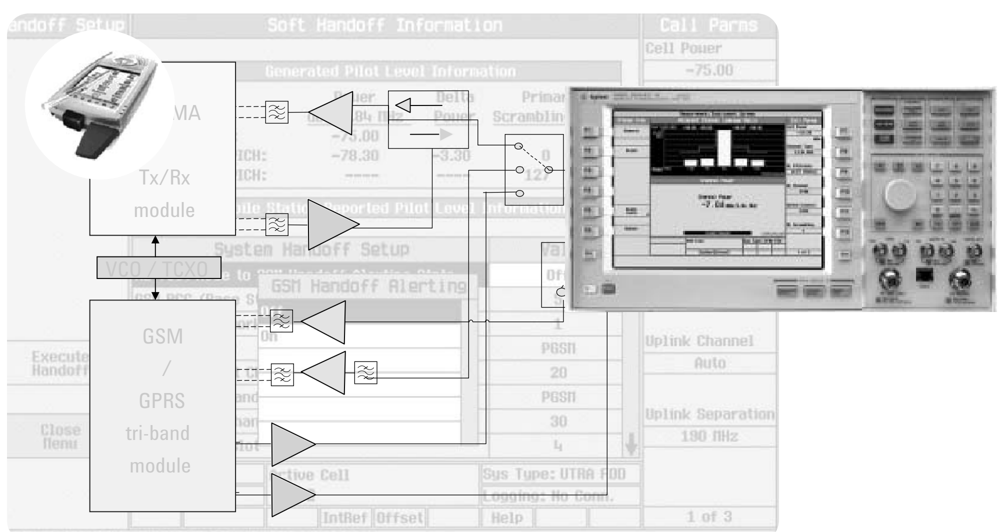
Agilent
Multi-mode Handset Manufacturing Challenges and Solutions

Application Note



Agilent Technologies

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Introduction

3G systems are much more taxing on components and modules than their 2G predecessors. One reason for this is the ever expanding set of requirements put forth by the 3GPP standards committees. W-CDMA differs from GSM in its frequency bands, modulation schemes, channel bandwidth, duplex spacing, power control, and on and on. Each of these system parameters comes with their own RF performance requirements and characteristics, such as sensitivity, higher order intercept points, phase noise, oscillator leakage, adjacent channel power leakage, and others.

Today, most of the 1G, 2G, 2.5G, and 3G technologies have a share of the market and there is a strong need for integration. Consequently, manufacturers need to produce mobiles that can operate on different networks in different parts of the world, which means user equipment (UE) must be able to operate in several different formats. The UE being produced today for global use must be able to cover a wide range of voice and high-speed data operations. For example, when a 3G network isn't present, the UE must be able to connect to a 2G or 2.5G network.

Multi-mode capability allows providers to service legacy customers, as well as offer new advanced services. The transceiver equipment of base stations and mobiles should at least support portions of these evolving standards, as well as existing ones for backward compatibility. Furthermore, realization of small size components and low power consumption is driving design components toward multi-mode compatibility.

However, multi-mode UE presents some unique challenges for device manufacturers. This paper looks at some of the specific challenges associated with testing multi-mode phones. A technology primer summarizes the main differences between how each format fundamentally works. Next, additional details on final test and calibration are provided. This paper also introduces several innovative test solutions available from Agilent to help manufacturers cope with the multi-mode challenges outlined above.

Multi-Mode Challenges in Manufacturing

There are three significant challenges in testing multi-mode devices during the manufacturing process. First, because the device supports multiple modulation formats, additional time for calibration can be needed during the manufacturing process. Secondly, multi-band performance and multi-format signaling must be verified. Finally, data services offered in multi-mode UE must also be verified.

Modulation and multiplexing types

Because each standard has its own set of conformance requirements, adding a new format adds an ever increasing suite of tests. For example, it is not satisfactory to verify W-CDMA functionality and assume GSM functionality is also working, because the operations are quite different in the UE.

Technologically speaking, how is W-CDMA different from GSM? One key difference is in their multiplexing techniques. GSM, GPRS, and EDGE all use frequency multiplexing to separate cells and time division multiplexing to talk to different users. A result of this is that neighboring cells must use different frequencies so as not to interfere with each other. In IS-136 and analog cellular systems, there is a seven cell repeat factor, with three sectors. This means that only one out of every 21 channels is available to each sector. GSM usually uses a repeat of four, with three sectors, for a reuse of one out of 12. On the other hand, W-CDMA uses different Walsh codes on a single frequency to separate users.

In a sense, everyone interferes with everyone else in a constant level of background noise. Each UE in a cell uses a code to filter out the noise that is not directed to it. It is more spectrally efficient than FDMA, but also more computationally complex.

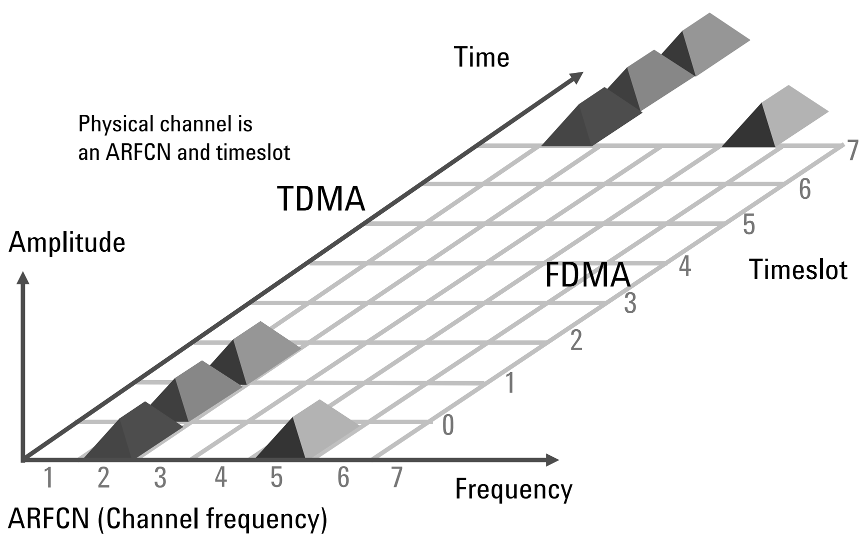

Figure 1. The GSM channel – TDMA and FDMA

To illustrate, Figure 1 shows the relationship between frequency and time in GSM. GSM uses time division multiple access (TDMA) and frequency division multiple access (FDMA.) Each band is divided into 200-kHz channels called absolute radio frequency channel numbers (ARFCNs). As well as dividing up the frequency, the ARFCN is also divided in time into eight timeslots (TS), with each TS being used in turn by a different mobile station (MS). The eight TSs together are known as a frame. The gray triangular boxes show that each of the four traffic channels (TCHs) uses a particular ARFCN and timeslot. Three of the TCHs are on the same ARFCN, using different timeslots, the other one is on a different ARFCN. The combination of a TS number and ARFCN is called a physical channel.

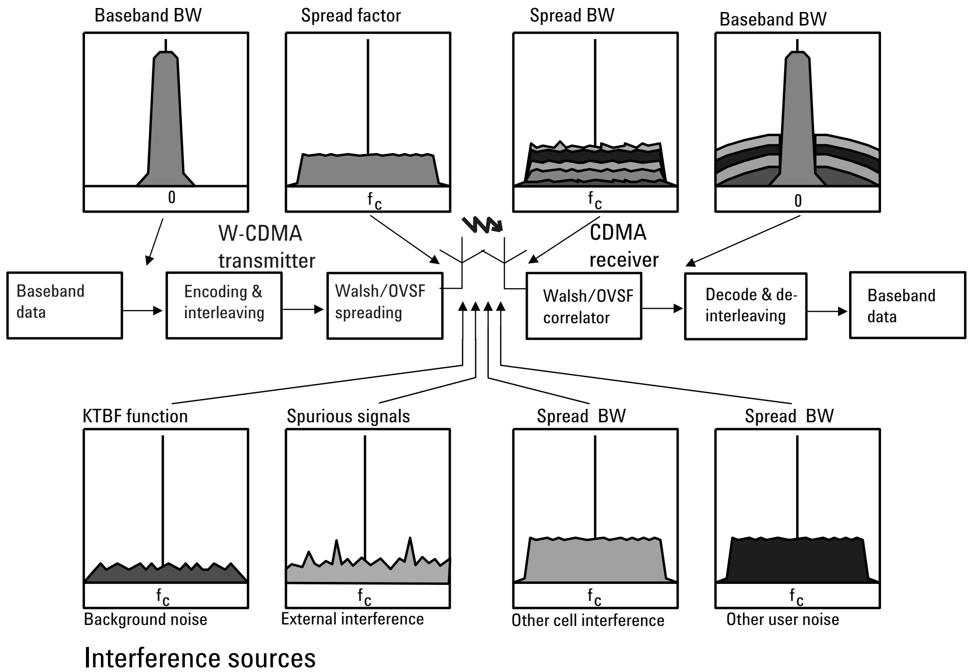

Figure 2. W-CDMA air interface

Figure 2 shows the spread spectrum process used in CDMA systems. The fundamental concept of CDMA is that each user is assigned a unique code. The data for that user is spread from a low data rate to the final spreading rate, which is 3.84 MC/s (mega chips per second) for W-CDMA. Many users share the same frequency. When the de-code is applied, the proper code goes back to the original narrow bandwidth, while every other code stays at the full bandwidth. The portion of energy from the wide signal that falls into the narrow bandwidth is very small. The spectrum view with stacked signals suggests measurement equipment that will analyze the transmission from a base station and display the constituent codes.

