MIMO Measurement Tips
with Agilent P-Series Power Meters and U2000 Series USB Power Sensors

Application Note
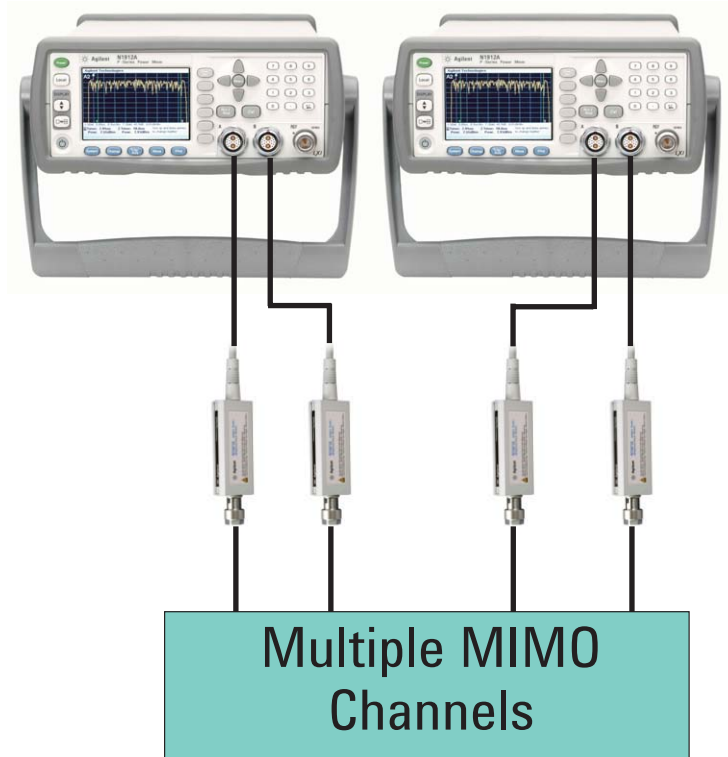

Multiple MIMO Channels

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1. Introduction

Multiple-input,multiple-output (MIMO) is the use of multiple antennas at both the transmitting and receiving ends simultaneously to improve spectral efficiency. MIMO technology offers tremendous performance improvement for wireless local area network (WLAN) or cellular technologies such as worldwide interoperability for microwave access (WiMAX), or long term evolution (LTE). With the MIMO technique, users will see immediate range/throughput benefits. Consequently, MIMO will play a key role in future wireless communication systems.

This application note explains why the Agilent power measurement solutions are ideal for enabling accurate and repeatable MIMO measurements. This application note then shows you how to use these measurement solutions step by step to perform accurate and repeatable MIMO power measurements. This note also describes MIMO-related measurements that can be supported by the power meter and sensor, as well as their key benefits. The procedures outlined in this application note apply to most measurements of any orthogonal frequency-division multiplexing (OFDM)-type signals.

Agilent Technologies
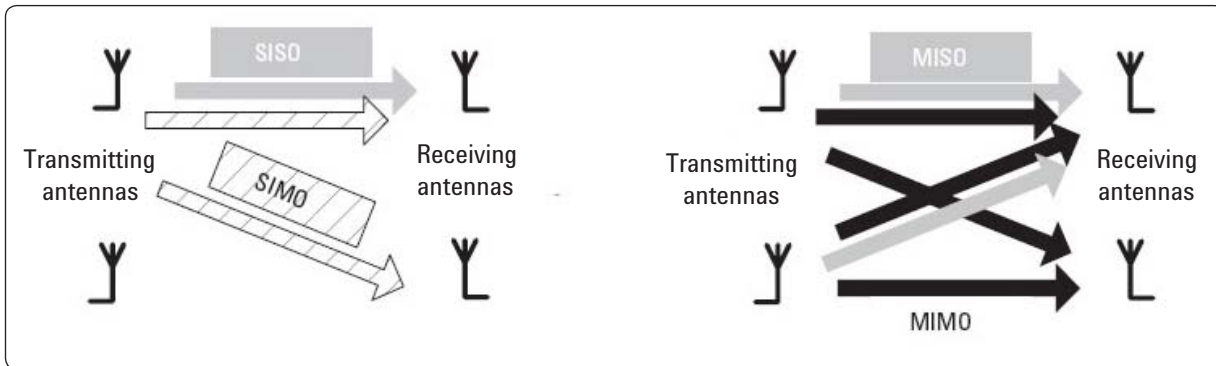
2. Overview of MIMO

Figure 1. Radio technology definitions are based on the type of channel being used

2.1. Concept

MIMO can be defined as a link where the transmitting end and the receiving end are both equipped with multiple antennas, as illustrated in Figure 1. With MIMO, the signals on the transmitting antennas and those on the receiving antennas are combined so that the quality (Bit error rate) or the data rate (bit/sec) of the communication is improved.

MIMO is a technology that sends data streams in parallel effectively as though we were using cables instead of radio. We can do this because the typical WLAN radio path is strongly characterized by the exact locations of the antennas. If you move an antenna a few centimeters (half a wavelength), different coefficients apply for the equation that defines the new path. The differences mathematically separate the signals. This gives rise to spatial separation and spatial streams of data, brought about by the physical separation of the antennas.

If we transmit from a number of antennas at the same time, we get a series of equations describing the characteristics of the channel between the combined paths. Once we know the transfer characteristics of the channel, we can calculate how data streams transmitted together will combine on the way to the receiving antennas.
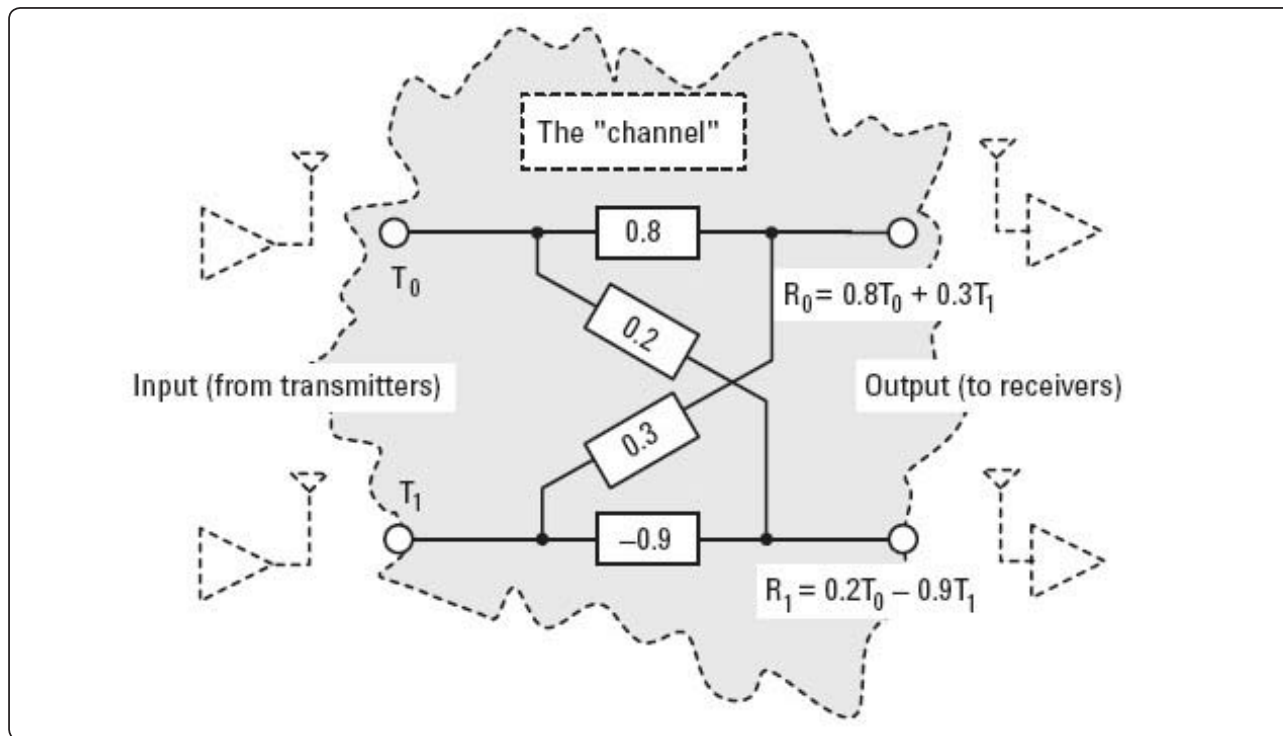

