Boonton

Application Note

Peak Power Meters for Crest Factor and Scalar Measurements Using Broadband OFDM Signals

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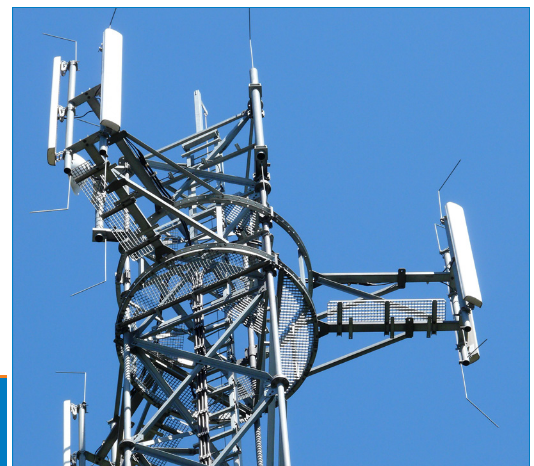


Abstract

In this application note we highlight how broadband LTE and WiFi power amplifier (PA) performance can be characterized using Boonton's high performance USB peak power meter. Figure of merit measurements like input and output crest factor can be performed to characterize amplifier compression using highly dynamic and broadband LTE & WiFi signals. With the use of a directional coupler the USB peak power meter is transformed to make scalar-like measurements such as gain and return loss.

Crest Factor and Scalar Like Measurements Using Modulated Broadband Signals for Power Amplifiers

A critical component of a base station is the power amplifier (PA). Over the past two decades the PA has experienced monumental changes in its architecture and performance. Two significant improvements have been in power-added efficiency & bandwidth. Fifteen years ago a 2G basestation PA housed in a ground base station cabinet would output 5 MHz multi carrier CDMA signals at 40W; running at 5% efficiency it would generate 760 Watts of heat, taking up a significant amount of space, power and cooling resources and costing thousands of dollars. Today's 4G amplifiers using Doherty architecture with predistortion has improved the efficiency of an amplifier to over 35%, significantly reducing the size and enabling integration of the PA with the transceiver and the duplexer into a remote radio head (RRH) placed near the antenna.

The other significant improvement has been in PA bandwidth. Today's RRHs are deployed in systems where the carriers are placed anywhere in a 70 MHz (or wider) frequency band. Measuring and characterizing the performance of the wideband PA requires test equipment that supports the bandwidths used in today's deployments. In this application note we show how using Boonton's high performance peak power meters with directional couplers enables the designer to make input, output and reflected power measurements; facilitating scalar analyzer like measurements such as gain and input return loss using multi-carrier, wide bandwidth (>100 MHz) test signals as opposed to narrowband CW. The statistical analysis tool of the peak power meter provides insight into the amplifier compression by measuring and comparing crest factor of input and output signals of the PA using wideband 4G signals while monitoring both peak and average power.

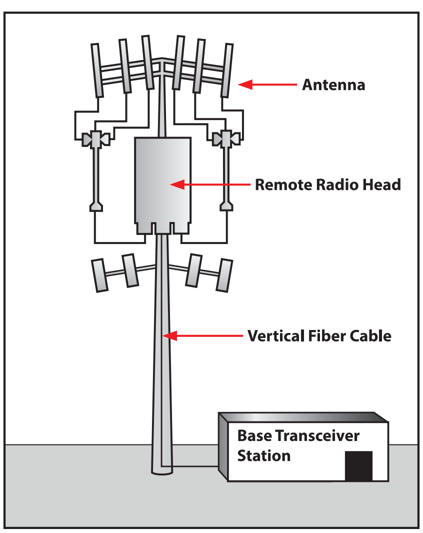


Figure 1. *RRH Base station*

Measuring PA Compression & Crest Factor

In an ideal world the PA output signal is an amplified version of the input signal; input power plotted vs output power produces a straight linear line, where the slope of the line is 1. In reality however, as the PA is driven harder, at a certain point the output will not increase as much as the input power; at this point the amplifier is in its non-linear region or is in compression. In the non-linear region the PA generates intermodulation products (Figure 2a.) which cause emission of spurious power into adjacent channels. Aside from effecting adjacent channels, non-linearity also degrades EVM of the desired signal which causes loss of signal quality. In wireless communication systems modulation schemes such as CDMA (2G), WCDMA (3G), QAM and OFDM (4G-LTE) the signal is highly dynamic where 10 dB crest factor or peak to average power ratio (PAPR) is not unusual. When the amplifier goes into compression driven by a CDMA or OFDM modulated wideband signal, rare occurring peaks get compressed first; so when an amplifier is in 0.2 dB average power compression, its peak can be compressed by 1.0 dB or more. For example, a PA with 40 dB gain, 0 dBm average input signal with a crest factor of 10 dB (peak 10 dBm) would output 39.8 dBm average power but the peak power would be clipped at 49 dBm (crest factor 9.2 dB). While average (true RMS) power meters measure the average power of the signal, they lack the bandwidth to capture the peaks, whereas Boonton's 55 series USB peak power meter in a dual channel configuration can accurately measure both input and output average and peak power in real-time. With statistical analysis capability the 55 series can display the statistical distribution of the signal power level relative to its average power in a format called complementary cumulative distribution function (CCDF). CCDF can give significant insight into the behavior of the PA as it is driven harder into saturation by measuring changes is in PAR and crest factor of the input and output signals simultaneously and providing a graphical view of the compression of the amplifier in real-time (Figure 2b).

