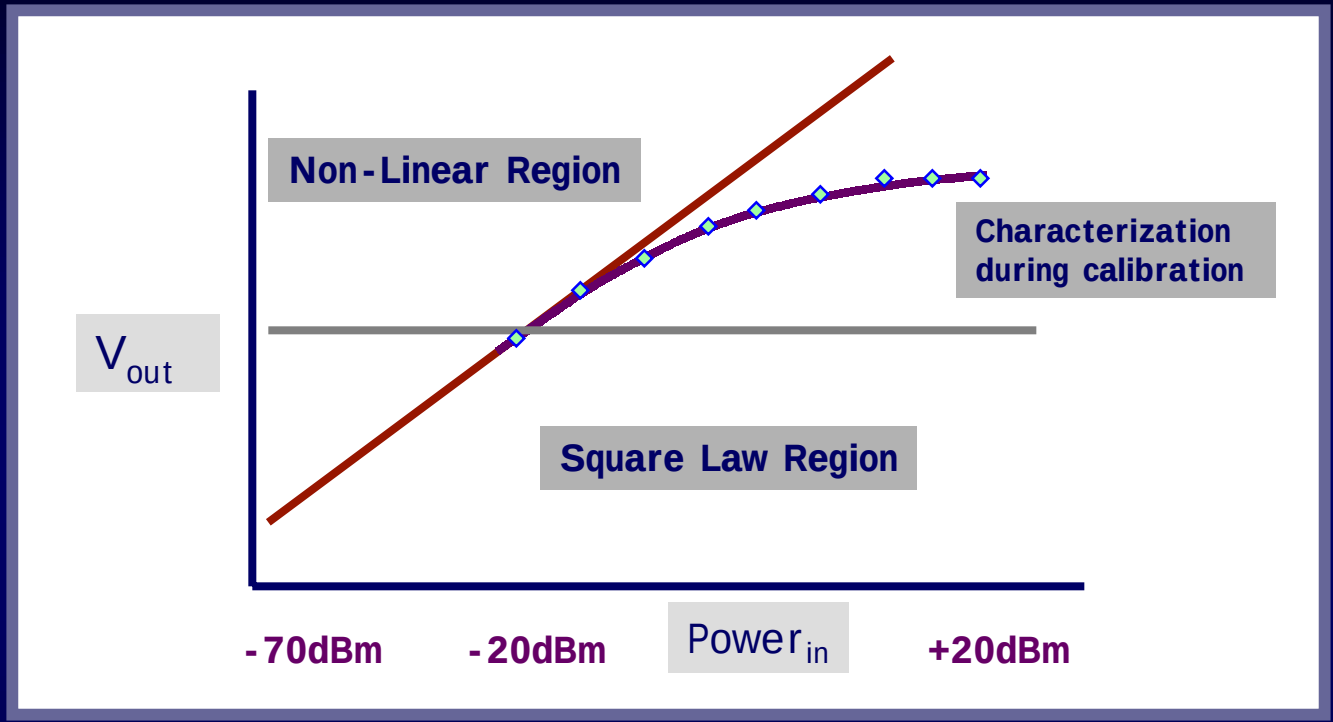
Measuring CW Power Using Diode Sensors



- Diode Sensors sample the average power of a CW signal and store the samples into buckets for further averaging

Giga-tronics

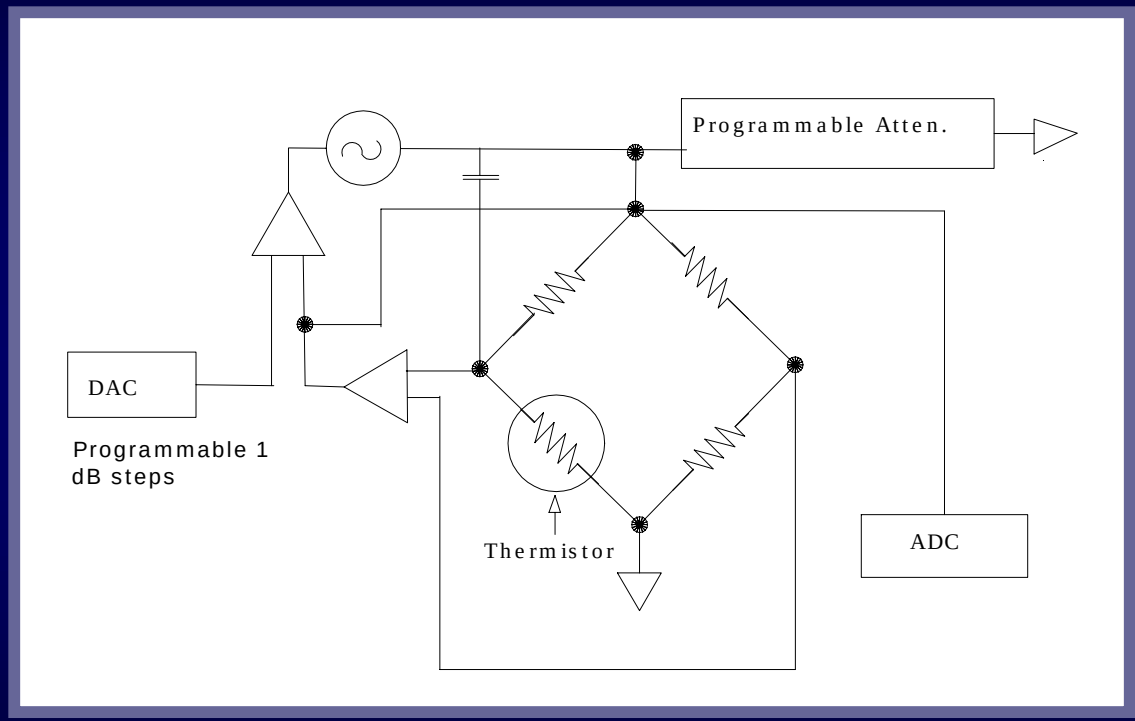
Giga-tronics 90 dB Dynamic Range Diode Sensors



- Square Law region from -70 to -20 dBm
- Non-linear characteristics from -30 to +20 dBm identified during calibration and corrected during measurement