Figure 2. A much simplified 2X2 MIMO channel example

Calculate the input from the output using the following equation:

$$\begin{bmatrix} T_0 \\ T_1 \end{bmatrix} = \begin{bmatrix} 1.15 & 0.39 \\ 0.26 & -1.03 \end{bmatrix} \begin{bmatrix} R_0 \\ R_1 \end{bmatrix}$$

Channel coefficients can be found in several ways. In Figure 2 on page 2, a pair of known and different signals are transmitted at T0 and T1, and are measured at R0 and R1. Inputs T0 and T1 represent the signals transmitted over the radio channel. The coefficients in the example represent the frequency-independent path losses and the cross-coupling on the way to the receiving antennas at R0 and R1.

If, during a training period, T0 and T1 are known and different, the coefficients in the channel can be calculated by measuring the two signals at the receiver inputs. Solving the resulting simultaneous equations reveals the channel coefficients, which can then be used to reconstruct the original data. The coefficients do not represent a realistic channel, but they do show how we can use the received signals, R0 and R1, to calculate the channel coefficients.

According to Shannon's theory of channel capacity:

$$C = B.\log_2(1+\rho)$$

where
    C = channel capacity (bit/sec)
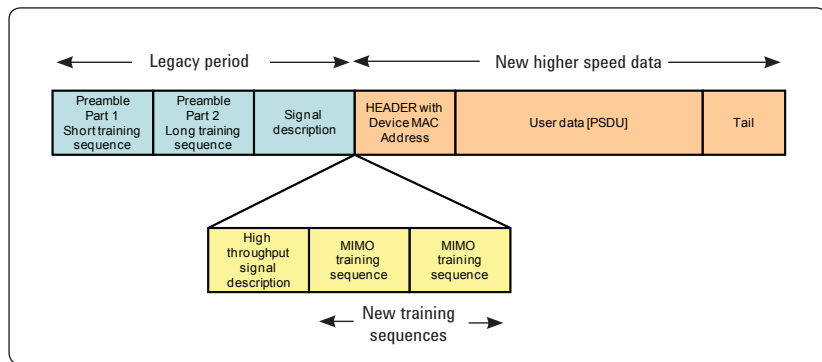   B = occupied bandwidth
    ρ = signal-to-noise ratio, (SNR) (linear ratio, not dB)

With MIMO, the advantage is significant. Assuming that M = number of transmit antennas and N = number of receiving antennas, for a large antenna installation where M = N, the average capacity increases linearly with M, as follows:

$$C_{MIMO} = M.B.\log_2(1+\rho)$$

MIMO has helped clear the bottlenecks of traffic capacity in many wireless communication systems. It is increasingly popular and is being adopted in many communication technologies such as WLAN, WiMAX and LTE.

2.2 MIMO packet structure

Note: For the figure above, the definition and time order of the packet segments are subject to further change

Figure 3. Sample MIMO packet structure modified from the WLAN packet with added new training sequences

The MIMO packet structure as shown in Figure 3 above is a sample packet from a TGn Sync proposal and shows how the start of the packet is the same as that of the 802.11a/g packet. At the end of the 'signal' symbol, a new sequence is inserted. This identifies the packet as an 802.11n packet, and also contains the extra training symbols needed for the MIMO radio to work. The new training sequences are vital in the operation of the WLAN MIMO radio. They enable the radio to calculate the details of the signal paths from the transmitters to the receivers.

3. Agilent Power Measurement Solutions for MIMO Measurements

Agilent's power meters and sensors have long been recognized as the industry standard for RF and microwave power measurements. These meters and sensors are widely used in a broad range of industries including aerospace and defense, electronic manufacturing, wireless communications, and also in metrology applications. Of particular relevance for MIMO measurements are the P-Series peak and average power meters and the U2000 Series USB power sensors. In the section that follows, we discuss in detail the capabilities and benefits of these power meters in making the MIMO measurements.

3.1 P-Series power meters and sensors

The P-Series power meters and sensors offer comprehensive measurements that fulfill the requirements of many applications in R&D and in manufacturing. These include:

- Peak power, minimum power, average power, and peak-to-average ratio power measurements
- Time-gated and free run measurement modes
- Automatic rise time, fall time, pulse width, pulse period, and duty cycle measurements

Table 1. Measurement capabilities of P-Series and U2000 Series

Test parameter	P-Series power meters/sensors	U2000 Series USB power sensors
Average power over a defined time frame	√	√
Peak power or peak-to-average ratio over a defined time frame	√	×
Waveform CCDF statistical analysis	√	×
True average power of the whole signal	√	√

- Auto-gate and auto-scale of pulse signal
- Complementary cumulative distribution function (CCDF) statistics

In designing MIMO components or subsystems, you need to analyze the burst signals. With a sampling rate of 100 Msa/s, the P-Series power meters and sensors can capture the signal bursts and measure the peak-to-average ratio of the transmitted power of your MIMO products. With video bandwidth of 30 MHz, the P-Series provides reasonably accurate measurements of the 40 MHz MIMO signals, comparable to power meters from other manufacturers that claim to have higher video bandwidth.

Figure 4 on page 5 shows the delta of P-Series burst average power measurements on 40 MHz MIMO burst compared with the set power on the Agilent E4438C ESG Vector Signal Generator. . The best accuracy and most repeatable measurements can be achieved using normal mode with a higher number of averages, while a faster measurement can be achieved using the buffer memory and trigger count method, with some trade-off in accuracy and repeatability.

