802.11ac Power Measurement and Timing Analysis

Using the 8990B Peak Power Analyzer

Application Note

Introduction

There are a number of challenges to anticipate when testing WLAN 802.11ac [1] power amplifier (PA) modules during design and verification. One of the key challenges is acquiring accurate peak burst measurements of the 802.11ac wide bandwidth signal, which goes up to 160 MHz. When measuring or troubleshooting such a wide bandwidth signal, it is important to select a power measurement instrument with sufficient video bandwidth. This capability ensures that the desired segment of the 802.11ac burst signal can be captured, analyzed and accurately measured.

The appropriate power measurement instrument also allows the analysis of the timing relationship between the control circuitry and the RF burst signal.

Selecting and configuring the correct test and measurement instruments ensures troubleshooting work during design and development goes quickly, minimizes the use of resources, and keeps costs low.

This paper provides a brief introduction to 802.11ac. It explains how the Agilent Technologies 8990B peak power analyzer (PPA) supports the unique 802.11ac power amplifier and transmitter design and validation test requirements. Testing applications such as burst power versus time, power ramp on/off, complimentary cumulative density function (CCDF), power-added efficiency (PAE), and control trigger delay measurements are highlighted using test setup configuration diagrams and screen captures.

802.11ac Standard Overview

802.11ac is the next generation wireless LAN (WLAN), designed to operate at a frequency less than 6 GHz and be three times faster than the current 802.11n WLAN. Currently the 802.11ac standard is in the working draft phase and expected to be finalized in late 2012 or 2013. Table 1 shows the overview of all 802.11 WLAN standards, including the 802.11ac.

Table1. Overview of all 802.11 standards

Standard	Release	Technology details	Frequency	Bandwidth	Highest data rate
802.11 (legacy)	1997	DSSS	2.4 GHz	20 MHz	2 Mbps
802.11b	1999	CCK	2.4 GHz	20 MHz	11 Mbps
802.11a	1999	OFDM	5 GHz	20 MHz	54 Mbps
802.11g	2003	OFDM	2.4 GHz	20 MHz	54 Mbps
802.11n	2009	OFDM, MIMO	2.4 and 5 GHz	20 and 40 MHz	1x1: 150 Mbps 2x2: 300 Mbps 3x3: 450 Mbps
802.11ac	2012-13 (expected)	PFDM, MIMO, MU_MIMO	5 GHz only	20, 40, and 80 MHz 160 MHz optional	2x2: 866 Mbps (80 MHz) 4x4: 1733 Mbps (80 MHz)

The 802.11ac WLAN physical layer is basically an extension of the existing 802.11n standard. It is defined to be backward compatible with 802.11n, so future electronic devices fitted with 802.11ac chips will be able to operate with the current 802.11n WLAN system. Based on the 8012.11ac working draft, the channel bandwidth options are 20, 40, 80, and 160 MHz. However, the 160 MHz channel bandwidth is optional at this point. The other bandwidths are compulsory. In other words, at the beginning stage of the real world system implementation, all infrastructures, chips, and user devices are likely to use the 20, 40, and 80 MHz bandwidth channels.

As for the channels allocations, the bandwidths mentioned can be either contiguous or non-contiguous, especially for the 80 MHz channels. For example, there can be two 80 MHz channels spread across two frequencies to construct a 160 MHz bandwidth communication link as illustrated in Figure 1.

