Keysight Technologies

Long-Term, Remote Monitoring of Satellite Performance

Using a Keysight High-Frequency USB Power Sensor

Application Note

KEYSIGHT TECHNOLOGIES

1.0 Introduction

Satellite communication systems are driven by demands for increased data rates. Many satellite communication systems are operating at microwave frequencies such as the X, Ku, and Ka bands, which help to support a wider modulation bandwidth, increase capacity, and enable the use of smaller antennas. The increase in bandwidth, coupled with high operating frequencies, create significant challenges for RF engineers in testing a satellite system, module, or component.

This application note describes typical satellite applications that require power measurements and recommends power measurement solutions. It also explains how these solutions can help simplify your work, and improve accuracy, reliability and test coverage.

2.0 Satellite applications

Power measurements are critical in conducting satellite-related tests. To illustrate, the following sections describe three major applications where obtaining power measurements is required.

2.1 Continuous monitoring of power received at a satellite antenna tower

Due to the long distance between a satellite and an earth station, the signal received at the earth station is usually very weak. The condition may worsen with weather conditions such as cloud cover, humidity, and extreme temperature ranges that cause high atmospheric attenuation. Antenna misalignment can also result in power degradation. Continuous remote signal monitoring is important to ensure that the received signal-to-noise ratio is high enough that the communication link can function properly.

In situations where the antenna is receiving a very low signal (below –100 dBm), using a spectrum analyzer along with a power sensor can help ensure accurate measurements are obtained. The typical setup is illustrated in Figure 1.

Keysight Technologies' performance signal generator (PSG) provides a clean test signal that is used as a calibration source. The test signal travels through the entire measurement path, just like a signal received at the feed-in point of the antenna. Both signals go through the same amount of amplification and attenuation. Once the delta between the measurements of the power sensor and the Keysight Technologies, Inc. N9020A MXA signal analyzer is obtained, it is input as an offset, and used to calculate the power that arrived at the antenna feed-in point.

2.2 Satellite manufacturing test

Before a satellite is launched into space, it needs to be meticulously tested in a thermal vacuum chamber in order to simulate space's various extreme environmental conditions. The tests last for a few months, running 24-hours, 7 days a week. During that time the chamber is cycled through hot and cold temperatures and other environmental conditions. Ports on the side of the chamber allow various test equipment, in numerous racks, to be connected to the satellite in the chamber.

Power measurement is very important during the testing stage because it monitors the output power of the transmitters and detects any instability, power spikes, or glitches. Up to 20 power meters and sensors can be connected simultaneously to the satellite in order to perform comprehensive testing over the Ku and Ka bands. Power measurements are polled about once per second to ensure stability. A strip chart recorder is connected to the power meter's recorder output to record the data. If the transmitted power starts to vary, the test software shuts down the satellite to prevent damage. With a test cost of close to $1 million per day, it is critical to ensure that all measurements are done correctly and accurately.

2.3 Satellite component test

Traveling wave tube amplifiers (TWTAs) and repeaters are key components of a satellite system and require accurate power measurements.

TWTAs are used as amplifiers in satellite transponders when the input signal is very weak and the output signal needs to be a higher power. TWTAs are commonly used in a satellite because of their wide frequency coverage and high power capability. All TWTAs need to be tested for output power in order to ensure that they can generate sufficient output power for the satellite transponder to function properly.

Repeaters are used to amplify and retransmit the signal at another frequency. Each repeater acts as a receiver, frequency translator, and transmitter. Sometimes called transponder, a repeater typically consists of a low noise amplifier, a mixer or local oscillator, and a high-power amplifier such as a TWTA. As the receiver and transmitter in the repeater are operating at the same time and in close proximity, careful testing needs to be carried out to ensure that the transmitter does not interfere with the receiver.