Figure 5 on page 5 shows the peak-to-average ratio power measurements of the 40 MHz MIMO burst.
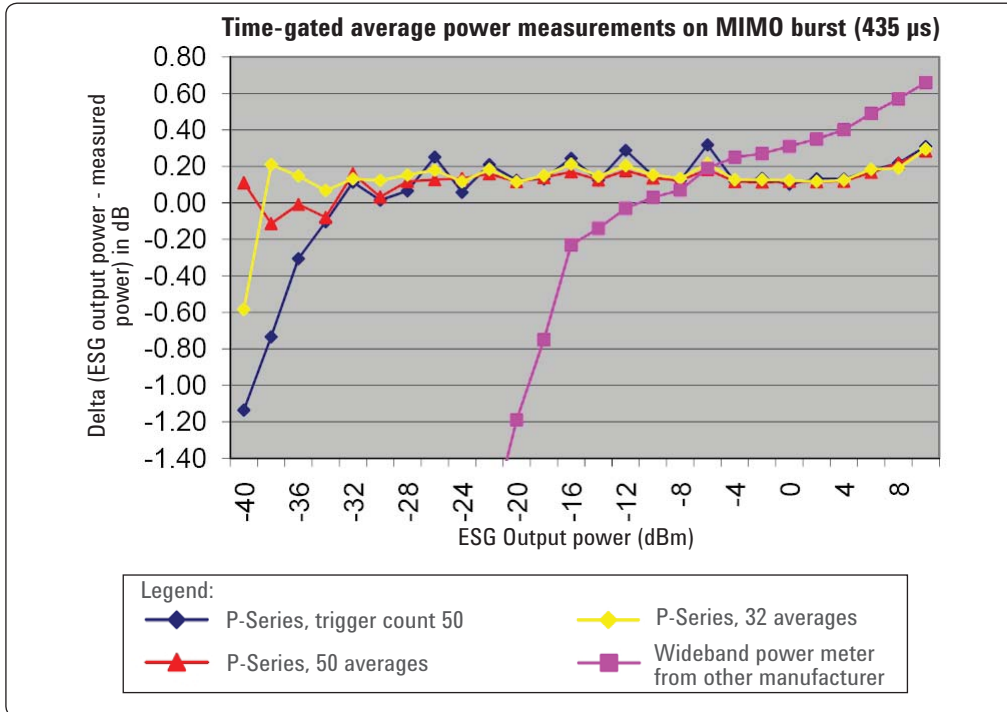
Figure 4. Time-gated average power measurement of MIMO burst using P-Series power meters/sensors
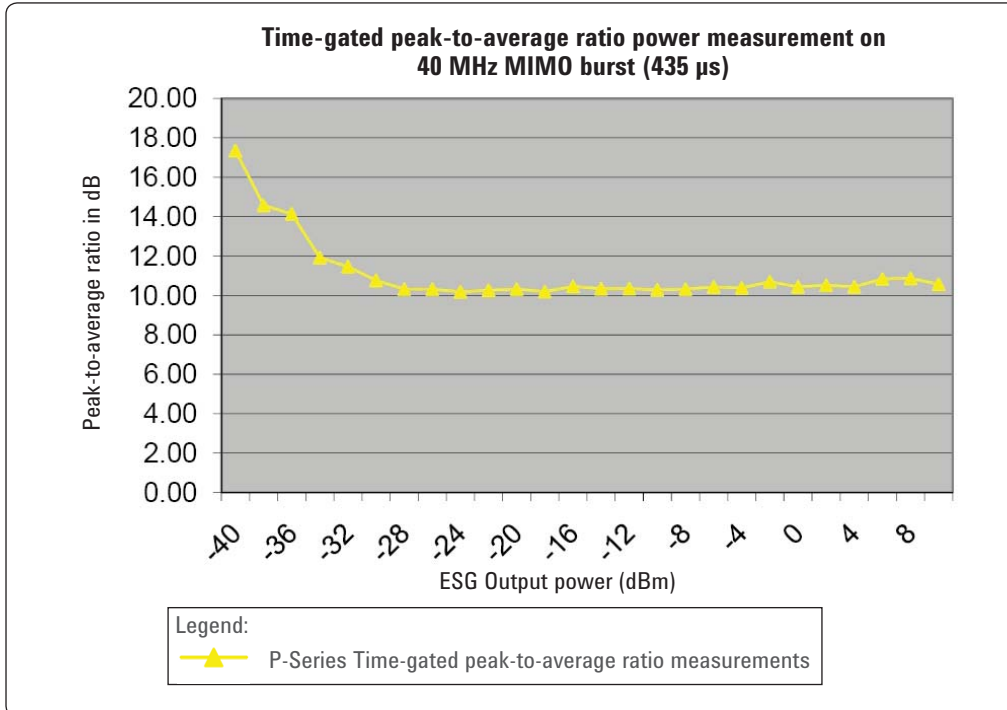

Figure 5. Time-gated peak-to-average ratio power measurement of MIMO burst using P-Series power meters/sensors

3.1.1 Time-gated power, power versus time, CCDF

With the P-Series power meters and sensors, you can verify the power profile and output power of your MIMO devices easily. The length of the burst of an MIMO signal is unpredictable, and it is influenced by the type of data transmitted and the data rate desired. You can configure the P-Series to display the whole burst and set up four pairs of gates over any portion of the MIMO burst that you choose, see Figure 6.

The P-Series power meters and sensors also enable measurements of the signal rise time and burst profile. You can identify any power transition issues that may cause interoperability problems in your MIMO systems. Measuring the peak-to-average ratio and the CCDF also allows you to verify that power amplifiers used in the MIMO system are not clipping.
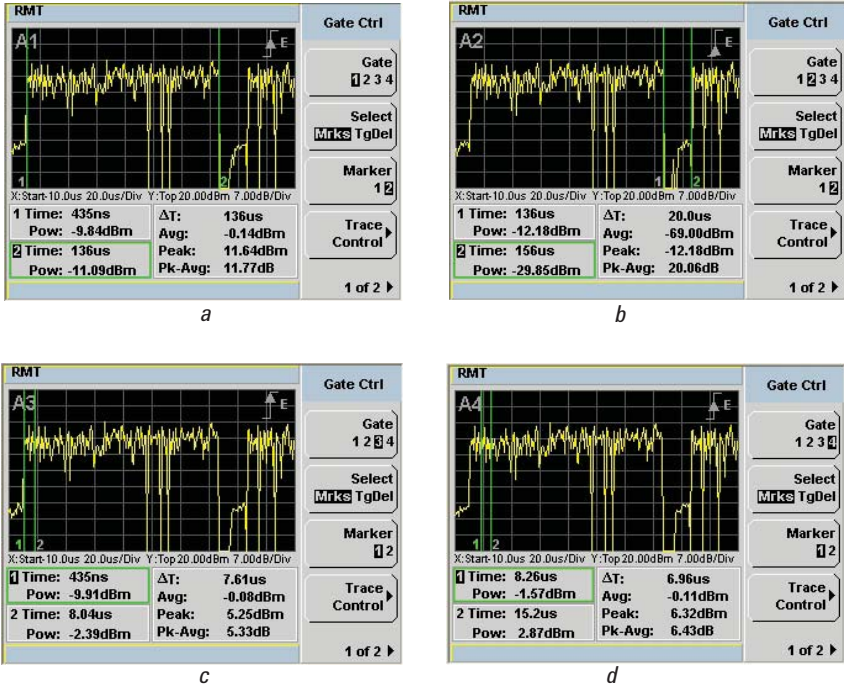

Figure 6. Measurement flexibility with four independent time gates:
 a. Gate 1: Time-gated measurements on the whole burst
 b. Gate 2: Time-gated measurements on the idle interval
 c. Gate 3: Time-gated measurements on the preamble part 1
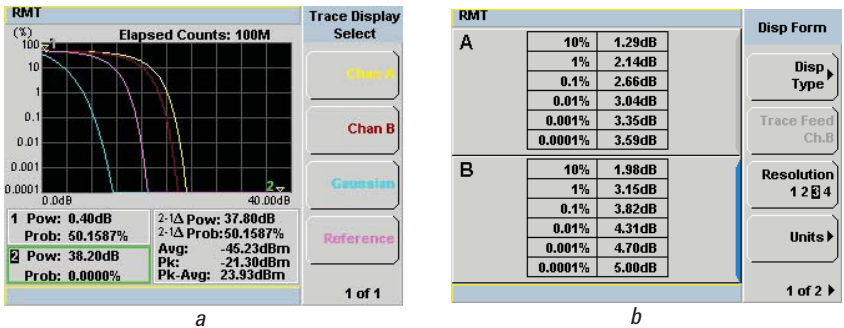 *d. Gate 4: Time-gated measurements on the preamble part 2*

Figure 7. The P-Series power meters support waveform CCDF statistical measurements in both graphical and tabular formats