Given the unique multiplexing techniques used by each technology, each format in a multi-mode UE is an individual path (refer to Figure 3.) Interference between formats is not necessarily a problem, because the RF switch takes care of most of the isolation issues. The problem is that you can't test multiple formats at one time; so testing all the formats in a phone can take a long time.

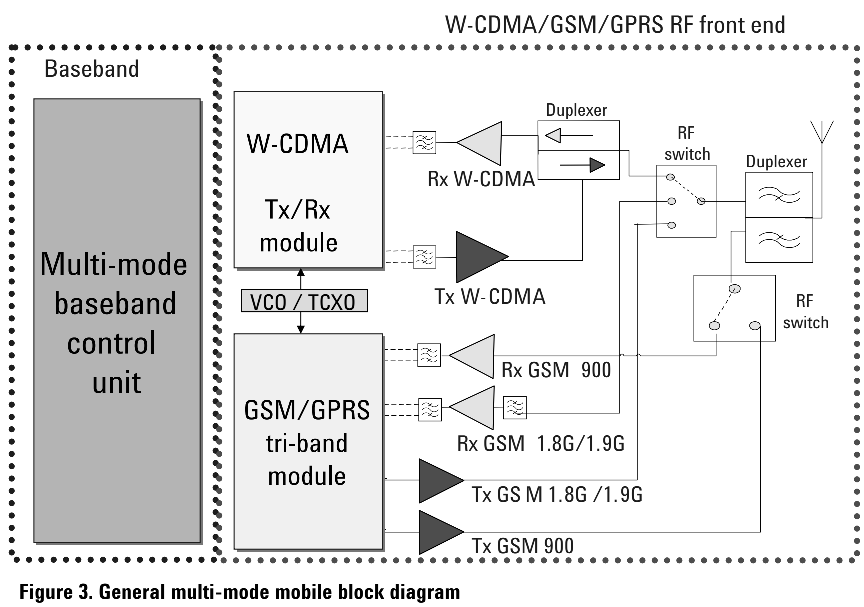

Figure 3. General multi-mode mobile block diagram

Increased calibration and final test times

To test multi-mode UE, we have to worry about different modulation types, different frequency bands, and different modes; all of which are difficult to integrate together into one test. Because each standard has its own set of conformance requirements, adding a new format adds an ever increasing suite of tests. This, in turn, adds to the time needed for calibration and final test because we have a greater number of parameters to verify.

Table 1 illustrates the calibration considerations for the different 3GPP formats. It's important to recognize within each format what configuration is most stressful for the mobile. This configuration is what should be tested in the manufacturing phase in order to verify that the mobile will work when connected to a real network.

Table 1. Typical calibration considerations for various wireless technologies

W-CDMA	GSM	GPRS	EDGE
5 MHz, QPSK, CDMA, 1DL x 1UL	200 KHz, GMSK, FDMA, 1DL x 1UL	200 KHz, GMSK, FDMA	200 KHz, GMSK, FDMA
Power (QPSK): 24 dBm (class 3) 21 dBm (class 4)	**Power (GMSK):** 33 dBm (max)	**Class 12 (DL/UL):** 1x1, 2x1, 3x1, 4x1 2x2, 3x2, 1x3, 2x3 1x4	**Class 12 (DL/UL):** 1x1, 2x1, 3x1, 4x1 2x2, 3x2, 1x3, 2x3 1x4
RMC: 12.2 K, 33 K (no coding), 64 K, 144 K, 384 K	**Timeslot:** 8 slots, 577 µs/slot 4.615 ms/frame	**Power (GMSK):** 33 dBm (max)	**Power (GMSK/8PSK):** 33 dBm (max)
Frequency channels: UE: 1920-1980 MHz 1850-1910 MHz 1710-1785 MHz BS: 2110-2170 MHz 1930-1990 MHz 1805-1880 MHz	**Frequency channels:** New China band GT800 (350 to 425) Asia/Europe 900 MHz, 1800 MHz US/Canada 850 MHz, 1900 MHz	**Timeslot:** 8 slots, 577 µs/slot 4.615 ms/frame	**Timeslot:** 8 slots, 577 µs/slot 4.615 ms/frame
		Frequency channels: Same as GSM	**Frequency channels:** Same as GSM

New requirements for data service

Additionally, new services are being offered by providers to take advantage of the higher throughput enabled by new data formats like W-CDMA and HSDPA. UE that supports these services, such as video streaming or video conferencing, should also be screened, either in the manufacturing test stage or the quality assurance phase, using new functional tests for digital performance.

Parametric and Functional Testing

In this next section, we will dive into more detail on parametric and functional testing of multi-mode handsets. We start with an overview of the production lifecycle, and how your test plan should be optimized for each stage. We will spend the bulk of the time talking about calibration considerations, since this is arguably the most important and time consuming part of production test.

Lifecycle view of manufacturing

As Figure 4 illustrates, along the production lifecycle, production volume varies. In the early stages it is small. As the product is released and gains popularity, production goes through a ramp up process. After the product hits maturity, production will crest and then finally go down again, making the way for a follow-on product to ramp up. Each stage of production has an optimized test method associated with it. Examples of these plans are located in Appendix A.

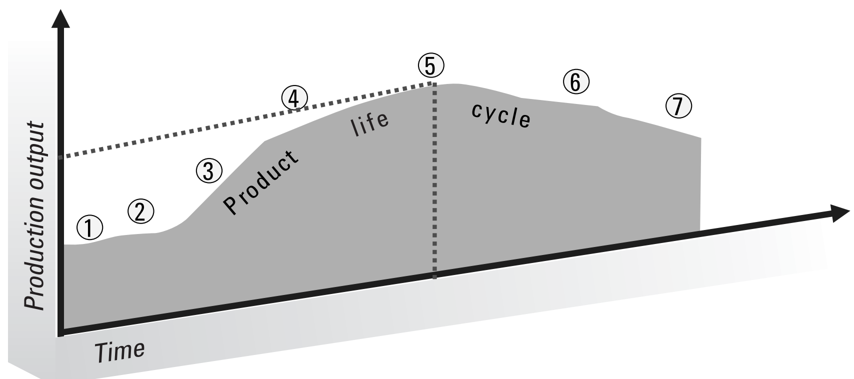

Figure 4. Test plan objectives over UE product life cycle

Stages 1 and 2

In the proof of concept and design verification stages, the target is to catch a bad phone design as soon as possible. While the phone is being produced at a small volume, it is easier and less expensive to make changes as failures are identified. During this phase, it is best to use a MAX test plan. This is the test plan that includes the most test items to test a complete set of scenarios. It is important to keep the R&D team involved in this phase to make design changes when needed.

Stages 3 and 4

When production is beginning to ramp up, the test plan objective now is to pass a good phone. The test plan most optimal for this phase is the TYPICAL test plan, which is a smaller subset of tests from the MAX test plan. The design should already be good with few bugs or no bugs. For maximum efficiency, it is best if R&D is not involved in the process anymore.

Stages 5 through 7

The manufacturer gains back all the profit to pay for the expenses of product development and production ramp up during stages 5 through 7 of the UE life cycle. During these stages, it is important to reduce cost of test so the optimal strategy is a MIN test plan. This is the smallest subset of critical tests. Of course, the art of good manufacturing is figuring out how to reduce test items to go from thoroughness to speed without missing important faults in the design of the phone or the production process itself.

Final test plan optimization

Table 2 shows an example of final test plan optimization. Final test is easier to make flexible than calibration, since calibration tends to have very fixed items which are hard to change depending on the phase of production. It's easy to have disagreements in the transition from R&D to manufacturing. The manufacturing test is the responsibility of the manufacturing group, but the calibration test plan is the responsibility of the R&D group. Calibration test is crucial; without it the phone will absolutely not work. This is why it is very important to have a robust plan before production starts.

Table 2. Example of a final test plan

1. Run W-CDMA tests with UE at MAX Power (+21 or +24 dBm), BTS at –106.7 dBm
   a) Maximum Output Power => Thermal Power measurement
   b) Transmit Modulation, Frequency Error (EVM, PCDE, Frequency error) => Waveform Quality measurement
   a) Spectrum => ACLR or Spectrum Emission Mask (SEM), Occupied Bandwidth (OBW)
   b) Receiver Sensitivity => Loopback BER
   c) Power Control => Inner Loop Power & open loop power
2. Run tests with UE at MIN Power (–50 dBm) Minimum Output Power (Using Channel Power RRC On)
3. Low, mid, high frequencies in each band, defined in 3GPP TS 34.108 Section 5.1.1
4. Switch to GSM
5. Run tests to verify Tx and Rx performance
   a) Tx = > power, phase & frequency error, output RF spectrum (ORFFS)
   b) Rx => Bit Error Rate (BER)
6. Low, high frequencies in each band, defined in ETSI 11.10

Tx and Rx calibration techniques

The calibration phase in production can consist of more than just RF. Calibration is also used in software, battery, and audio testing. This paper will focus only on RF calibration. First we will discuss calibration in a general sense, justifying why it's important to calibrate both transmitters and receivers. Dynamic range and frequency response measurements will be evaluated. Then we will go into more detail on how to properly calibrate, and what considerations must be taken into account for W-CDMA.