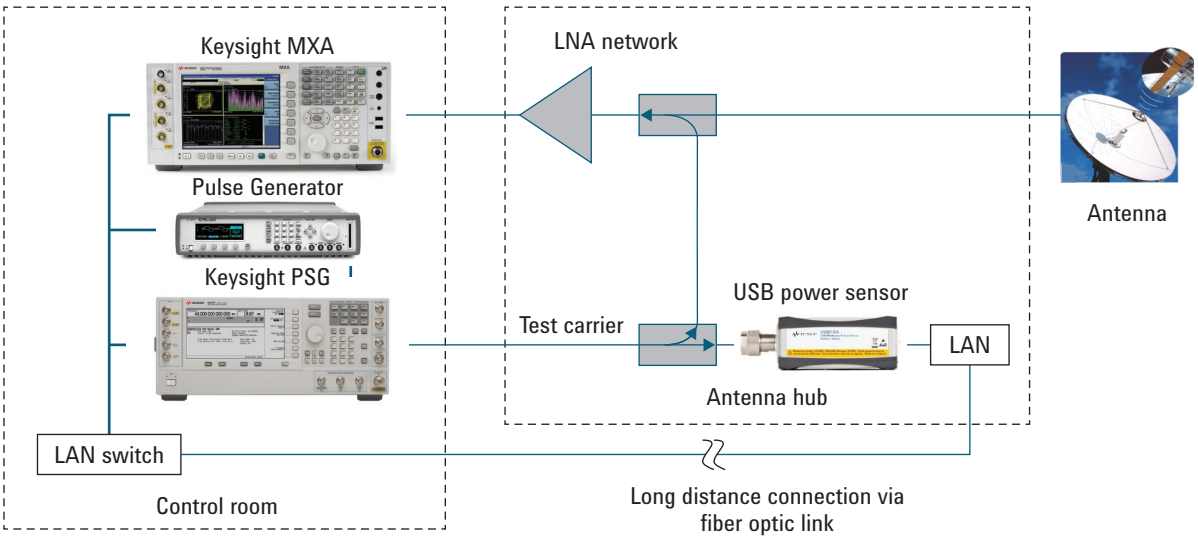

Figure 1. Typical test setup for continuous monitoring of the received power at a satellite antenna tower

3.0 Keysight power measurement solutions for satellite testing

The Keysight U2000 Series USB power sensors and U8480 Series thermocouple USB power sensors are ideal solutions for satellite testing applications.

Figure 2. Keysight USB power sensors

3.1 U2000 Series USB power sensors

The Keysight U2000 Series covers a wide dynamic range of –60 to +20 dBm and operates over a frequency range of 9 kHz to 26.5 GHz. With an internal zeroing feature, the U2000 Series enables users to perform zeroing without setting up external RF switches to remove the RF input to the sensors. This is particularly useful for remote and automated test environments where access to the sensor is not convenient or possible, such as in a vacuum chamber. The U2000 Series provides accurate average power measurements for any signal format whether it is a CW or modulated signal. The sensor's unlimited video bandwidth also means it is suitable to measure any signal format whether it is low or high bandwidth.

3.2 U8480 Series thermocouple USB power sensors

The Keysight U8480 Series covers a wide frequency range of DC to 67 GHz (sensor and option dependent), ideal for satellite testing up to Ku or Ka bands. With its thermocouple sensing element, the U8480 Series offers superior linearity and best-in-class standing wave ratio (SWR) performance for high accuracy measurements over a range of –35 to +20 dBm. Each sensor in the U8480 Series includes an integrated high-stability DC reference source and switching circuits, allowing the user to perform calibration while the sensor remains connected to the device under test (DUT). This feature removes the need to connect and disconnect from the external calibration source, thereby reducing test times, measurement uncertainty, and wear and tear on the connectors. This is very useful for satellite testing in a chamber where access to the sensors for calibration is inconvenient.

Although the U8480 Series does not come with internal zeroing, which typically means the user needs to remove the RF input power before performing zeroing, the U8480 exhibits extremely good long-term drift performance that can last for a few months before the next zeroing needs to be performed. This means that frequent zeroing is not require and only needs to be done at the beginning of the test. Figure 3 shows the long-term drift performance of U8480 Series and its impact to measurement uncertainty over power. The U8480 Series is also suitable for measuring any signal formats with unlimited video bandwidth.