3.1.2 P-Series power meters and sensors are the ideal solution to complement your MIMO measurement system

The multiple-channel architecture and stringent performance requirements of MIMO devices present certain challenges for their design and manufacture. The increase in the number of transmitters and receivers on each device will imply an increase in the test time and test system complexity compared with those needed for single-channel 802.11a/b/g devices. The cost of testing is directly proportional to the test time, so we can unload the time-consuming power measurements from the expensive signal-analysis system and move them to the power measurement system. This enables parallel testing on both systems, thus minimizing the increase in test time for multiple-channel devices. The typical high-performance power meter costing about $11,000 will not significantly increase the cost of testing but will help reduce the test cycle time of your MIMO devices. **The cost-efficient power meters enable parallel testing of all transmission channels simultaneously, as shown in Figure 8.**

Moreover, the P-Series power meters and sensors can achieve higher accuracy than any other instruments, thus providing more margin for your production test limits. The P-Series power meters and sensors can detect up to more than 0.2 dB (around 4%) in overall measurement uncertainty.
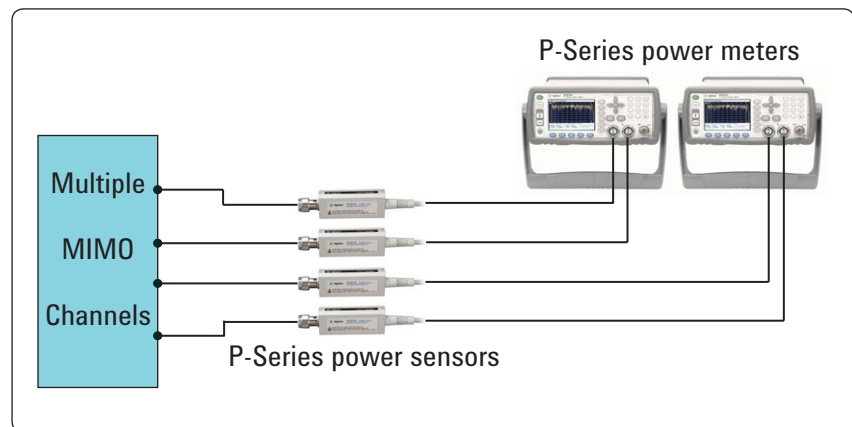

Figure 8. P-Series power meters and sensors enable parallel testing of all transmission channels

3.2 U2000 Series USB power sensors

The U2000 Series USB Power Sensors can display power measurements on a PC or on another instrument without requiring a separate power meter. The U2000 Series provide the same functionality and performance as traditional power meters and sensors. It is a complete solution that simplifies your measurement setup while meeting most of your measurement needs.

Apart from the conventional average power measurements, the U2000 Series can perform time-gated average power measurements, which typically are supported only by peak and average power meters. With the time-gating feature, you can set up the start of gate and length of gate, with reference to the trigger input signal, to select the portion of the signal in which you are interested as shown in Figure 10 on page 8.
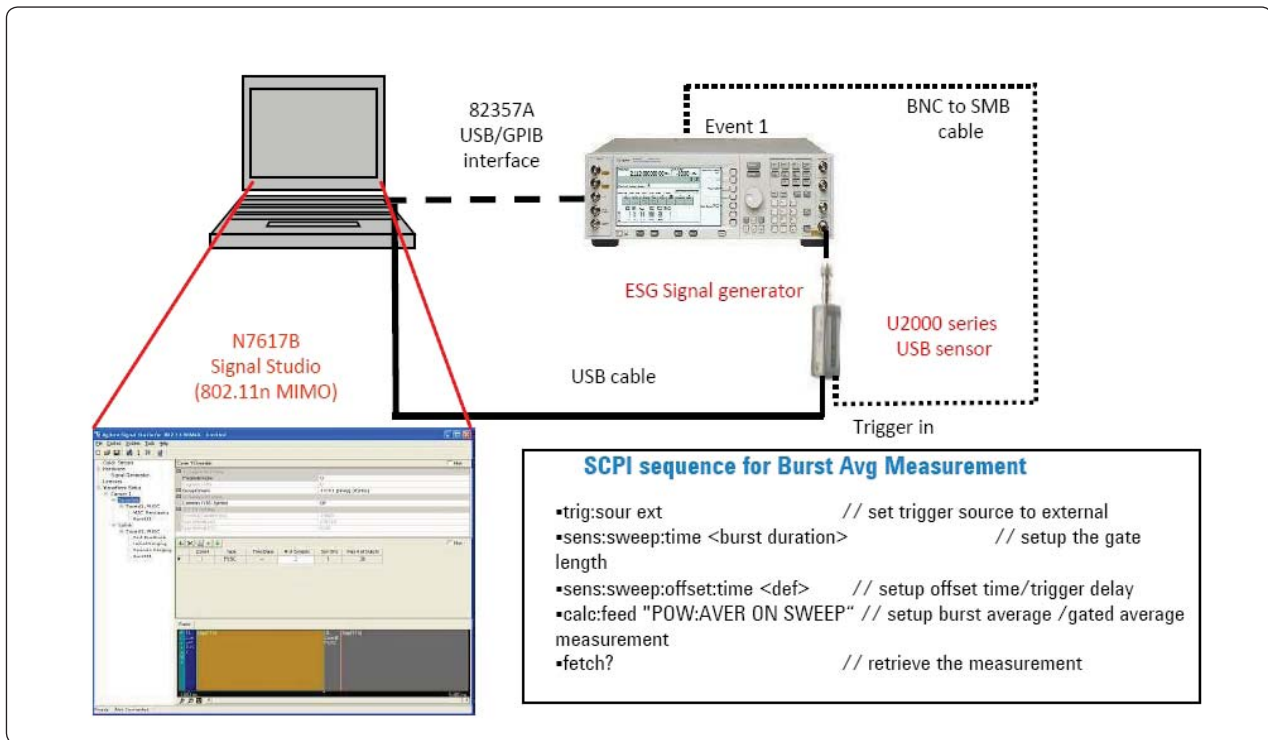
Figure 9. Example of hardware connections for time-gated average power measurements using U2000 Series power sensor and Agilent E4438C ESG signal generator

The U2000 Series USB power sensors with dual-path diode architecture are capable of performing true average power measurements. In addition, they can accurately measure the burst average power by using the time-gating feature that allows the user to set up a pair of gates around a burst signal and measure the average power within the gates. Even though with its limited video bandwidth of a few tenths of a kilohertz, the sensor, with its dual-path diode architecture, can perform accurate signal-envelope profiling while operating full in the square-law region. Unlike the peak power sensor, there is no compression to the top portion of the voltage waveform due to the non-linearity of the diode. Thus, the U2000 Series can convert the burst power into proportional voltage waveform. The voltage waveform will then pass through the video bandwidth correction. This is done

Figure 10. The SCPI commands set the offset time and gate length with reference to the trigger input signal

by the RC filter circuit in the sensor that corrects for any error within the filter's passband. The RC filter bandwidth measured in tenths of a kilohertz will filter out the high-frequency components that contribute to the peaks and troughs of the burst signal in time domain. However, it will leave the average power unchanged. Thus the U2000 Series can still provide an accurate profiling of the signal envelope. These sensors are also able to provide accurate burst average power measurements.

