Tips for Querying CW and Average Power Without Compromising Measurement Accuracy

Using Agilent power meters and sensors

Application Brief

This application note applies to the following products from Agilent Technologies

- N1913/14A EPM power meter
- E4416/17A EPM-P power meter
- N1911/12A P-Series power meter
- U2020 X-Series USB peak and average power sensor
- U2000A Series USB average power sensor
- U8480A USB Thermocouple USB power sensor
- Agilent power sensors

Introduction

This application brief demonstrates the capabilities Agilent power meters and power sensors have for measuring CW and average power signals. It also explains the advantages and disadvantages of select SCPI commands and settings for Agilent power meters and power sensors, illustrating how to these items to improve power measurement speed without compromising measurement accuracy.

Power measurements

There are many ways to analyze a modulated signal. The power-versus-time measurement is a very useful method for examining power level changes due to pulsed or burst carriers (see Figure 1).

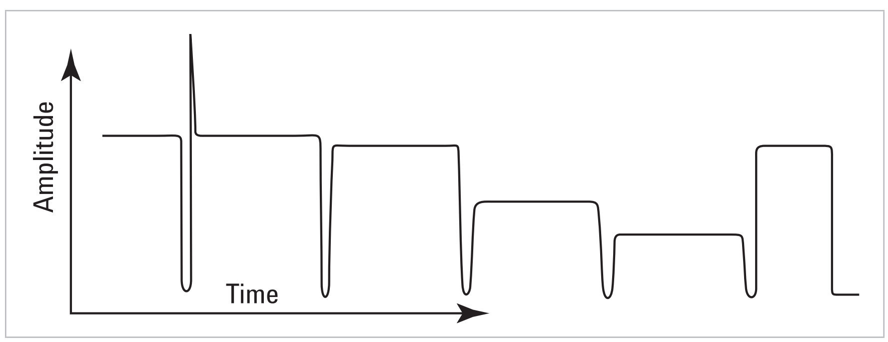

Figure 1. Power-versus-time measurement graph

Power measurements (cont'd)

Average, pulse, and peak envelope power measurements provide different types of information about the signal (see Figure 2).

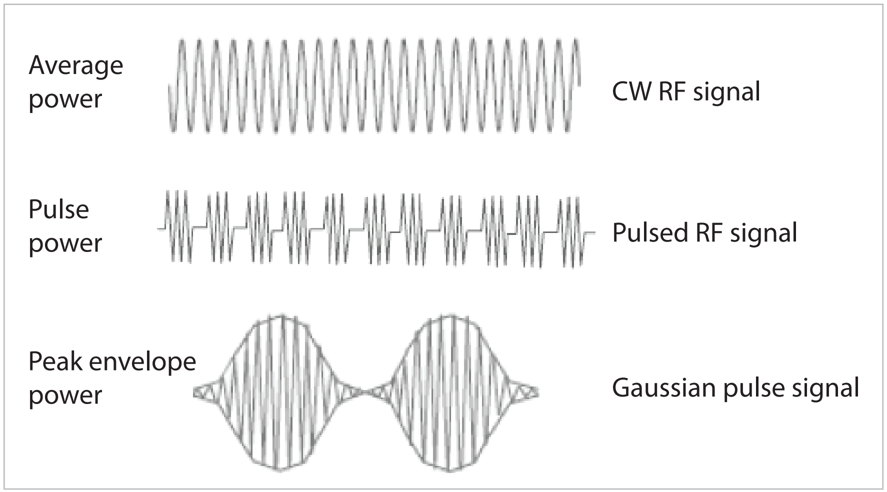

Figure 2. Average, pulse, and peak envelope signal power

Pulse power is determined by measuring the average power of the pulse and then dividing the result by the pulse duty cycle. This is a mathematical representation of the pulse power rather than an actual measurement and assumes constant pulse power. Pulse power measurement averages out any aberrations in the pulse, such as overshoot or ringing. For this reason, it is called pulse power and not peak power or peak envelope power. To ensure accurate pulse power readings, the modulating signal must be a rectangular pulse with a constant duty cycle. Other pulse shapes such as triangular or Gaussian will cause erroneous results. This technique is not applicable for digital modulation systems, where the duty cycle is not constant, and the pulse amplitude and shape varies.

When the power pulse becomes non-rectangular and the pulse-power measurement equations become inaccurate, using peak envelop power measurements is a better measurement method. This technique is the most suitable for modern digital communication systems with variable duty cycles and pulse widths.

