

The LitePoint Factory Efficiency Module: Maximizing Production Throughput and Increasing Station Up-Time



Wireless device manufacturers are always striving to deliver high volumes of high-quality products to market, but one of the most essential stages in the manufacturing process—RF testing—is becoming increasingly challenging. The testing is difficult to perform, it is time consuming and it impacts manufacturing throughput.

RF testing is particularly challenging in today's smartphone market because most devices are built with multimode capabilities to offer LTE/HSPA/GSM/CDMA services as well as Wi-Fi, Bluetooth and GPS. The use of multiple antennas in a device increases the number of tests required along with the number of RF parts that can fail, underscoring the need for rigorous testing. For these and all types of wireless devices, manufacturers are seeking ways to guarantee the highest quality of each product while optimizing yield. They must ensure test accuracy and prevent test failures that can erroneously reject healthy products.

One of the most critical issues manufacturers deal with during testing is the need to maintain RF signal integrity between the device under test (DUT) and the test equipment. Material handling procedures can often impact RF signal integrity and for this reason many production facilities deploy test equipment fixtures that automate connecting DUTs to the test equipment via RF cables and RF probes. However, these systems can become compromised. RF probes are subject to wear and tear, for example, which can degrade the RF signal. If a spring-loaded RF probe is bent, locked in the compressed position or misaligned in the fixture so that it does not connect properly to the intended touch point, a test can fail, requiring retesting of the affected DUTs and servicing of the test fixture.

The LitePoint Factory Efficiency Module embeds RF signal integrity diagnostics into the test equipment and can automatically assess the RF performance of a fixture to detect and diagnose fixture-related failures. The tool dramatically improves production yield while minimizing the time and costs associated with scheduled fixture maintenance.

This paper highlights LitePoint Factory Efficiency Module features and their benefits and provides general guidelines for their use.

Enhancing RF Production Test Flow with the LitePoint Factory Efficiency Module

The LitePoint Factory Efficiency Module has firmware, installed in the test platform, that can automate the test fixture calibration process, help detect component wear and tear, ensure that DUTs are properly installed in the test fixture, and perform return loss measurements. The features include Fixture Health Check, DUT Sense, and Return Loss.

Fixture Health Check (HCH) is a feature that tests and measures RF path characteristics represented in the time domain. It establishes a reference value for a "healthy" fixture (HCH Ref). Subsequent fixture measurements (HCH Tests), compared against that reference value, reveal changes in the performance of the fixture and all cables. The feature can be used to alert the user if the fixture's RF measurements vary from the reference value, indicating degradation of performance. Fixture Health Check benefits include detecting potential wear and tear issues that affect system performance. The feature helps minimize yield losses attributed to inaccurate tests. It also enables companies to perform path loss calibration procedures only as necessary, reducing the need for scheduled calibration.

DUT Sense (DS) reveals whether or not the DUT is properly installed in the test fixture. If one or more of the devices on the DUT are not fully connected it alerts the user. It can be used to prevent initiation of the DUT test program until the DUT is detected, or to automatically initiate the test program when the DUT is properly inserted. The DUT Sense feature is important because it eliminates false starts and resulting test failures caused by RF continuity problems that lead to placing the DUT in a retest flow. The benefits are achieved without impacting test time because the DUT Sense feature can be performed during device boot.

Return Loss (RLOSS) enables the user to perform return loss measurements for each RF port on the test equipment. It makes these measurements readily available to the test line, eliminating the need to bring specialized vector network analyzer equipment to the test station. It also provides a general purpose tool for troubleshooting RF problems at factory or lab test setups.

A Streamlined Setup and Test Process

Testing wireless devices with the LitePoint Factory Efficiency Module takes place in two stages, test station setup and device test. The entire process involves **8 steps** (see Fig. 1).