Time-gated average power measurements on 40 MHz MIMO burst (435 μs)

Legend:
- P-Series time-gated average power measurements -50 averages -34s
- U2000A time-gated average power measurement - normal mode, 32 averages - 60 ms
- Time-gated average power meaasurement by wide bandwidth power meter from other manufacturer
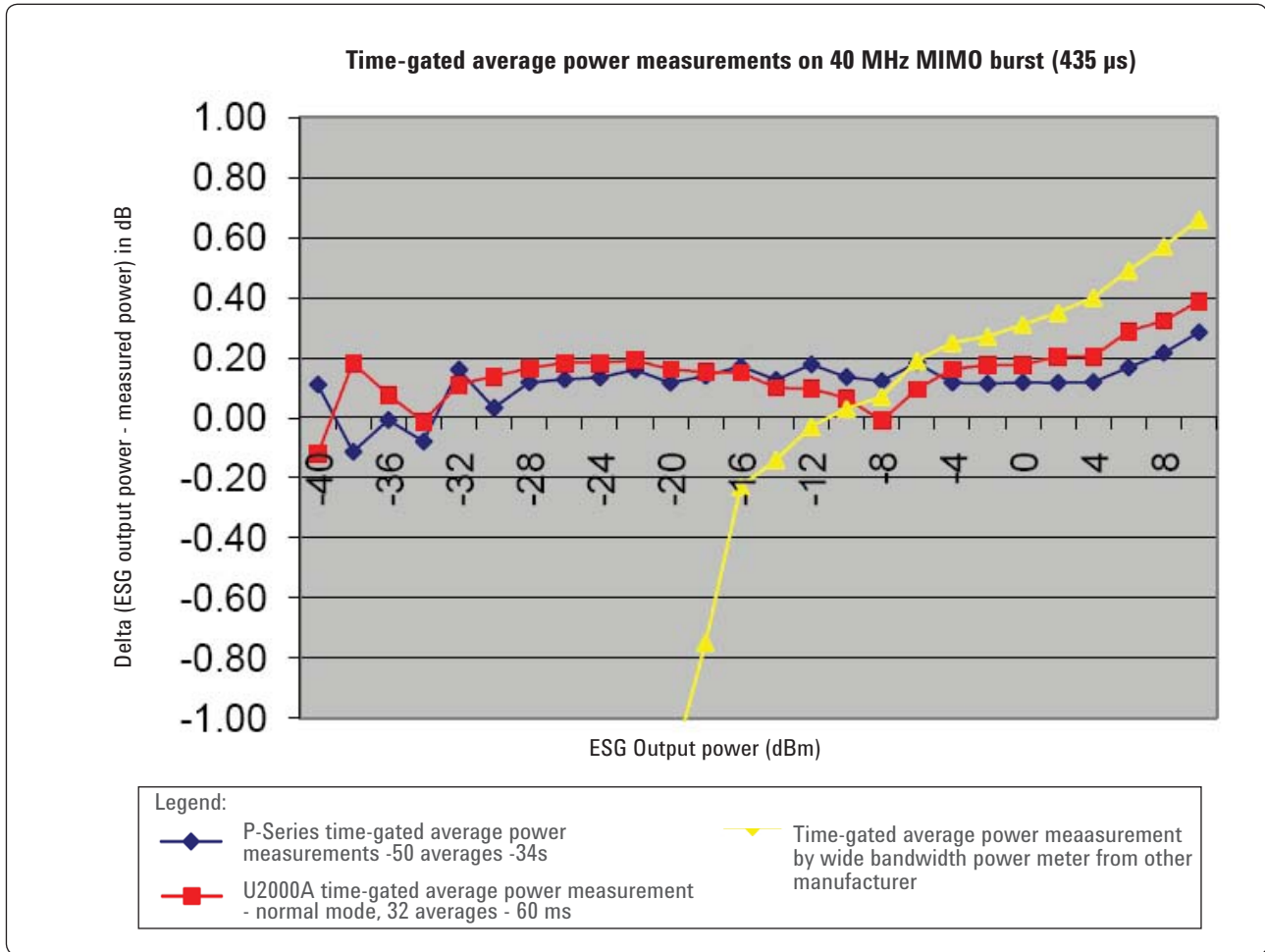
Figure 11. MIMO burst average measurements comparisons between P-Series power meter, U20001A, and a 65 MHz video bandwidth power meter from another manufacturer

Figure 11 shows the measurement comparisons between the Agilent P-Series power meters and the U2000 Series USB power sensors in measuring a 40 MHz bandwidth MIMO burst. The X-axis represents the output power from the ESG where it is swept from low (–40 dBm) to high (+10 dBm) power. The Y-axis represents the delta in dB as compared to the ESG output power (i.e., Delta = ESG output power – Power meter/sensor measured power). The U2000 Series can perform very accurate time-gated average power (also known as burst average power) of any burst signals including WiMAX, LTE, or MIMO WLAN bursts. The U2000 Series also has an advantage in measurement speed. The U2000 Series can perform the time-gated average measurement at a rate of up to 10 ms per reading, which is much faster than the P-Series power meters. However, the U2000 Series has its limitations. It can only measure the true average power within a time-gate, whereas the P-Series is able to also perform peak and peak-to-average ratio power measurements, in addition to the true average power measurements. The P-Series also support CCDF statistical analysis, which is very useful for testing system components such as power amplifiers to ensure that they can handle proposed power peaks.

For the greatest accuracy and repeatable time-gated average power measurements, it is recommended that a 80 μs offset from the pulse leading edge and 50 μs offset from the pulse trailing edge be used to determine the gate start and gate length of the U2000 Series.

4.   Demonstration Guide

To achieve MIMO capability, it is necessary to have multiple transmitters and receivers at each end of the link. In this demonstration guide, we use ESG to simulate MIMO devices under test (DUTs) and use the P-Series power meters/sensors and the U2000 Series USB power sensors to analyze the MIMO waveform generated by the MIMO DUT (simulated by the ESG). This demonstration only shows the MIMO waveform measurement from a single MIMO DUT. In an actual setup, multiple MIMO DUTs are measured, and this can be done by using a power splitter/combiner and switch matrix and following procedures similar to those outlined in the following sections.
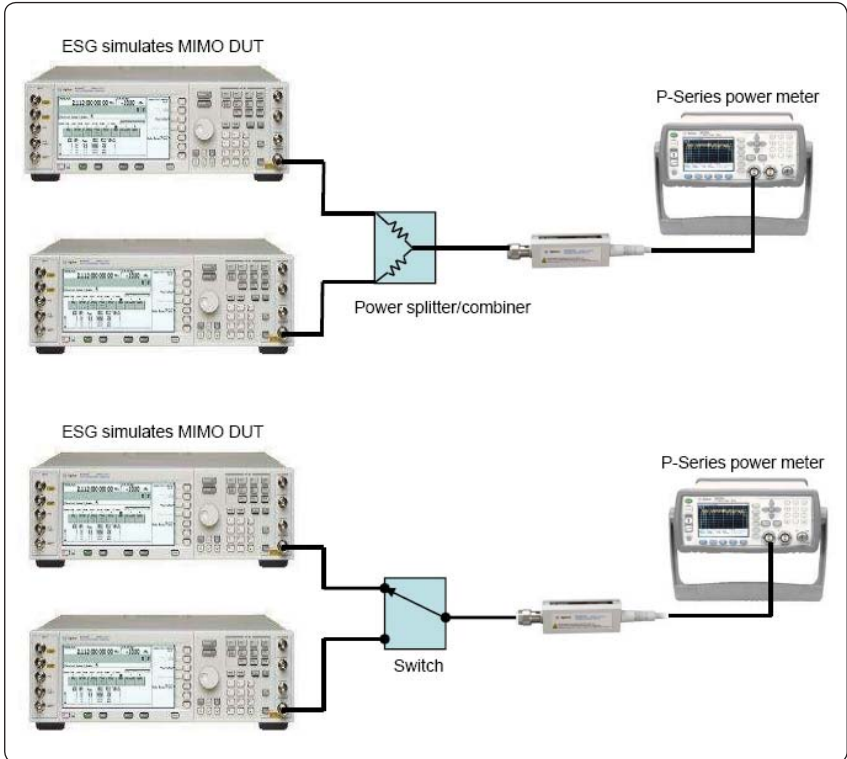

Figure 12. Using a single P-Series power meter and sensor to measure multiple MIMO DUT via power splitter, combiner, or switch

4.1 Demonstration setup and procedures for P-Series power meters and sensors

This demonstration focuses on IEEE 802.11n MIMO signal measurements using the P-Series power meters/sensors over GPIB.
The instruments and software needed for this demonstration are shown in Table 2.