Why calibrate?

The accurate calibration of the transmitter power affects all of the 34.121 Tx tests: maximum power, minimum power, inner loop power control, open loop power control, EVM, ACLR, and spectrum emission mask (SEM.) It also affects some of the other performance parameters of the mobile, including battery life and specific absorption rate.

Calibrating the power of the receiver is needed because regardless of the instrument used to generate the W-CDMA signal, the manufacturing bench has many sources of uncertainty. In fact, the instrument can have as much as ±1 dB of uncertainty due to the large dynamic range of the W-CDMA signal. It is extremely important to have a bench compensation/calibration process that removes all of these sources of error.

Additionally, there are many other factors that introduce uncertainty into testing if calibration is not done. For example, the use of golden phones for test cannot measure W-CDMA RSSI in normal call processing mode. This would require a special test mode in the phone. Additionally, the phone can vary due to thermal and battery considerations. Another approach is to use a calibration cart with a power meter and a vector signal analyzer. This approach is more repeatable and less susceptible to other factors.

Dynamic range

Although the designs of UE can be (and are) unique, the goal of Tx calibration is the same: the algorithm must compensate for the non-linearity of the dynamic range of the Tx Amp Block such that it will be linear (within specified limits) after compensation.

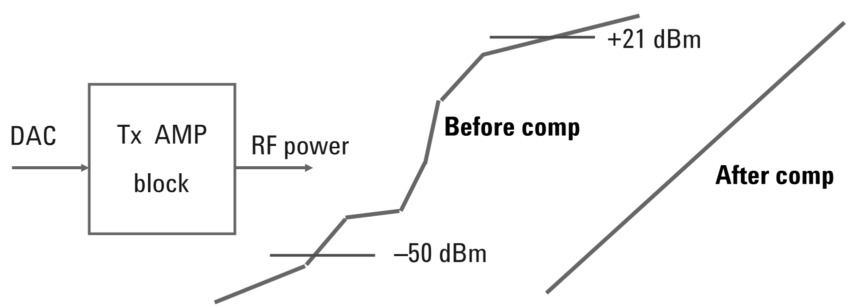

Figure 5. Model of the Tx of the mobile as a block

As can be seen in Figure 5, the dynamic range of the mobile is from +21 to –50 dBm, but the compensation must cover an even wider range. Thus, there are no power steps as in GSM. The Tx must cover all power levels in the range. Also, the phone must have this "linear" performance at all channels in the band. The number of channels that require their own DAC table for dynamic range depends on the design of the mobile.

The mobile designer will typically divide the dynamic range of the transmitter into sections. The number and size of the sections depends on the design of the transmitter. These sections are chosen such that the output of the Tx can be linear (within specified limits) by manipulating the DAC values between section points.

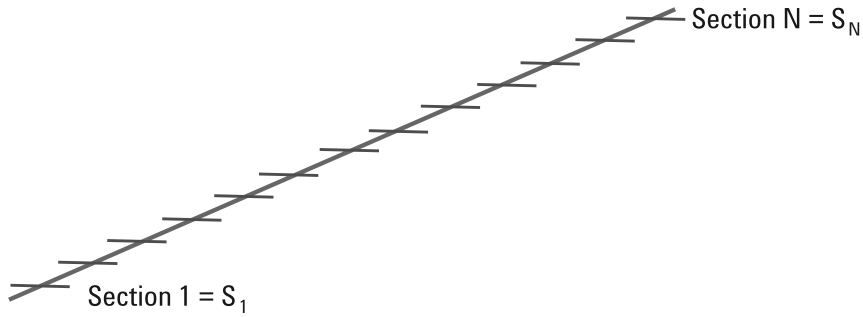

Figure 6. Example of uniformly-spaced Tx calibration compensation sections

In Figure 6, we show the sections labeled S_1 to S_N. In this simplistic example, the sections are uniform and the Tx power is already very linear. In the real world, the sections may be more concentrated in non-linear regions and fewer may exist in linear regions. The reason for this is that non-linear regions need more compensation to become linear, whereas linear regions don’t need as much. Again, these items will be unique to each design.

The main issue to understand in this case is that not all of the sections may require a measurement. It may be that only some points at the lower power level and some points at the higher power level (usually more non-linear areas of the curve) will require accurate measurements, and the other points can be interpolated. This will save time, but adds complexity. Also, some phones may not comply with the interpolation and fail during verification testing. Most importantly, if the phone DAC table(s) require a value, the value must be populated by either defaults, measurement, or calculation/interpolation. It should be noted that some phones may not comply with the interpolation and fail during verification testing.

Similar to the Tx model, the dynamic range for the Rx of a UE is unique to each mobile designer. However, the Rx calibration goal is universal: the algorithm must compensate for the loss of the UE’s Rx such that an accurate received signal strength indicator (RSSI) can be obtained within the UE (see Figure 7.) Typically, this results in the transformation of a non-linear response into a somewhat linear response. However, the linearity requirements are not as stringent as those for Tx RF power, which must meet the inner loop power requirements of 34.121.

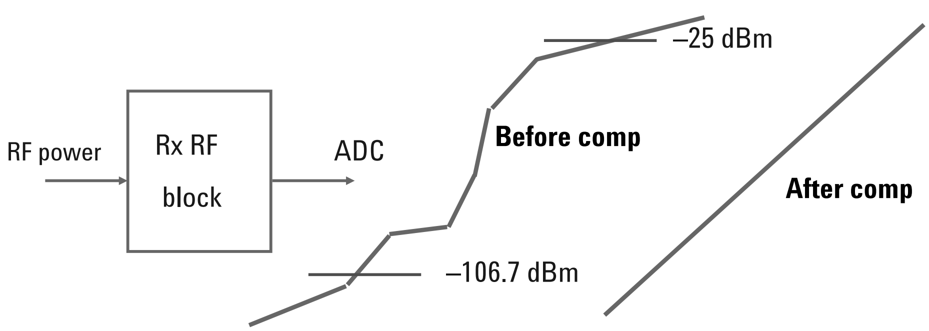

Figure 7. Model of the Rx of the mobile as a block

As illustrated in Figure 7, the dynamic range of the mobile is from –25 to –106.7 dBm, but the compensation must cover an even wider range. The phone must have this performance at all channels in the band. The number of channels that require their own ADC table for dynamic range depends on the design of the mobile.

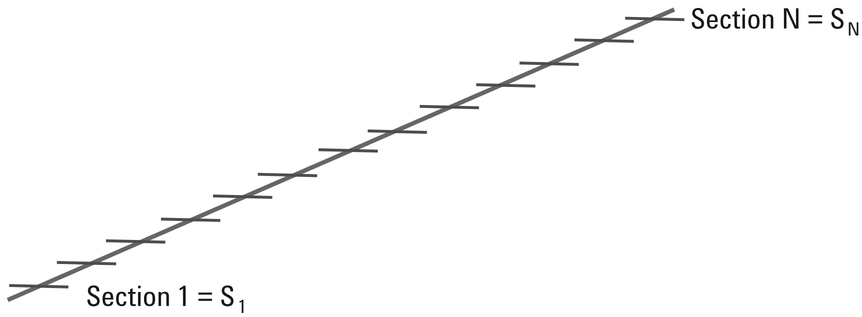

Figure 8. Example of uniformly-spaced Rx calibration compensation sections

The mobile designer will typically divide the dynamic range of the receiver into sections. The number and size of the sections depends on the design of the receiver. These sections are chosen such that the measurement of the Rx can be somewhat linear (within specified limits) by manipulating the ADC values between section points. The linearity is desired so that the Rx power can be measured by interpolating between two ADC values.

As Figure 8 shows a simplistic example, where uniform sections are labeled S_1 to S_N and Rx power is already very linear. There will be some regions where the pre-amp will be turned on or off. Also, attenuators will be switched in/out as the power increases.

The main issue to understand in this case is that not all of the sections may require a measurement. It may be that only some points will require accurate measurements, and the other points can be interpolated. This will save time, but adds complexity. Also, some phones may not comply with the interpolation and fail during verification testing. Most importantly, if the phone ADC table(s) require a value, the value must be populated by either defaults, measurement, or calculation/interpolation.

Frequency response

To calibrate frequency response, the mobile designer will typically divide the response of the receiver into sections. Similar to how the dynamic range of the receiver was divided into sections, the number and size of the frequency response sections depends on the design of the receiver. These sections are chosen such that the output of the Tx can be flat (within specification limits) by manipulating the DAC values between section points.