Giga-tronics

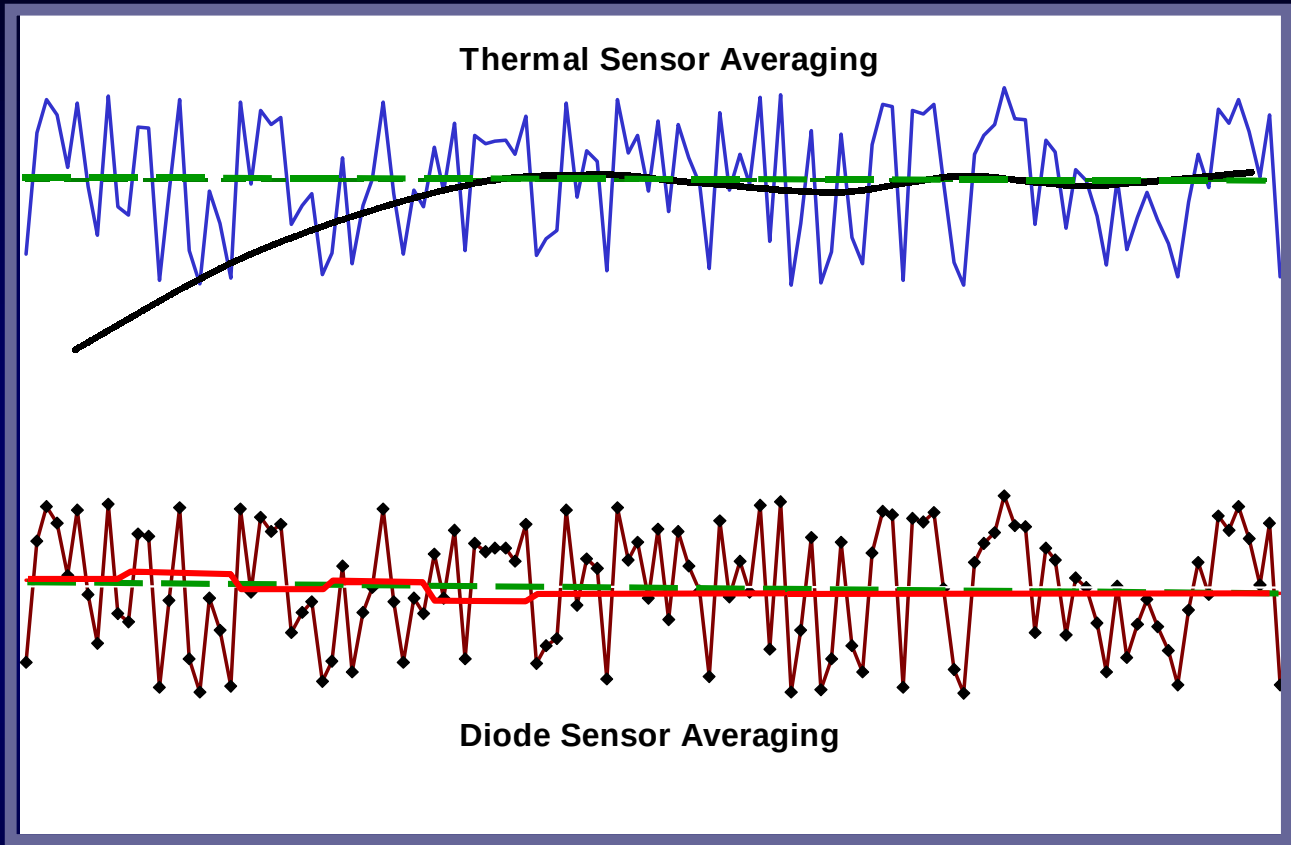
Giga-tronics Sensor Calibration Techniques



- Thermistor used in a patented swept power bridge circuit provides NIST-traceable 90 dB dynamic range