The N7617B Signal Studio for 802.11 WLAN is a Windows® based software application that simplifies the creation of standard or customized WLAN waveforms. With the Signal Studio software, the desired MIMO waveform can be configured. Waveform parameters are then input into the ESG.

To update the instrument firmware or download the software, visit:
- www.agilent.com/find/ESG
- www.agilent.com/find/MXG
- www.agilent.com/find/pm_firmware
- www.agilent.com/find/signal-studio

Power-level transmission is an important IEEE 802.11n conformance specification. It is defined as the time-averaged power over the useful period of UL or DL burst. Peak-to-average power ratio can also be measured during this period. To make accurate and repeatable measurements, it is important to capture the desired complete frame consistently within the fixed time frame. This can be achieved with proper setup such as one that includes trigger level, trigger hold off, delay, and graph scales in the P-Series power meters.

Table 2. A list of instruments and software needed for this demonstration

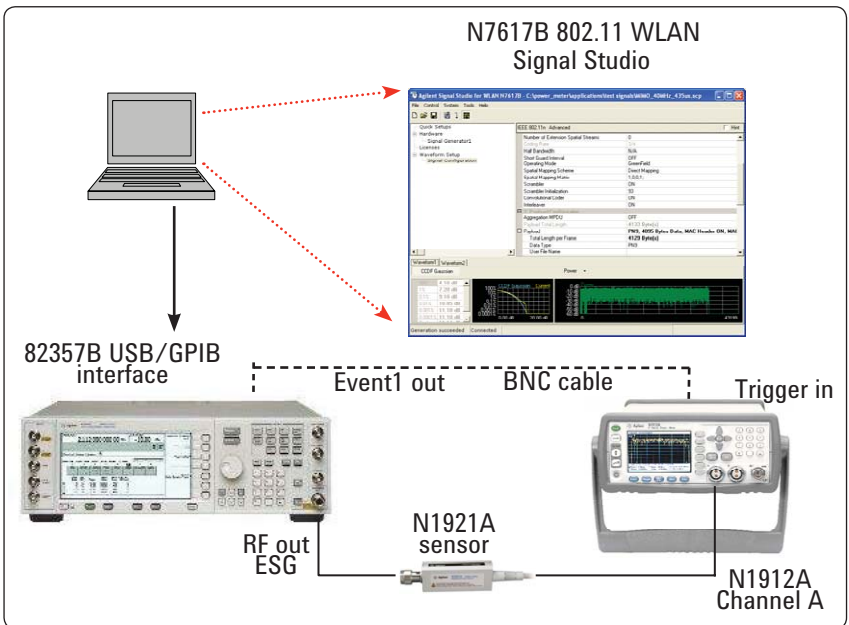| Model	Description	Firmware/software version	Quantity
E4438C	ESG vector signal generator	C.04.98 or later	1
N1911/12A	P-Series single or dual channel power meter	A.03.01 or later	1
N1921 /22A	P-Series wideband power sensor, 18GHz or 40GHz	-	1
N7617B	Agilent Signal Studio for 802.11 WLAN	1.3.0.0 or later	1
Controller PC	Installed with N7617B Signal Studio to generate MIMO signal into the ESG	-	1

Figure 13. MIMO measurement setup using P-Series and ESG

Following this section, we provide step-by-step procedures for setting up the ESG to generate IEEE 802.11n waveforms and the configurations required on the P-Series for capturing and measuring stable and accurate MIMO bursts.

4.1.1 Setting up ESG and Signal Studio to generate MIMO burst
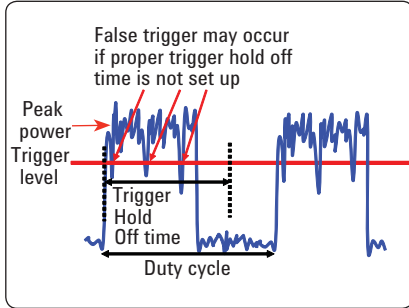
Instructions:

1. Connect the PC to the E4438C ESG via the 82357B GPIB-USB interface.
2. Launch Agilent Connection Expert application and verify successful connection of the ESG.
3. Connect the P-Series power meter and sensor as shown in Figure 13 on page 11.

Keystrokes enclosed by [] represent front panel keys of the instrument, while keystrokes enclosed by {} represent softkeys.

Instructions	Keystrokes
On the ESG:	
1. Set the instrument to its default settings.	Press [**Preset**]
On the controller PC:	
2. Run the Signal Studio for N7617B 802.11 WLAN	Double-click the 802.11 WLAN shortcut on the desktop or access via the Windows start menu.
3. Connect to the ESG	• Click {**New hardware configuration**}, {OK}. • Click {IEEE 802.11n MxN MIMO (with 1 SG switching between...}, {**Next**} • Confirm {ESG/MXG + Internal Arb} is selected, click {Next}. • Click {**Next**} again. • On {Select Signal Generator:}, enter "GPIB, 0, 19, 0". Then click {**Next**}. (You may check the GPIB address on Agilent Connection Expert to confirm it is 19). • If Connections are established successfully, click {**Next**}. • Input a name, then click {**Finish**}.
On the Signal Studio software:	
4. Set the basic parameters of the signal at center frequency of 2.412 GHz, power level 0 dBm.	Click **Signal Generator** on the left of the Explorer menu. Frequency = 2.412 GHz • Amplitude = 0 dBm • RF Output = ON
5. Configure the Waveform Setup	Click **Waveform Setup** on the left of Explorer menu. • Capability = Advanced • Waveform name = WLAN • Format = HT • Generation mode = Framed • Idle Interval = 100.00 μs • Bandwidth = 40 MHz
6. Configure the data length	Click **Signal Configuration** on the left of the Explorer menu. • Under payload -> data length = 4095 B
7. Download signal to ESG	On the top menu bar, go to **Control > Generate and Download** (If you encounter any errors, refer to *Signal Studio's Online Help*.)
8. Save file setting for future use	On the top menu bar, go to **File > Save Settings File > 40MHz_MIMO_ burst.scp** (or enter any file name of your choice)

4.1.2 Setting P-Series power meters and sensors for MIMO power measurements

Details 1

The P-Series power meters' trigger level is typically set at auto-level. Trigger hold off ensures that the acquisition will not occur until the hold off time is over and a valid trigger is found. This is very useful for burst signals that have huge amplitude variations such as WLAN, WiMAX, or LTE signals because these variations can cause false triggering.
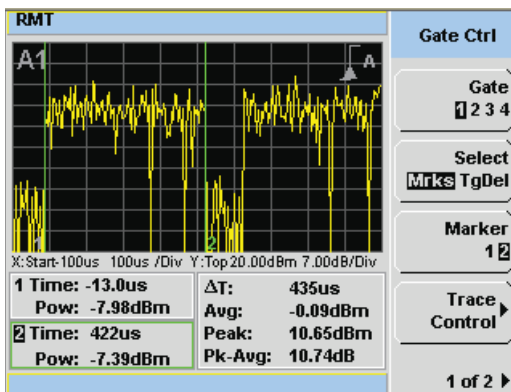
The ESG will generate a trigger signal corresponding to the MIMO burst from the Event1 output connector at the rear of the ESG. The user may connect the Event1 output of ESG to the Trigger In connector of the P-Series power meters and switch the trigger source to External. With External trigger source, the setting up of trigger hold off can be ignored because the acquisition will only happen when the power meter receives a trigger signal from the ESG.

