EXT Wireless Communications Test Set

Non-signaling Test Overview

Application Note

Agilent Technologies

Contents

Introduction

As wireless communication technologies are evolving, so too are device testing methods. Given the traditional signaling test process, the need to test additional wireless formats is typically accomplished only by increasing test times. This has triggered interest in the advantages offered by non-signaling test. Non-signaling is widely accepted as the fastest, most cost-effective technique for testing next-generation wireless devices in manufacturing. Non-signaling test methods make it possible for manufacturers to reduce both test times and test equipment costs across a range of wireless technologies such as LTE FDD/TDD, GSM, cdma2000®, 1xEV-DO, W-CDMA, TD-SCDMA, *Bluetooth*®, WiMAX™, and HSPA+.

There are different levels to which non-signaling test modes are implemented in cellular chipsets. The capability within the test modes influences the degree to which test-time reductions can be made. Chipset vendors are investigating ways in which they can provide non-signaling test speed improvements to manufacturers, and their efforts are leading to the development of proprietary, chipset-specific, test modes, particularly for cellular verification test. By taking advantage of test modes built into the new chipsets, non-signaling test can eliminate costly signaling overhead from the manufacturing test process, increasing throughput while maintaining the integrity of the test and quality of the finished product.

This application note describes the evolution of non-signaling test and explores the challenges of the varying degrees of non-signaling test mode capability found in chipsets.

Emergence of non-signaling test

Traditionally, the primary control for the cellular phone device during signaling test required over-the-air (OTA) protocol. Test equipment emulated a base station that the device responded to and then provided the capability to measure key RF parameters on both the uplink (UL) and downlink (DL).

In non-signaling test, the focus is not on the test set's OTA signal emulation but rather the direct control of the device under test (DUT), typically over a serial connection and through use of chipset-specific device drivers. The direct communication enables the use of the available non-signaling test mode in order to test the cell phone in a more efficient manner. **Figure 1** compares the approach using a signaling and non-signaling one box test (OBT).
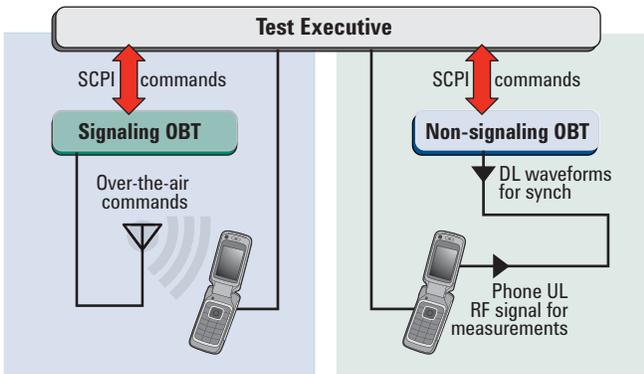
Figure 1:

Comparison of control commands for signaling and non-signaling OBTs

Around the turn of the millennium, non-signaling test applications were designed into OBT solutions. For example, the idea of using predefined transmissions in a device test mode is widely adopted in calibration techniques, such as Fast Device Tune. Now, there is significant interest in optimizing the verification stage of the test plan by exploiting new non-signaling test modes and capabilities in next-generation cellular devices.

The importance of chipset test modes

Non-signaling test techniques are only made possible by having appropriate chipset control over the device, referred to as test modes. A test mode can be thought of as a proprietary engineering mode within a device, which is specifically designed to fulfill the requirements of the test. Use of the test mode is available for programming via device drivers into the software test script or test executive. The test-mode configuration puts the device into a known state, allowing test equipment to measure predefined transmission patterns, usually power and frequency as a minimum. Test mode control offers engineers the potential to shorten the test development time and test time of cellular devices in which multiple bands and formats are combined into single chipsets or products.

As new chipsets are designed, test vendors and chipset vendors are looking for new test techniques from test equipment, chipset designers and test vendors must cooperate in the development of non-signaling test modes and the corresponding next-generation test equipment for cellular technologies. By leveraging existing silicon-vendor relationships, test-equipment manufacturers can provide test equipment that fulfills the potential of non-signaling-oriented test.

Transition to fast sequenced non-signaling

The evolution in non-signaling technology has led to chipset test modes with varying degrees of capability for a given proprietary test mode within a particular manufacturer's cell phone. The potential to which non-signaling use reduces test time can be grouped with two terms, non-signaling, as we know it today, and the emerging fast-sequenced non-signaling.