Giga-tronics

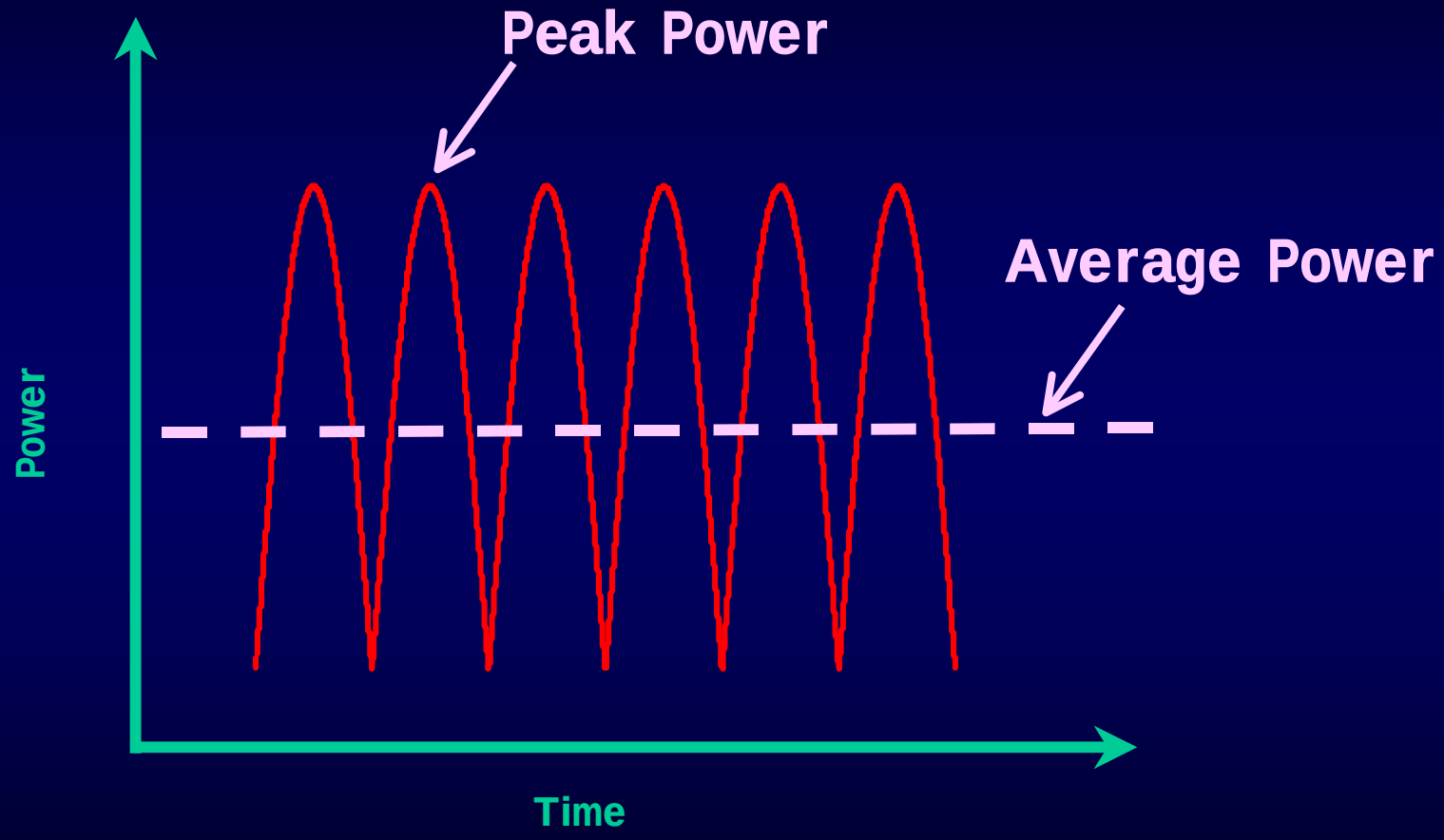
Measuring CW Power with Noise



- Multiple readings of normally distributed noise settles to average power

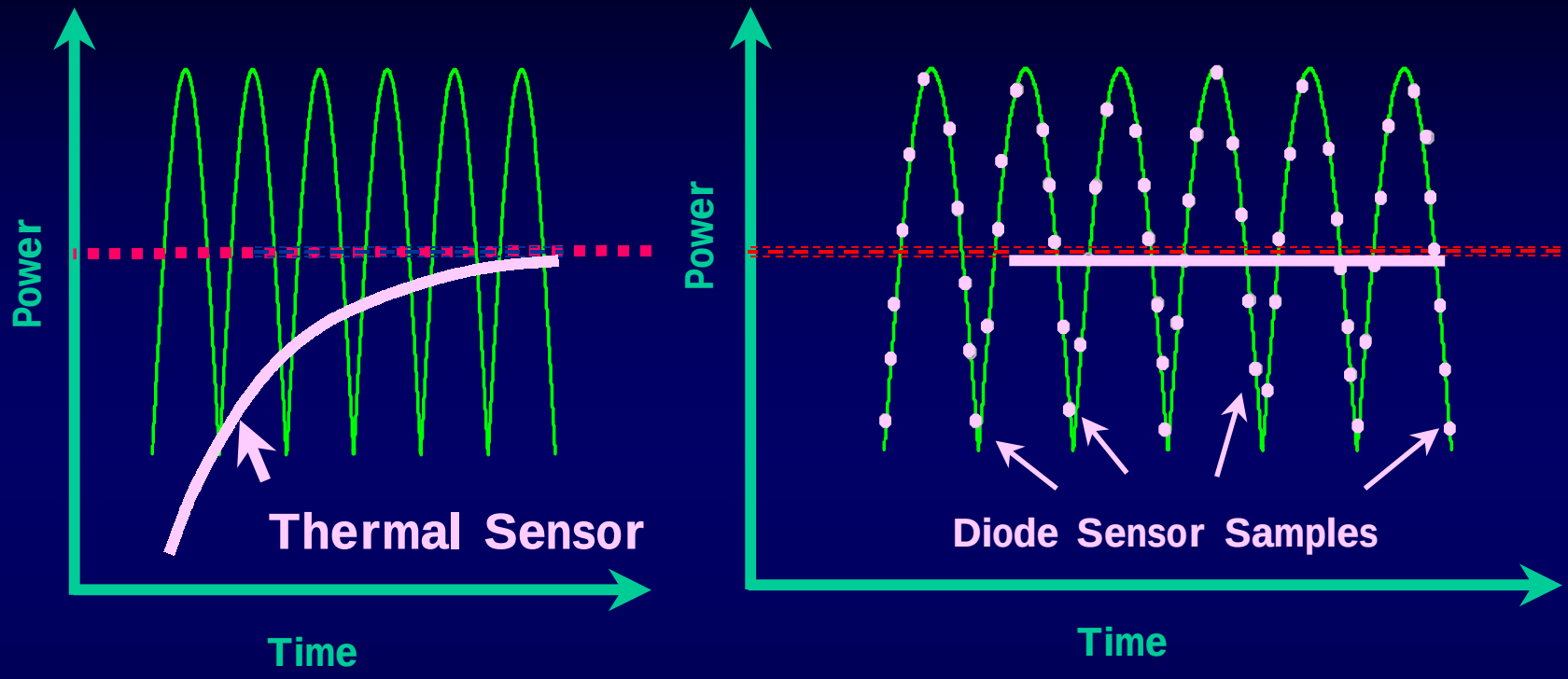
Giga-tronics

AM Modulated Power



Giga-tronics

AM Modulated Power

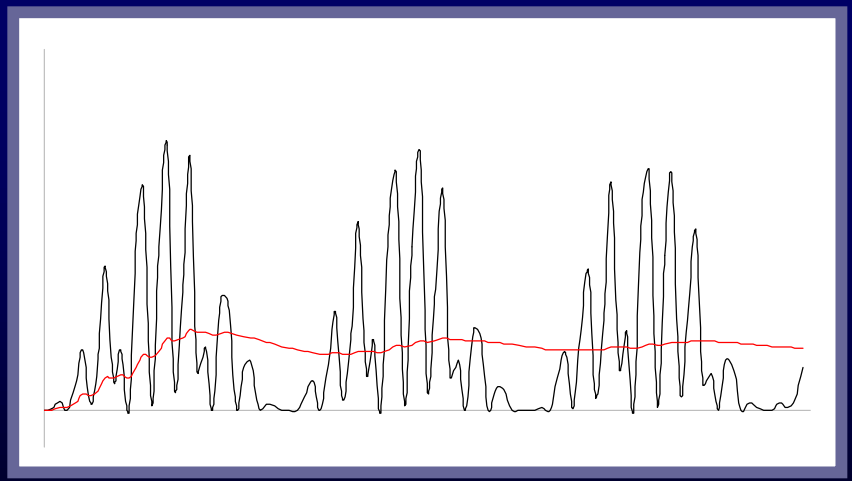


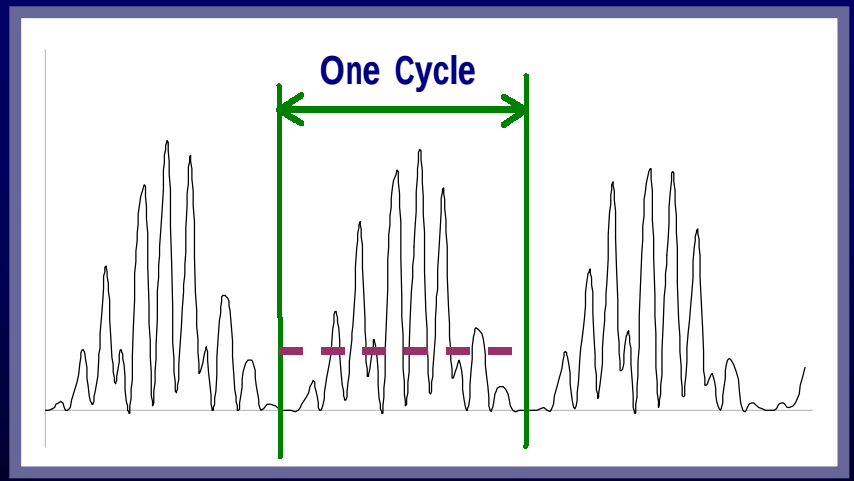
- For diode sensors; power meter accumulates the samples and calculates the average power
- Diode sensor must have the video bandwidth to track the modulation envelope for maximum dynamic range

Giga-tronics

Average Power of a Modulated Signal

- If modulation is not randomly distributed, cyclical patterns will cause average power fluctuations
- With cyclical modulation, measurement time period should be one cycle, or a large number of cycles, in order to mask the fractional N contribution