You have just successfully downloaded the MIMO waveform to your ESG. To configure the P-Series power meters and sensors for MIMO burst, power measurements, follow the procedures below.
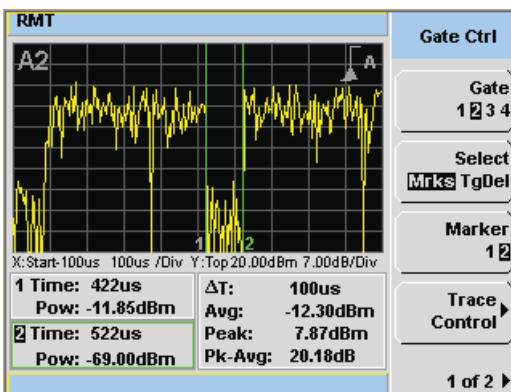
On the P-Series power meter:

Instructions	Keystrokes
1. Select 802.11b/g preset.	Press [Preset], then use [⬆] or [⬇] to choose {802.11b/g}. Then press [Select] and {Confirm}.
2. Set trace display	[Disp], {Disp Type}, {Trace}.
3. Set the trigger hold off to 500 μs (This step may be skipped, if external trigger source is selected. Refer to Details 1)	[Trig/Acq], {Settings}, {1 of 2}, {hold off 500 μs}
4. Expand the display size and change the scale	[⬜↔⬜] {Trace Control} • {X start = -100 μs} • {X Scale = 100 μs} • {Y max = 20 dBm} • {Y scale = 7 dB}
5. Set up Gate 1 to measure peak and average power of the burst signal	{Gate Control}, use [◀] or [▶]to move Gate1 to the rising edge. Press [⬇] to toggle to Gate2. Use [◀]or [▶] to move Gate2 to the falling edge. You can now view the time-gated average, peak and peak-to-average ratio at the bottom of the trace.
6. Set up Gate 2 to measure the idle time	Press on {Gate} to move to Gate 2. Use [◀] or [▶] to move Gate1 to the falling edge of burst 1. Press [⬇] to toggle to Gate2. Use[◀] or [▶] to move Gate2 to the rising edge of burst 2. You can now view the idle time and the burst off power level at the bottom of the trace.

The P-Series power meters allow up to four pairs of gates to be set up around a burst signal to measure the total burst power, idle time, and preamble power of the signals.

(a)

(b)

Figure 14. MIMO waveform duration at 435 μs and idle time at 100 μs
(a) The green lines (Gate1 and Gate2) are used to capture the MIMO burst
(b) The green lines (Gate1 and Gate2) are used to capture the idle time

4.1.3 Setting up the P-Series power meters and sensors for CCDF statistical analysis on MIMO burst

A CCDF curve shows how much time the signal spends at or above a given power level. The power level is expressed in dB relative to the average power. The CCDF curve indicates the degree of peak-to-average deviation, with more stressful signals further to the right.

CCDF is an important parameter in characterizing power amplifiers that must handle high peak-to-average signals. The P-Series power meters enable waveform CCDF characterization, which is primarily used in the wireless communication market for evaluating multicarrier power amplifier performance. With a sampling rate of 100 MSa/s, the P-Series enable 100 Msa to be histogrammed in real time to give you the statistics of 100 million sa/s. This provides extremely fast real time updates of the CCDF curve during power amplifier tuning.

On the P-Series power meter:

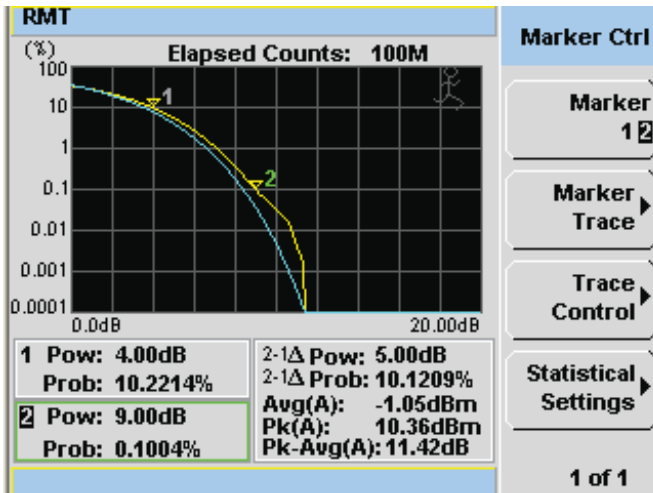| Instructions		Keystrokes
1.	Set the acquisition to 'free run'	[Trig/Acq], {Acqn A}, {Free Run},
2.	Measure CCDF in trace format	[Disp], {Disp Type}, {1 of 2}, {CCDF Trace}.
3.	Set the trace scale to 2dB/div	{Trace Control}, {Scale/Div}, [2], {Enter}.
4.	Turn on the Gaussian noise reference curve and expand the display	{Trace Display}, {Gaussian}, [⬚↔⊟].
5.	Display CCDF in table format and expand the display	[Disp], {Disp Type}, {1 of 2}, {CCDF Table}, [⬚↔⊟].

Figure 15. CCDF graphical format. The yellow line is the waveform CCDF of the MIMO signals. The blue line is the band-limited Gaussian noise curve. Marker 1 and Marker 2 indicate 10% and 0.1% of time where the signal is at 4 dB and 9 dB respectively above the average power.

Figure 16. CCDF in table format for easy data viewing and recording

4.2   Demonstration Setup and Procedures for U2000 Series USB Power Sensors

This demonstration focuses on IEEE 802.11n MIMO signal measurements using the U2000 Series USB power sensors and the N1918A Power Analysis Manager software.

The instruments and software that are needed in this demonstration are shown in Table 3.

The N7617B Signal Studio for 802.11 WLAN is a Windows based software application that simplifies the creation of standard or customized WLAN waveforms. With the Signal Studio software, the desired MIMO waveform can be configured. Waveform parameters are then input to the ESG.

To update the instrument firmware or download the software, visit:
  • www.agilent.com/find/ESG
  • www.agilent.com/find/MXG
  • www.agilent.com/find/
    pm_firmware
  • www.agilent.com/find/signal-
    studio
  • www.agilent.com/find/
    N1918A_download

Follow section 4.1.1 on the setup of Signal Studio and ESG in generating IEEE 802.11n signals.