Signaling to non-signaling

Non-signaling test modes often evolve from existing signaling test modes and some call this entry into non-signaling reduced signaling. During this transition, chipset firmware is designed to reduce the types of channels needed for the device to synchronize to a DL signal. The device still needs to receive appropriate DL traffic signals as well as broadcast or pilot channels for some level of synchronization or control as if it were from a base station or signaling test equipment. Because of this, the initial non-signaling test modes offer less potential for reducing test times when compared to advanced fast-sequenced non-signaling test modes that do not require synchronization. The capability to create complex waveform files is required with non-signaling test equipment to simulate base station DL signals. Additionally, a means to orchestrate between the test equipment and chipset is required throughout the process of DL sync, setting up transmission, and subsequent measurements.

Fast-sequenced non-signaling

The progression from signaling through early non-signaling towards fast-sequenced non-signaling is typically tied to chipset development and is therefore generally a gradual process (**Figure 2**). Fast sequenced non-signaling removes the need for any control via the RF signal from the test set, simplifying RF test development and subsequently shortening the ramp to production volume testing while reducing test times. Where a new chipset is designed for a new technology such as Long Term Evolution (LTE), there is an opportunity to aim the design of the test mode towards fast-sequenced non-signaling mode from the outset.
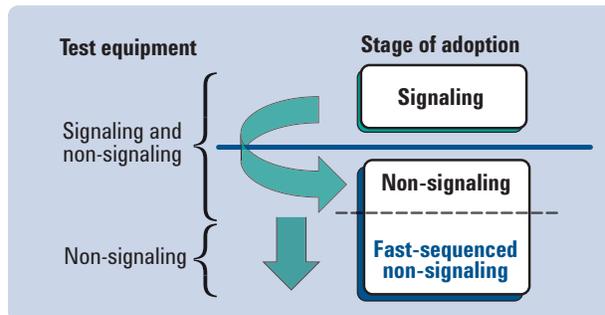
Figure 2:
The proprietary nature of test modes makes integration into manufacturing unique for any given example

By understanding the distinction between early non-signaling and fast-sequenced non-signaling test modes, design and test engineers can better leverage the advantages of non-signaling test techniques. This knowledge can be used to expedite the speed and extent to which a device can be tested. It also allows for collaboration with test vendors to determine the best choice of test equipment given the device test mode in question. New non-signaling test equipment is set to play an increasing role in this choice.

Realizing savings

Calibration

As discussed previously, the test techniques employed over the years within calibration have been proven to reduce test time and cost of cell phone manufacture.

An example was the introduction of power ramp measurements at the GSM frame rate in a single channel within OBTs. Similar and subsequent enhancements included support for EDGE, W-CDMA, and cdma2000 1xRTT. These types of measurements required the cell phone to provide a predefined test mode power ramp at each calibration channel. A further extension to this was to have the test equipment measure phase and amplitude versus time to increase the flexibility of the power measurement ramping capability.

Designers of OBTs continue to seek test time reductions through the use of specific calibration techniques that include simultaneous testing of both the transmitter and the receiver, such as with fast device tune. This requires chipsets to allow the cell phone to output and receive at a series of frequencies and levels so that the device transmitter and receiver can be calibrated simultaneously. In this area, measurements and applications have been provided to support leading chipsets.

Verification

Verification test is now the next frontier for non-signaling test mode development to allow fast sequenced test to reduce test time. Similar to calibration techniques, the aim is also to calibrate both transmitter and receiver in parallel. What is different from calibration however is that the measurements typically include modulation quality and return a great number of measurements from the same analyzed data. There also exists the potential to test across multiple modes (formats) in one test mode predefined sequence.

Test evolution

For a given format in a given chipset, a test engineer should be able to use **Figure 3** to identify the current stage of the non-signaling test mode evolution. In some circumstances, this may point to an area in the table that overlaps the two categories, which is logical since device modes are developed over time and are proprietary.

Receiver test

For receiver verification testing, the DUT must receive a suitable DL signal from the test equipment so that a bit error rate (BER) measurement can be made. As shown in **Figure 3,** there are two mechanisms for reporting BER: loopback BER and single-ended BER.

