APPLICATION NOTE

Keysight X8711A IoT Device Functional Test Solution

Accurately Measure Path Loss for Over the Air Transmitter and Receiver Measurements

The Internet of Things (IoT) is revolutionizing our world. It brings tremendous convenience to our daily activities, improves our safety, and makes our world a better place to live. Many electronics companies are riding the IoT wave to increase the competitiveness of their products by incorporating IoT connectivity. However, many engineers face challenges in connecting the devices, because devices such as hearing aids, sensors, wearables, and implantable devices are very small. It is impossible to include a connector on the product in order to perform measurements.

The Keysight X8711A IoT Device Functional Test Solution solves this problem by enabling engineers to perform over-the-air testing without a physical connection to the device. Its ability to communicate wirelessly with an IoT device, combined with a shield box to filter out interference, allows the user to perform accurate transmitter power, receiver sensitivity, and packet-error-rate (PER) tests in just seconds. By using the right system offset to compensate for over the air (OTA) and cable losses, the user can easily make accurate measurements.

This application note describes how to improve the accuracy of the Keysight X8711A by properly measuring path loss and applying the right system offset in the test plan.

Test IoT devices in final form and actual operation—no chipset specific driver or wired connection required.

Ensure your IoT devices meet quality levels by measuring key parameters, including transmitter power, receiver sensitivity, and packet-error-rate.

Maximize production throughput – complete transmitter and receiver tests in seconds.

Ensuring Good Accuracy and Repeatable Measurements

The X8711A's accuracy is specified at the RFIO port of the Keysight 34999A RF module, which interfaces with the device under test (DUT). Measurements can be either conducted measurements via wired connection (Figure 1a) or radiated measurements using an antenna coupler and shield box (Figure 1b). To ensure accuracy and repeatability, the user applies a system offset to compensate for the losses of the wiring and the antenna coupler.

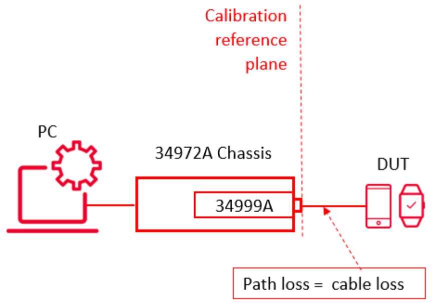


Figure 1a: Conducted measurements via wired connections

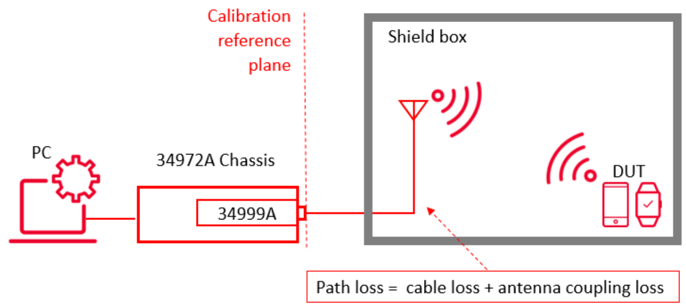


Figure 1b: Radiated measurements using antenna and shield box

System offset is the gain or loss between the RFIO port of the 34999A and the DUT. For example, in Figure 1a, the DUT is connected to the 34999A RFIO port via a cable with 0.5 dB loss. The system offset is therefore -0.5 dB. In Figure 1b, the DUT is inside a shield box with an antenna coupler, and the shield box is connected to the 34999A RFIO port via a cable. The system offset is the cable loss plus the OTA antenna coupling loss.

There are typically three ways to obtain the RF cable loss. You can read it from the cable datasheet (Figure 2), perform S-parameter measurements using a network analyzer, or use a combination of signal generator and signal analyzer to measure and calculate the cable loss. With the network analyzer, the S21 measurement will be the cable loss. For signal generator and signal analyzer combination, the cable loss will be the signal generator output power minus the signal analyzer measured power.