Giga-tronics

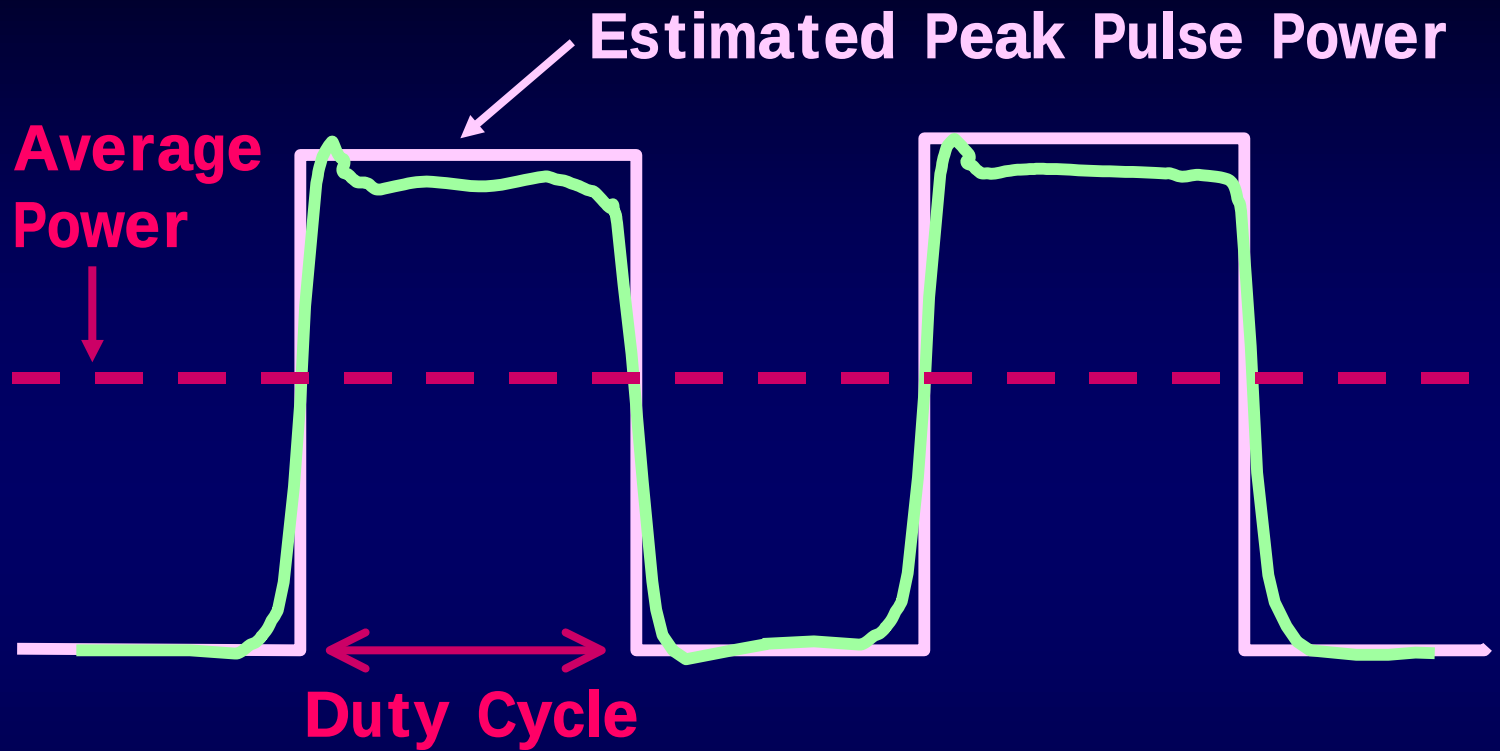
Giga-tronics Universal Power Meters

- Models 8540C and new 8650A are designed to measure CW and modulated power
- Both meters use asynchronous sampling to minimize aliasing of modulated signals
- The 8650A asynchronous sample rate of 2.5 to 5 MHz maximizes measurement speed of complex modulated waveforms
- The 8650A provides the choice of Averaging N or Time Averaging for optimum settling when measuring periodic modulated signals

Power Sensor Definitions

- The term *Peak* sensors and *Modulation* sensors are often used interchangeably for diode sensors
- Giga-tronics uses the term Peak Power Sensor for sensors performing peak pulse measurements and Modulation Power Sensor for sensors performing complex modulation measurements
- The modulation bandwidth of a sensor describes the modulation rate capability in the *non-linear* region. Also referred to as video bandwidth.
- Average power measurements can be made beyond the modulation bandwidth of the sensor by staying within the square law region

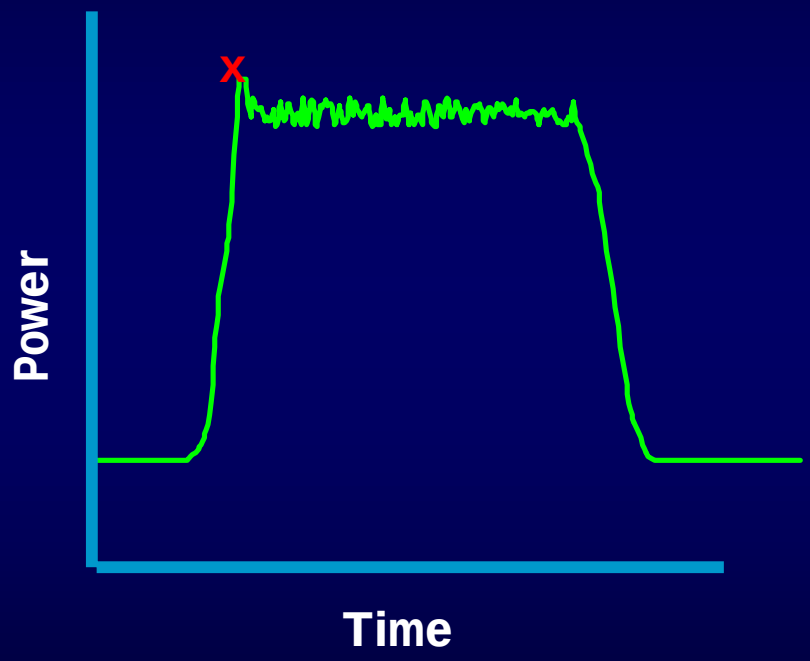
Peak Pulse Measurements



- Thermal or average detectors estimate peak pulse power using duty cycle:

  Pk Power = Avg Pwr / Duty Cycle

Giga-tronics Peak Pulse Measurements



- Peak pulse power measured at specified time
- 80350A Peak Pulse Sensor, rise time of 100 nsec, compatible with 8540C or 8650A