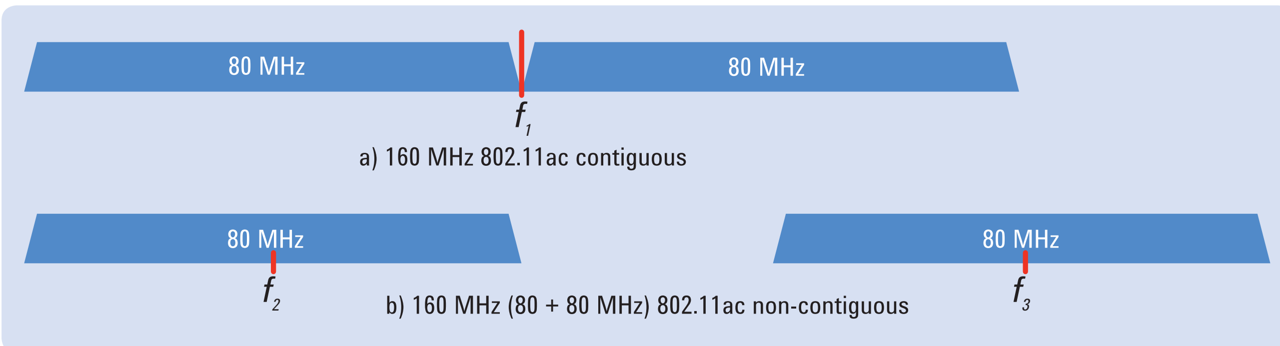

Figure 1. 802.11ac 160 MHz bandwidth channelization

802.11ac Power Amplifier or Transmitter Design and Validation Test Application Examples

Output power

One of the key 802.11ac transmitter performance tests is output power. During the design and development stage, the output power is measured and validated to meet the regulatory specification. The power measurement setup shown in Figure 2, measures the average, peak, and peak-to-average power ratio. It is important to note that in order to obtain accurate measurement results, it is necessary to keep the captured burst signal stable. This can be achieved by selecting the appropriate time-triggering setting such as trigger level, hold-off, and delays using PPA.

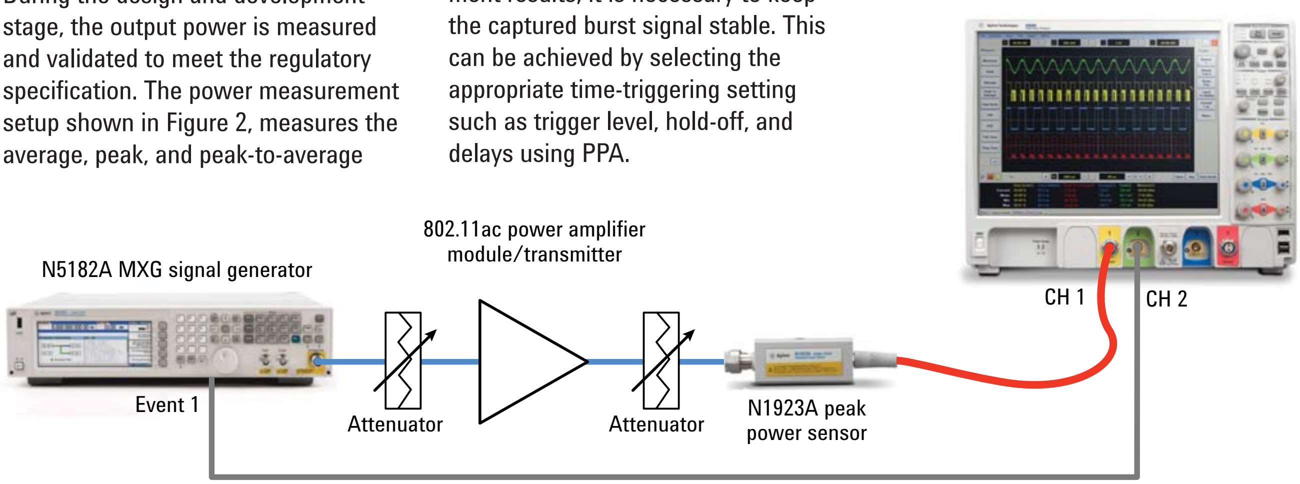

Figure 2. 802.11ac transmitter power measurement setup diagram

Power versus time (PvT)

Although the IEEE 802.11ac does not specify the test requirement for PvT analysis, this test is an important measurement for all radio standards. For example, when analyzing the preamble segment of the 802.11ac, the PvT burst measurement is useful. The preambles are essential for things such as packet detection, automatic gain control, symbol timing, frequency estimation, and channel estimation. For 802.11ac, there are ten symbols at the preamble, which translate to a 40 μs burst length. Figure 3 shows an 80 MHz 802.11ac burst signal measured by an 8990B PPA. Preamble burst measurement such as average, peak, and peak-to-average can be obtained using the zoom function or by adjusting the time scale of the PPA.

