Application Note

Berkeley Nucleonics' Wi-Fi 6 Solutions: Crest Factor and CCDF

The latest wireless standard referred to as Wi-Fi 6 (802.11ax) introduces new technologies to mitigate the shortcomings of previous generations. Consequently, these technical improvements challenge the capabilities of Wi-Fi testing, including RF power measurement. With conventional methods failing to fully characterize high-performance Wi-Fi 6 chipsets and devices, crest factor measurements and statistical depictions like the complementary cumulative distribution function (CCDF) are proving as valuable analysis tools to address Wi-Fi power measurement requirements.

Crest Factor

Digitally modulated signals like those used for Wi-Fi transmissions appear quite noise-like in the time domain, and therefore typical characterizations like average power are often not sufficient on their own. Peak power measurements have emerged as a more useful means of analysis and enable the calculation of a related metric known as crest factor. Also referred to as peak-to-average-power ratio (PAPR), crest factor is the ratio of a signal's peak amplitude to its average power, which helps engineers understand how extreme the peaks are in a particular waveform.

Wi-Fi 6 regularly has a high crest factor due to its capacity to have 1,992 subcarriers and the modulation of each, which can be up to 1024-QAM. For example, Figure 1 uses only four frequency tones to illustrate how subcarriers and their modulation can influence the magnitude of a waveform's crest factor. The dark blue waveform represents the summed signal of all four tones, resulting in a severe peak in overall power.

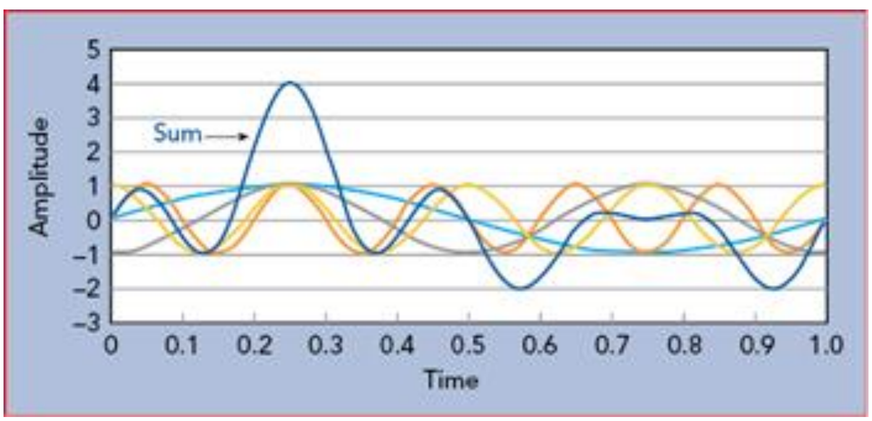


Figure 1: The sum of four sinusoidal subcarriers results in an occasional large peak.

While engineers are employing technologies that support the growing demand for higher data rates, these methods also escalate crest factor figures. Such elevated measurements can threaten signal fidelity along a communications chain, causing an adverse effect on the linear behavior of components.

In the example depicted in Figure 2, amplifier linearity is determined by applying a modulated signal and measuring the crest factors of both the input and output signals with a peak power sensor. The crest factors of the initial graph (left) are very close, indicating linearity. However, the resultant graph (right) of increasing the input power to the amplifier causes a discrepancy between crest factors, indicating non-linearity.

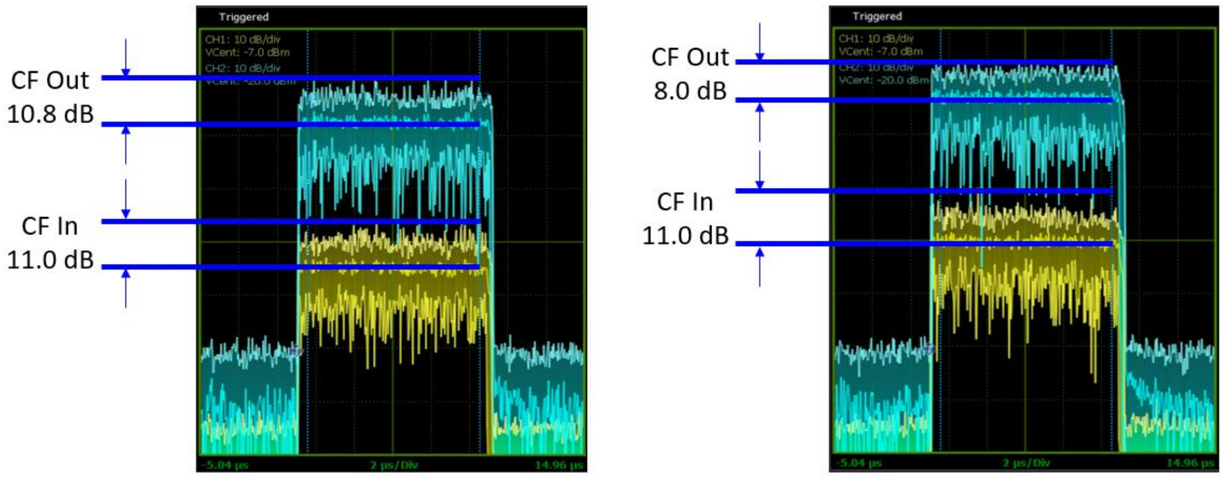


Figure 2: Similar crest factors of input and output signals verify amplifier linearity (left), while dissimilar crest factors indicate non-linear performance (right).