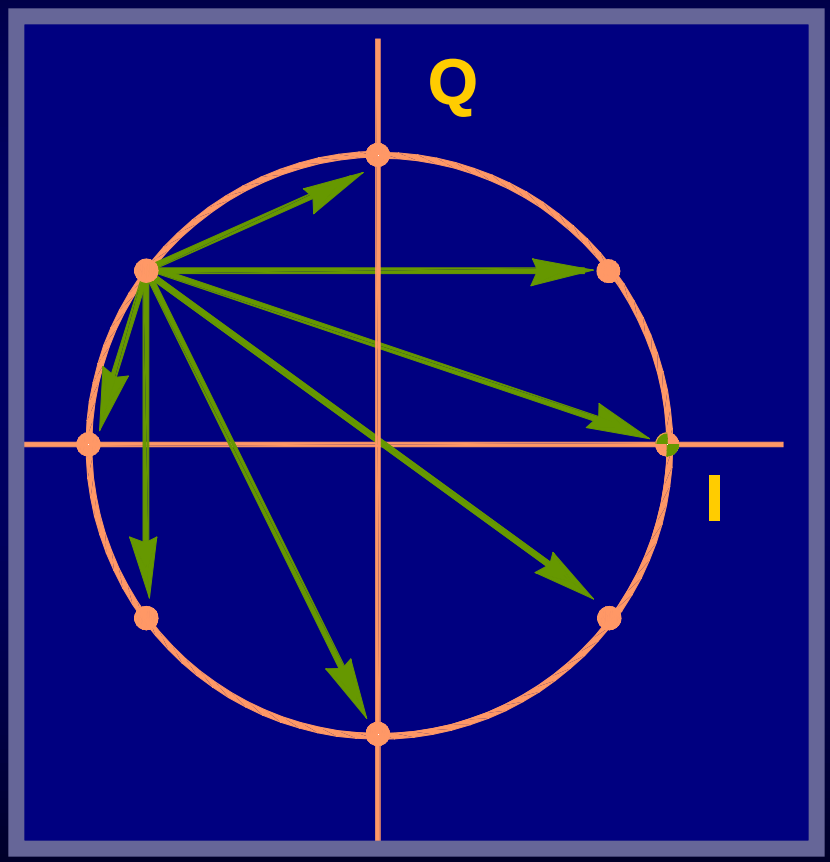
Giga-tronics

Digital Modulation Formats

Wireless Systems	TDMA IS-54/ IS-136	GSM	GSM/ EDGE	CDMA IS-95/ IS-95B	WCDMA (3G)
Modulation Type	Pi/4 DQPSK	0.3 GMSK	8-PSK	BPSK, QPSK	BPSK, QPSK
Modulation Data Rate	48.6 kbps	270.8 kbps	812.5 kbps	9.6/64 kbps, 1.2288 MHz Channel	5, 10, 20 MHz Channels

- For power measurements, primary concern is the modulation rate

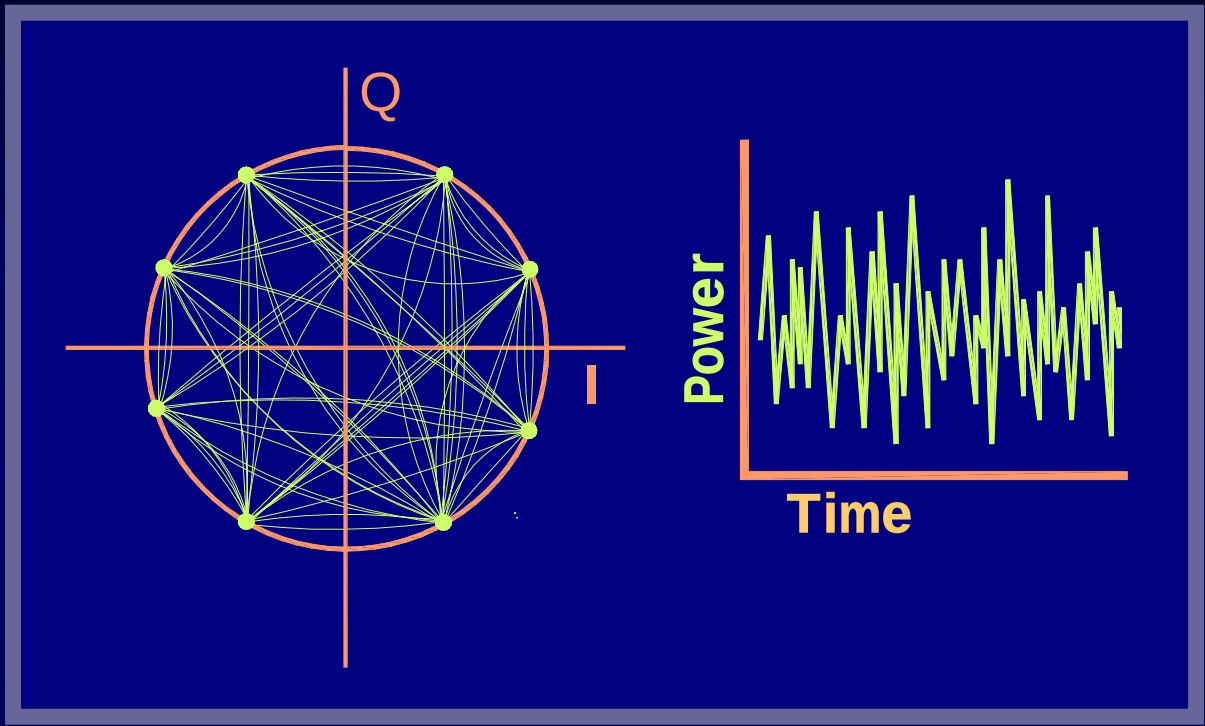
Quadrature Phase Shift Keying (QPSK) Modulation



- QPSK used in TDMA and CDMA systems
- Carrier signal is coded using QPSK techniques within the four quadrants at eight positions
- Transitions from one position to another results in change in amplitude

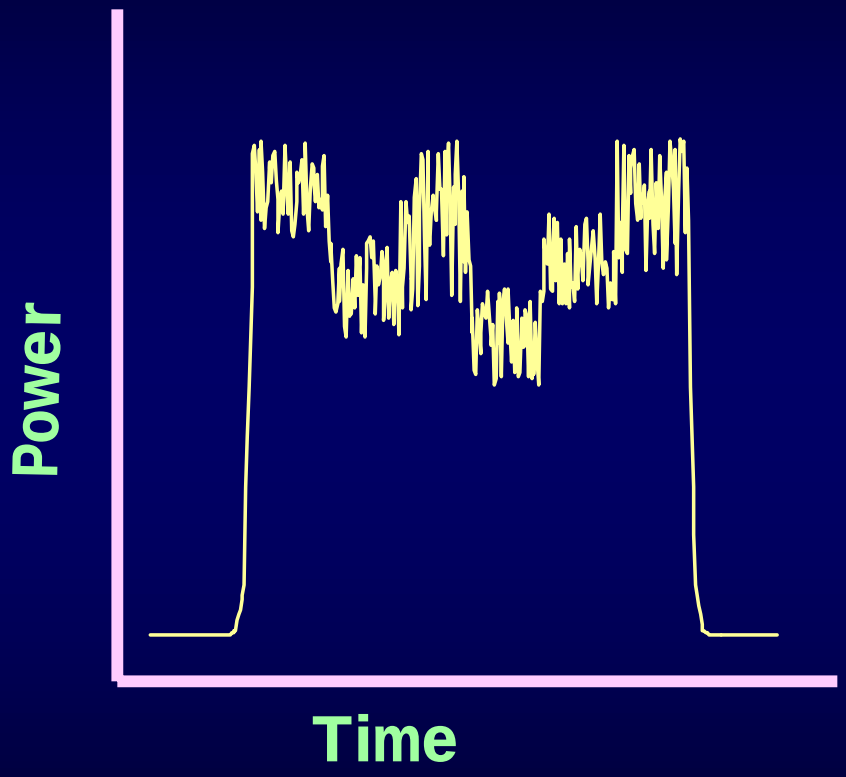
Giga-tronics

QPSK Modulation



- Transitions between the four quadrants cause psudo-random amplitude modulation
- Amplitude modulation rate dependent on vocoder or, in the case of CDMA, channel width.

