Keysight Technologies
Achieving Fast and Accurate Multi-Channel Power Measurements Over a Wide Dynamic Range for Wireless Manufacturing

Application Note

KEYSIGHT TECHNOLOGIES

1.0 Introduction

The traditional key requirements for RF power measurements for wireless chipset or power amplifier manufacturing are good repeatability, fast measurement speed, and high accuracy. Now, an emerging requirement is becoming increasingly important: obtaining a wide power measurement range, especially on the lower power level. This new requirement is due to the emergence of chipsets designed to handle a wider power range in order to support higher data throughput and wider coverage area.

In this application note, we illustrate the typical power measurement test setup for wireless chipset or power amplifier manufacturing, and explain the recommended sensor's settings base on different signal formats. These setups will help you achieve the fastest measurement speed, and most accurate power measurement over the widest power range. The paper concludes with the key features and benefits offered by the Keysight Technologies, Inc. U2040 X-Series power sensors, which have the world's widest dynamic range of 96 dB. The U2040 X-Series delivers the speed, accuracy, and wide power range that you need to ramp up and maximize your manufacturing throughput.

2.0 Typical Test Setup

Figure 1 shows the typical test setup for wireless chipset manufacturing test. Three power sensors are used to measure the chipset's input power, output power, and reflected power. A spectrum analyzer, like the Keysight Technologies MXA, is used to measure other critical parameters such as ACPR, EVM, and harmonics. Care should be taken to ensure that the power to be measured does not exceed the sensor's measurable power range in order to avoid damaging the sensor, particularly at the power amplifier's output. Depending on the signal formats, a trigger output signal from the signal source can be connected to the trigger input ports of the power sensors in order to synchronize the signal timing and sensors' measurement acquisitions.