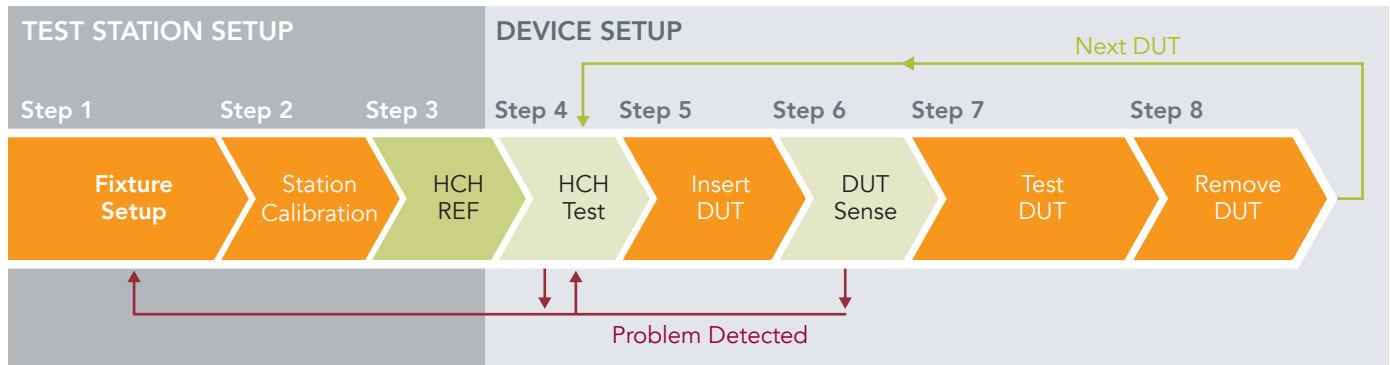


Figure I.1. Production Test Flow with Factory Efficiency features

Test station setup is usually performed once, at the beginning of each shift, to set up the fixture and establish the state of the equipment before the test process begins. The procedures include **step 1**: connecting the test equipment to the fixture; **step 2**: performing calibration of the station as per standard process; and **step 3**: capturing and storing the reference measurement for characterizing the “healthy” fixture (HCH Ref).

The device test stage begins as soon as setup is complete. The procedures include **step 4**: testing the health of the fixture against the reference measurement while the fixture is empty to ensure it is working properly (HCH Test), which prompts service of the fixture if necessary. This is followed by **step 5**: inserting a DUT into the fixture. **Step 6** takes place during boot-up: the fixture automatically determines if the DUT is inserted properly (DUT Sense). If the DUT Sense function detects an insertion problem, the DUT is reinserted and tested again. If the DUT is inserted properly, it is followed by **step 7**: the DUT Test. The last step is **step 8**: removing the DUT from the fixture.

After the operator removes the DUT and prior to the insertion of the next DUT, while the fixture is empty, the HCH Test function evaluates the fixture’s state again and prompts fixture service if necessary. The HCH Test, DUT insertion, DUT Sense, DUT Test and DUT removal process is repeated for all DUTs that are evaluated.

Benefits: The streamlined setup and test process offers many benefits. In general, the HCH Test and DUT Sense functions work together to detect problems, such as those that arise from wear and tear of the fixture. The process minimizes yield loss caused by test fixture quality problems. The process can eliminate unnecessary scheduled or periodic maintenance tests and offers other important conveniences as well. For example, there is no need to repeat the setup procedure as long as the fixture is working properly; this is only repeated if a fixture problem is detected during HCH Test. Further, there is no overall impact on test time for either feature because the tests can be performed during other routine functions. Fixture Health Check is performed during material handling time and DUT Sense is performed during the device boot.

Establishing the Fixture Health Check Reference Measurement

Establishing a Fixture Health Check reference measurement is part of the setup process (see Fig. 2, Step 3).