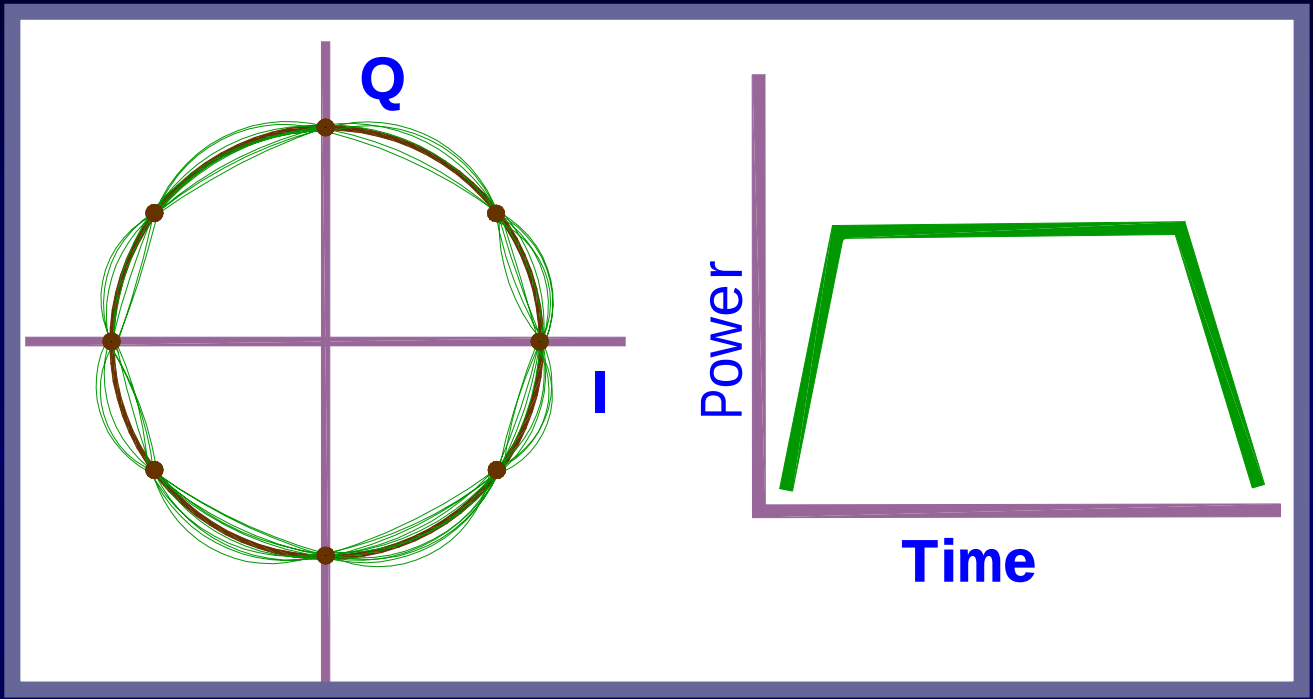
Time Division Multiple Access - TDMA



- TDMA uses QPSK and time division to distinguish callers on the same frequency channel
- Amount of amplitude pk-pk variation depends on method of modulation, filter used, and other system parameters.

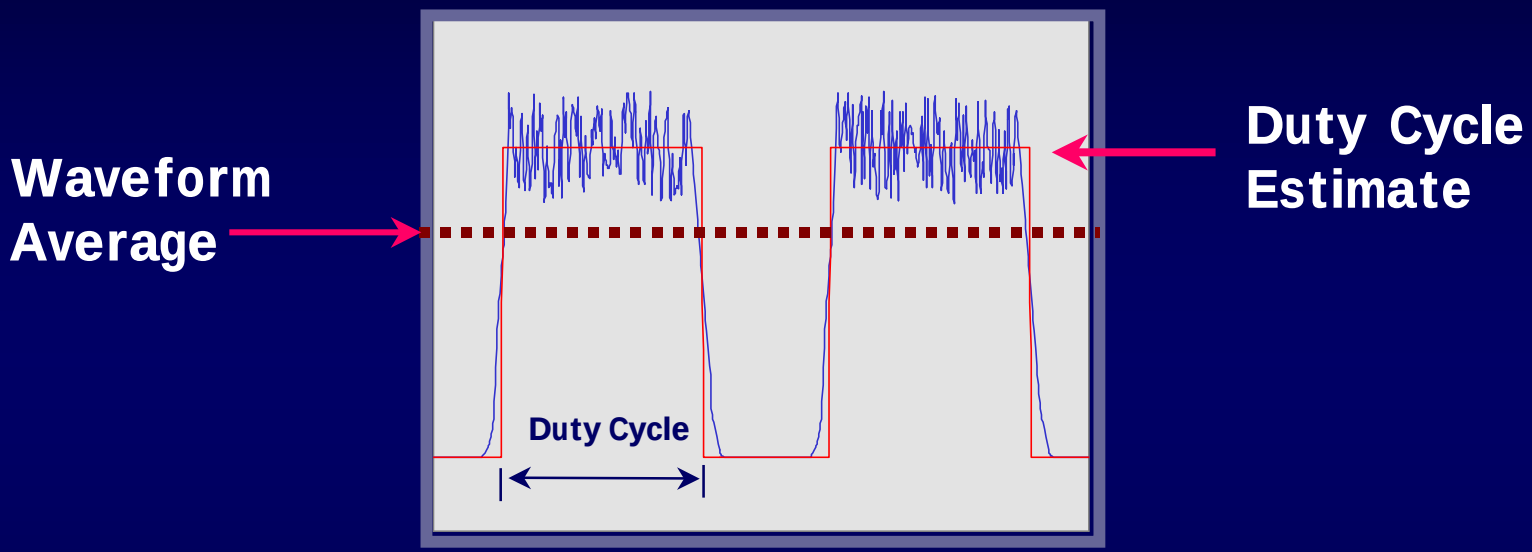
Giga-tronics

GSM/GMSK Modulation



- GSM uses Gaussian Minimum Shift Keying (GMSK) modulation technique
- GMSK modulation is a phase shift technique resulting in a constant amplitude signal during the burst-on period
- Average power for GSM is therefore constant within the burst slot