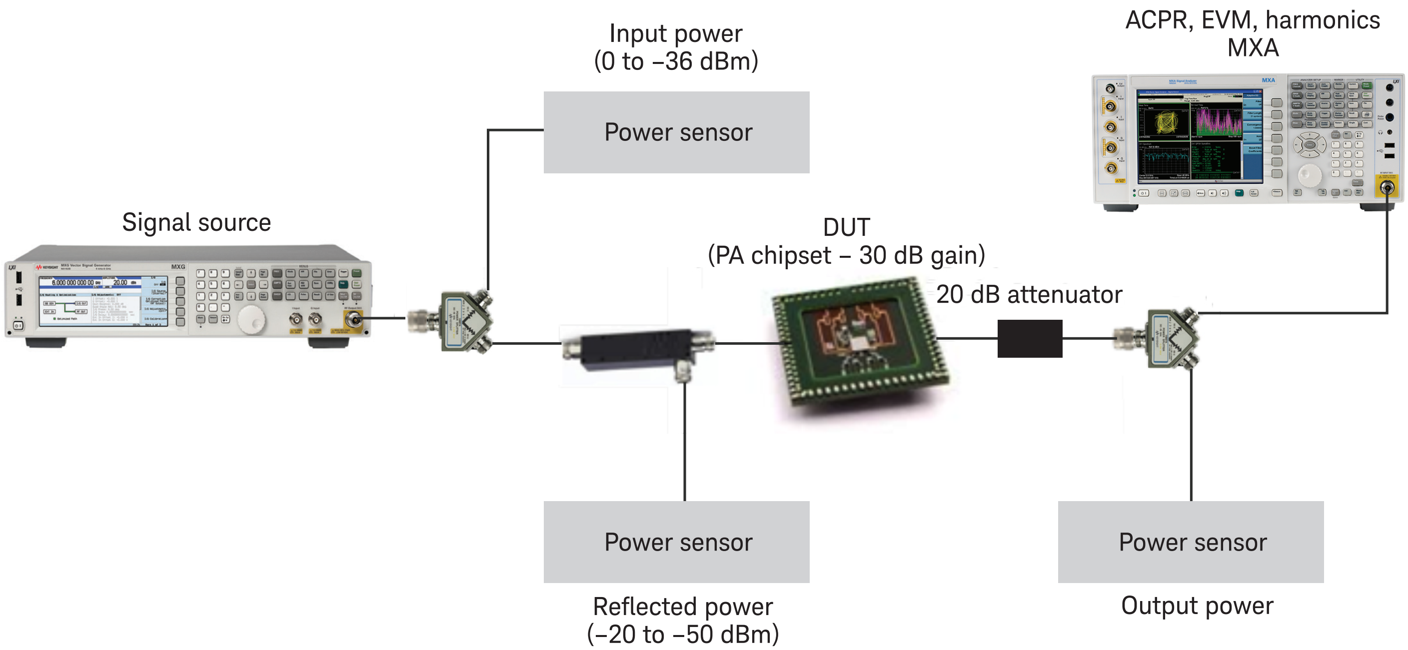


Figure 1. Typical test setup for wireless chipset manufacturing test

3.0 Recommended Sensor Settings for Wireless Tests

In order to achieve the most accurate and fastest measurements, the U2040 X-Series can be configured into different modes based on the signal formats. Below are a few common wireless signal formats and the recommended sensor settings.

Table 1. Common wireless signal formats and recommended settings

Type of measurement	Signals	Recommend sensor settings	Topic reference
Burst average power for signals with burst/ frame structure	LTE-TDD, GSM, EDGE, WLAN	Average mode time-selectivity	Example 1
Waveform average power for signals with burst/frame structure	LTE-TDD, GSM, EDGE, WLAN	Average mode time-selectivity	Example 2
Waveform average power for continuous modulated signals	W-CDMA, LTE-FDD	Free run, fast mode	Example 3
Time slotted signals without external trig-ger signals	GSM, EDGE	Normal mode time-gated power measurement	Example 4
Time slotted signals with external trigger signals	GSM, EDGE	Normal mode time-gated power measurement, or Average mode time-selectivity	Example 5 Example 6
Multi-format signals	A sequence that steps through a series of signal formats	Advance list mode	

4.0 Average Mode Time-Selectivity Measurements

The Keysight U2040 X-Series offers a new feature called average mode time-selectivity which allows you to configure the aperture duration of measurement capture with reference to the immediate trigger or external trigger. The aperture duration is settable from 100 µs to 200 ms with a resolution of 100 ns — a resolution low enough to cover any radio format. This new feature allows you to control which portion of the waveform is measured, giving you the same results as those provided by time-gated power measurements made in conventional normal mode (peak mode). The key benefits of this feature are that it enables the sensor to perform both waveform average and time-selectivity average power measurement across the full 96 dB of dynamic range, and offers real time measurements of up to 10,000 readings per second. This is a significant improvement compared to conventional sensors, which typically clip time gated power dynamic range measurement at around 50 dB and have a maximum speed of 1000 readings per second.

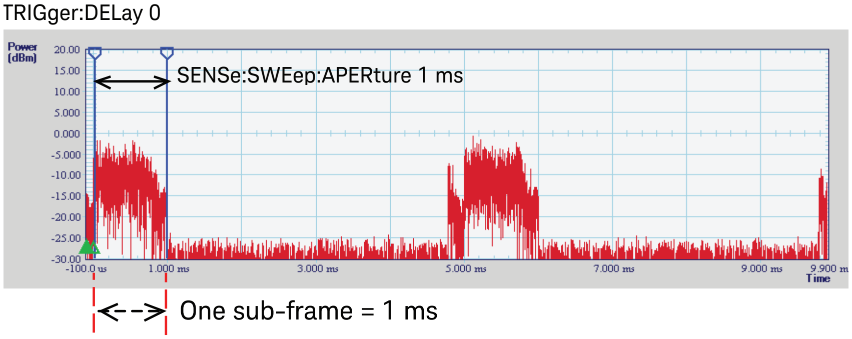
Examples 1 and 2 below show how to perform average mode time-selectivity measurements for LTE signals.

Example 1. LTE-TDD measurement using burst average power

For an LTE-TDD sub-frame of 1 ms, for example, you can measure the burst average power of one sub-frame by setting the aperture duration to match the sub-frame length (1 ms in this case). With the external trigger setting, the U2040A X-Series enables accurate measurement down to –50 dBm with an average count of 1. This provides you with assurance that the sensors are measuring every continuous 1 ms sub-frame.