Unlike measuring a pulsed signal that has a pulse repetition period and a constant duty cycle, burst signal measurement is considerably more challenging (see Figure 3). Measuring a burst signal with an unpredictable burst length that lacks a constant duty cycle requires time-gated functionality (independent measurement gates). This can be accomplished using high-performance power meters and power sensors.

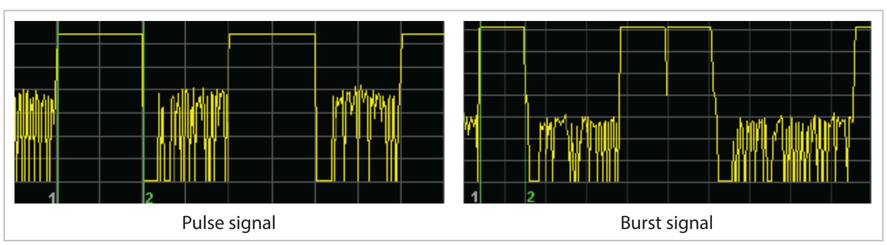

Figure 3. Pulse signal with a constant duty cycle versus burst signal without a constant duty cycle.

Power measurements (cont'd)

Agilent power meters and power sensors offer the ability to measure CW and average power. The following example provides some tips for using power meters and power sensors to acquire an accurate power without increasing the test time.

Querying tips

Measurement query method

There are three different methods that can be used to query a measurement from the power meter or power sensor. It is beneficial to understand the basic differences between these three commands in order to fully optimize measurement speed.

MEASure?

This command is compound command consisting of ABORt, CONFigure, and READ?. It is the simplest of the query commands because it relies on the power meter to select the best settings for the requested configuration and immediately perform the measurement. One drawback to this command is that its use results in a longer test time and overrides some of the power meter's settings, such as switching the meter from Free Run to Single Shot mode or changing the average count set to the ON state.

READ?

The READ? command is another compound command that is equivalent to an ABORt followed by an INITiate and FETCH?. The READ? query is similar to MEAS? in that it causes the meter to perform initializations and auto configuration. However, READ? gives users the flexibility to change certain settings such as the average count. The READ? command allows user to manipulate the settings in order to optimize the measurement speed, resulting in a shorter test time than that realized using the MEAS? command.

FETCH?

This command retrieves a reading upon measurement completion and puts it in the output buffer. The FETCH? command allows users to manipulate settings such as the average count. However, this command requires additional settling time to complete the average count process or else FETCH? will return invalid data.

Measurement averaging

Measurement average count is primarily used to reduce signal noise in order to obtain better measurement accuracy, especially for a lower power signal. The power meter uses a digital filter to average the power readings. The number of readings averaged can range from 1 to 1,024. While increasing the number of measurements averaged reduces the measurement noise, the measurement time is increased. Users can manually configure the measurement average or keep the measurement average in Auto mode (the default). When the auto measurement average mode is enabled, the power meter automatically sets the number of readings averaged base on the power level currently being measured as defined by the power meter.

For example, a high power signal of +10 dBm requires a smaller average count for accurate measurement. The average count might set to "1" by default from the power meter. Using the FETCH? command to query +10 dBm power gives an accurate measurement upon completion of the average count process. The FETCH? command produces results faster than READ? and MEAS?.

Querying tips (cont'd)

Measurement query method (cont'd)

Conversely, at low power, a noisy signal of –40 dBm requires a higher average count to reduce the noise. In this case, the power meter could, for example, select 128 for the average count. Using the FETCH? command, if insufficient WAIT time is specified for the meter, all 128 readings may not be obtained before the results are averaged and the final value returned. The FETCH? query is faster because it returns measurements with or without completion of the average count process. Using either the READ? or MEAS? query, 128 fresh readings would be taken and the average count process completed before returning a final average value however, the measurement speed would be slower than the FETCH? command.

Command:

FETCH?|READ?|MEAS?