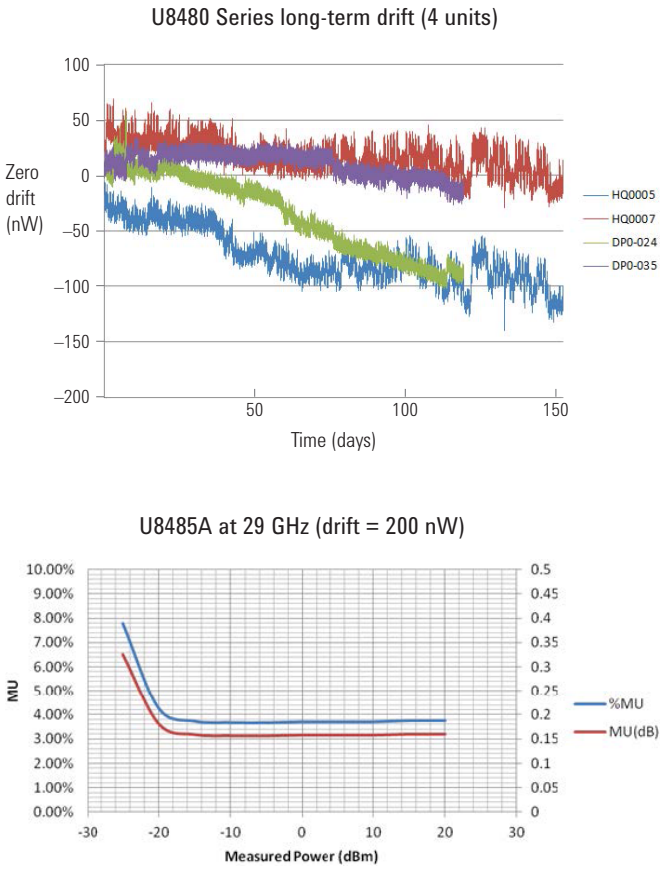

Figure 3. Long term drift performance of U8480 Series USB thermocouple power sensors and its impact to measurement uncertainty over power range

3.3 U2020 X-Series peak and average USB power sensors

The Keysight U2020 X-Series covers a wide frequency range of 50 MHz to 40 GHz. It is capable of performing peak, average, and peak-to-average power ratio measurements, as well as pulse parameter characterizations from –35 to +20 dBm with a video bandwidth up to 30 MHz. Each U2020 sensor comes with Keysight's patented internal zeroing and calibration technology that integrates a DC reference source and switching circuits into the sensor so that the user can perform zeroing and calibration while the sensor is still connected to a DUT. This is a particularly useful test solution for unmanned satellite remote monitoring.

3.4 Temperature compensated measurements

All of Keysight's USB power sensors go through stringent product characterization and testing in production and to ensure conformance to exacting quality standards prior to shipment. The sensors go through careful characterization over frequencies, power levels, and a wide temperature range of 0 to 55 °C. Correction factors are stored in the sensor's memory to correct for variations due to frequencies, power levels, and temperature. The sensor's built-in thermistor detects ambient temperature changes so that the right correction factor will be applied to compensate for any temperature-related drift. Therefore, all the USB power sensors are able to maintain high accuracy over a wide temperature range.

4.0 Long term, remote monitoring made easy with USB power sensors

4.1 Programming versatility

All Keysight power meters and sensors can be programmed remotely using direct SCPI commands or through the available IVI-COM, IVI-C, or Labview/Labwindows CVI drivers. This enables test software development to be done using your choice of programming languages whether it is Keysight VEE, Labview, C, C++, C#, Visual Basic or Mathlab.

4.2 Length extension with hub or extender

In satellite applications, whether it is remote monitoring of a satellite antenna tower, or testing a satellite in a vacuum chamber, the distance between the control room to the actual measurement point can be several hundred feet. Conventional power meter and sensor solutions are limited by a 200-foot maximum cable length. A USB sensor with its USB-specific length limit can extend up to a maximum of 5 meters. However, with the use of a commercially-available network USB hub or USB extender, the maximum cable length can be extended up to 90 meters (depending on the specifications of the hub or extender).

Figure 4. Sample of USB extender (left) and a commercially-available network USB hub (right)

4.3 Software for long-term remote monitoring and data logging

A powerful and capable software application is important to complement the USB power sensor in performance monitoring of a satellite system. The Keysight N1918A power analysis manager software (Option 100 or 200) enables remote monitoring and data logging for up to 500 days. Users can schedule the data logging to start and end at any time, and the data acquisition rate can be set between 40 ms to 5 s per reading. The software can also be setup to monitor the power over a range of limits. When the limits are violated, the software alerts the user and the measured readings are recorded with a timestamp for post-processing. Alternatively, users can elect to write their own software program using the standard SCPI commands or drivers provided to record and monitor the measurements.