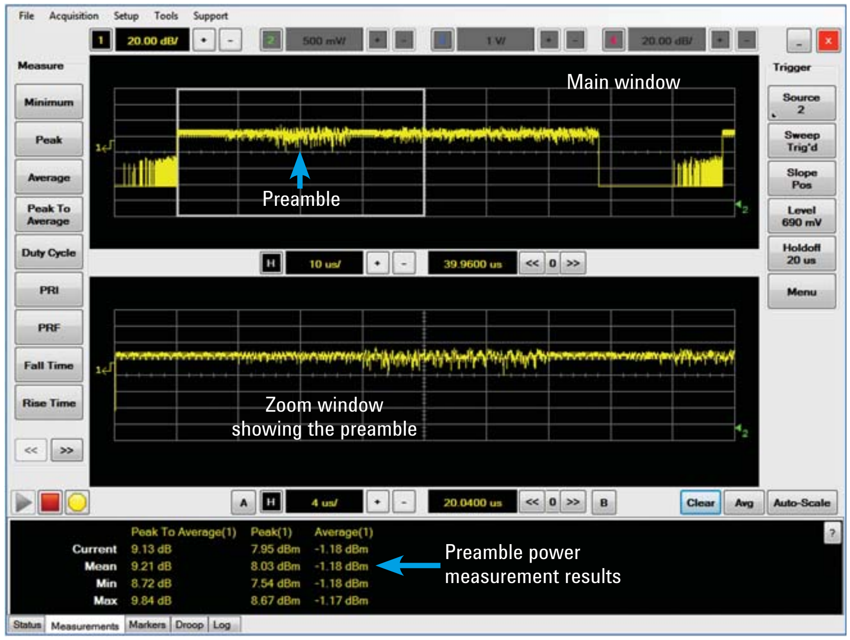

Figure 3. 802.11ac 80MHz bandwidth preamble power measurement

Power on/off ramping test

This test analyzes the time taken for the transmitter to fully power on or power off, and it is commonly performed during design and validation. This transient time response specification varies, depending on factors such as the PA design (which amplifier class) or other controlling circuits. The 802.11ac transmitter design has to comply with the short guard interval of 400 ns. In other words, the transmitter on/off time must be much faster than 400 ns. If the transmitter turns on too slowly then data in the beginning might be lost. However, if it turns off too quickly, the power spread into adjacent frequency channels increases. The 8990B analyses the power on/off or the rise/fall time of the transmitter, as well as the receiver, as shown in Figures 4a and 4b.

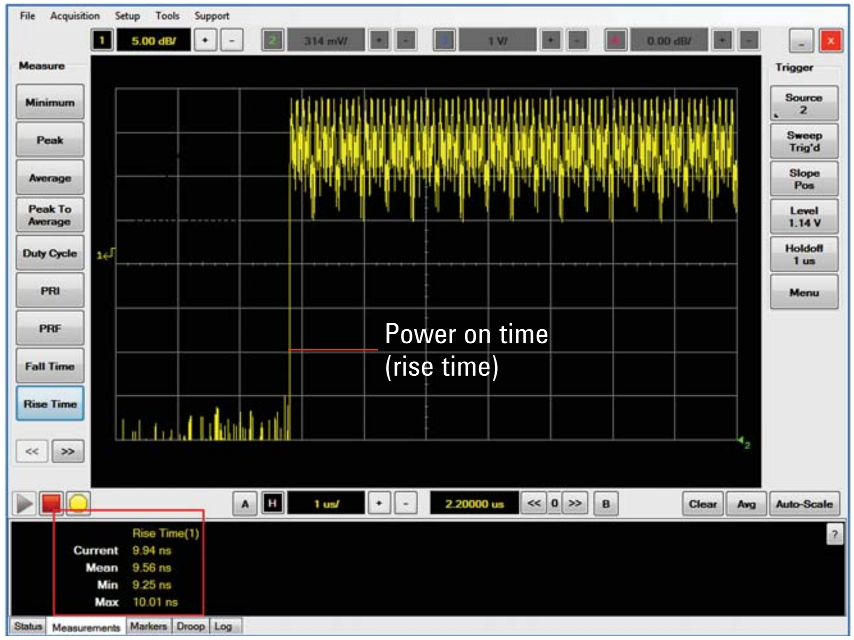

Figure 4a. Power on (rise time)