Command:

SENSe:AVERage:
COUNt AUTO ON|OFF

SENSe:AVERage:
COUNt <numeric _value>

Query Method	Pros	Cons
FETCH?	Faster speed. Accurate measurement at high power levels. Allows average count to be manually configured but requires defined settling time	Less accurate measurement especially at lower power level
READ?	Accurate measurement. Allows average count to be manually configured thus improving speed without a defined settling time	Slower speed than FETCH?
MEAS?	Accurate measurement	Slower speed. Does not allow manually-configured average count. Overrides some of the meter's settings

Table 1. Pros and cons of querying method

Triggering mode

A power meter has a very flexible triggering system and it can be described as having three selectable modes: Free Run, Single Shot, or Continuous Trigger.

Free Run mode

In this mode the power meter takes measurements continuously without entering into the idle state. INITiate:CONTinuous is set to ON and TRIGger:SOURce is set to IMMediate. In Free Run mode, the FETCH or MEAS command can be used to query the measurement.

Single Shot or Single Trigger mode

Here the power meter takes one reading and returns to idle state. INITiate:CONTinous is set to OFF and TRIGger:SOURce is set to IMMediate. In Single Shot or Single Trigger mode, the INIT and FETCH, or READ? or MEAS commands can be used to query the measurement.

Continuous Trigger mode

Using this mode the power meter takes a new measurement after each detection of an INTERNAL or EXTERNAL trigger event, by setting the instrument to TRIGger:SOURce INTERNAL or EXTERNAL. Both internal and external triggers are used to capture the complex modulated burst signal, particularly to measure the time-gated average, peak, peak-to-average, and average of the burst signal.

Querying tips (cont'd)

Triggering mode (cont'd)

Trigger Mode	TRIG:SOUR IMM		TRIG:SOUR INT|EXT	
	Free Run (INIT:CONT ON)	Single Shot (INIT:CONT OFF)	Continuous Trigger (INIT:CONT ON)	Continuous Trigger (INIT:CONT OFF)
Query Method				
FETCH?	FETCH?	INIT + FETCH?	FETCH?	INIT + FETCH?
READ?	–	READ?	–	READ?
MEAS?	MEAS?	MEAS?	MEAS?	MEAS?
Description	Continuously takes measurement	Take a measurement and then returns to IDLE state	Takes a measurement each time a trigger event is detected	Takes a measurement when a trigger event is detected and then returns to IDLE state
Type of Power	CW and average power		Time-gated average, peak, and peak-to-average power	

Table 2. Triggering mode comparison and summary

Command:

TRIGger:SOURce IMM|INT|EXT

Average mode vs. Normal mode

Each power meter and power sensor provides two different detector functions: Average mode and Normal mode.

Average mode is used to measure CW, or modulated, repeatable signals. It involves chopping the signals (to reduce 1/f noise) and includes RC filtering, which helps to further reduce the noise of the measured signal. Measurement speed is determined by the measurement mode: Normal, Double, and Fast.

Normal mode is used to measure time-gated average, peak, peak-to-average, or average power. In Normal mode, there is no chopper (hence no 1/f noise reduction) and no RC filtering. The reason for this is that Normal mode is targeting non-periodic, modulated signals. RC filtering constants are impossible to derive and apply to those signals. Chopping, which generates spikes as a side effect, requires blanking by removing samples around chopping spikes—this would completely destroy the measured modulated signal and any information during that period. To offset those noise disadvantages, Normal mode allows user to specify the measurement interval and its position relative to internal or external trigger events.

Detector function mode	Average	Normal
Type of power	CW and average power	Time-gated average, peak, peak-to-average power
Chopper and RC filter	Enables reduction of signal noise	Disable
Dynamic range	+20 to –60 dBm (example)	+20 to –30 dBm (example)
Gate length	Disable	Allowed to configure various durations
Measurement speed	Determined by NORMAL, DOUBLE, or FAST mode	Determined by gate length. The longer the gate length the slower the measurement speed and vice cersa
Triggering mode	Free run, single shot, and continuous external only	Free run, single shot, and continuous external only

Table 3. Comparison between Average mode and Normal mode

Power sensor measurement speed

There are three possible measurement speed settings: Normal, Double, and Fast. The default speed setting is Normal. In Normal and Double speed modes, full instrument functionality is available and these settings can be used with all power sensors. Double speed mode is two times faster than Normal speed mode. Fast speed mode is the fastest measurement speed however, it provide less accurate measurements compared to Normal and Double speed mode due to limiting functions such as average count.