Measure one LTE sub-frame of 1 ms (Burst average power)

TRIGger:DELay 0



SENS:MRATE FAST
TRIG:COUN 100
TRIG:SOUR EXT
SENS:SWE:APER 1 ms
TRIG:DEL 0
*OPC?
FETC? //Read back the burst average power with an array of 100 data

Figure 2. Measurement results for one 1 ms LTE sub-frame using burst average power setting.

Example 2. LTE-TDD measurement using waveform average power measurements

If you want to measure the average power of the whole LTE-TDD waveform, the aperture duration should be set equal to the LTE frame duration of 10 ms (which includes both the burst on and off period). No trigger alignment (TRIG:SOUR IMM) or high average count setting is required since the sensor is always measuring the full period of the burst, returning highly accurate and repeatable power measurements, while providing fast power measurement of the entire LTE waveform.

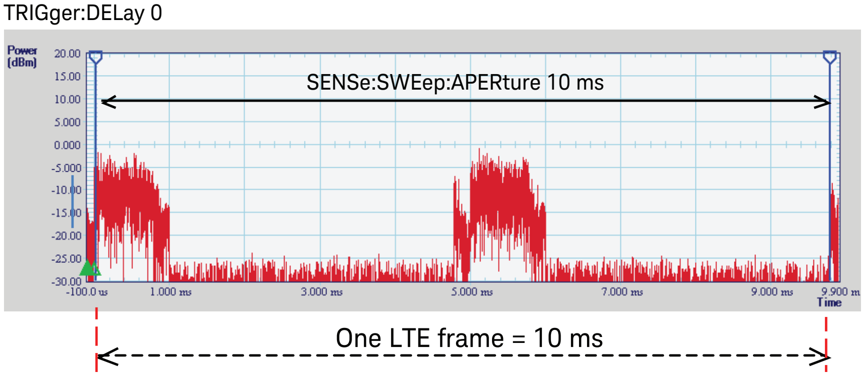
Alternatively, you can set the average count multiplied by the aperture duration to equal multiple integers of the pulse period:

Average count x Aperture duration = N x pulse period

Performing the same measurement with a conventional sensor requires a high average count since you have no control over the aperture duration, which needs to match the burst period.

Measure one LTE frame of 10 ms

TRIGger:DELay 0



SENS:MRATE FAST
TRIG:COUN 100
SENS:SWE:APER 10 ms
SENS:SOUR IMM
TRIG:DEL 0
*OPC?
FETC? //Read back the waveform average power with an array of 100 data

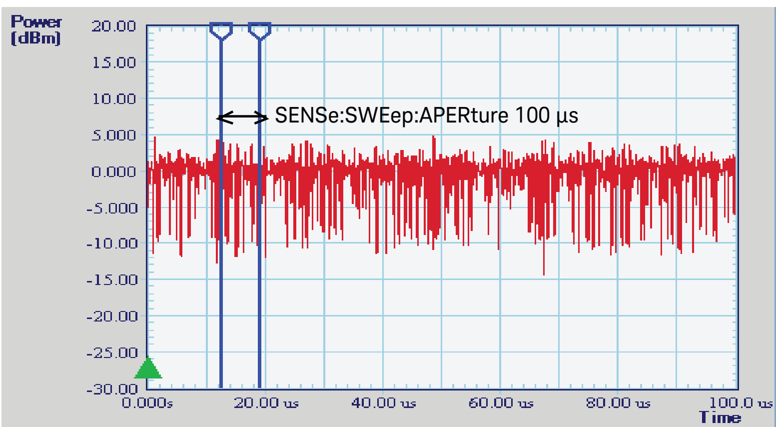
Figure 3. Measurement of one LTE frame over 10 ms using waveform average power setting.

Example 3. W-CDMA measurement using waveform average power measurement setting

The new average mode time-selectivity also can be used for continuous modulated signals such as W-CDMA or LTE-FDD. Typically for these types of signals, only the average power of the waveform is measured. Using the U2040, no special setting is required to complete this task when the sensor is set to its default-free run. The U2040 X-Series provides highly accurate average power measurements. To obtain the fastest measurement speed, set the speed mode to fast, aperture duration to 100 µs, and trigger count to 100. Real-time measurements performed at 10,000 readings per second are achievable using these settings.