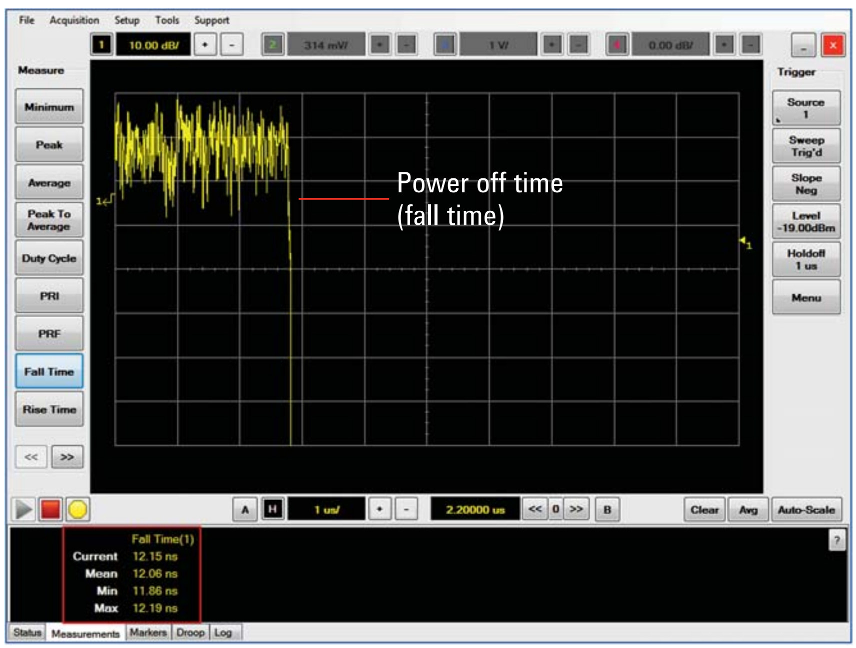

Figure 4b. Power off (fall time)

Complimentary Cumulative Density Function (CCDF)

The CCDF measurement defines the characteristics and behavior of the PA, which is typically designed to operate with a high crest factor. The CCDF provides a measure on the percentage of time where the burst power is at or exceeds a specific power level. As shown in Figure 5, the 8990 CCDF trace plots the Y axis in probability (in percentage) that the signal power is at or exceeds the power specified by the X axis, in dB. A typical CCDF analysis for 802.11ac signal is on the preamble segment of the burst. This is because the modulation scheme in the preamble segment is different from the data or payload segment. Hence the CCDF curve at the preamble is different from the data segment. In Figure 5, the yellow trace is the CCDF plot of an 802.11ac preamble segment and the blue trace is the Gaussian line; normally turned on as a reference [2]. The 8990B also is able to plot and analyze CCDF traces on both RF channels. This is useful for comparing the input and output 802.11ac signal on the PA module.