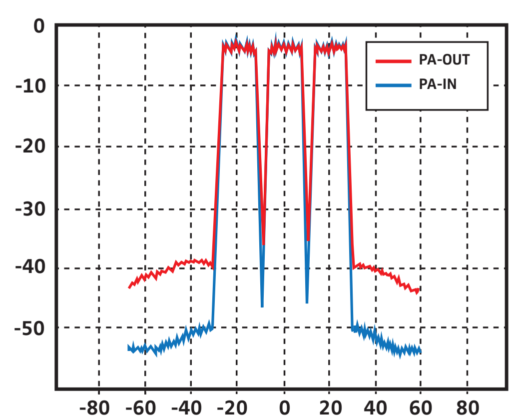


Figure 2a. *Spectral regrowth (IMD) in multi-carrier LTE signals. Red trace is PA OUT, blue PA IN*

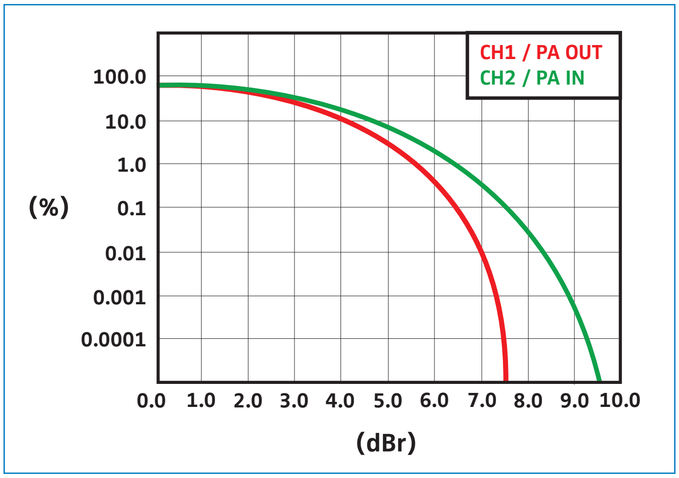


Figure 2b. *CCDF curve shows % of time the signal is above its average power (Pavg). For example PA IN is 4.8 dB above Pavg 10% of the time. Example of a dual channel power meter monitoring amplifier compression – input green, compressed output red.*

Performing Scalar Analyzer Like Measurements – Gain & Input Return Loss

Figure 3. shows a typical PA test set-up using peak power meters and a bidirectional coupler to make scalar analyzer like measurements such as gain and return loss. The input power is measured coupling off the input signal to the amplifier by using a bi-directional coupler. The reflected power from the input of the amplifier can be measured using the reverse coupling port of the same bi-directional coupler. Since the typical average power rating of a power meter is about +20 dBm, the output of the PA is attenuated to protect the power sensor while making output power measurements. It is important to note that the bi-directional coupler needs to have excellent directivity.

Before measurements can be taken a basic calibration procedure is required at the frequencies in which the amplifier is going to be tested; all unused ports of the coupler need to be terminated with 50 ohms while making measurements.

L1: Loss from LTE Generator output to the FWD port of the bi-directional coupler.

L2: Loss from LTE Generator output to the power amplifier input.

L3: Loss from amplifier output to the 40 dB attenuator output.

L4: Loss from amplifier input into the REV port of the bi-directional coupler.

Once the losses are measured, input, output and reflected power measurements can be made:

P1: Power reading at FWD port of the bidirectional coupler.

PA input power = P1+L1-L2.

P2: Power measured at the 40 dB attenuator output.

PA output power = P2+L3.

P3: Power measured at REV port of the bidirectional coupler.

PA input reflected power = P3+L4.