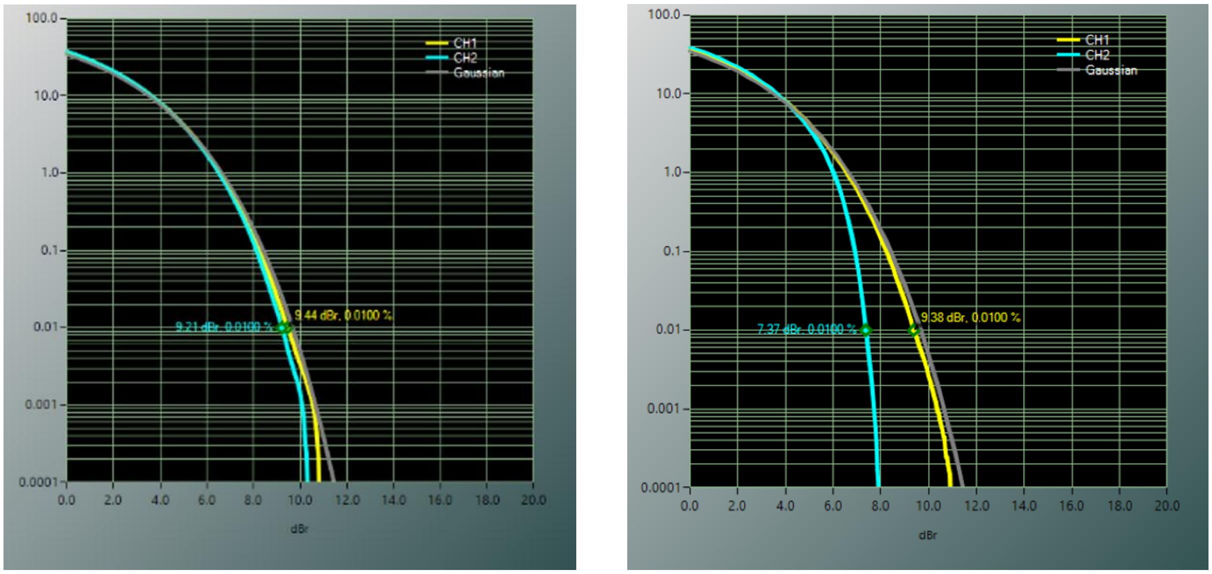
Berkeley Nucleonics 12200 Series of USB RF peak power sensors, including the Wi-Fi 6-focused 12208 sensor, are well suited to measure the crest factor of wide bandwidth Wi-Fi signals. Using the Berkeley Nucleonics Power Analyzer software for sensor control, signal capture, and waveform analysis, users can easily determine the maximum crest factor of a Wi-Fi waveform.

CCDF

To further quantify noise-like, modulated Wi-Fi signals beyond just its maximum crest factor, engineers can view the frequency of crest factor occurrence with a statistical analysis tool known as CCDF. The x-axis of a CCDF graph represents the power (expressed in dB) above the average signal power. The y-axis of the graph represents the rate of occurrence the signal power is greater than or equal to the average power, as defined by the x-axis.

It is important to note that CCDF plots can give a more accurate depiction of signal compression compared to the commonly used method of tracking changes in gain at differing power levels. Although popular, this approach can deceptively show minor reductions in dB, while the CCDF curve can reveal the truthful extent of a signal's compression.

An example of a CCDF plotting measured crest factors can be seen in Figure 3. With an application-dependent rate of crest factor occurrence set at 0.01%, the graph on the left verifies linear operation since the CH1 input (yellow) and CH2 output (blue) crest factor curves are



nearly identical for 99.9% of the time. The input to the amplifier has been increased in the right-hand side graph, causing a difference in crest factor measurements that indicates output signal compression and amplifier non-linearity. Even though the CCDF plot shows the output crest factor reduced by nearly 3 dB, the amplifier gain only reduced by 0.2 dB, masking the true magnitude of compression.

Figure 3: CCDF plots can reveal linear operation (left) or signal compression (right).

The Berkeley Nucleonics 12200 Series and Berkeley Nucleonics Power Profile software enable CCDF statistical analysis of ultra-wideband Wi-Fi waveforms as well as supplementary signal data to detect signal compression of critical components, such as a communications power amplifier. Berkeley Nucleonics 12200 Series sensors also work in conjunction with the 12000 RF power meter to provide a benchtop experience while still delivering USB sensor versatility and performance. The benchtop meter offers a "Statistical Mode," which clearly plots CCDF curves to deliver a thorough assessment of Wi-Fi chipset performance.

Gain Change = -0.2 dB
CF Change = -2.6 dB

Average Input Power = -11.9 dBm		
Input CF = 9.5 dB	Output CF = 9.2 dB	Delta CF = -0.3 dB
Pin = -11.9 dBm	Pout = 2.5 dBm	Gain = 14.4 dB

Meeting Wi-Fi 6 Testing Demands

The Berkeley Nucleonics 12200 Series and the convenient Berkeley Nucleonics Power Profile software are ready to handle the testing demands of today's Wi-Fi 6 signals by determining crest factor and plotting CCDF graphs.

Average Input Power = -7.1 dBm		
Input CF = 9.3 dB	Output CF = 7.4 dB	Delta CF = -2.9 dB
Pin = -7.1 dBm	Pout = 7.1 dBm	Gain = 14.2 dB