Table 3. List of instruments and software needed for the demonstration

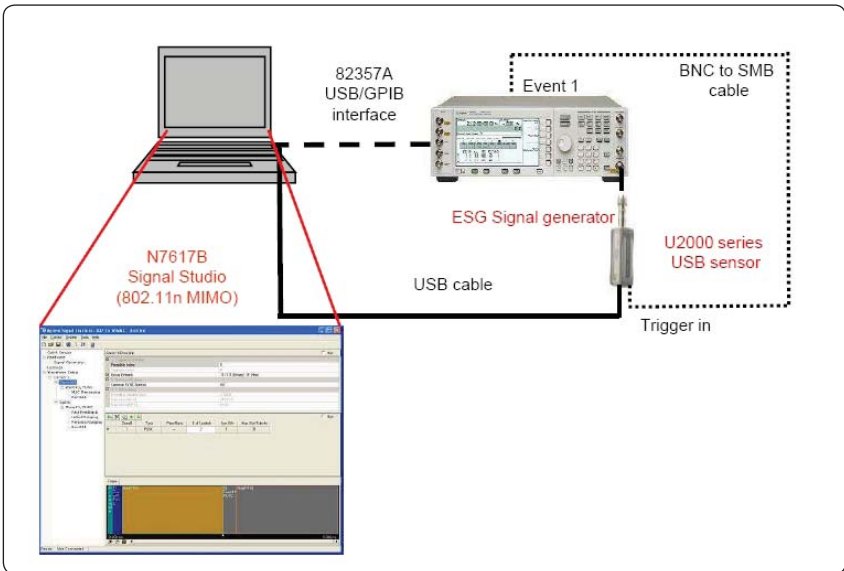| Model	Description	Firmware/ software version	Quantity
E4438C	ESG vector signal generator	C.04.98 or later	1
U2000/1/2A	USB power sensor	A1.02.00 or later	1
N1918A	Power Analyser Manager	R02.00.00 or later	1
N7617B	Agilent Signal Studio for 802.11 WLAN	1.3.0.0 or later	1
Controller PC	• Installed with N7617B Signal Studio to generate MIMO signal into the ESG • Installed with N1918A software for power measurement display	-	1

Figure 17. Demonstration setup for the U2000 Series in measuring MIMO burst signals

4.2.1 Setting up the U2000 Series USB Power Sensor for MIMO power measurements

Apart from the conventional average power measurements, the U2000 Series can perform time-gated average power measurements, which typically are supported by only peak and average power meters. With the time-gated feature, you can set up the start of gate and the length of gate, with reference to the trigger input signal, to select the portion of the signal in which you are interested.

The table on the right provides step-by-step procedures on how to set up the U2000 Series for measuring time-gated average power of MIMO burst signals based on the hardware connections shown in Figure 17 on page 16.

On the controller PC:

Instructions	Keystrokes
1. Launch the **N1918A Power Analysis Manager > Power Panel** software, which is the free soft front panel for U2000 Series.	Double-click the **Power Panel** shortcut on the desktop or access **N1918A** via the Windows start menu.
2. Connect to the USB sensor.	Select **Find USB only** on the Instrument Selector window. Then click **Find**. Check the connected USB sensor and select **Connect**.
3. Perform zeroing.	Click **U2000x – MY47000xxx** on the **Instrument Navigator** panel on the left. Select **Int** or **Ext** zeroing on the **Instrument Properties** pane on the right. Then click **Zero**. Wait for about 30 s for the zeroing to complete. (Note: If Ext zeroing is selected, do not input any power to the USB sensor)
4. Set the input frequency to 2.4 GHz.	On the same **Instrument Properties** panel, key in [2.4 G] on the **Frequency (Hz)** column.
5. Set up gated average measurement.	On the **Instrument Navigator** panel, click **Gate A**. On the **Instrument Properties** panel, check **Enable Gate**. • Gate 1 Start = 50 μ • Length = 335 μ
6. Set up for external trigger input.	On the **Instrument Navigator** panel, click **Trigger**. On the **Instrument Properties** panel, check **Cont Trig**. The external Trigger Source will be selected automatically as U2000 can only support External Trigger Input at the moment.
7. Set up Numerical display for power measurements.	On the middle panel, click the **Custom Views** tab. Click ⊞ on the top menu. Right-click the **Custom Views** window, **Assign Measurement**, click the USB sensor and select **Assign**.

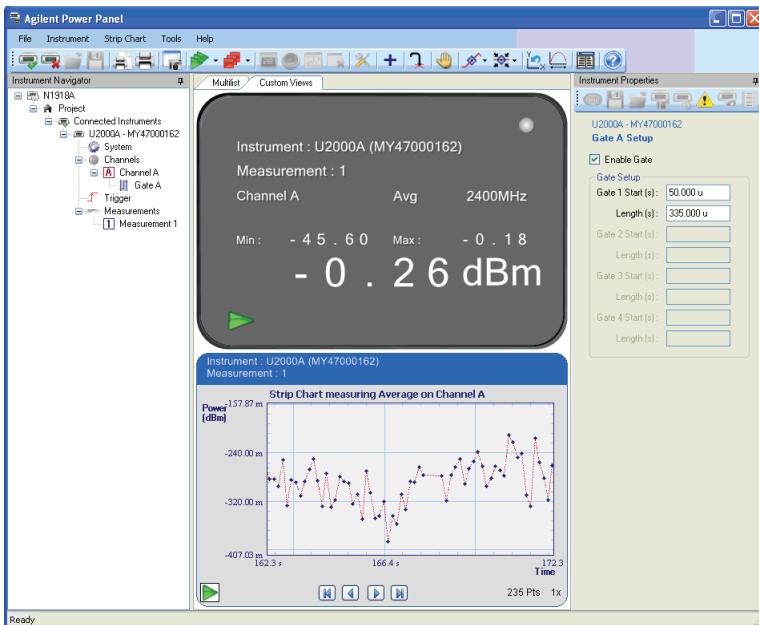| Instructions	Keystrokes
8. Start the time-gated average power measurements.	Before starting the measurement, ensure that the ESG output power is turned off by pressing [local], [RF on/off] on the ESG's front panel. Start the U2000 measurements by clicking ▶ on the top menu. Turn on the ESG RF out by pressing [RF on/off] on the ESG's front panel. You can now read the time-gated average measurement from the display.
9. Set up Strip Chart display to monitor the trend of measurements. Note that the N1918A allows changes to the setting without stopping the measurements.	Click 〽 on the top menu. Then right-click the **Strip Chart** window and click **Assign measurement**. Click on USB sensor and select **Assign**. You can now monitor the trend of the time-gated average power. You may right-click to change the graph properties or add markers.

Figure 18. The bundled N1918A Power Panel functions as the soft front panel for the U2000 Series USB power sensors. It enables numerical display, strip chart, or multilist view, when connected to multiple sensors. The Advanced N1918A Power Analyzer, Option 100 offers more functionality and can be purchased separately.

Ordering Information

Product type	Model number
P-Series power meters	N1911A or N1912A
P-Series wideband power sensors, 18 GHz or 40 GHz	N1921A or N1922A
10 MHz – 18 GHz USB sensor	U2000A
10 MHz – 6 GHz USB sensor	U2001A
50 MHz – 24 GHz USB sensor	U2002A
9 kHz – 6 GHz USB sensor	U2004A
10 MHz - 18 GHz, –50 to +30 dBm USB sensor	U2000H
10MHz – 6 GHz, –50 to +30 dBm USB sensor	U2001H
50MHz – 24 GHz, –50 to +30 dBm USB sensor	U2002H
10MHz – 18 GHz, –30 to +44 dBm USB sensor	U2000B
10MHz – 6 GHz, –30 to +44 dBm USB sensor	U2001B
Power Analysis Manager software	N1918A

References

Agilent Technologies, MIMO Wireless LAN PHY Layer [RF] Operation & Measurement, Application Note 1509, Literature Number 5989-3443EN, April 29, 2008.

Breaking the barrier of Shannon's capacity: An overview of MIMO wireless systems. Telenor's Journal: Telektronikk 2002; 98:53-64. Gesbert, David; Akhtar, Jabran.

Related Agilent Literature

Publication title	Pub number
P-Series power meters and Power Sensors Configuration Guide	5989-1252EN
P-Series Power Meters and Sensors, Technical Overview	5989-1049EN
N1911A/N1912A P-Series Power Meters and N1921A/N1922A Power Sensors Datasheet	5989-2471
U2000 Series USB Power Sensors Datasheet	5989-6278EN
U2000 Series USB Power Sensors Configuration Guide	5989-6281EN
U2000 Series USB Power Sensors Technical Overview	5989-6279EN

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