Loopback BER testing sends data to the device on the DL, which is looped back to the tester via the UL. The tester then can post-process BER for comparison to the data sent originally on the DL. When loopback BER is used for receiver test, the DL signal normally requires full channel coding. DL requirements for channel coding are linked with receiver verification test requirements. As indicated in **Figure 3**, the degree to which devices must be able to decode key pieces of channel-coding information on the DL depends upon the test mode.

Taking cdma2000 as an example, the specified convolution encoding, symbol repetition, and interleaving may be required within the synch channel for correct coding of the synch channel message data. This data is important for replicating real-world system synchronization and fields such as the system identification (ID).

Non-signaling devices may use a test mode for loopback BER and are likely to have adopted optimizations already in use within signaling test. For example, the 3GPP 44.14 standard specifies various internal types of loopback for the purposes of receiver sensitivity testing of GSM- and GPRS/EDGE-capable devices. Cell phone manufacturers can choose to use loopback Type C for GSM where the mobile sends back its received data stream to the tester without taking it through channel decoding.

Alternatively, BER measurements can be obtained by the device reporting the data directly over the chipset control. This is typically referred to as single-ended BER. Next generation non-signaling test equipment uses arbitrary waveform files to transmit across a test sequence to provide a continuous and frame-coherent DL signal to the device. With single-ended BER, the channel coding is either full or partial depending upon the test mode.

Figure 3 shows single-ended BER in the non-signaling and fast-sequenced non-signaling categories. For single-ended BER, the test mode must account for use of arbitrary waveform generator files. This means that the specific data pattern that the device must receive on the DL often is simplified for easier and faster computation. The test mode also might need to include the capability to resynchronize to a repeating data pattern caused by the repetition of the waveform file.

	Rx test		Tx test			Tx & Rx parallel sequencing
	DL requirements for channel coding	Receiver verification test requirements	UL operation requirements	Chipset control capability/flexibility	Transmitter sequencing limitations	Verification sequencing limitations
Non-signaling	Full coding	Loopback BER	DL synch	Limited predefined setup (discrete steps)	Single step & mode	UL max power only during loopback BER
	Full to partial coding	Single-ended BER	Significantly less DL synch	Comprehensive predefined setup (sequence)	Single mode	None
Fast sequenced non-signaling	Full to partial + none	Less single-ended BER + RSSI	NO DL synch	Comprehensive predefined setup & multimode	None	None
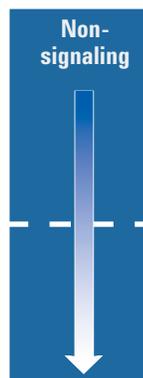
Figure 3:

Comparison of non-signaling test modes and their evolution within verification test

Typically, a fast-sequenced non-signaling chipset mode is less strict about the specific requirements of the DL signal, and channel coding may not be required for signals that only need to be spectrally correct on the DL. Fast sequenced non-signaling uses a combination of single-ended BER and received signal strength indication (RSSI). In the case of RSSI, there is no need for any channel coding.

BER measurements, whether single-ended or loopback, are one of the key bottlenecks in a test plan. If there is a way to reduce the amount of BER testing without compromising on quality, then this would be highly beneficial to the test time.

Transmitter test

Figure 3 indicates the requirements that must be met for the UL to be active within the test mode for transmitter testing to occur. This is primarily about the synch requirements on the DL but also is related to the channel-coding requirements. The DL synch requirement determines whether the cell phone needs the full broadcast within the DL for subsequent transmission on the UL, or no signal at all on the DL because the chipset control is the only prerequisite for the UL operation.

Once synchronized via a DL signal, the cell phone can be controlled to loopback the DL traffic channel onto the UL. This is where the DL channel coding comes into play, for example, the DL transmit power control (TPC) bits which subsequently control the UL power transmitted from the cell phone. A gradual reduction in synch requirement occurs as devices move toward the fast-sequenced non-signaling category.

A fast-sequenced non-signaling device allows the UL to be transmitted without the need to first synch on the DL. This makes the device much more flexible and easier to integrate into a predefined sequence-based test.

Independent UL control is possible through focused chipset design work, but the approach is not without its challenges. For example, with GSM, without a DL for frequency correction, the UL transmit signal may not be as accurate and exhibit frequency error. For this reason, within **Figure 3** the fast-sequenced non-signaling category still indicates that synchronization may be required.