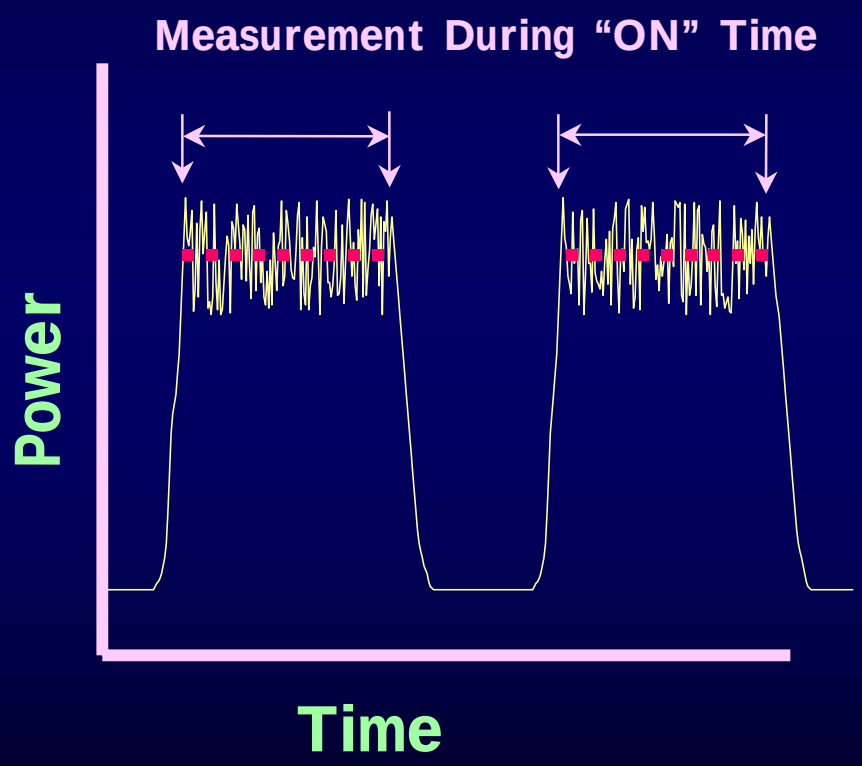
Measuring Pulse Power of Burst Signals



- Thermal and average-only diode sensors include measurement errors due to uncertainty of duty cycle, non-ideal pulse, and complex modulation

Giga-tronics

Giga-tronics Burst Average Power Measurements (BAP Mode)

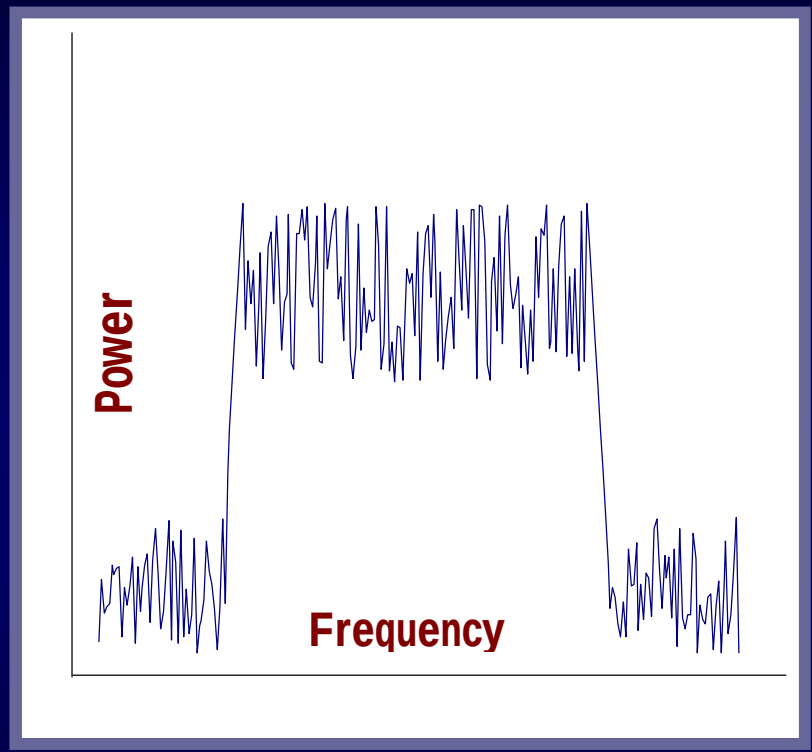


- Automatic duty cycle correction & synchronization
- Errors due to risetime, overshoot and falltime are avoided
- Available in Models 8540C and 8650A

Giga-tronics

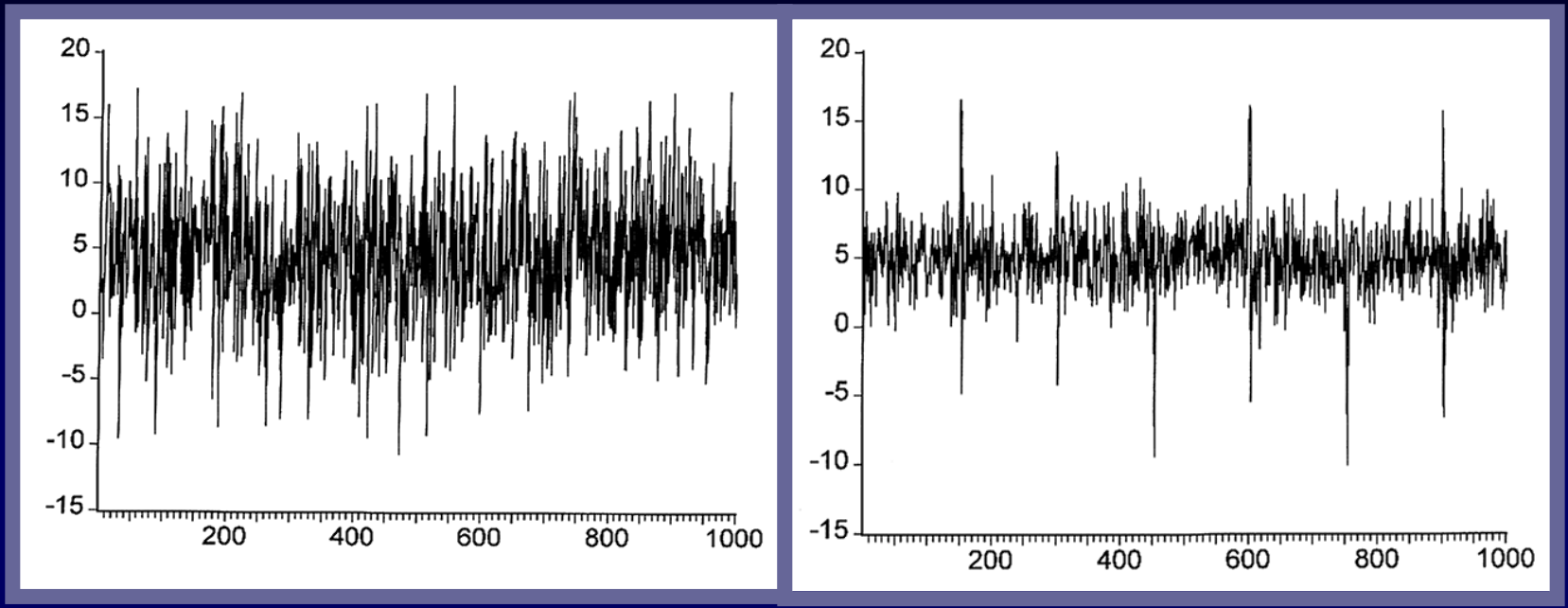
Code Division Multiple Access - CDMA

- CDMA uses QPSK and spread spectrum coding techniques to distinguish callers
- Without coding correlation, each caller appears as noise
- For maximum dynamic range, sensor video bandwidth must be high enough to track the highest modulation rate, determined by the channel bandwidth



