Sequencing with next-generation non-signaling test equipment

By Robin Irwin, Agilent Technologies

Test equipment vendors have developed cellular phone one-box-test (OBT) solutions for over twenty years to achieve cell phone test coverage of the entire device lifecycle from research and design through to manufacturing and post-sales service, providing test solutions that cover all the major cellular technologies. New test features and capabilities have been introduced consistently over the years to help manufacturers maintain desired levels of device quality while reducing test time. These testing advances have happened in tandem with cell phones adopting more formats and supported bands. This new phone capability would otherwise result in increased test time without the evolution of new cellular test techniques in the test equipment and the support of non-signaling chipset test modes.

The Importance of Chipset Test Modes

Non-signaling (also referred to as non-call processing: NCP) applications have been made available on one-box-test solutions since around the turn of the millennium. These applications and the test techniques they employ can only be implemented by having appropriate chipset control over the cell phone. This is achieved by the inclusion of chipset-specific test modes within the cellular chipsets. 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 engineer. Non-signaling test modes operate in conjunction with test equipment by enabling predefined outputs from the cell phone such as power and frequency. The test mode configuration puts the cell phone into a known state, allowing test equipment to measure predefined transmission patterns.

With signaling test, the primary control of the device is over-the-air (OTA) signals from the test equipment. In non-signaling, the focus is not on the OTA signal but rather the direct control of the phone, 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 or non-signaling OBT.
Early Advances (Calibration)

The idea of using predefined transmissions in a device test mode can be related to earlier advances in cellular phone testing for calibration. An example was the introduction of power ramp measurements at the GSM frame rate in a single channel within one-box-testers. Similar and subsequent enhancements included support for the likes 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 one-box-testers continued to seek test time reductions through the use of specific calibration techniques that included testing of both the transmitter and the receiver. This required chipsets to allow the cell phone to output and receive at a series of frequencies and levels so that the device transmitter and receiver could be calibrated simultaneously. Measurements and applications were provided to support leading chipsets approved by test vendors.

The Next Frontier (Verification)

The test techniques employed over the years within calibration have been proven to reduce test time and cost of cell phone manufacture. For this reason, verification test is now the next frontier for non-signaling test modes to reduce test time. As with calibration, the aim is to
calibrate both transmitter and receiver in parallel. What is different however is that the measurements typically include modulation quality and return a great number of measurements off of the same analyzed data. There also exists the potential to test across multiple modes (formats).

**Verification Test “Sequences”**

As attention has shifted to trimming verification test times, test engineers seek to define predefined output from the cell phone so that test time can be minimized. While this is 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 being investigated for verification test. 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 the 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. The other aspect to this (regardless of whether the test stage is calibration or verification) is that the test engineer has a desire to reduce the need to “set and measure” continuously via chipset control due to the time and cost penalty associated with this methodology:

- The “set” refers to associated setup that must be done before a test can be conducted, primarily the setup and preparation of the device test mode.
- The “measure” refers to the commands that request the test equipment to conduct the test.

As discussed earlier, in non-signaling test the focus is not on the OTA signal for control of the cell phone but rather the direct control of the phone. This means that the mechanism over which the chipset can be controlled or automated should ideally be one in which the test engineer can use efficiently (the “set”). Moreover, the mechanism should be one which can be easily integrated with automated control of test equipment (the “measure”).

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. While there might be enough capability to produce the required output, if the device must communicate with the test executive over the duration of the defined sequence then the benefits of the entire sequence can be undermined. It could be said that this is not actually a sequence which the test equipment can measure with the device because the device execution cannot take place all in one go (regardless if the test equipment could). This is because the test executive must continually setup and communicate with the device.

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 is used to demonstrate how the test engineer might setup the device to synchronize to a downlink signal. Once complete the phone transmits on the uplink 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 that channel). This includes the need to read back the status of the
device:
1. For completion of synchronization
2. Completion of BER
3. 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 go and must be executed as a series of
steps, not a sequence.

The diagram below 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):
By showing the order of some example pseudo API calls to both the device and the test equipment, it demonstrates that the device API is often the bottleneck. Therefore, there is a need to interact with the test executive which then 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.

**Figure 2:** A “set” and “measure” approach to verification test sequencing

The best way to overcome such challenges and to 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 (like above) and, most importantly, to be able to setup 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 maybe 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 the API below):

```
DUT_GSM_testmodeA(channels, powerlevels, bits);
```

In the above example 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 3: An optimized approach to verification test sequencing using next-generation non-signaling test equipment**

**Next-generation Test Equipment Techniques**

Given the ability to configure a device for an entire sequence, new next-generation non-signaling test equipment is designed to match this capability. In the same efficient way that a device may be configured using its API for an entire sequence or verification test plan, the test equipment can be configured once in advance for the entire sequence and will measure for the duration of the sequence. In this case, there is only one “set and measure”: one “set” for the device and test equipment parameters, one “measure” for the test equipment. Once measurements are completed, the test equipment can return an array of results for the whole predefined sequence. This optimized approach is sometimes referred to as fast-sequenced, non-signaling test.

**Conclusion**

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 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 without any bottlenecks in device communication.

**About the Author:**

**Robin Irwin**

Robin Irwin works for the Mobile Communications Division in the Electronics Measurement Group at Agilent Technologies. Robin joined Agilent Technologies as a graduate from Queens University Belfast after achieving a first class Master’s degree in Electrical and Electronic Engineering. He started his career working on power meters, noise figure analysis and one-box-testers.

Robin is now a Wireless Application Engineer supporting a global customer base in emerging communications and cellular technologies. He is currently investigating non-signaling test techniques with devices, working in partnership with customers on requirements and technical evaluations.