Command:

SENSe:MRATe
NORMAL|DOUBLE|FAST

Measurement mode	Pros	Cons
Normal (by default)	Accurate measurement. Full function applied	Slower speed
Double	Accurate measurement. Full function applied and two times faster than normal speed mode	–
Fast	Faster speed than double speed mode	Less accurate measurement. Some functions are disabled (such as average count)

Table 4. Pros and cons of various measurement speed modes

Test configuration and SCPI commands

Figure 4 illustrates the configuration used to obtain CW and average power measurements.

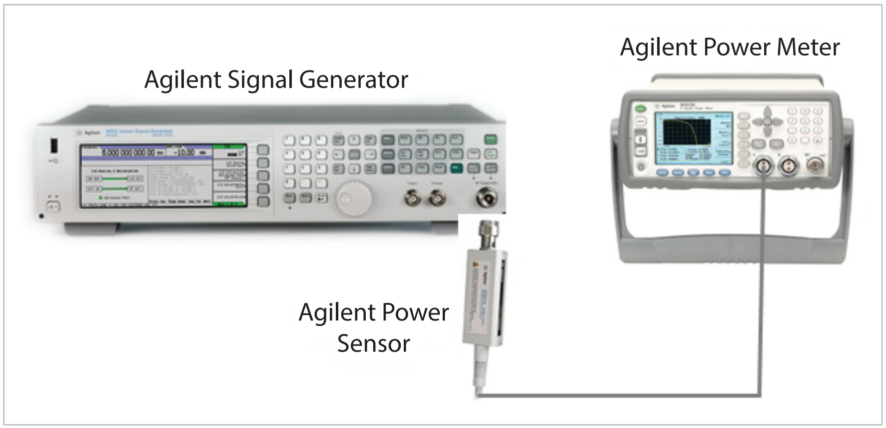

Figure 4. Configuration for obtaining CW and average power measurements

Test configuration and SCPI commands (cont'd)

Measurement data is acquired using the following SCPI commands.

SCPI	Description
Signal generator (Agilent ESG, PSG, EXT, and MXG)	
SYST:PRES	Preset the instrument to its default settings
FREQ 1GHZ	Set frequency to 1 GHz (example)
POW:LEVEL 0DBM	Set output power to 0 dBm (example)
OUTP:STAT ON	Turn on RF output
Power meter/sensor initialization	
SYST:PRES	Preset the instrument to its default settings
SENS:FREQ 1GHZ	Set frequency to 1 GHz (example)
SENS:DET:FUNC AVERAGE	Set measurement to Average mode for CW/ Average power measurement
SENS:AVER:COUNT:AUTO ON or SENS:AVER:COUNT 1	Set average count to Auto mode (by default it is auto average count) Set the average count to 1
SENS:MRATE NORMAL	Set measurement speed mode to Normal speed (Normal is the speed mode default Normal)
Querying CW/Average power	
Option 1: Query power in Free Run mode INIT:CONT ON FETCH?	Set to Free Run mode. In this mode, return the measurement using FETCH?
Option 2: Querying power in Single Trigger mode INIT:CONT OFF READ?	Set to Single Trigger mode. In this mode, return the measurement using READ? or INIT + FETCH?

Table 5 illustrates the differences between these three modes using various Agilent power meters and power sensors.

Power sensor	Measurement speed mode		
	Normal (20 readings/s)	**Double** (40 readings/s)	**Fast** (readings/sec)
8480 and N8480 series	50 ms	25 ms	–
E-Series E4410 and E9300	50 ms	25 ms	Up to 400
E-Series E9320 (average mode)	50 ms	25 ms	Up to 400
E-Series E9320 (normal mode)	50 ms	25 ms	Up to 1000
P-Series wideband	50 ms	25 ms	Up to 1500
U2000A Series USB average	50 ms	25 ms	Up to 110
U2020XA Series USB peak	50 ms	25 ms	Up to 180
U8480A Series USB thermocouple	50 ms	25 ms	Up to 400

Table 5. Comparison of measurement speed modes by power sensor

Conclusion

There a several ways to shorten the time it takes to acquire CW and average power measurements. Understanding the power meter's or power sensor's settings and available program commands plays a significant role in streamlining the data acquisition process. Agilent offers a variety of power sensors and power meters to provide measurement speed and data accuracy solutions for a range of budgets and application needs.

Reference

- *Agilent Practices to Optimize Power Meter/Sensor Measurement Speed and Shorten Test Time,* application note, literature 5990-8471EN.

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Published in USA, July 02, 2013
5991-2641EN

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