This step requires taking a time-domain reflectometry (TDR) measurement when the fixture is in its open (disconnected) state to create a reference measurement of the RF path between the test equipment and the DUT side of the fixture. This step is performed at the end of the setup process and before the production test flow begins. The results are stored for later use by the Fixture Health Check Test and DUT Sense functions.

To perform the reference test, the user specifies the approximate maximum path loss expected, specifies the required resolution bandwidth if desired, and initiates a fixture reference measurement. After the measurement is taken, the user has the option to retrieve the fixture TDR magnitude and distance lists. Programming commands used for these procedures are listed in Example 2. Graphical illustrations of the process used to establish the reference measurement, with sample results, are depicted in Figure 3.

Once the Fixture Health Check reference measurement has been established (HCH Ref), the fixture is ready for operation. The user will not need to perform this step again as long as the fixture connections are not altered. If the fixture is reconfigured or serviced, or if there is any material change in the state of the fixture, the reference measurement must be repeated.

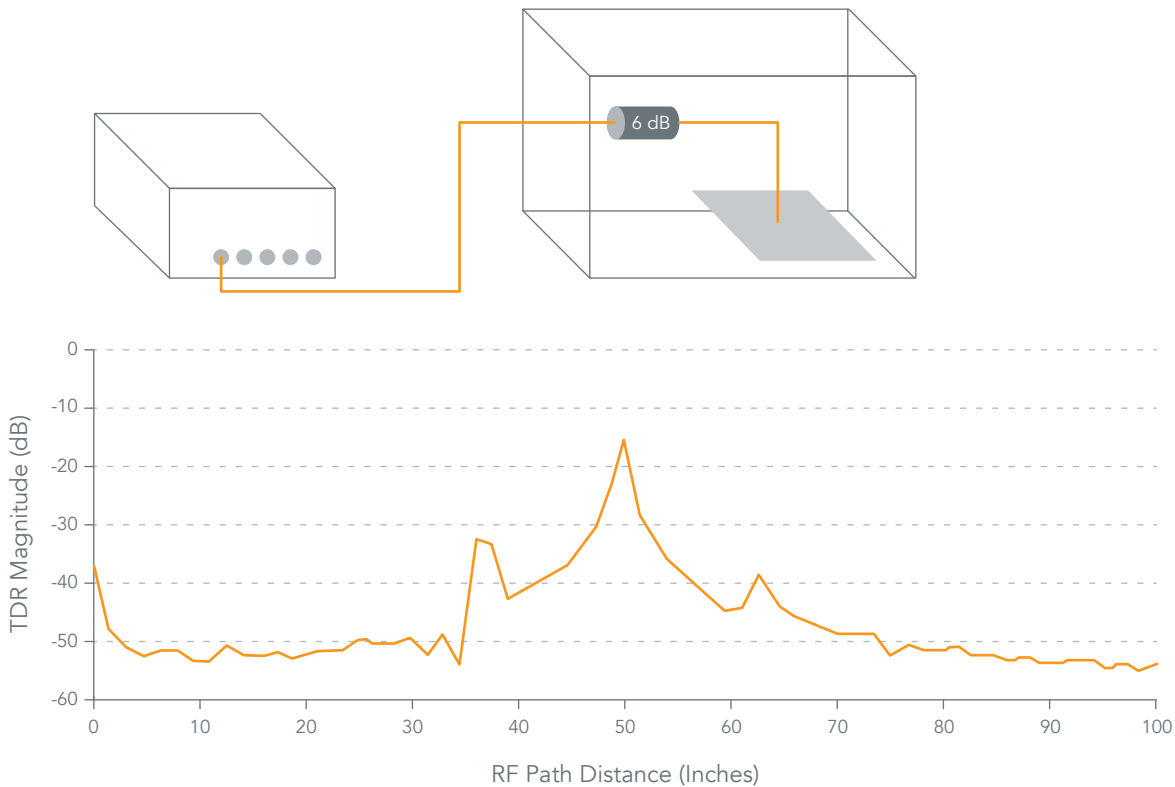


Figure 3: Establishing the Health Check Reference Measurement

Example 2: Establishing the Fixture Health Check Reference

Specify Maximum Path Loss	FEFFiciency:HCHeck:MPLoss 15
Specify Resolution BW (optional)	FEFFiciency:HCHeck:FREquency:RBW 50e6
Measure and Store Reference	FEFFiciency:HCHeck:REFerence RF1A
Retrieve TDR Magnitude List (optional)	FEFFiciency:HCHeck:REFerence:TDR? RF1A