Figure 9 shows the sections labeled S_1 to S_N. In this simplistic example, the sections are uniform and the Tx power has a uniform slope. In the real world, the sections may be more concentrated in non-linear regions and fewer may exist in flat or linear regions. The reason for this is that non-linear regions need more compensation to become flat, whereas linear regions don’t need as much. Again, these items will be unique to each design.

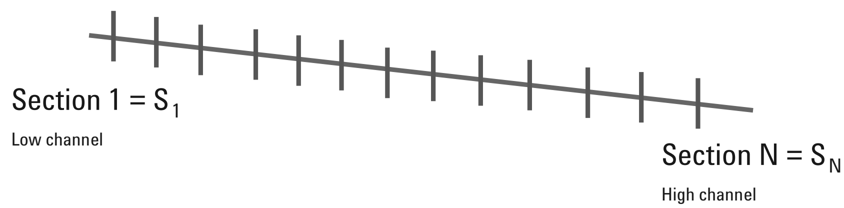

Figure 9. Frequency response of receiver

The main issue to understand in this case is that not all of the sections may require a measurement. Just as with the Tx dynamic range, trade-offs can be made between measurements and interpolation. Most importantly, if the phone DAC table(s) require a value, the value must be populated by either defaults, measurement, or calculation/interpolation.

Similarly, the RSSI measurement of the Rx can be flat (within specified limits) by manipulating the DAC values between section points. Again, this flatness is not as critical as the flatness required of the Tx because there is no equivalent maximum power test for the Rx in 34.121. Not all sections may requirement measurement; trade-offs can be made between measurements and interpolation. As with all other dynamic range and frequency response values, if the ADC table(s) require a value, the value must be populated by either defaults, measurements, or calculation/interpolation.

General calibration procedure

The Tx and Rx calibration procedures cannot be found in the 34.121 standard. They are unique for each phone manufacturer and sometimes for each phone model. However, some general points about Tx and Rx calibration are listed in Table 3.

Table 3. W-CDMA UE Tx and Rx calibration considerations

UE Tx calibration
1. UE Tx power level sweep (several power levels, one frequency) • UE sweeps several power levels, adjusts DAC values based on power measurement • possibly two sweeps required to cover > 70 dB range • currently use channel power measurement
2. Transmit power frequency response (several frequencies, one power level) • UE sweeps several frequencies, one power level. Apply frequency correction factor (dB) to all power levels at one frequency • use channel power measurement
3. Maximum output power (several frequencies, max power) • max power requires high accuracy due to regulations, SAR, battery life, etc. • use thermal power measurement (or channel power without root raised cosine (RRC) filter)
UE Rx calibration
1. Calibrate both UE output power and Rx power (RSSI) • number of calibration points/method are different for every chip set • UE typically in 'test mode' (controlled serially, USB, other) • relating UE DAC values to UE Tx or Rx power levels
2. Calibrate receive power (RSSI) • Rx power level sweep (several power levels, one frequency) • sweep test set output level, UE measures power and stores value in non-volatile RAM • Rx power frequency correction (several frequencies, one power level) • sweep test set output frequency, holding output level steady • apply one frequency correction (dB) to all power levels at that frequency

In general terms, the calibration procedure is heavily influenced by the specific mobile architecture, and calibration is typically performed at a single voltage and at room temperature.

Calibration of the transmitter boils down to populating values into digital-to-analog converter (DAC) table(s) that will control the Tx to provide the desired output power level across the entire dynamic range. The Rx calibration boils down to populating values into a calibration table table(s) that will correlate RF Rx power from the base station to analog-to-digital converter (ADC) values within the mobile's Rx. Knowledge of the RF Rx level is critical for open loop law and for ensuring the proper signal-to-noise ratio at all input levels for proper BER performance.

The manufacturer is not required to make measurements for each value of the DAC or ADC. However, all of the points must be populated via some method. For example, default values could simply be loaded into the look up table(s) and the phone sent to the verification step. This would be very fast, but has a high risk of low yield. Another approach is to measure every single DAC/ADC point. However, this normally increases test time. Finally, a common compromise is to include some type of curve-fitting or interpolation to calculate non-measured points from measured point values. This approach is typically a good compromise, but increases the complexity of the software and can have lower yields depending on the accuracy/repeatability of the curve-fitting.

W-CDMA calibration considerations

With W-CDMA comes new issues. Since the mobile must now work from +21 to –50 dBm, the chance for interference between test benches is greater. This is further complicated by the fact that the 3.84 MHz bandwidth of the W-CDMA signal makes it very probable that adjacent benches will be measuring within the same RF bandwidth (or significant overlap).

With one phone at +21 dBm, it can interfere with an adjacent bench at levels near or above the –50 dBm minimum power level. This occurs when the phone's RF direct connect port and the antenna have limited RF isolation (which is typical). For example, if we consider a mobile phone design that has 15 dB of isolation between the RF direct connect port and the antenna, then we can see the interfering power at an adjacent bench of –44 dBm! This can be calculated by envisioning the +21 dBm maximum power signal attenuated by 15 dB from the port isolation, another 35 dB for free space loss to the adjacent bench, and then another 15 dB from the port isolation on the adjacent bench mobile. Even though there is 65 dB of attenuation, this is still not enough to prevent interference at a level of –44 dBm. In GSM, this was not an issue because the minimum power was around 0 dBm, which is much higher than the interference level.

This problem can be overcome by having shielded enclosures, sophisticated software, or good isolation between the RF direct connect and the antenna.

Tx power VSWR mismatch uncertainty

A poor TX output VSWR can cause significant power measurement uncertainty. This uncertainty can be reduced by including a low-VSWR attenuator directly at the mobile's RF direct connect. The VSWR and attenuation of the matching pad depends on the output VSWR of the mobile Tx and the desired uncertainty.

CW versus QPSK

There may be some advantage to use continuous wave (CW) signals during calibration rather than the normal HPSK and QPSK signals for W-CDMA. This can help to reduce the cost of the power meter sensor and can also reduce Tx power interference by using a different CW frequency within the same 3.84 MHz bandwidth on different benches. Similarly, on the Rx side, a less expensive signal generator can be used. Of course, both of these methods would require correlation testing between CW and the QPSK or HPSK modulation.

Dynamic power analysis

The 8960 test set provides a test-mode only measurement, dynamic power analysis, to permit quick calibration of the entire W-CDMA dynamic range. The advantage of this approach is that it makes measurements of all DAC value compensation sections to decrease the risk of interpolation over the dynamic range, without increasing test time.

Use of the 8960's dynamic power analysis measurement requires a special test mode in the mobile. This test mode must follow the triggering requirements of the measurement in order to work with the 8960.

Agilent Solutions for Multi-mode Manufacturing

This next section focuses on some of the features of the Agilent 8960 (E5515C) Wireless Communications Test Set that can enhance manufacturing test. First, we will offer several tips on how to shave valuable seconds off of the typical test time of a multi-mode mobile phone. Then, we will introduce a novel solution to verify the end-to-end performance of a video data link.

Multi-format testing

Most multi-mode testing is now done in two separate stages. First W-CDMA functionality is evaluated, and then GSM/GPRS/EDGE features are tested. This procedure wastes extra time while the test engineer waits for the mobile to switch on and off, camp on the broadcast signal, and handle storage.

Persistent attach

Persistent attach is a new feature that allows testing W-CDMA, GSM, GPRS, EDGE without switching mobiles on/off. The 8960 performs as a real network which can change cell parameters on-the-fly without dropping the registration of mobiles in the cell. This function can support W-CDMA->GSM->GPRS->EDGE (EGPRS) without turning off the mobile, and hence will save 10 to 15 seconds.