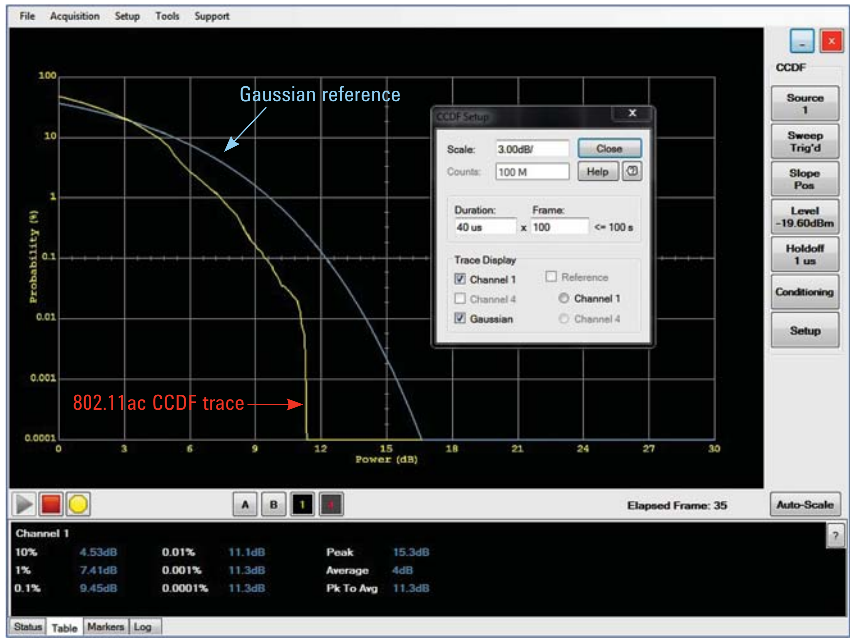

Figure 5. 802.11ac CCDF plot obtained using an 8990B PPA

Power Added Efficiency Test

One of the challenges in transmitter design is optimizing the PA's efficiency. PAE measures the power conversion efficiency of the PA to determine how much DC power is converted to RF power in terms of efficiency (percentage). Equation 1 shows how PAE is calculated. PAE performance can be affected by the PA operation class and the type of the active device used. Specifications can range from the 20s to the 60s.

$$\text{PAE (in percentage)} = \frac{\text{RF power out - RF power in}}{\text{DC power supplied}} \times 100\% \qquad \textit{Equation 1}$$

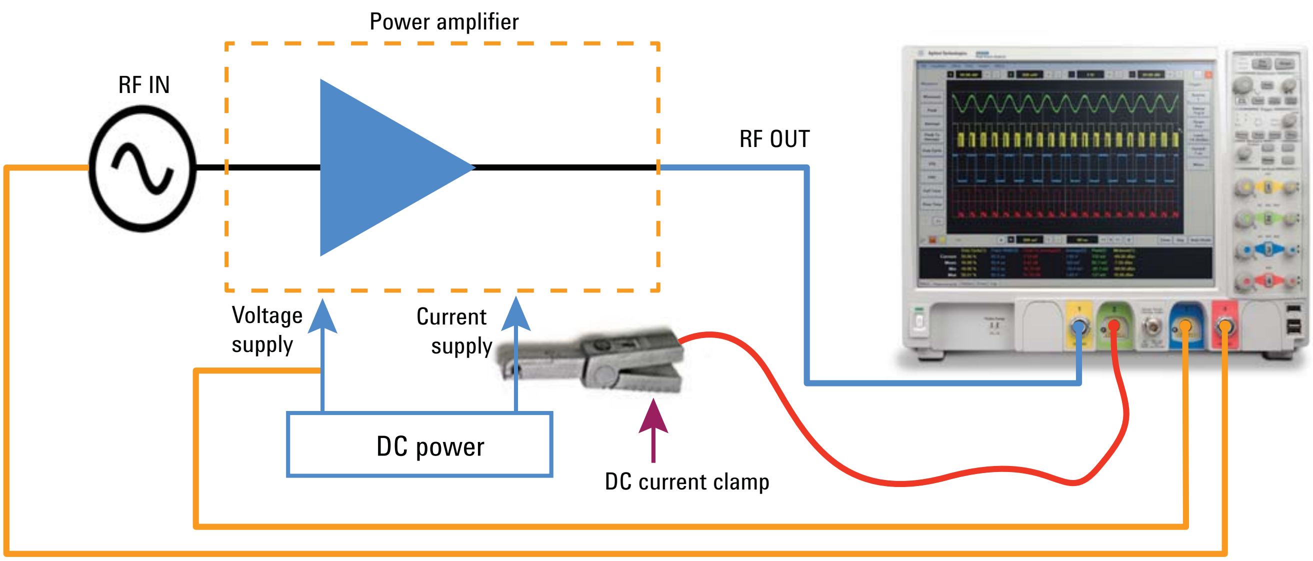

Figure 6. Power added efficiency test setup

In the measurement setup illustrated in Figure 6, DC power into the amplifier is obtained by measuring the DC voltage supply and the DC current supply. The DC current is obtained using an active current probe connected to Channel 2 of the 8990B. The current probe converts the measured current to an equivalent voltage at the PPA. The DC voltage is directly connected to video Channel 3. Both Channels 2 and 3 will yield the DC power measurement by multiplying both channels. The RF input and output power is measured and monitored at RF Channels 1 and 4 of the PPA.

With this setup all four parameters can be measured and monitored on one measurement screen. The measurement results can then be exported to Microsoft® Excel and the efficiency chart can be computed and plotted for reporting.