Retrieve TDR Distance List (optional)	FEFFiciency:HCH:DLIST?

Performing the Fixture Health Check Test

Once the fixture is ready for operation, the Fixture Health Check test is performed to confirm the RF integrity of the fixture (see Fig. 2, Step 4).

The Fixture Health Check test (HCH Test) takes place at the beginning of the test cycle, before every DUT insertion. The test can reveal if anything in the test fixture is faulty, if it has excessive wear or tear, or if the fixture needs service. A problem is indicated by a change in path loss compared to the reference measurement. The test can detect problems that cause a path loss change of 0.25 dB or more.

To perform the test, the user is given an option to configure HCH sensitivity. If this configuration is not used, the test will use a default value of 50%. The user then executes the HCH Test and, if desired, retrieves the TDR magnitude list and TDR distance list. Programming commands used for these procedures are listed in Example 3.

The option of configuring the sensitivity threshold is available for users who want to establish how much path loss change the algorithm needs to detect. The objective is to make the test sensitive enough to detect real failures but not so sensitive that it generates false failures. Configuring the sensitivity level based on a path loss change of 0.25 dB is ideal for most test conditions. However, the appropriate sensitivity threshold depends on many factors, including path loss external to the fixture and the location of the continuity problem as well as the frequency used. Furthermore, at certain sensitivity levels, thermal noise can adversely influence the test. Figure 4 illustrates the impact of these considerations on sensitivity settings and can be used to set a threshold level.