Giga-tronics

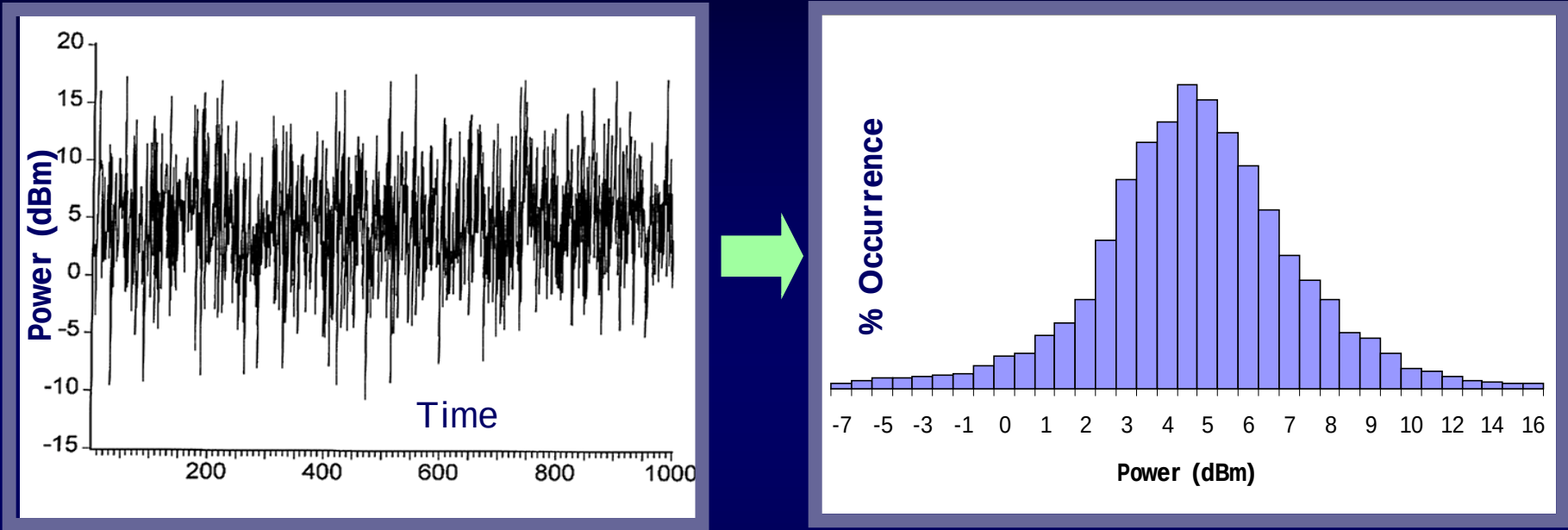
Crest Factor of QPSK Modulation



- Crest Factor, available in the 8540C and 8650A, provides data on worse case peak to average power
- Two examples exhibit same 12 dB crest factor. Power distribution and percent occurrence of worse case condition are quite different
- Histogram graph needed for additional analysis

Giga-tronics

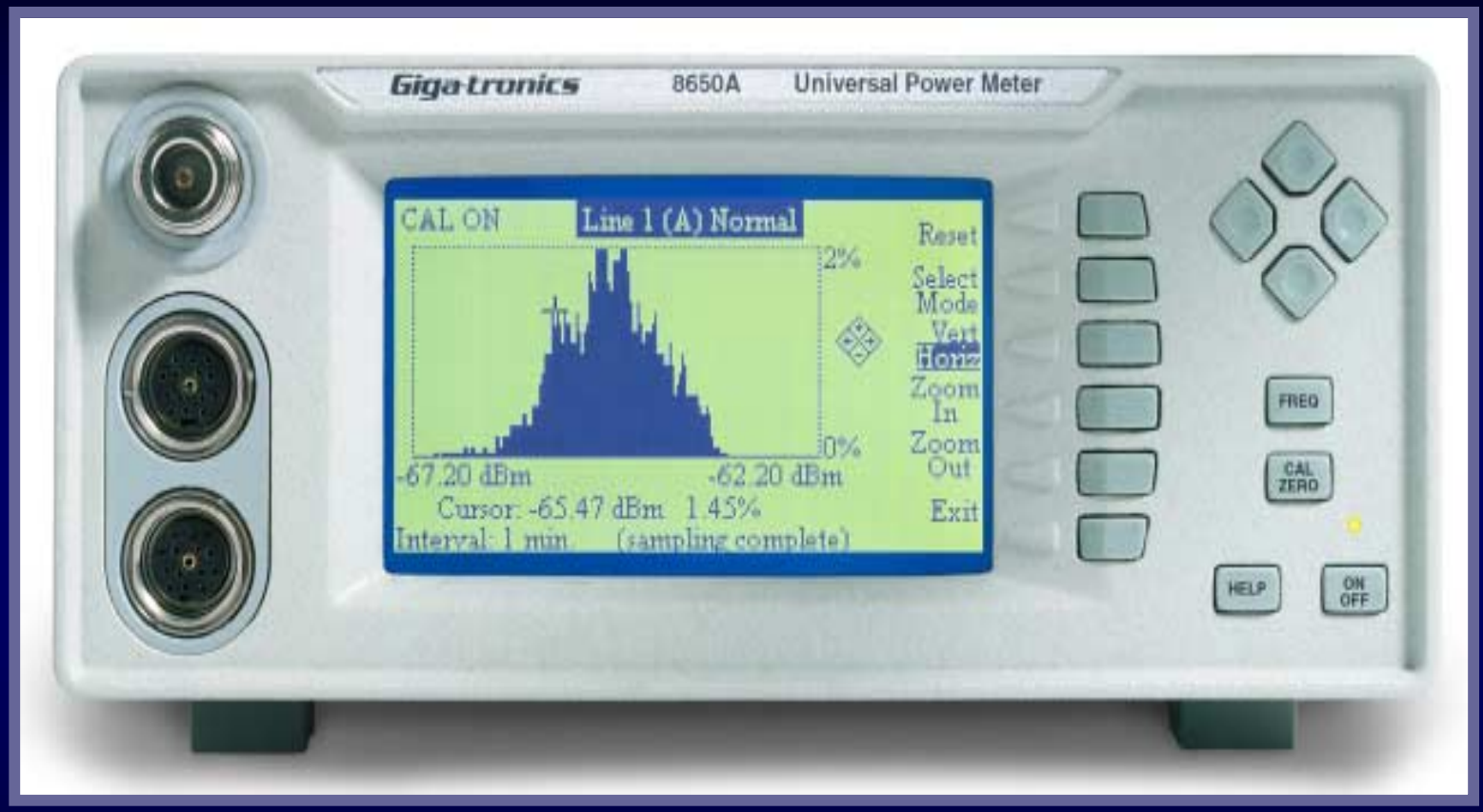
Histogram Graph of Power Distribution



- A histogram displays the power distribution as a percent (or count) occurrence within equal length intervals or bins. Easily identifies probable occurrence of worse case peak to average condition.

Giga-tronics

8650A With Histogram Display



- Modulation sensors with wide video bandwidth provide the information needed for in-depth statistical analysis

Giga-tronics

For more information on Giga-tronics products, visit our web site at www.gigatronics.com