Transmitter sequencing

The columns "Chipset control" and "Transmitter sequencing limitations" under the heading "Tx test" in **Figure 3** denote the link between the chipset control capability and the resultant capability to accommodate transmitter verification sequencing test. The test mode may contain the capability to carry out predefined single steps but may not be able to sequence completely unless sufficient control is included.

This control capability increases toward the fast-sequenced non-signaling category to the extent that sequencing can take place across multiple radio formats. Once fast-sequenced non-signaling is realized, limitations are removed.

Transmitter and receiver parallel sequencing

When sequencing both the cell phone's transmitter and receiver in a fast-sequenced non-signaling mode, single-ended BER enables the UL test and DL test to be truly independent, allowing test development of simultaneous test of UL and DL. For example, the cell phone could be doing inner-loop power control on the UL while measuring single-ended BER on the DL. This contrasts with loopback BER limitations where the cell phone must transmit back on the UL at maximum power.

Advances in verification test

Today, test engineers seek to predefine output from the cell phone so that verification test time can be minimized. While this is being achieved by the inclusion of proprietary test modes and building upon the knowledge gained from calibration test modes, it is also leading to more complex predefined data patterns. These are often referred to as verification test "sequences," or "sweeps," and apply to both the device receiver (output from the test equipment) and transmitter chain (input to the analyzer of the test equipment).

Defining and enabling a predefined sequence within the test mode is one part of the implementation that the chipset designer must complete before the test engineer can make use of it. This requires minimizing the need to "set and measure" continuously via chipset control (regardless of whether the test stage is calibration or verification), due to the time and cost penalty associated with this methodology. The "set" refers to associated device setup before each test, primarily the setup and preparation of the device test mode. The "measure" refers to sending the test equipment commands to set the equipment up, performing the measurement, and returning the result for each test (**Figure 4**).
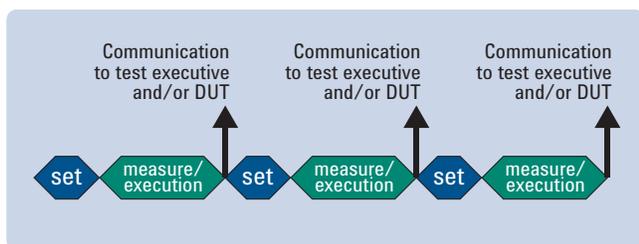
Figure 4:

A "set" and "measure" approach to verification test sequencing

A non-signaling test mode contains a range of controls over which the engineer can ask the device to respond or provide information back to the controlling test executive. However, while there might be enough capability to produce the required output, if the test executive must communicate frequently with the device over the duration of the defined sequence then the benefits of the entire sequence can be undermined. This is because the test executive must continually setup and communicate with the device which is time consuming.

An example of this is best demonstrated by a controlling application programmable interface (API) being called in the test executive to control a device in a GSM test mode. The following pseudo code demonstrates how the test engineer might setup the device to synchronize to a downlink signal. Once complete the phone transmits on the UL at maximum power while obtaining a count of BER in parallel.

Finally, the device is then asked to switch to another channel:

```
DUT_GSM_synch(channel);

while (DUT_GSM_synchcomplete() == 0)

{

wait(5);

}

DUT_GSM_TX(maxpower);

DUT_GSM_startBER(bits);

while (DUT_GSM_BERcomplete() == 0)

{

DUT_GSM_calcBER();

}

DUT_GSM_stopBER();

DUT_GSM_readBER();

.

.

.

DUT_GSM_TX(channel2);

.

.

.
```

The key point here is that the non-signaling test mode exists to control the phone in order for the test engineer to request the required non-signaling capability, but this requires eight API calls to the device (for just one channel). This includes the need to read back the status of the device for completion of synchronization, at the completion of BER, and for the calculation of BER results (for reading into the test executive).

Subsequently, when attempting to pace the device with test equipment, it becomes more difficult because the device state must be known and accounted for before determining the control of the test equipment. The result is that the test sequence is no longer predetermined in nature, which reduces the effectiveness of the device's non-signaling test mode for test purposes. In effect this cannot be sequenced in one sweep and must be executed as a series of sequential steps, not a sequence.