Continuous WCDMA waveform (Free run average power)

TRIGger:SOURce:IMMediate



To obtain real time measurement of 10,000 readings per second, set the following:

```
CAL:AUTO OFF   //optional setting
SENS:AVER:COUN 1   //optional setting
SENS:AVER:SDET OFF   //optional setting
TRIG:DEL:AUTO OFF  //optional setting
UNIT:POW W   //optional setting
FORM REAL
SENS:MRATE FAST
TRIG:COUN 100
SENS:SOUR IMM
SENS:SWE:APER 100 µs
TRIG:DEL 0
*OPC?
FETC?    //Read back the waveform average power with an array of 100 data
```

Figure 4. Continuous W-CDMA waveform capture using free run average power setting.

5.0 Normal Mode Time-Gated Power Measurements

In some wireless applications, such as wireless module or board level testing, it is not possible to derive an external trigger signal from the device-under-test (DUT) or signal generator. Therefore it is the power sensor that must provide the internal trigger function. Using the internal trigger, the DUT output signal level is compared against the internal trigger level setting in the sensor in order to qualify for a valid trigger.

As shown in the prior section, the new average-only mode time-selectivity function only supports the immediate trigger and external trigger for measurement timing control. For an application where the external trigger signal is not available and timing of the measurement is important, Keysight recommends using the conventional time-gated measurement mode under normal mode (peak mode). In this mode, you can set the trigger source to immediate, internal, or external.

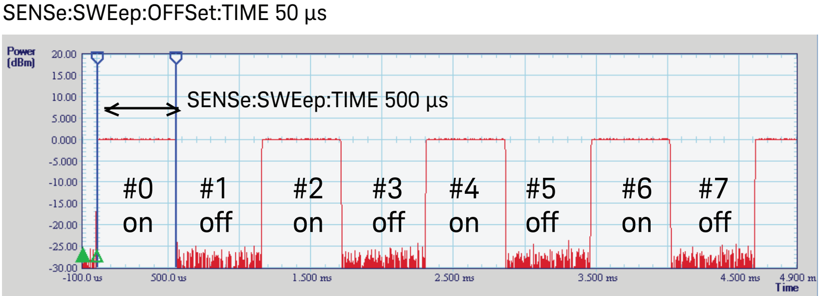
Example 4. GSM measurements using internal trigger time-gated average power measurement

To obtain measurements as quickly as possible, set the speed mode to fast, and set the gate start and gate length to match the GSM timeslot.

In this example, the objective is to measure the GSM timeslot with alternate slots set to on and off. The U2040 X-Series, with its internal trigger setting, is able to synchronize with the timeslot rate to achieve 1.2 ms per reading (equivalent to the time of two timeslots).

Measure GSM alternate timeslot
(Internal trigger time-gated average power)

SENSe:SWEep:OFFSet:TIME 50 µs



SENS:MRATE FAST
TRIG:COUN 100
TRIG:SOUR INT
TRIG:SEQ:LEV -10
SENS:SWE:OFFS:TIME 500 µs
SENS:SWE:TIME 50 µs
CALC:FEED “POW:AVER ON SWEEP”
FETC? //Read back gated average power with an array of 100 data

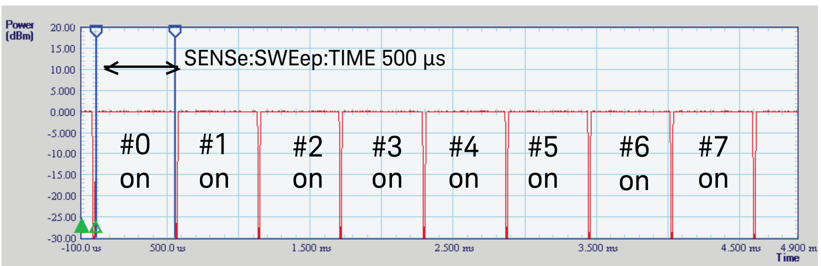
Figure 5. Measurement of GSM alternative time slot using internal trigger time-gated average power.