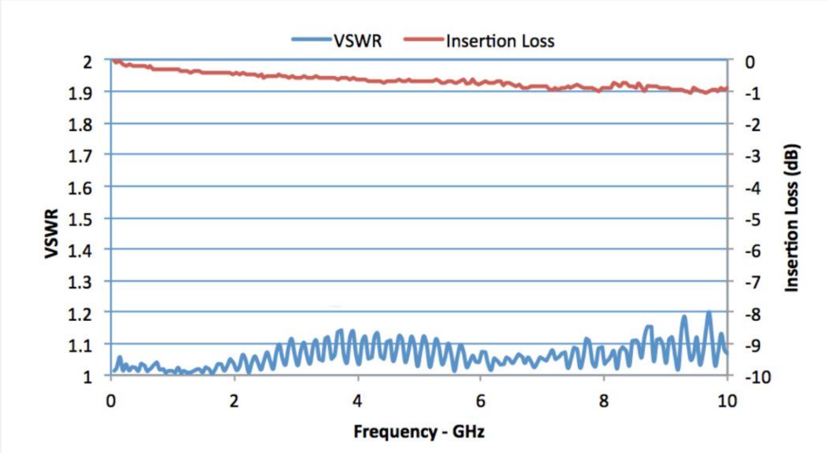


Figure 2: Typical insertion loss and VSWR of a RF cable

The next step is to measure the OTA antenna coupling loss. You must perform an experiment to determine the coupling loss, as described in the following section.

Determining System Offset

Follow these simple steps to determine the system offset.

1. Identify or create a good reference unit (golden unit).
2. Measure the antenna coupling loss of the golden unit.
3. Calculate the system offset.
4. Apply the system offset and verify measurement results.

Step 1: Identify or create a good reference unit (golden unit)

First, pick a good reference unit with a known output power. For example, in this application note, the DUT we are using is a Bluetooth® Low Energy (BLE) device with default output power specified as 0 dBm. The actual output power from the device could be different from what is specified in the specification. If the difference is significant, this could add additional error to the measurement results. In the following section, we will describe how to measure the actual output power of the DUT to create a good reference DUT using the X8711A.

Creating a good reference unit

If you do not have a good reference unit with known output power, you can create one by performing these simple steps.

Identify five or more samples of your DUT. Eventually we will choose one with the best performance as the reference unit. Connect one DUT to the 34999A RFIO port directly through a wired connection (as in Figure 1b). You may also replace X8711A with any spectrum analyzer or power meter for added accuracy. Modify a copy of the BLE signaling test plan in “C:\Program Files\Keysight\TAP8\IoTDeviceTest\TapFiles\” by setting the system offsets to 0 for all three advertising channels. Set up the test step so that the advertising power measurements to repeat at least three times.

Run the test plan for each sample DUT and obtain the measurements results from “C:\Program Files\Keysight\TAP8\Results”. Calculate the average and standard deviation of advertising power measurements for each DUT and choose the unit with the smallest standard deviation to be your good reference DUT. Record the average of the three advertising power readings (P_{out}) of this DUT to use in the subsequent procedure.

Using the procedures above, we have measured the BLE device using the X8711A and calculated the P_{out}:

P_{out} (ch 37, 38, 39) = -1.2 dBm, -0.59 dBm, -0.71 dBm

Step 2: Measure Antenna Coupling Loss

Put the reference DUT in the shield box. Create a 'Coupling loss test plan' by leveraging one of the test plan comes with the KS833A1A software.

1. Set System Offset to Zero.
2. Specify MAC address of DUT (set mode to User Entry).
3. Repeat Advertising power measurement for at least three times.
4. Verify that the test plan runs successfully.
5. Rename and save the test plan.

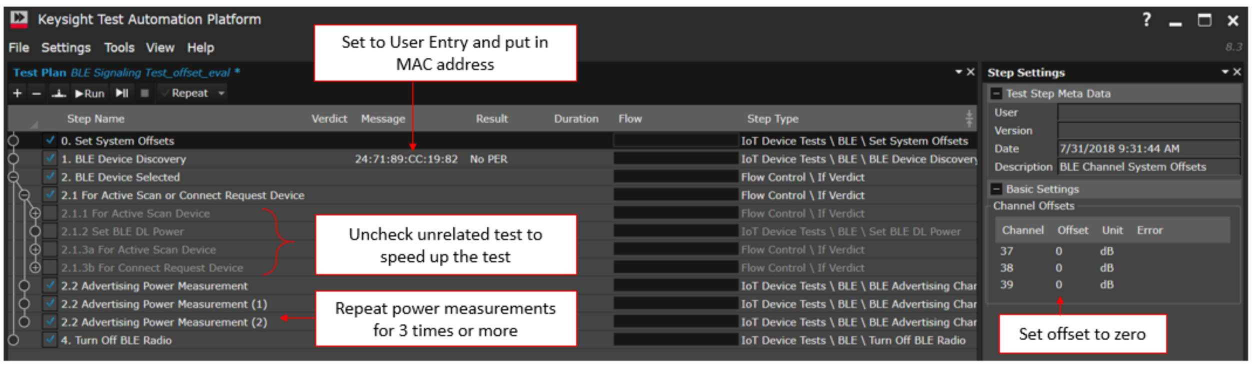
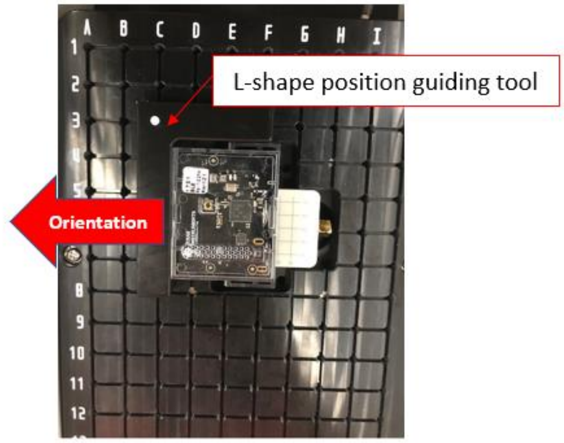