Control or trigger delay measurement

During development of the transmitter module, it is necessary to determine and measure the delay time of the triggering or controlling signal to the actual RF burst output. In other words, it is necessary to analyze the timing relationship between the actual RF burst and voltage bias circuits [4] such as DC power supply bias, switches, driver controls, and voltage control oscillator (VCO) signals. Figure 7 shows a typical transmitter block diagram. Design efforts typically focus on getting the minimum time delay results as quickly as possible unless it is the design intent to apply the time delay. For example, from the transceiver perspective, ensuring minimum delay time minimizes the "dead time" during transmit and receive operation. The 8990B PPA, shown in Figure 7, analyzes the timing information of the related control signals and the RF burst. It also has a special feature that automatically measures the time delay between two channels and places markers on each signal [3].

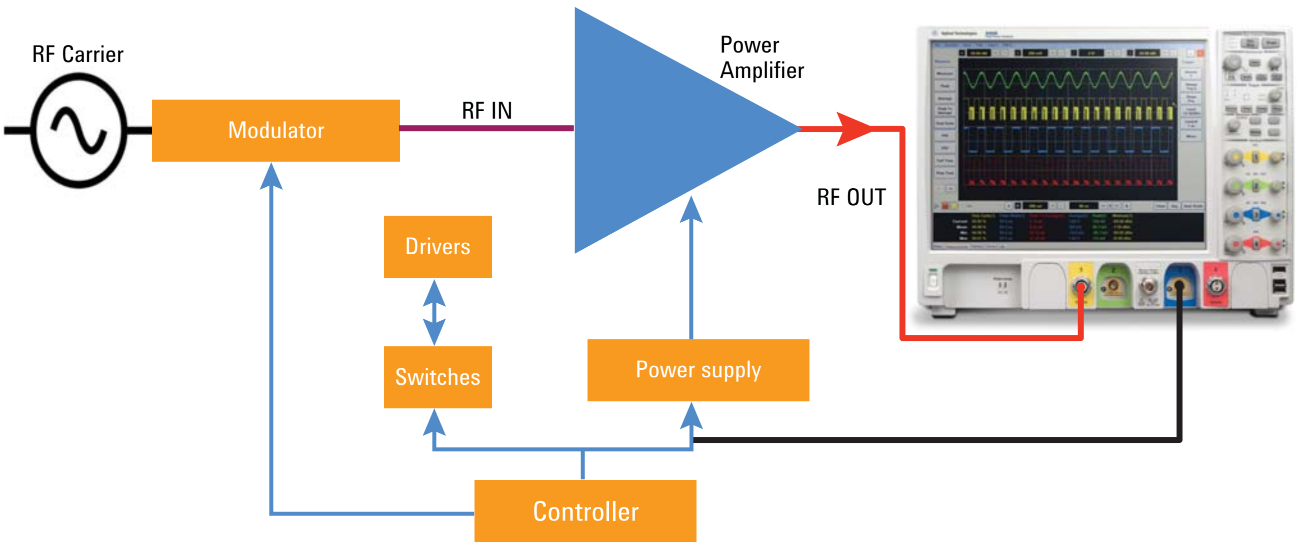

Figure 7. Analyzing timing information of RF burst and control signals

Conclusion

In summary, the operating requirements of the new 802.11ac provide new challenges for PAs and transmitter design test and validation. The 80 MHz and optional 160 MHz channel bandwidth requires more powerful RF power measurement instruments. The 8990B PPA is the right power meter for this test requirement.

As this paper has illustrated, the 8990B PPA can be used for typical RF power measurements such as average, peak, peak-to-average and CCDF analysis. It can be used to analyze the power added efficiency of the power amplifier and the delay timing information of the controlling signals inside the transmitter block. This is because the PPA comes with two RF channels and two analog video channels in one LCD instrument. Designed with an intuitive user interface, the PPA is a powerful meter to use during design and validation of 802.11ac power amplifier modules and transmitters.

References:

[1] 802.11ac Wireless LAN: *What's New and the Impact on Design and Test*, EE Times, Mirin Lew

[2] *Characterizing Digitally Modulated Signals with CCDF Curve*, Part Number 5968-6875E

[3] *8990B Peak Power Analyzer User's Guide*, Agilent Technologies Part Number 08990-90005

[4] *RF And Microwave Transmitter Design (Chapters 13 and 14)*, Andrei Grebennikov, Willey

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