Example 5. GSM measurements using external trigger time-gated average power measurement

To measure every timeslot of a GSM frame, Keysight recommends using the external trigger setting. The U2040 X-Series is able to measure every timeslot with a measurement speed of 577 µs per reading; a rate that is similar to the GSM timeslot duration.

Measure GSM all timeslot (External trigger time-gated average power)

SENSe:SWEep:OFFSet:TIME 50 µs



SENS:MRATE FAST
TRIG:COUN 100
TRIG:SOUR EXT
SENS:SWE:OFFS:TIME 500 µs
SENS:SWE:TIME 50 µs
CALC:FEED “POW:AVER ON SWEEP”
FETC? //Read back gated average power with an array of 100 data

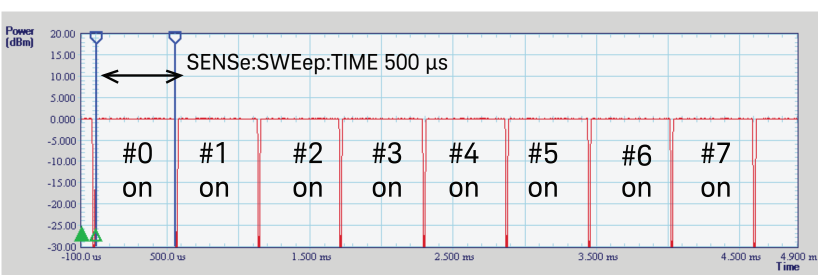
Figure 6. Measurement of all GSM timeslots using external trigger time-gated average power setting.

Example 6. GSM measurements using external trigger average mode time-selectivity

As an alternative to using the external trigger time-gated average power measurement, you can use average mode time-selectivity to measure every timeslot of GSM frame. The benefit of this method is that it provides a much wider dynamic range.

Measure GSM all timeslot (External trigger average mode time-selectivity)

SENSe:SWEep:OFFSet:TIME 50 µs



SENS:MRATE FAST
TRIG:COUN 100
TRIG:SOUR EXT
SENS:SWE:APER 500 µs
TRIG:DEL 50 µs
*OPC?
FETC? //Read back time-selectivity average power with an array of 100 data

Figure 7. Measurement of all GSM timeslots using external trigger average mode time-selectivity.

6.0 Advance List Mode

Most wireless chipsets are designed to operate under multiple modes or support multiple signal formats. It is therefore important to test all of the formats supported by the chipsets to ensure that they are meeting performance specifications, but testing all the supported formats results in long test times. The U2040 X-Series features an advance list mode to expedite this type of testing.

The advance list mode allows real-time, flexible measurement configuration of the sensor's settings from one acquisition to another acquisition. For instance, the sensor can be setup to measure a GSM timeslot with an aperture size of 500 µs at 900 MHz for the first three acquisitions, measure an LTE sub-frame with an aperture size of 1 ms at 700 MHz for the three subsequent acquisitions, and measure a WLAN preamble with an aperture size of 192 µs at 2.4 GHz for subsequent acquisitions.

Timing synchronization between the sensor and the DUT/source is achieved through a hardware handshake with the power sensor's built-in trigger in and trigger out ports. With every trigger input signal received, the sensor performs measurement capture base on the predefined settings and saves the measurement in its buffer memory. Once the whole sequence is completed, you can perform one fetch to retrieve all the measurements. This reduces programming overhead and idle times in the setup of the sensor or DUT/source.