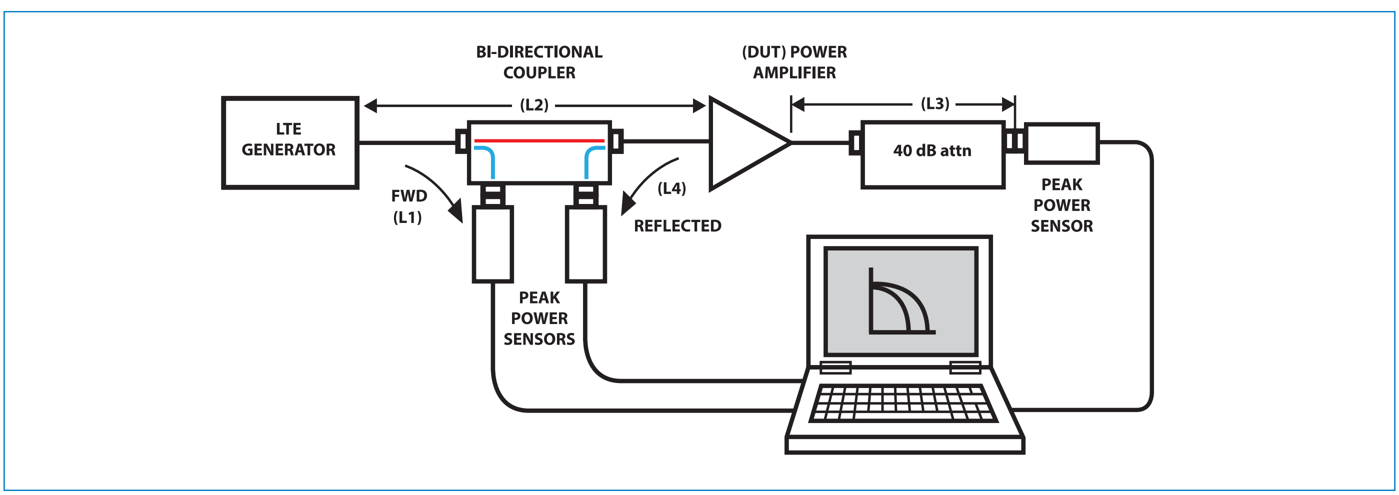


Figure 3. *Amplifier test set-up using peak power meters*

The input, output and reflected power measurements can be used to compute gain (S21) and input return loss (S11).

PA Gain(dB) = PA output power(dBm)– PA input power (dBm)

PA input return loss(dB) = PA input power(dBm) – PA input reflected power(dBm)

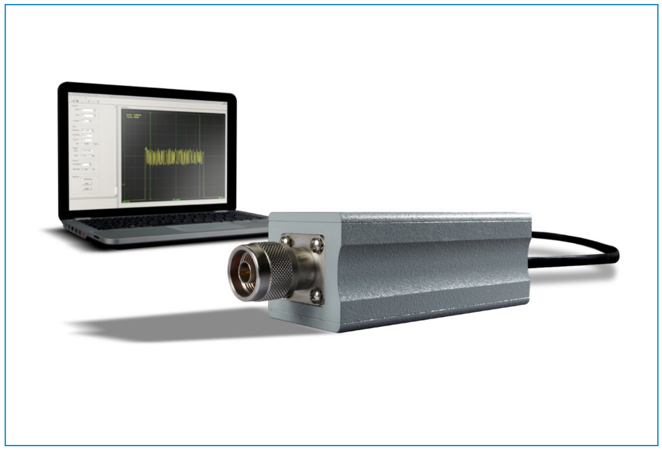
For example average input power of 0 dBm and output power of 46 dBm would mean 46 dB gain and average reflected power of -10 dBm would be 10 dB input return loss. Making the measurements in statistical mode provides average power and peak power of all three measurements (input, output and reflected power). Reading average and peak power simultaneously allows monitoring amplifier compression and making crest factor measurements that were described previously.

Conclusion

In scalar analyzer-like configuration, three peak power sensors, like average power sensors, can measure input, output and reflected power of the amplifier, enabling average power gain and return loss measurements. Measuring peak power as well as the average power is something average power sensors cannot do and differentiates peak power sensors in RF Power Amplifier characterization. As the input power is increased and the amplifier starts going into compression at the rear peaks, its peak power gain drops much faster than its average power gain; making crest factor a figure of merit in characterizing amplifier performance. However, not all peak power meters can handle today's wide bandwidth signals for crest factor measurements. The ability to measure average and peak power of wideband multi-carrier LTE as well as 802.11ac signals makes the Boonton 55 series USB peak power sensor ideal for highly accurate crest factor measurements.

Boonton Peak Power Meter Solutions

Measuring peak power & crest factor of multi-carrier LTE signals (70+ MHz) as well as 802.11ac Wifi signals (160 MHz) requires wide bandwidth peak power meters. Boonton's 55006 USB peak power sensor with 195 MHz video bandwidth can handle the challenging LTE and WiFi 802.11ac signals. 55006 GUI supports up to 8 channel measurements which is more than what is covered in this application note for scalar-like measurements. In statistical mode with sampling speed of 100 million points (samples) per second, crest factor measurements converge rapidly. While the high performance of the sensor makes it well suited for R&D, 100,000 triggered measurements per second also makes it the fastest sensor to use in manufacturing. Affordability allows quality engineers to use the same model sensor used in R&D in verification. The small form factor enables field engineers to use the same R&D equipment in the field for measurements that correlate well with the lab measurements.



55 Series USB Peak Power Sensor

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