8960 setup

1. Send out a GPIB command turning on persistent attach CALL:MS:PATT ON
2. Send out a GPIB command change W-CDMA/GSM handoff alert state OFF CALL:SET:SYST:GSM:ALER OFF
3. Turn on W-CDMA call processing mode
4. Perform W-CDMA tests
5. Handover from W-CDMA to GSM (without alerting)
6. Perform GSM tests
7. End GSM Call. Change to GPRS ETSI Test-mode
8. Perform GPRS tests
9. End GPRS data connection
10. Change to EGPRS cell
11. Perform EGPRS tests
12. End

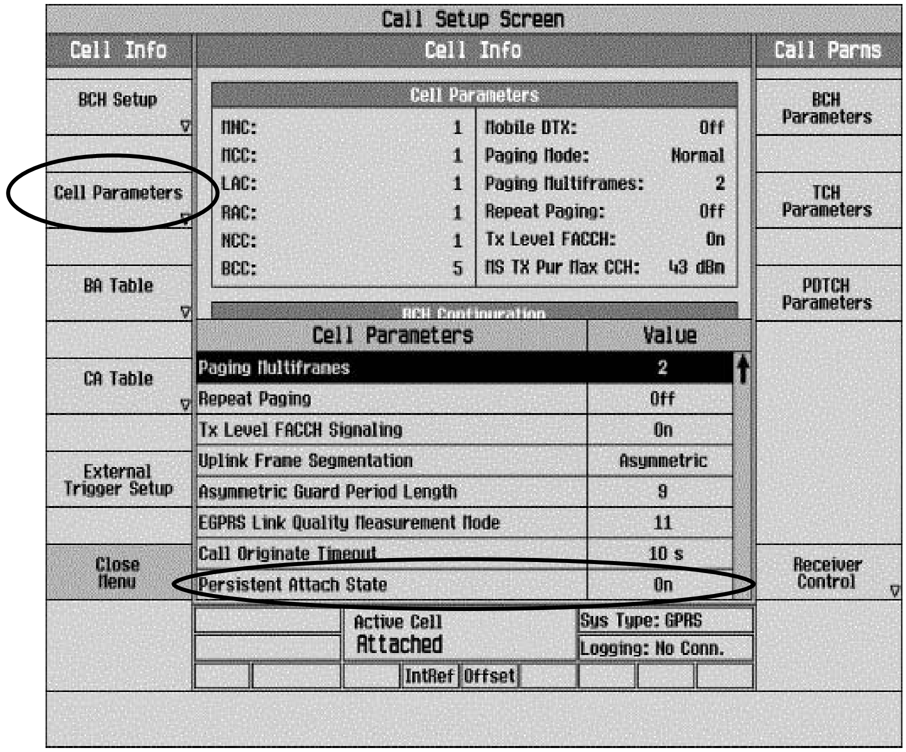

Figure 10. Illustration of persistent attach feature set to "On"

Test procedure

1. Turn on persistent attach
2. Turn off handoff alert
3. Activate W-CDMA call processing mode
4. Perform W-CDMA tests
5. Handover from W-CDMA to GSM (no alert)
6. Perform GSM tests
7. Change to GPRS ETSI test mode
8. Perform GPRS tests
9. Change to EGPRS cell
10. Perform EGPRS tests
11. End

Notes on measurement setup

GPRS mobility management remains in the registered state. This is an internal process that is not directly visible to the user. It controls the 8960's response to the DUT attempting a routing area update (RAU) without re-attaching. The 8960 test set rejects the RAU_REQUEST. The result of this change will be that the sequence [Operating Mode OFF – change cell parameter (e.g. routing area code) – Operating Mode Active Cell (GPRS or EGPRS)] will allow the UE to perform a routing area update without having to re-attach.

W-CDMA to GSM handoff

There are two ways to perform RB test mode (W-CDMA RMS) to GSM handover tests: alert and automatic switch. If alert is on, you must press a key to answer the call. If the alert is off, echo is not available, i.e. the UE will not ring when handed over from W-CDMA RB test mode to GSM voice. This will not affect the results of any test, but the engineer must be aware of this if he or she expects to hear an echo. When the handoff is completed, the connection is left in the RR connected state. Data loopback (for BER testing) is available in this state, but voice echo is not.

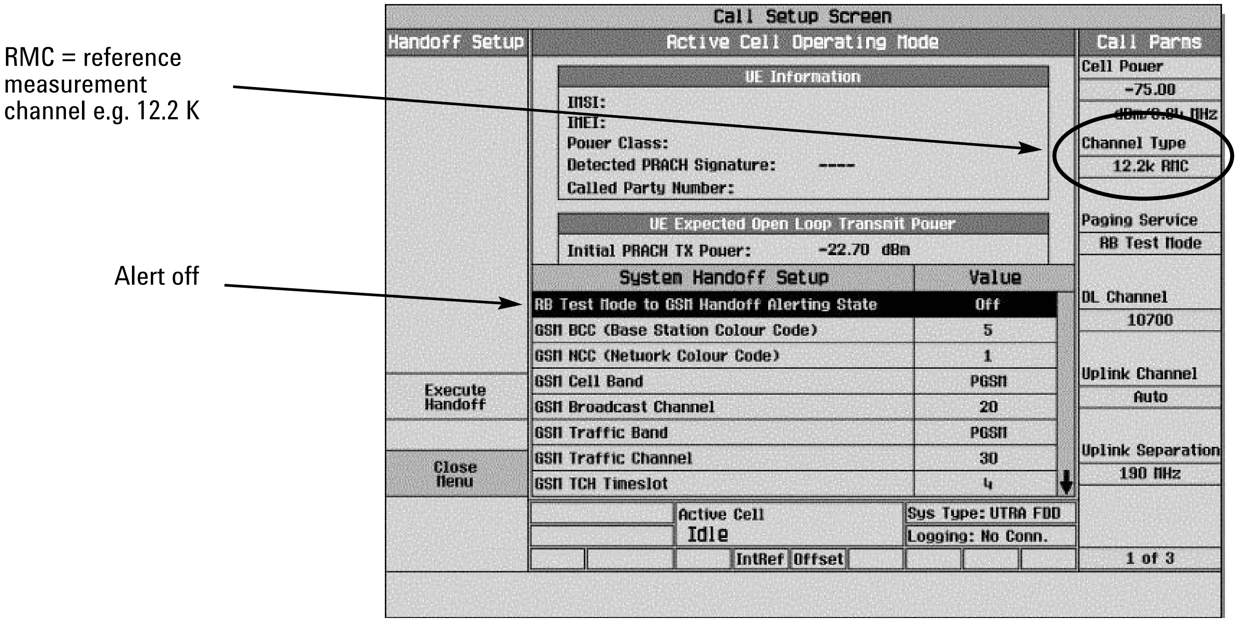

Figure 11. Example of handoff with ringing alert set to "Off"

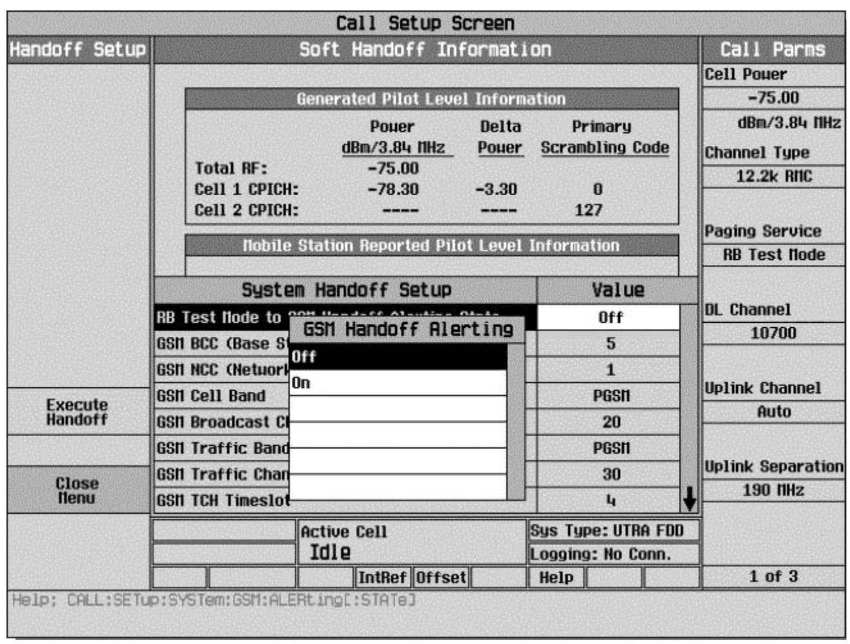

Figure 12. Turn alert off using the CALL:SETup:SYSTem:GSM:ALERting OFF command

GSM/GPRS/EGPRS multiple-band handover

There is some confusion when handing over from DCS bands (1.8 GHz) to PCS bands (1.9 GHz) because different countries use similar channel numbers but different frequencies. The BTS only tells the mobile a channel number, not a channel number and frequency. Because the channel numbers overlap, connection will be dropped if the phone receives a message it doesn't understand. This means that on production lines, the mobile must end the call connection. The typical method is to switch from GSM/DCS band to PCS band, then re-camp on the new broadcast channel (BCH). This process takes approximately 10 to 15 seconds. For each format in a multimode phone, any extra time used for band switching is time wasted.

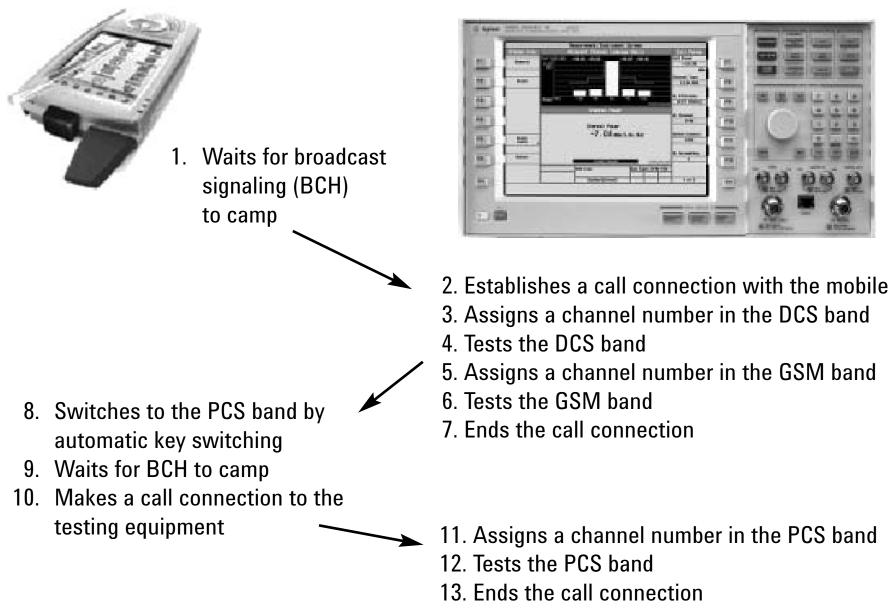

Figure 13. Traditional method for testing multiple bands

Figure 13 illustrates a snapshot of the traditional method for testing multiple bands. In order to perform the handover from DCS to PCS, manual switching is used. Between steps 8 and 9 we lose 10 to 15 seconds to re-camp. We don't want to waste this time.