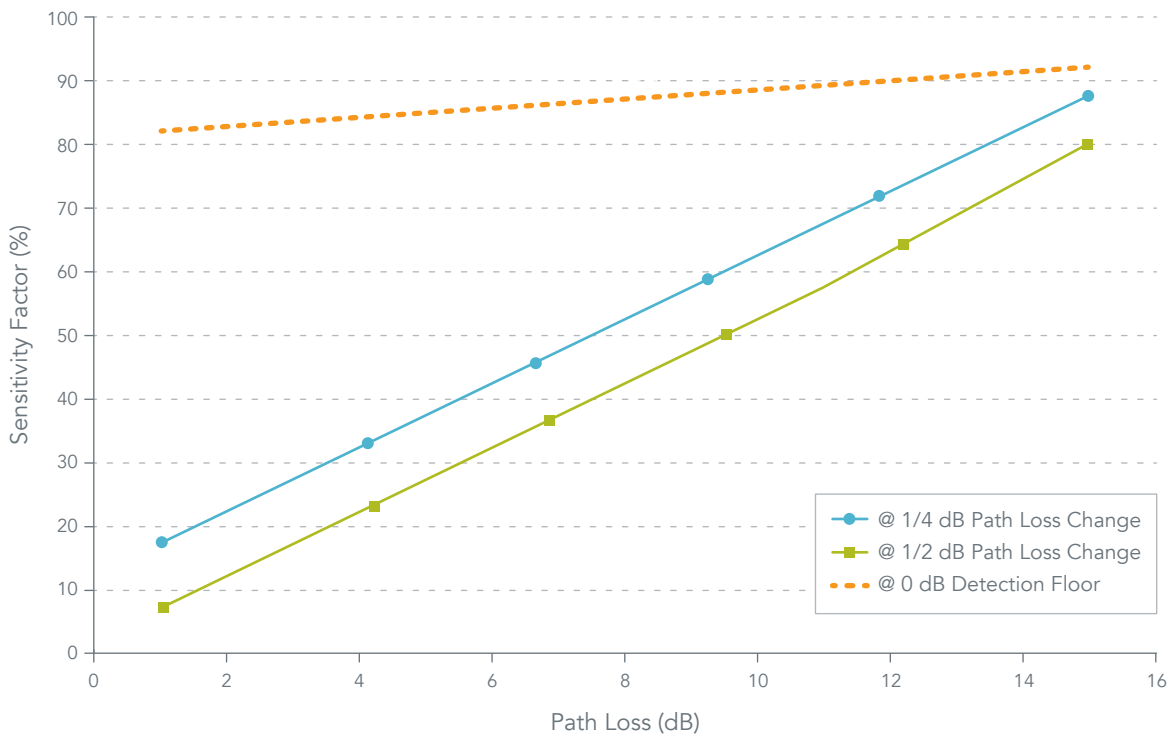


Figure 4: Figure Health Check Detection Sensitivity

Example 3: Fixture Health Check Test

Configure HCH Sensitivity (optional)	FEFFiciency:HCHeck:SENS 50
Execute HCH Test	FEFFiciency:HCHeck? RF1A
Retrieve TDR magnitude list (optional)	FEFFiciency:HCHeck:TDR? RF1A
Retrieve TDR distance list (optional)	FEFFiciency:HCHeck:DLIST?
Retrieve TDR delta list (optional)	FEFFiciency:HCHeck:DELTA:TDR? RF1A

Test Function Results

The test function measures the state of the fixture and returns one of three results: disconnected, connected or error. The results must be considered within the context of the test being performed (Fixture Health Check Test or DUT Sense).

0 = Disconnected: The Fixture Health Check Test (HCH Test) matches the reference state, indicating a PASS condition for a successful fixture health test

1 = Connected: The DUT is properly connected, indicating a PASS condition for a successful DUT Sense

2 = Error: A generalized error result that can signify an error in setup or an unsuccessful test

DUT Sense

DUT Sense determines if a DUT is properly seated in the test fixture (See Fig. 2, steps 5-6)

Every time a DUT is inserted into the fixture, DUT Sense looks for a change in impedance to indicate that the DUT is properly connected to the fixture. If the DUT is inserted correctly, DUT Sense can be used to initiate the DUT Test program. If the DUT is not inserted correctly, DUT Sense will prevent the test from starting. DUT Sense can also indicate if the DUT itself is faulty.

To optimize DUT Sense performance, the user has the option of configuring a DUT Sense threshold. This threshold specifies the amount of reflection energy from the fixture Open state that should be eliminated when the DUT is connected. Next, the user inserts the DUT and executes DUT Sense. The user can then retrieve the TDR data, TDR distance list and TDR delta list if desired. Programming commands used for these procedures are listed in Example 4.

Note that the DUT Sense function detects the load change at the reflection distance of the previously open RF probe and the resulting metric represents the relative change in energy reflected from the probe (dBr). When the impedance at the RF probe connection is perfectly matched, all reflected energy from the RF probe is eliminated, resulting in a DUT Sense metric of 0 dBr. A negative DUT Sense metric indicates that the impedance match is not optimal; it will be accompanied by path loss. The relationship between DUT Sense metric and path loss is illustrated in Figure 5.

When compared to the Fixture Health Check Reference in a disconnected state, a well-matched connection will eliminate the signal path reflection at the probe distance. However, the DUT connector is typically well matched only for the operational frequency range and will present reflections on the other frequencies. These reflections will exhibit a shift in phase resembling the transition from an Open to a Short. In this case, the DUT Sense metric returns a positive number, which is still indicative of a good connection established at the RF probe. In some cases, as well, a negative value can also indicate a passing result.