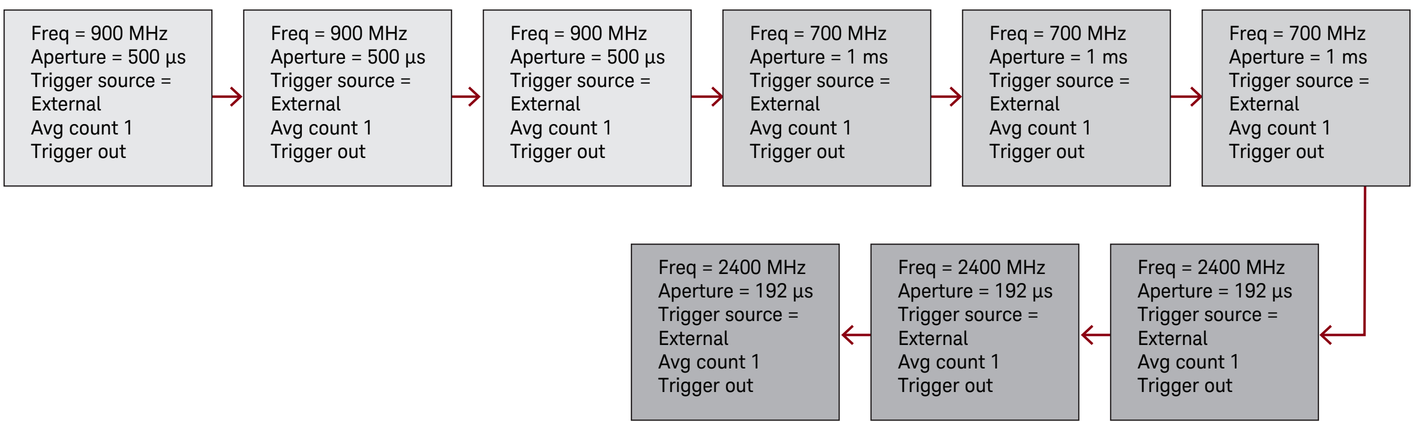


Figure 8. Speed up the measurements of multiple format signals with advance list mode of U2040 series

7.0 Keysight U2040 X-Series Key Features and Benefits

The Keysight U2040 X-Series is the ideal solution to reduce the cost of testing, and increase production throughput while maintaining high accuracy and repeatability. It offers unique features that:

- Increase test coverage with its wide dynamic range
- Cover a broad range of wireless signal formats including the broadband LTE-Advance or WLAN 802.11ac
- Achieve very good accuracy down to 0.2 dB over the full specified operating temperature and frequency range
- Enable flexible configuration and cost effective multi-channel power measurements

Fast measurement speed

The U2040 X-Series takes up to 10,000 real time readings per second in average mode. This is a 10x improvement over Keysight's previous sensor offerings. This measurement speed is fast enough to measure every continuous pulse without leaving time gaps in between measurement acquisitions.

World widest dynamic range power sensor

With its total dynamic range of 96 dB, no other sensor can match the Keysight U2040 X-Series' capability. Having the industry's widest dynamic range allows the sensor to measure a wide range of signals whether they are high power amplifier (PA) outputs or small reflected signals from the well-matched PA.

High accuracy and repeatability

This power sensor offers high accuracy: < 0.2 dB over the full operating temperature range of 0 to 55 °C and over the entire frequency range to 33 GHz. There is no other instrument that is able to offer a similar level of accuracy over this temperature or frequency range. You may be able to find a spectrum analyzer or network analyzer that provides accuracy close to this range, but that accuracy is only valid for certain power levels and at a specific temperature. With U2040 X-Series, you can be assured that there will be no over rejecting of good parts due to tight tolerances or limited specification margins. All the measurements obtained with the U2040 X-Series are traceable to standards set by national or international standard laboratories.

Broadband coverage

The U2040 X-Series makes accurate average or time-gated average power measurements for any modulated signal, and covers all common wireless signals such as LTE, LTE-Advanced with 100 MHz bandwidth, and WLAN 802.11ac with 80/160 MHz bandwidth. A four-path diode stack design with parallel paths to ADC (analog to digital converter) provides seamless range transition with high accuracy and repeatability. The four-path diode stack design enables all the diodes to operate in the diode's square law region, allowing the U2040 X-Series to function like thermocouple power sensors to provide accurate RMS power for broadband modulated signals.

Cost-effective and flexible solution for multi-channel power measurements

This series of sensors is a cost effective solution for multi-channel power measurements as illustrated in Figure 1. A complete multi-channel power measurement solution of a PA's chipset's input power, output power, and reflected power can be achieved with three U2040 X-Series sensors, while providing high accuracy and fast measurement speed that is suitable for any broadband wireless signal format. The sensors provide a very flexible solution and can be reused for other calibration purposes to improve the accuracy of a test system over a wide frequency, power, and temperature range.

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