Each Keysight U2020 X-Series sensor also has a built-in recorder output. Using an SCPI command it can be activated to output a voltage proportional to the measured reading. This allows the user to connect it to a plotter or strip chart recorder, and print out the history of measurements for hardcopy filing. The recorder output provides a voltage output proportional to the measurement readings over a range of 0 to 1 V.

4.4 Multi-channel power measurements

Multi-channel power measurements are easy to make using Keysight USB power sensors in combination with an active USB hub. The N1918A power analysis manager software allows users to connect more than 20 USB power sensors and use the multi-list view to see all of the measurements on one screen (see Figure 5). This allows users to continuously monitor many different RF channel measurements at the same time and to perform mathematic operations between the channels such as ratio and delta.

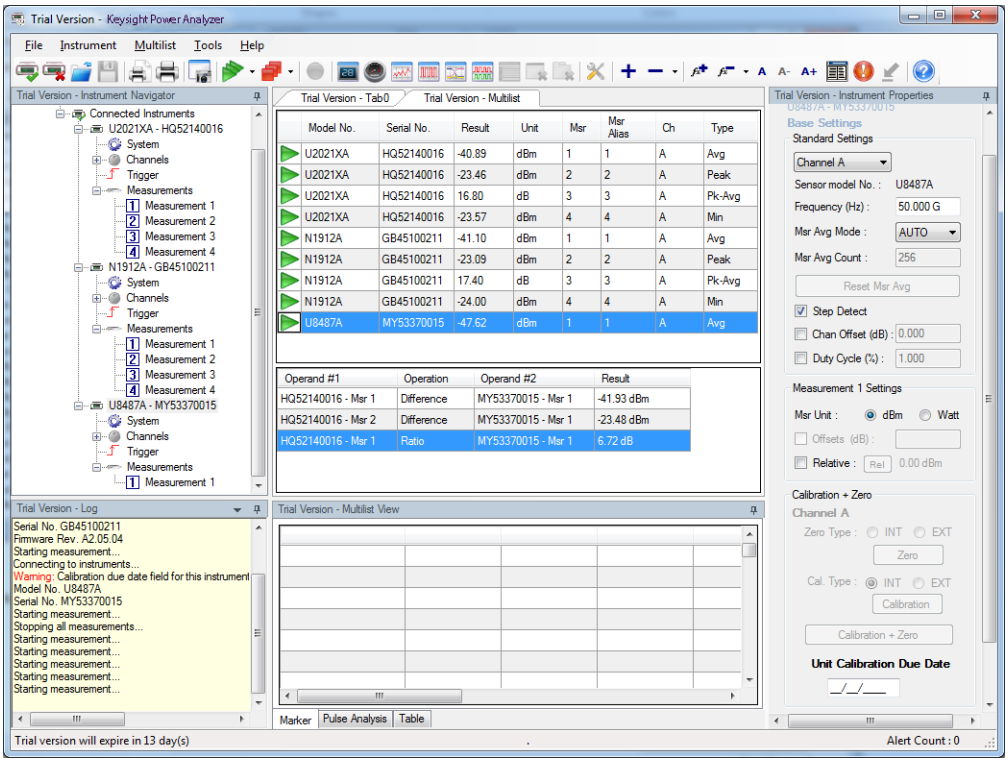

Figure 5. Multi-list display format of Keysight N1918A power analysis manager supports more than 20 USB power sensors simultaneously

5.0 Other useful USB sensor features

5.1 Fast measurement speed

The U8480 Series USB power sensor is the one of the world's fastest thermocouple USB power sensor with a measurement speed of 900 readings per second (in Fast mode). Coupled with its thermocouple sensing element, it makes fast measurements without compromising accuracy. With a slight trade off of accuracy, the U2020 X-Series, with its diode sensing element, provides measurement speeds up to 25,000 readings per second. The fast measurement speed of the U2020 and U8420 means it takes less time to carry out the same number of test; a feature that is especially important in high volume manufacturing where it is essential to maximize production throughput and increase productivity.

5.2 Gamma and S-parameter corrections

Both the U8480 and U2020 Series USB power sensors are the first sensors from Keysight to offer gamma and S-parameter corrections to improve overall measurement uncertainties (see Figures 6 and 7).