The 8960 can support two methods of avoiding the re-camp between DCS and PCS bands. 3GPP Release 99 includes new protocol message called “band indicator.” Using this indicator is the first method for reducing re-camp time (Figure 14.) Using this process, the handover from DCS to PCS by includes band indicator value. The BS will assign mobile to change from “DCS and 512” to “PCS and 512”. The problem with this method is that most phones don’t use this band indicator protocol message.

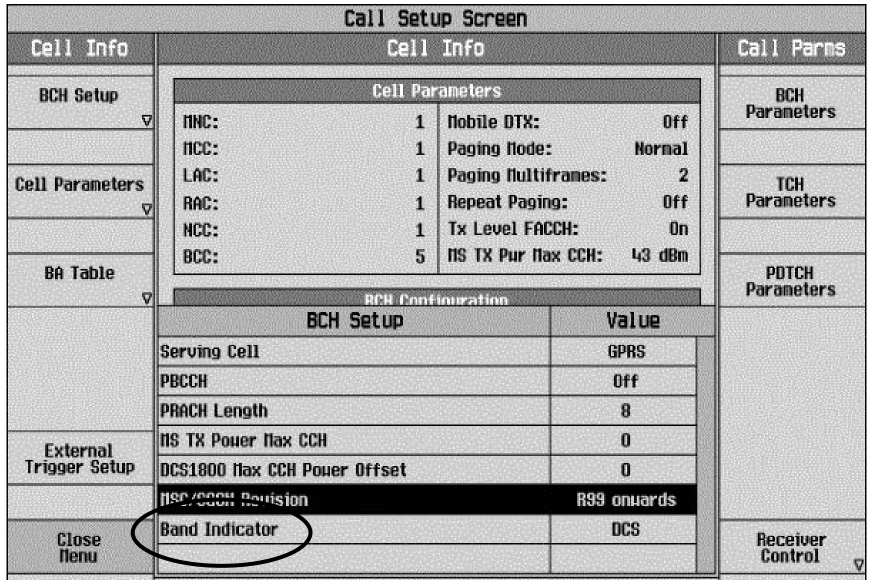

Figure 14. Using “band indicator” method to reduce re-camp between bands

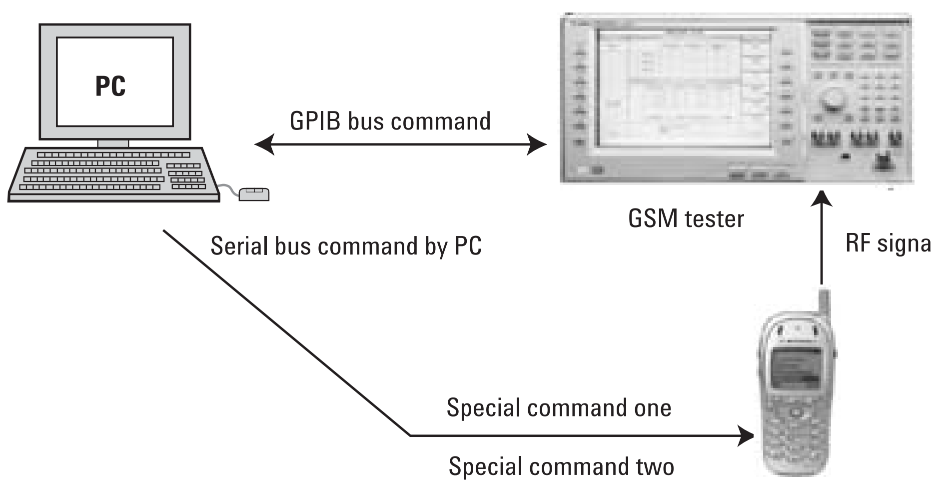

Figure 15. Forcing a band switch using special commands

In the second method, we send two special commands to the phone over the serial port in order to avoid the manual switch. The special commands remove the ambiguity of the channel numbers by forcing the phone to a particular frequency band (Figure 16).

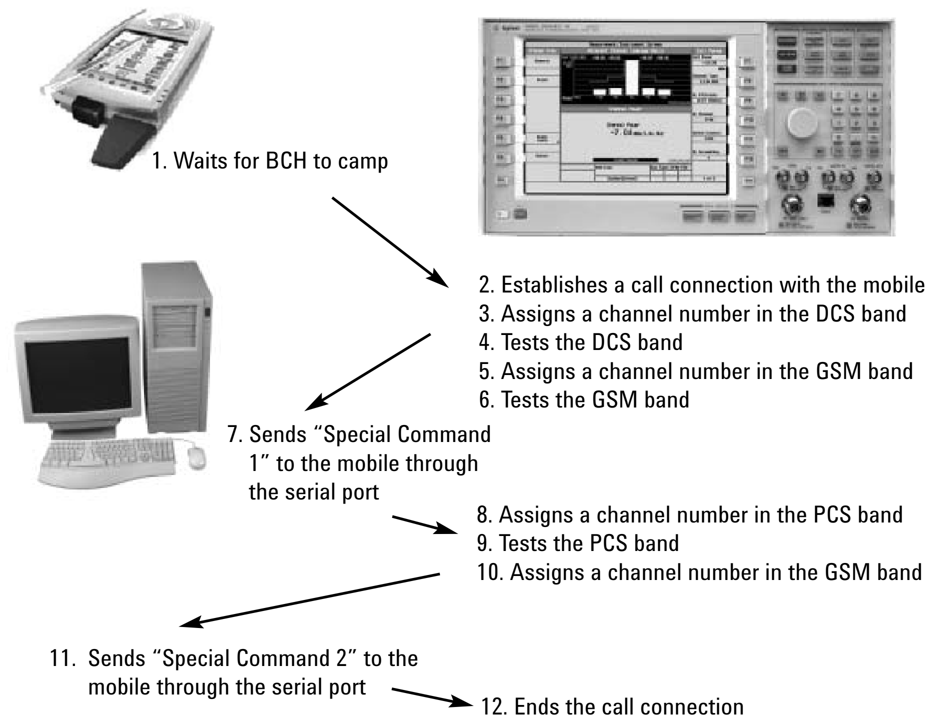

Figure 16. Testing procedure for forcing a band switch

Special command one
The mobile will operate in the PCS band when a handover command with a channel number between 512 and 810 is received. **From this moment, the mobile receives channel number 512 to 810. It will not jump to DCS band. It will jump to PCS band.**

Special command two
The mobile will operate in the DCS band when a handover command with a channel number between 512 and 810 is received. **From this moment, the mobile receives channel number 512 to 885. It will not jump to PCS band. It will jump tp DCS band. This command brings the mobile back to normal state.**

With the new method, instead of camping between DCS and PCS bands, we send a special command over the serial port to force the phone into the frequency band we want to test.

The advantage of the second procedure is increased speed with no tradeoffs for power accuracy or stability. In order to implement this procedure, manufacturers must change the protocol within the phone to accept the two new commands. This is a fairly simple change though, and should not take much development time to implement.

Fast parameters setting (GSM, GPRS, EDGE)

A unique attribute of the 8960 is the support of simultaneous setting of new parameters. As shown in Table 4, these include parameters for a variety of technologies.

Table 4: Fast setting parameters available with the 8960

Technology	Parameters
GSM	Channel, band, power level, timeslot
GPRS	Channel, band, CS, power level (burst 1 and burst 2), multiple slot (3D2U)
EGPRS	Channel, band, MCS, power level (burst 1 and burst 2), multiple slot (3D2U)

In the 3GPP conformance standards, parameters are constantly changing from test to test. To change each of these parameters manually could take a lot of extra time. With the 8960, parameters can be set before testing begins, then implemented simultaneously, saving time in production lines.