Test evolution

Figure 5 shows how test equipment might be integrated with this particular test mode (it is assumed that the downlink is already present from the test equipment).
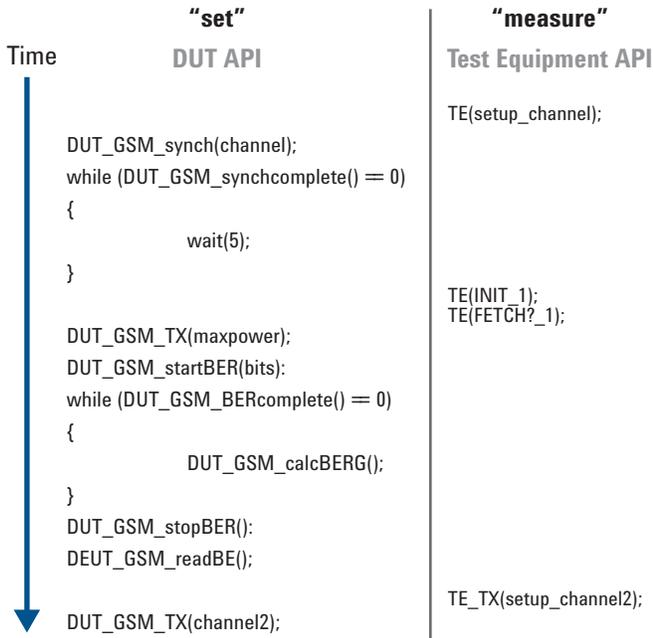
Figure 5:

Interaction per channel between DUT API (set) and test equipment API (measure)

In this example, the order of pseudo API calls to both the device and the test equipment demonstrates that the device API is often the bottleneck. Therefore, there is a need to interact with the test executive which then also has an effect on the test equipment, particularly if the test equipment has an expectation for new events to occur continuously. If events do not occur uninterrupted, then often further commands must be sent to the test equipment to essentially have it wait for further instruction. In addition, this sometimes also implies that results must be returned from the test equipment back to the test executive before the sequence is actually complete.

The best way to overcome such challenges and improve test time is to setup the device's transmit and receive parameters once for the entire run of events (the sequence) e.g. for all levels and frequencies. This requires the test mode to have sufficient control available and, most importantly, to be able to set it up just once. This is best demonstrated by taking the example of an API again. This would be like having one function or method call available that can pass enough parameters so that the test engineer can customize the entire sequence with just one method call:

DUT_GSM_testmodeA(channels, powerlevels, bits);

The method above can be readily integrated with next-generation non-signaling test equipment and the test executive. For example, the test mode may be designed to ramp to max power after synchronization without any need for a status poll from the test executive. Also, the test mode could cache the BER results and return them at the end of a sequence, for example, after test of all channels. Next-generation non-signaling test equipment can be setup in advance to expect such predefined outputs at each channel with its setup stage accounting for the entire sequence (highlighted in red below):
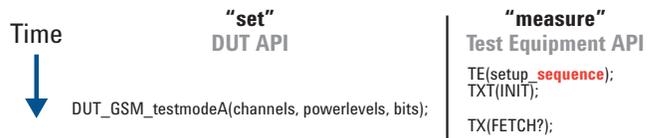
This example shows there is no need for individual setup, initiate, and fetch commands for the test equipment at each channel. The entire verification sequence across all channels and levels is treated in the test equipment as some initial setup for the test sequence, an initiation of the test sequence and a fetch of all results back to the test executive once compete (**Figure 6**).

Figure 6:

An optimized approach to verification test sequencing using next-generation non-signaling test equipment

Test equipment choices

For devices with early non-signaling test modes, either existing or next-generation test equipment can provide the necessary tests (**Figure 7**). If you want to continue to use signaling test equipment for these tests, you must consider the precise technical requirements to ensure complete compatibility. The point at which signaling equipment becomes less attractive and you must switch to next-generation non-signaling test equipment depends on the chipset's test mode progression to fast-sequenced non-signaling capability and on the obvious test-speed benefits. It is also worth considering upgrading existing signaling equipment with non-signaling support where test modes and test capability permit.
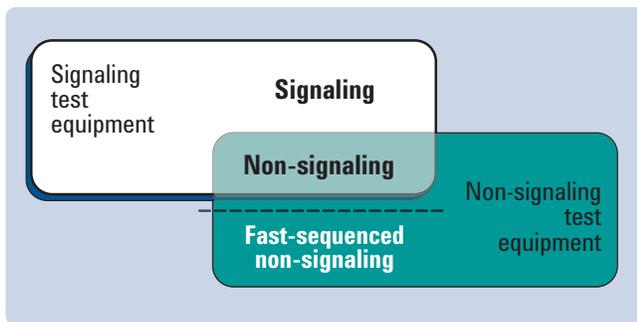
Figure 7:

Signaling and next-generation non-signaling test equipment can handle standard non-signaling test modes, but only next generation equipment can handle the fast sequenced non-signaling test modes that are currently being developed

Typically the evolution to a non-signaling test environment will call for the use of both signaling and non-signaling test equipment and they will likely coexist on the manufacturing line. The role that each type of test equipment plays will depend on both the technical merits of the test mode and on the non-signaling test techniques featured in the equipment.