Figure 3: Sample Path Loss Test Plan leveraged from C:\Program Files\Keysight\TAP8\IoTDeviceTest\TapFiles\BLE Signaling Test.tapplan

Because losses vary based on the DUT's position, you should measure the DUT in several locations and orientations within the shield box. Record the advertising power measurement readings of these different positions and average the power measurement results from "C:\Program Files\Keysight\TAP8\Results" to form a heat map (Figure 4).

		B	C	D	E	F	G
2	CH37 Power	-18.87	-16.78	-19.47	-21.05	-22.51	Fail
	CH38 Power	-18.88	-16.92	-18.48	-22.59	-24.88	Fail
	CH39 Power	-21.01	-19.19	-20.77	-22.91	-25.55	Fail
3	CH37 Power	-19.01	-15.43	-18.15	-16.70	-17.29	Fail
	CH38 Power	-19.04	-14.92	-17.11	-15.96	-15.94	Fail
	CH39 Power	-20.17	-16.48	-18.59	-17.05	-18.13	Fail
4	CH37 Power	-21.92	-23.96	-18.01	Fail	Fail	-22.53
	CH38 Power	-21.07	-23.25	-16.92	Fail	Fail	-21.19
	CH39 Power	-23.07	-22.82	-18.44	Fail	Fail	-28.90
5	CH37 Power	Fail	-21.00	-24.02	-17.36	-19.99	-25.20
	CH38 Power	Fail	-22.38	-20.34	-16.85	-19.60	-25.43
	CH39 Power	Fail	-26.70	-22.88	-19.08	-22.10	-29.39
6	CH37 Power	Fail	Fail	Fail	Fail	Fail	Fail
	CH38 Power	Fail	Fail	Fail	Fail	Fail	Fail
	CH39 Power	Fail	Fail	Fail	Fail	Fail	Fail



Best position and orientation with lowest loss

		A	B	C	D	E	F
2	CH37 Power	-20.00	-13.04	-10.92	fail	-20.00	fail
	CH38 Power	-18.47	-11.96	-11.01	fail	-20.34	fail
	CH39 Power	-18.88	-13.84	-13.82	fail	-21.35	fail
3	CH37 Power	-19.28	-12.42	-11.53	-14.13	-17.32	fail
	CH38 Power	-18.10	-11.71	-11.87	-14.32	-18.50	fail
	CH39 Power	-16.89	-12.90	-14.14	-16.00	-19.55	fail
4	CH37 Power	-17.33	-15.75	-20.99	fail	fail	fail
	CH38 Power	-16.02	-15.41	-22.52	fail	fail	fail
	CH39 Power	-16.49	-22.91	-28.00	fail	fail	fail

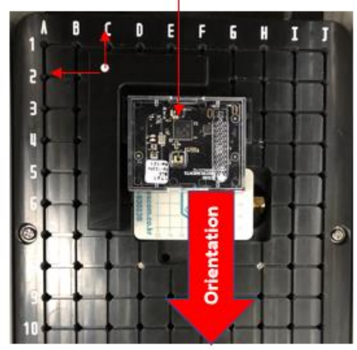


Figure 4: Sample heat map with Texas Instrument BLE sensor tag and Tescom TC-5910D shield box and antenna coupler

Find the position and orientation for the DUT with the lowest loss. Mark the position and orientation of the DUT in the shield box and record the power measurement as $P_{measured}$.

$P_{measured}$ (ch 37, 38, 39) = -10.92 dBm, -11.01 dBm, -13.82 dBm

Some shield boxes come with gridlines and a position guiding tool that helps user to place the DUT in a fixed location that can be used for subsequent measurements.