This feature can also be programmed remotely

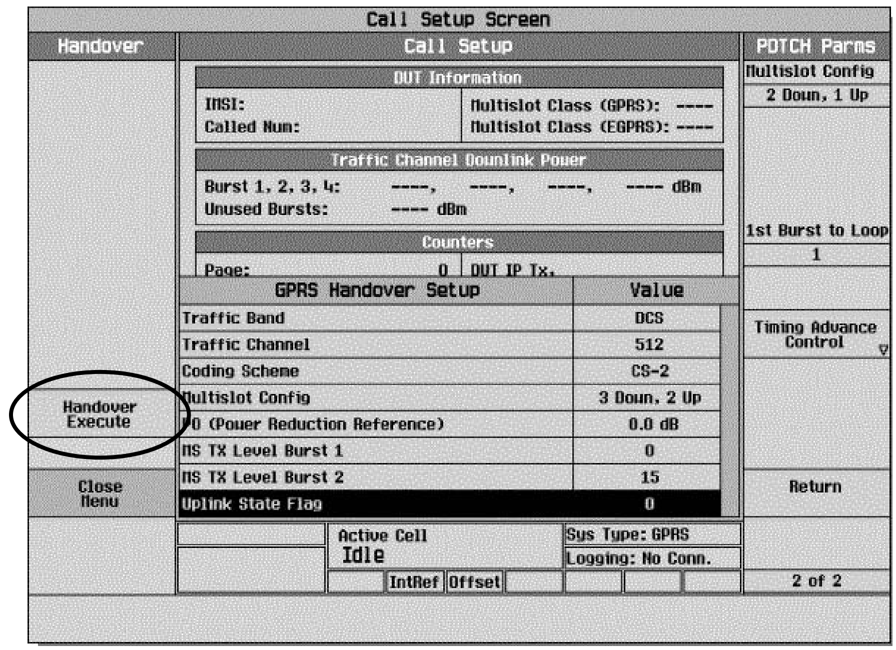

Figure 17. Simultaneous parameter setting on the 8960 test set saves time

To use this feature, set all the parameters at one time, then hit 'Handover Execute.' All of the adjusted parameters change at one time.

This can also be programmed remotely:

```
OUTPUT 714;"CALL:SETup:PDTCh:BAND DCS"        ! Sets the deferred band to DCS
OUTPUT 714;"CALL:SETup:PDTCh 515"             ! Sets the ARFCN to 515
OUTPUT 714;"CALL:SETup:PDTCh:CSCHeme CS4"  ! Sets the coding scheme to CS4
OUTPUT 714;"CALL:SETup:PDTCh:MSLot:CONFiguration D2U2"  ! Sets to 2 x2.
OUTPUT 714;"CALL:SETup:PDTCh:MS:TXLevel:DCS:BURST1 0"  ! Sets burst 1 power level
OUTPUT 714;"CALL:SETup:PDTCh:MS:TXLevel:DCS:BURST1 15"! Sets burst 2 power level
```

When remote programming is used, the mobile does not make any RF change until the "CALL:HAND" command is received.

```
OUTPUT 714;"CALL:HANDover:IMMediate"
```

End-to-end video verification

One of the promises of 3G is to enable high bandwidth applications like real time video streaming. It is important to verify in production that this application will work on a real network. For accurate simulation of the network, two linked instruments are needed.

The Agilent solution, offered in the E6703C lab application and as an option for the E1963A test application, is the only one box test solution to provide real network call setup for this critical network application (Figure 18). Other solutions currently available on the market only verify the end connection, typically not where most of the trouble lies. Call setup continues to stress UE's from different vendors operating on the same network.

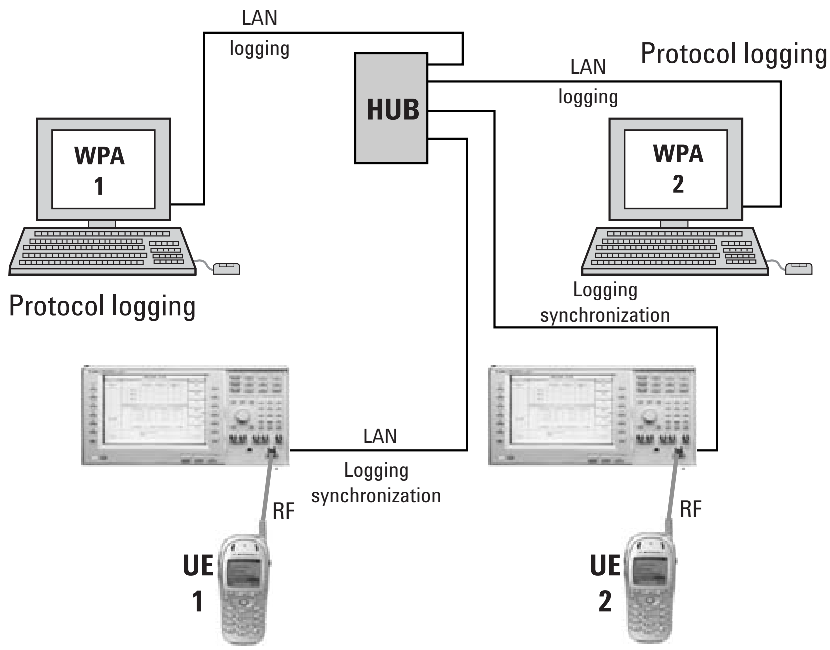

Figure 18. Test configuration for testing UE end-to-end video conferencing capabilities

With the Agilent solution, you can easily:

- analyze call setup messages from both mobiles during realistic call setup
- verify video/audio quality in real network situations, stressing and validating your application performance
- verify compatibility between dissimilar mobiles through regression testing

Video test in the 8960 requires two instruments loaded with the necessary firmware and hardware.

The sequence of events for a successful call connection are:

1. Connect instruments using a LAN crossover cable, or through a hub.
2. Select one instrument and use Ping/Connect over LAN with the other instrument, establishing control communication between instruments.
3. Power on mobiles and register each one to the test set it is connected to.
4. User makes a mobile originated call to any number, selecting video call from the mobile. (This differs for each mobile, but they generally have a special button for video calls.)
5. The first 8960 receives the call request from the first mobile and communicates this with the second 8960.
6. The second 8960 pages the second mobile with "video call" as the requested service.
7. User acknowledges the alert on the second phone.
8. The second 8960 signals the first 8960 that the second user has acknowledged the call.
9. The first 8960 completes connection with first mobile.
10. Real time video/audio connection has been established between mobiles using H.324 protocol.

Conclusion

The UE being produced today must be able to cover a wide range of high-speed data operations and operate in several different formats. However, there are significant challenges in testing multi-mode devices. Given the different modulation formats used by various wireless technologies, additional time for calibration is needed. Multi-band and multi-format signaling must be verified. New and emerging data services, such as HSDPA, must also be tested. These requirements can make test plans for multi-mode devices complex and require more time to operate. Using the Agilent 8960 (E5515C) one-box test set and technology-specific test applications deliver time-saving techniques to verify the UEs perform in accordance to industry-defined standards, helping manufacturing test engineers overcome the challenges of producing multi-mode handsets.

For More Information

To learn more about Agilent test solutions and industry standards, visit the following Web sites:

Wireless technology portal
www.agilent.com/find/3g

Inter-band handover technique for testing tri-band GSM
http://www.eie.polyu.edu.hk/~encmlau/paper/conference/con2004feb-1.pdf

Evolution of standards wireless technology poster
http://cpliterature.product.agilent.com/litweb/pdf/5989-0467EN.pdf

Appendix A

Average GSM+GPRS final test plan

Chan	Cell power	Tx lev	Test item
			Call connection
			GSM section
High	–60 dBm	5	PFER
			PvT
			ORFS (mod + switching)
	–100 dBm		Rx Level, RX Qual
			FBER
	–85 dBm	19	PFER
			PvT
Low	–85 dBm	19	PFER
			PvT
	–60 dBm	5	PFER
			PvT
			ORFS (mod + switching)
	–100 dBm		Rx Level, RX Qual
			FBER
			Handover to DCS
Low	–100 dBm	0	Rx Level, RX Qual
			FBER
			PvT
			PFER
			ORFS (mod + switching)
	–85 dBm	15	PvT
			PFER
High	–85 dBm	15	PFER
			PvT
	–100 dBm	0	Rx Level, RX Qual
			FBER
			PvT
			PFER
			ORFS (mod + switching)
			GPRS section
62	–80 dBm	P1=5; P2=9	PvT
	P0 = 10		BLER @50 Block
	PRL1 = 1		
	PRL 2 = 11		

Note:
TXP Measurement Count = 5
PvT & PFER Measurement Count = 10
BER Count= 10000