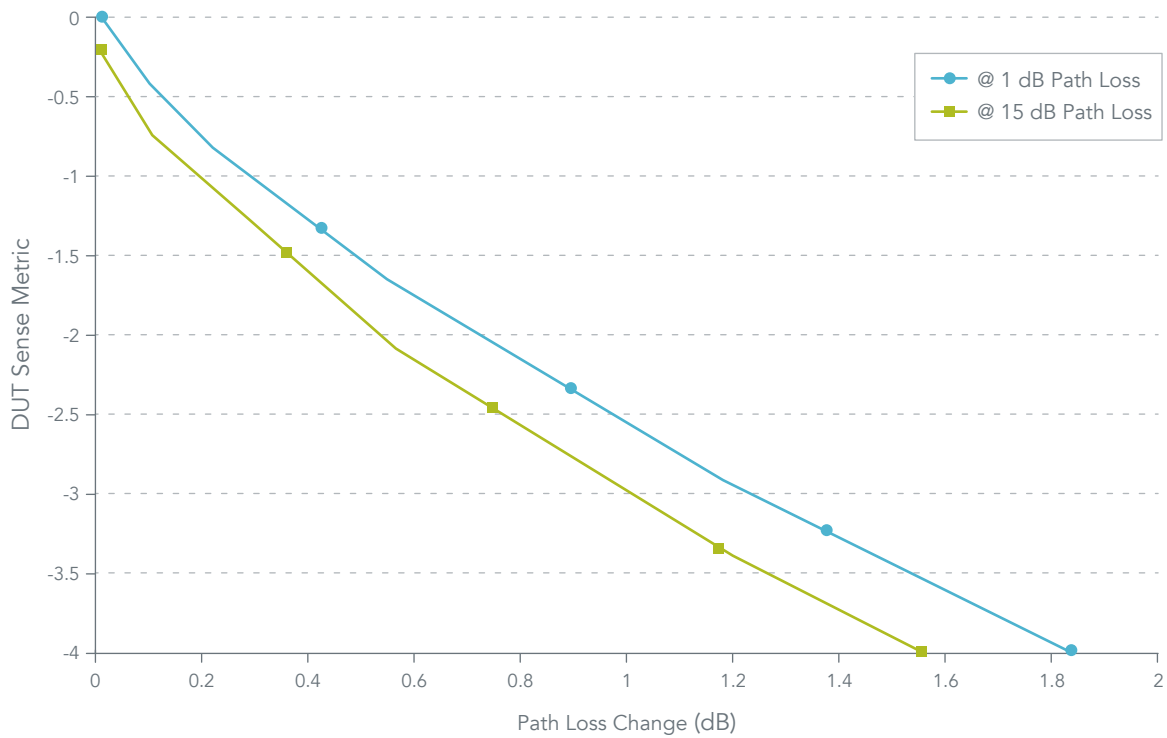


Figure 5: DUT Sense Metric

Example 4: DUT Sense Test

Configure DUT Sense Threshold (optional)	FEFFiciency:HCheck:THReshold -3
Execute HCH Test	FEFFiciency:HCheck? RF1A
Retrieve TDR Data (optional)	FEFFiciency:HCheck:TDR? RF1A
Retrieve TDR Distance List (optional)	FEFFiciency:HCheck:DLIST?
Retrieve TDR Delta List (optional)	FEFFiciency:HCheck:DELTA:TDR? RF1A

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Measuring Return Loss

All test systems supporting the LitePoint Factory Efficiency Module are precalibrated for accurate return loss measurements. If necessary, the user can update the system calibration at the port reference plane by following and Open-Short-Load (OSL) calibration process with a standard OSL calibration kit.

To update system OSL calibration, simply connect Open and calibrate. Connect Short and calibrate and then connect Load and calibrate. An option is offered for restoring factory calibration settings. Programming commands used for these procedures are listed in Example 5.