The gamma correction corrects for mismatch between the sensor and

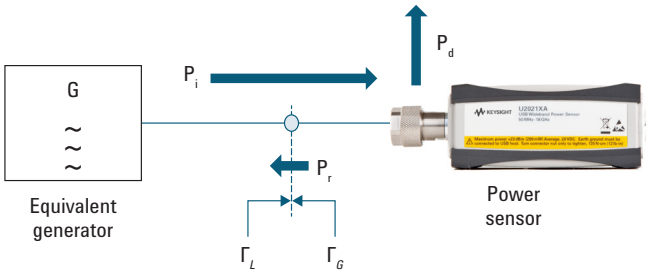

Figure 6. Gamma correction

DUT. This is accomplished by users entering in the reflection coefficient of the DUT to the sensor via the Keysight N1918A software, or via direct SCPI commands. The sensors then perform the necessary complex mathematic algorithm to correct for mismatch errors.

In a lot of applications, the sensor is not able to connect to the DUT

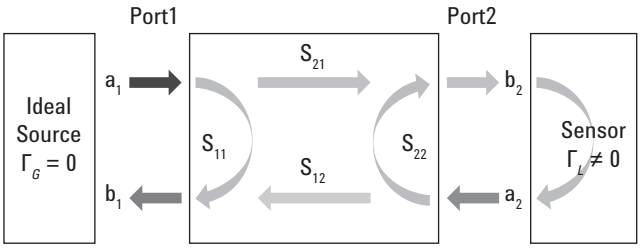

Figure 7. S-parameter correction

directly. Instead the connection is made using cables, adapters, attenuators, or amplifiers. The S-parameter correction feature enables users to input the S-parameters files of these components (obtained easily with vector network analyzer (VNA) in touchstone format) into the sensor via the N1918A software, or via direct SCPI commands (see Figure 8). Using the S-parameter correction feature, the mismatch, gain, or loss of these two-port devices is corrected. The sensor behaves as if it is connected to the DUT directly so users obtain highly accurate power measurements.

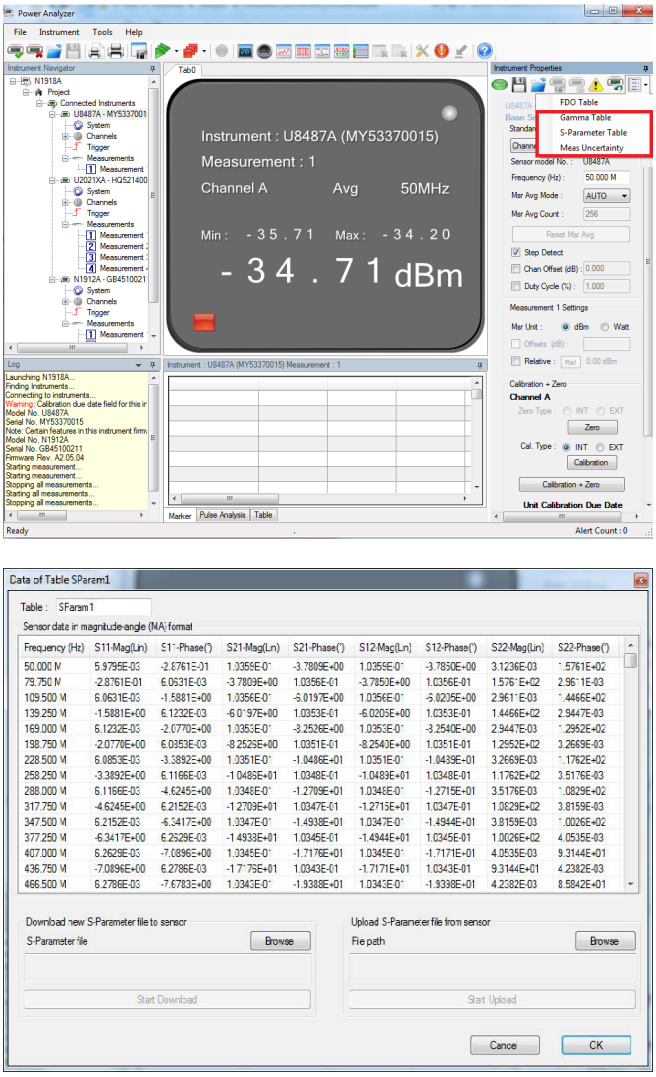

Figure 8. Keysight N1918A power analysis manager enables easy input of the DUT gamma and S-parameter files into the sensor's memory for gamma and S-parameter corrections