Signaling test still has a place

Because manufacturers need to build stability and confidence into their processes when moving to non-signaling test, they are likely to continue to use signaling test equipment throughout the adoption of non-signaling techniques for a variety of reasons:

• Signaling test can serve as a traceable reference (measurement correlation) of device RF performance during design (between signaling and non-signaling test modes) and on through the transition to manufacturing test.

• Signaling test provides a starting point or benchmark for test-time improvements.

• Signaling test can serve as a standard for the design of arbitrary waveforms for the purposes of receiver test and downlink synchronization within new next-generation equipment. Arbitrary-waveform generation capability is important for non-signaling devices that require a specific downlink signal.

• Major chipset providers and cell phone manufacturers have collaborated with test vendors using signaling equipment as a target platform for many years. Many test modes and tools are developed around such equipment.

• The significant installed base of proven signaling test equipment in manufacturing has proven to be trustworthy, robust, and reliable and wholesale changes would require extensive code rewrites and evaluation time.

While existing signaling test equipment does provide test coverage for devices that integrate non-signaling in manufacturing, signaling test equipment does not offer sequence-based test and cannot maximize the potential of the fast-sequenced non-signaling test modes.

Conclusion

Non-signaling manufacturing test

Non-signaling test modes benefit most from test-speed improvements by using next-generation non-signaling test equipment. Next-generation non-signaling testers, remove limitations on band, cellular format, channel, power range, and time slot that may have been enforced within signaling.

Focused non-signaling test equipment, therefore, can pave the way for adoption of new fast sequenced non-signaling test modes and ultimately provide new and faster test techniques. They are also capable of comprehensive debugging of non-signaling sequences being designed for manufacturing using format specific tools. Similarly, a well-featured source in an OBT can provide test coverage like a separate signal generator. For sequencing purposes, specific tools can be provided to drive the source across a sequence simultaneously with the analyzer.

Non-signaling test tools

Since the technical capabilities of a device's non-signaling test modes drive the requirements for the test equipment, test vendors also must provide tools that simplify the adoption of non-signaling test, particularly in cases where a cell phone manufacturer is using a variety of chipsets from a number of chipset vendors.

In next-generation non-signaling test equipment, arbitrary waveform files are used to transmit signals to devices. This is a significant change in how test equipment provides a DL, and both R&D and manufacturing test engineers, therefore, need easy to use, comprehensive signal creation tools to create standard-based DL test waveforms that can handle the sometimes complex chipset test-mode requirements. For the R&D engineer, the tools must provide wide coverage. For the manufacturing test engineer, the tools should offer a user interface that makes it easy to select the key signal parameters for a test. Test vendors can offer these types of focused software packages by again collaborating with chipset vendors and cell phone manufacturers to capture key requirements and implementing them as parameters in the user interface. Additionally, a means to create the test sequences that coordinate between the test equipment and chipset is required throughout the process of DL sync, setting up transmission, and subsequent measurements.

Next-generation, non-signaling test equipment solutions that support fast-sequenced, non-signaling test are required to pave the way for adoption of new non-signaling chipsets and ultimately provide new and faster test techniques. This next generation test methodology makes use of proprietary calibration and verification non-signaling test modes. Moreover, such device test modes can be executed more efficiently when there is no need for a test executive to continually interact with a device API and test executive, allowing the test equipment to execute a sequence from start to finish minimizing bottlenecks in device communication.

Related literature

E6607B EXT Wireless Communications Test Set, Flyer, Literature number 5990-9255EN

E6607B EXT Wireless Communications Test Set, Brochure, Literature number 5990-9259EN

E6607B EXT Wireless Communications Test Set, Configuration guide, Literature number 5990-9373EN

Solutions for Manufacturing Next-Generation Wireless Devices, Application note, Literature number 5990-7209EN

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