Step 3: Calculate System Offset

Now you can calculate system offset, or path loss:

$$\text{System offset} = \text{Path loss} = P_{measured} - P_{out}$$

Use the P_{out} and $P_{measured}$ calculated from step 1 and 2:

System offset (Ch 37) = –10.92 – (–1.2) = –9.72 dB
System offset (Ch 38) = –11.01 – (–0.59) = –10.42 dB
System offset (Ch 39) = –13.82 –(–0.71) = –13.11 dB

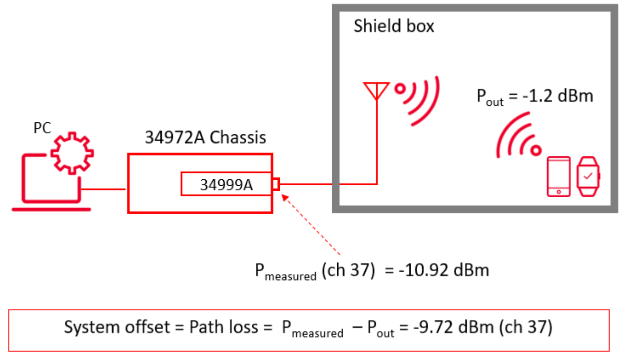


Figure 5: System offset calculation

Step 4: Apply System Offset and Verify Measurement Results

Once you have calculated the system offset, enter them in the 'System Offset' test step.

Run the test plan again, using the reference DUT to verify the accuracy and repeatability of measurements. With the right system offset applied, you should get very close to the DUT P_{out} as calculated in step 1 for the Advertising Power Measurement. (Figure 6)

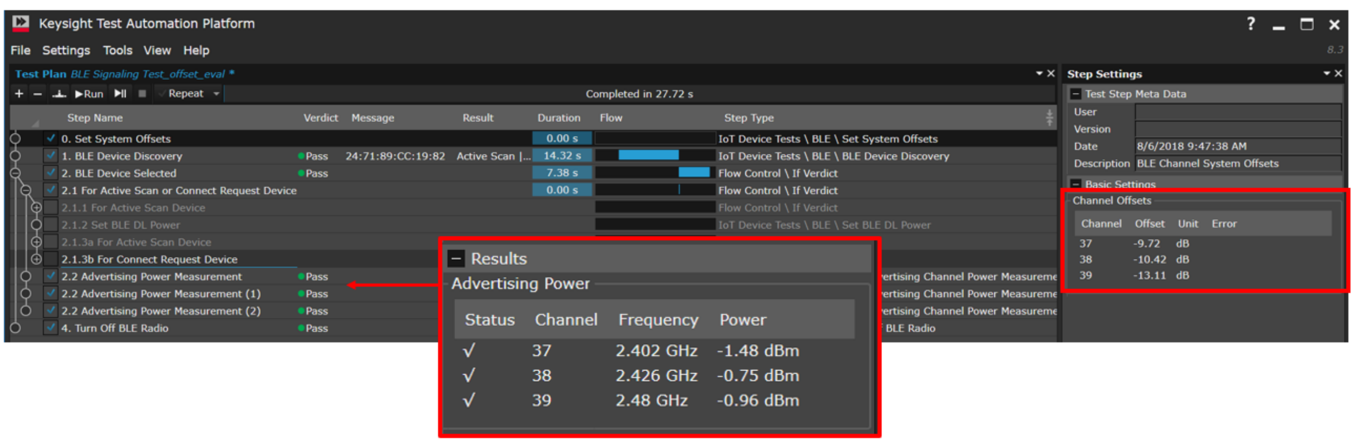


Figure 6: Applying system offset into the test plan to compensate for the path loss

Now the system is properly adjusted to measure the output power for other DUTs. It is a good practice to perform this adjustment daily before the start of production testing to ensure the system performance is not degraded due to wear and tear of some of the components.

Summary

The Keysight X8711A enables accurate OTA transmitter power and receiver packet error rate measurements on IoT devices without physical connection to the device under test. By properly measuring for the path losses and applying these losses as system offsets in the test plan, accurate transmitter power measurements can be achieved down to ±2 dB accuracy.

For More Information

X8711A IoT device functional test solution datasheet
https://literature.cdn.keysight.com/litweb/pdf/5992-2810EN.pdf

Top 5 challenges in IoT device manufacturing test
https://literature.cdn.keysight.com/litweb/pdf/5992-3008EN.pdf

X8711A IoT device functional test solution YouTube playlist

https://www.youtube.com/playlist?list=PLvQ5Bzr3tM52nITxPhwBJWZzEEnMSbGv4