5.3 Real-time measurement uncertainty (RTMU) display

Measurement uncertainty (MU) analysis is normally a very tedious, time-consuming process involving a lot of manual calculations. It is even more complex and tedious when a user is measuring over a range of frequencies or power levels. The user has to calculate the MU for each of these points individually. The Keysight U8480 Series is the world's first power sensor that computes these values automatically in real time and at any given point, eliminating manual calculations, simplifying work, and shortening test time (see Figure 9). The overall measurement uncertainty is also improved since the calculation uses characterized data in the sensor's memory, which is unique to each sensor, instead of using the specifications data which normally includes a guard band to allow for variations between production batches. The RTMU display is enabled on the Keysight N1918A software, or using new SCPI commands, to turn on ("SENS:MUNC:STAT ON") and fetch the results ("FETC:MUNC?").

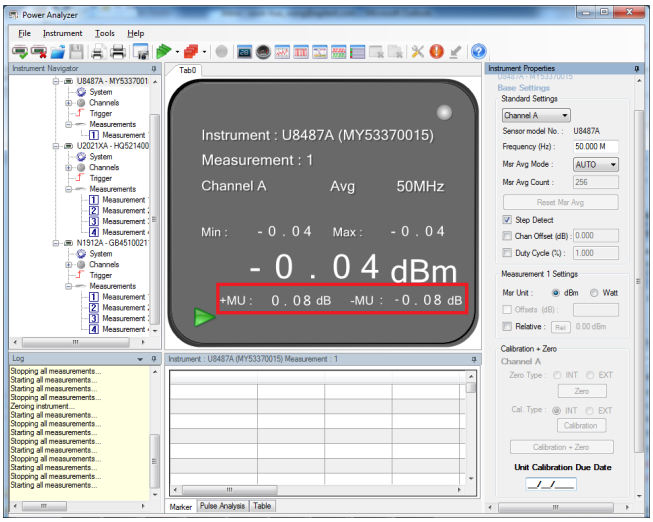

Figure 9. Real-time measurement uncertainty display of the Keysight U8480 Series thermocouple power sensor

5.4 Compatibility with other Keysight instruments

All Keysight USB power sensors are compatible with the PNA Series of network analyzers, MXG X-Series and EXG X-Series signal generators, Fieldfox handheld RF and microwave analyzers, and other handheld instruments.

For more details and the latest compatibility information, refer to *Compatibility of USB Power Sensors with Keysight Instruments*, literature number 5989-8743EN.

Capabilities of compatible instruments

- PNA, PNA-L, PNA-X for source power calibration and receiver testing
- MXG/EXG for external power leveling and support of up to two USB power sensor measurements
- Fieldfox for average power, peak power and pulse characterization

6.0 Conclusion

Satellite testing, whether it is for components, modules, or the whole system, is growing increasingly complex and demanding higher accuracy and reliability. Defects and non-conformance can lead to dramatic consequences, and sometimes lives are at stake. As a result, manufacturers must deliver high quality products with utmost reliability. Effective satellite testing requires high performance testing equipment combined with thorough testing in order to meet the stringent expectations of customers. Keysight offers a wide variety of power measurement equipment that is ideal for accurate and reliable satellite testing.

Related literature

Publication title	Publication type	Publication number
Keysight U8480 Series USB Thermocouple Power Sensors	Data sheet	5991-1410EN
Keysight U2020 X-Series USB Peak and Average Power Sensors	Data sheet	5991-0310EN
Keysight U2000 Series USB Power Sensor	Data sheet	5989-6278EN
Keysight N1918A Power Analysis Manager	Data sheet	5989-6612EN
Keysight Power Meters and Sensors	Selection Guide	5989-7837EN
Compatibility of USB Power Sensors with Keysight Instruments	Application note	5989-8743EN
Single / Multi-Channel Power Measurement	Application note	5989-6280EN

Additional information

More information about Keysight power meters and sensors is available at www.keysight.com/find/powermeters

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