Average W-CDMA final test plan

Chan	Cell power	Tx lev	Test item
Low	–75		Registration
	–106.7		TX On/Off
			Pre Burst Off Power@ –106.7 dBm
			Burst On Power@ –106.7 dBm
			Post Burst Off Power@ –106.7 dBm
	–25		Open Loop Power Err@ –25 dBm
	–65.7		Open Loop Power Err@ –65.7 dBm
	–106.7		Open Loop Power Err@ –106.7 dBm
	–75		**RB test mode 12.2k connection**
	–93		Maximum Output Power
			ACLR @ –5 MHz Offset
			ACLR @ +5 MHz Offset
			ACLR @ –10 MHz Offset
			ACLR @ +10 MHz Offset
			Spectrum Emission Mask
			Occupied Bandwidth
		max	EVM
			Minimum Output Power
			Inner Loop Power Segment E
			Inner Loop Power Segment H
	–106.7		Ref Sensitivity Level BER Ratio
	–25		Maximum Input Level BER
Mid	–93		Maximum Output Power
			ACLR @ –5 MHz Offset
			ACLR @ +5 MHz Offset
			ACLR @ –10 MHz Offset
			ACLR @ +10 MHz Offset
			Spectrum Emission Mask
			Occupied Bandwidth
		max	EVM
			Mininum Output Power
			Inner Loop Power Segment E
			Inner Loop Power Segment H
	–106.7		Ref Sensitivity Level BER Ratio
	–25		Maximum Input Level BER
High	–93		Maximum Output Power
			ACLR @ –5 MHz Offset
			ACLR @ +5 MHz Offset
			ACLR @ –10 MHz Offset
			ACLR @ +10 MHz Offset
			Spectrum Emission Mask
			Occupied Bandwidth
		max	EVM
			Mininum Output Power
			Inner Loop Power Segment E
			Inner Loop Power Segment H
	–106.7		Ref Sensitivity Level BER Ratio
	–25		Maximum Input Level BER
			End Call
	–106.7		TX On/Off
			Pre Burst Off Power@ –106.7 dBm
			Burst On Power@ –106.7 dBm
			Post Burst Off Power@ –106.7 dBm
	–25		Open Loop Power Err@ –25 dBm
	–65.7		Open Loop Power Err@ –65.7 dBm
	–106.7		Open Loop Power Err@ –106.7 dBm

Note:
BER Measurements set to 10,000 Max Bits
EVM run at max power text condition only. For a combo GSM/GPRS/WCDMA test plan – Delete the last TX On/Off and OLP tests and replace End Call with a WCDMA to GSM Handover

Minimal GSM+GPRS final test plan

Chan	Cell power	Tx lev	Test item
	–85 dBm		Call Connection
			GSM Section
High	–100 dBm	5	PFER
			PvT
			ORFS (mod + switching)
			FBER
Low	–85 dBm	19	PFER
			PvT
			Handover to DCS
Low	–85 dBm	15	PFER
			PvT
High	–100 dBm	0	FBER
			PvT
			PFER
			ORFS (mod + switching)

Note:

Some customers are not testing GPRS, so the minimal test does not include GPRS tests.
TXP Measurement Count = 5
PvT & PFER Measurement Count = 10
BER Count= 10000

Minimal W-CDMA Final Test Plan

Chan	Cell power	Tx lev	Test item
Low	–75		Registration
	–106.7		TX On/Off
			Pre Burst Off Power@ –106.7 dBm
			Burst On Power@ –106.7dBm
			Post Burst Off Power@ –106.7dBm
	–75		**RB test mode 12.2k connection**
	–93		Maximum Output Power
			ACLR @ –5 MHz Offset
			ACLR @ +5 MHz Offset
			ACLR @ –10 MHz Offset
			ACLR @ +10 MHz Offset
			Spectrum Emission Mask
		max	EVM
			Mininum Output Power
			Inner Loop Power Segment E
			Inner Loop Power Segment H
	–106.7		Ref Sensitivity Level BER Ratio
	–25		Maximum Input Level BER
Mid	–93		Maximum Output Power
			ACLR @ –5 MHz Offset
			ACLR @ +5 MHz Offset
			ACLR @ –10 MHz Offset
			ACLR @ +10 MHz Offset
			Spectrum Emission Mask
		max	EVM
			Mininum Output Power
			Inner Loop Power Segment E
			Inner Loop Power Segment H
	–106.7		Ref Sensitivity Level BER Ratio
	–25		Maximum Input Level BER
High	–93		Maximum Output Power
			ACLR @ –5 MHz Offset
			ACLR @ +5 MHz Offset
			ACLR @ –10 MHz Offset
			ACLR @ +10 MHz Offset
			Spectrum Emission Mask
		max	EVM
			Mininum Output Power
			Inner Loop Power Segment E
			Inner Loop Power Segment H
	–106.7		Ref Sensitivity Level BER Ratio
	–25		Maximum Input Level BER
			End Call
	–106.7		TX On/Off
			Pre Burst Off Power@ –106.7 dBm
			Burst On Power@ –106.7 dBm
			Post Burst Off Power@ –106.7 dBm

Note:

BER Measurements set to 10,000 Max Bits
EVM run at max power text condition only.
For a combo GSM/GPRS/WCDMA test plan – Delete the last TX On/Off test and replace End Call with a WCDMA to GSM Handover

Large GSM+GPRS Final Test Plan

Chan	Cell power	Tx lev	Test item
			Call Connection
			GSM Section
High	-60 dBm	5	PFER
			PvT
			ORFS (mod + switching)
	–100 dBm		Rx Level, RX Qual
			FBER
	–85dBm	19	PFER
			PvT
Mid	–85 dBm	19	PFER
			PvT
	–60 dBm	5	PFER
			PvT
			ORFS (mod + switching)
	–100 dBm		Rx Level, RX Qual
			FBER
Low	–60 dBm	5	PFER
			PvT
			ORFS (mod + switching)
	–100 dBm		Rx Level, RX Qual
			FBER
	–85 dBm	19	PFER
			PvT
			Handover to DCS
Low	–100 dBm	0	Rx Level, RX Qual
			FBER
			PvT
			PFER
			ORFS (mod + switching)
	–85 dBm	15	PvT
			PFER
Mid	–85 dBm	15	PFER
			PvT
	–100 dBm	0	Rx Level, RX Qual
			FBER
			PvT
			PFER
			ORFS (mod + switching)
Low	–100 dBm	0	Rx Level, RX Qual
			FBER
			PvT
			PFER
			ORFS (mod + switching)
	–85 dBm	15	PvT
			PFER
			GPRS Section
62	–80 dBm	P1=5; P2=9	PvT
	P0 = 10		BLER @50 Block
	PRL1 = 1		
	PRL 2 = 11		

Note:
TXP Measurement Count = 5
PvT & PFER Measurement Count = 10
BER Count= 10000

Note:
BER Measurements set to 10,000 Max Bits
EVM run at max power text condition only.
For a combo GSM/GPRS/WCDMA test plan – Delete the last TX On/Off and OLP tests and replace End Call with a WCDMA to GSM Handover

Large W-CDMA final test plan

Chan	Cell power	Tx lev	Test item
Low	–75		Registration
	–106.7		TX On/Off
			Pre Burst Off Power@ –106.7 dBm
			Burst On Power@ –106.7 dBm
			Post Burst Off Power@ –106.7 dBm
	–25		Open Loop Power Err@ –25 dBm
	–65.7		Open Loop Power Err@ –65.7 dBm
	–106.7		Open Loop Power Err@ –106.7 dBm
	–75		**RB test mode 12.2k connection**
	–93		Maximum Output Power
			ACLR @ –5 MHz Offset
			ACLR @ +5 MHz Offset
			ACLR @ –10 MHz Offset
			ACLR @ +10 MHz Offset
			Spectrum Emission Mask
			Occupied Bandwidth
		max	EVM
			Minimum Output Power
			Inner Loop Power Segment B
			Inner Loop Power Segment C
			Inner Loop Power Segment E
			Inner Loop Power Segment F
			Inner Loop Power Segment G
			Inner Loop Power Segment H
	–106.7		Ref Sensitivity Level BER Ratio
	–25		Maximum Input Level BER
Mid	–93		Maximum Output Power
			ACLR @ –5 MHz Offset
			ACLR @ +5 MHz Offset
			ACLR @ –10 MHz Offset
			ACLR @ +10 MHz Offset
			Spectrum Emission Mask
			Occupied Bandwidth
		max	EVM
			Mininum Output Power
			Inner Loop Power Segment B
			Inner Loop Power Segment C
			Inner Loop Power Segment E
			Inner Loop Power Segment F
			Inner Loop Power Segment G
			Inner Loop Power Segment H
	–106.7		Ref Sensitivity Level BER Ratio
	–25		Maximum Input Level BER
High	–93		Maximum Output Power
			ACLR @ –5 MHz Offset
			ACLR @ +5 MHz Offset
			ACLR @ –10 MHz Offset
			ACLR @ +10 MHz Offset
			Spectrum Emission Mask
			Occupied Bandwidth
		max	EVM
			Mininum Output Power
			Inner Loop Power Segment B
			Inner Loop Power Segment C
			Inner Loop Power Segment E
			Inner Loop Power Segment F
			Inner Loop Power Segment G
			Inner Loop Power Segment H
	–106.7		Ref Sensitivity Level BER Ratio
	–25		Maximum Input Level BER
			End Call
	–106.7		TX On/Off
			Pre Burst Off Power@ –106.7 dBm
			Burst On Power@ –106.7 dBm
			Post Burst Off Power@ –106.7 dBm
	–25		Open Loop Power Err@ –25 dBm
	–65.7		Open Loop Power Err@ –65.7 dBm
	–106.7		Open Loop Power Err@ –106.7 dBm

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Printed in USA, November 15, 2005
5989-4083EN

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