# Power Measurements I

## Measuring Peak And Average Power In Complex Signals

Modern communications systems are relying on increased signal complexity to pack more data into each symbol transmitted. These complex signals may result in data dependent, high peak to average power ratios requiring amplifiers and related components with large dynamic ranges. LeCroy oscilloscopes help designers of such systems evaluate the dynamic range requirements by providing a fast, easy method to measure instantaneous power on very long data records. Measurement parameters can read the average and peak power levels directly from the instantaneous power waveform. The following example illustrates the techniques that can be used to measure instantaneous power.

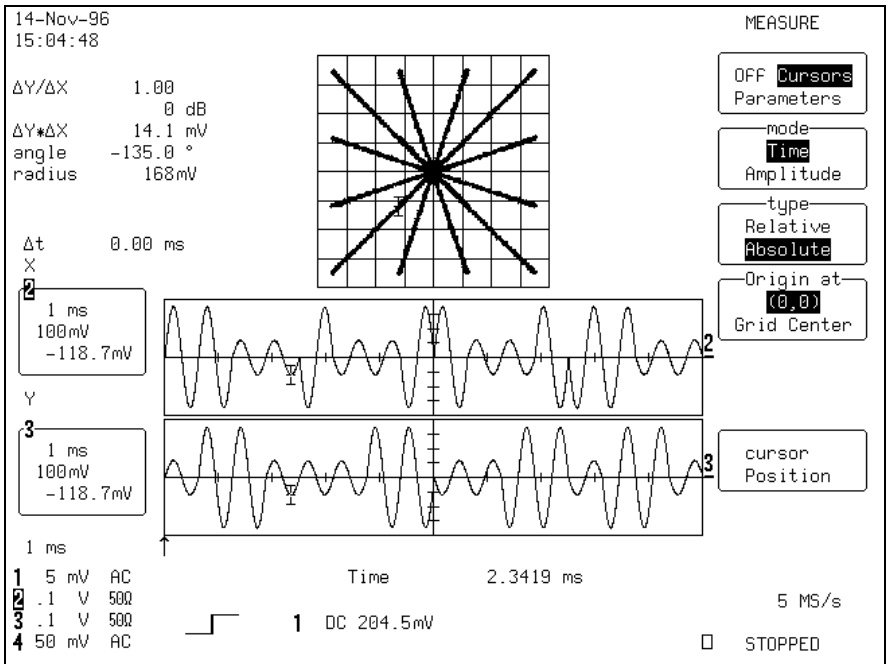


**Figure 1 - Trace 2 shows the in-phase (I) component and trace 3 the quadrature (Q) component of a 16 QAM signal. The state transitions are shown in the X-Y diagram. Note that cursors mark a typical peak in the I and Q signals and simultaneously measure the phase and amplitude (radius) of the resultant vector sum.**

The in-phase (I) and quadrature (Q) components of a 16 state quadrature amplitude modulated (16 QAM) signal are shown in traces 2 and 3 , respectively, in figure 1. The 16 states shown utilize 3 distinct average power levels corresponding to the 3 possible combinations of the I and Q voltage levels of 0.707and 0.236 V $_{P-P}$. The power levels are:

$P_A = 0.126\ V^2$
$P_B = 0.069\ V^2$
$P_C = 0.014\ V^2$

*Note that since we will be taking power ratios the power is expressed as a squared voltage, $V^2$, to simply the measurements. If required the square of the voltage can be divided by the impedance using the rescale function.*

The expected average power in the waveform based on the 16 states included can be calculated as:

$(4 P_A + 8 P_B + 4 P_C)/16$
$= 0.069\ V^2$

**The peak power, corresponding to $P_A$ is $0.249\ V^2$.**

We have now derived the expected average and peak power for a known waveform from purely theoretical considerations:

**Average Power = $0.069\ V^2$**

**Peak Power = $0.249\ V^2$**

Figure 2 shows the steps used to measure the instantaneous power waveform and derive the peak and average power levels. The instantaneous power of the output signal is calculated by taking the sum of the squares of the I and Q waveforms. This is displayed in trace C. The data in trace C is histogrammed and shown in trace D. This trace shows three overlapping distributions. The average and peak values were determined in two ways. The average value of the histogram data and the mean value of trace C were both measured using the appropriate parameters. Likewise, the peak power was determined using Maximum of C and Highest value in the histogram (HIGH[D]). Maximum of C, an average of over 2200 maxima, was used in order to evaluate the range of maximum values encountered and determine the effect of noise peaks on the peak power measurement. Based on the measured values the ratio of peak to average power is:

**$P_{PEAK}/P_{AVG}$ = 0.2546/0.067**
**= 3.8**
**or 10 log (3.8) = 5.79 dB**

Based on the expected values which were derived previously:

**$P_{PEAK}/P_{AVG}$ = 0.249/0.069**
**= 3.61**
**or 10 log (3.61) = 5.57 dB**

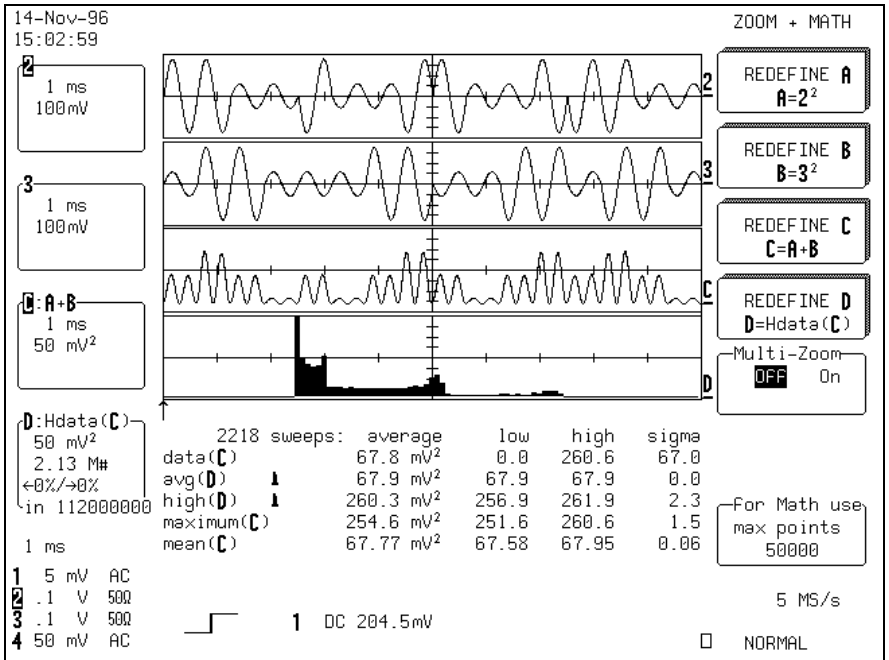


**Figure 2: Trace 2 (top)-I signal, Trace 3-Q signal, Trace C-$I^2+Q^2$ (sum of the squares )**

This is a difference of about 0.2 dB or about 5% of the expected value.

*Note that this error margin includes the errors due to two sources, the arbitrary waveform generator which produced the waveforms and the oscilloscope. Since both units have similar DC accuracy specifications we can assume that the error is equally distributed between them.*

It should be apparent that the LeCroy oscilloscopes offer many features to make this type of measurement. They include the ability to do chained mathematical calculations on long waveforms and extract key waveform parameters automatically.