Example 5: Updating System OSL Calibration

Connect OPEN and Calibrate	FEFFiciency:CALibrate:OPEN RF1A
Connect SHORT and Calibrate	FEFFiciency:CALibrate:SHORT RF1A
Connect LOAD and Calibrate	FEFFiciency:CALibrate:LOAD RF1A
Restore Factory Calibration (optional)	FEFFiciency:FACTory:CALibrate:RESTore RF1A

The factory efficiency module uses return loss measurements when evaluating fixture quality. The system interface provisions for two independent reference planes:

PORT: The test equipment port reference plane

- When the LitePoint Factory Efficiency Module is enabled, factory calibration for the PORT reference is included.

FIXT: The fixture reference plane

- User calibration is required before return loss functionality can be used.
- Return loss is not typically measured at the FIXT plane, but if the user wants to extend the calibration plane to the end of the fixture it requires an Open, a Short and a Load calibration.

To measure return loss at the test equipment port, simply specify the preferred frequency list and then measure and retrieve the return loss data. Programming commands used for these procedures are listed in Example 6.

Example 6: Measuring Return Loss at the Test Equipment Port

Specify Frequency List	FEFFiciency:RLOS:FREQuency:LIST (500e6:3000e6:10e6) or FEFFiciency:RLOS:FREQuency:LIST (1000e6,2000e6,3000e6)
Measure and Retrieve Return Loss Data	FEFFiciency:RLOS? RF1A

To measure return loss at the fixture RF probe, specify the preferred frequency list, set the frequency list source, then insert Open and calibrate, insert Short and calibrate, insert Load and calibrate and then measure and retrieve the return loss data.

Example 7: Measuring Return Loss at the Fixture RF Probe

Specify Frequency List	FEFFiciency:RLOS:FREQuency:LIST (500e6:3000e6:10e6) or FEFFiciency:RLOS:FREQuency:LIST (1000e6,2000e6,3000e6)
Set Frequency List Source	FEFFiciency:CALibrate:FIXTure:FLISt:SOURce RLOSS
Insert OPEN and Calibrate	FEFFiciency:CALibrate:FIXTure:OPEN RF1A
Insert SHORT and Calibrate	FEFFiciency:CALibrate:FIXTure:SHOR RF1A
Insert LOAD and Calibrate	FEFFiciency:CALibrate:FIXTure:LOAD RF1A
Measure and Retrieve Return Loss Data	FEFFiciency:FIXTure:RLOS? RF1A

The Factory Efficiency Module and LitePoint’s Role

In the competitive and fast-paced wireless industry, device manufacturers are under considerable pressure to improve and accelerate the production of products that employ cellular or WLAN connectivity. Due to the complexity of mobile devices and their mass-market volumes, manufacturers must apply very rigorous testing procedures during production to ensure that only reliable and high-performing devices enter the market. Companies need tools that ensure the accuracy of tests performed while improving yield to increase manufacturing throughput.

LitePoint continually develops tools and test platforms to improve the production testing of wireless devices, and the Factory Efficiency Module is designed specifically to help manufacturers improve test accuracy and device quality while optimizing yield. The Factory Efficiency Module embeds RF signal integrity diagnostics into test equipment to dramatically improve these performance objectives while also reducing costs and shortening time to market.

LitePoint looks forward to helping companies employ the factory efficiency tools to improve production testing. For more information about the LitePoint Factory Efficiency Module and other solutions, please visit www.litepoint.com.

About LitePoint

LitePoint, a wholly owned subsidiary of Teradyne, Inc. (NYSE:TER), is based in Sunnyvale, California. The company designs, develops and supports advanced wireless test solutions for developers of wireless devices and consumer electronics, contract manufacturers and wireless integrated circuit designers. LitePoint solutions have enabled optimization and verification of the operation of more than one billion wireless devices worldwide. LitePoint products are used in development and high-volume manufacturing, providing its customers with improved ROI, time-to-market, manufacturing yields, and product quality.

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