application note

Testing GAIT Phase One Mobiles

by Rob Barden, Senior Product Marketing Manager

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Nothing is ever static in the world of digital cellular and wireless communications. With the recent explosion of digital cellular service and the acquisitions and mergers of wireless cellular operators, there has been a sudden resurgence in the concept of the "world phone." Since 450 million subscribers worldwide are using GSM (Global System for Mobility) technology, you can count on GSM to be the cornerstone of any "world phone" development. Accordingly, the GAIT (GSM - ANSI-136 Interoperability Team) phone features GSM as part of its core technology, along with ANSI-136 (American National Standards Institute) or TDMA (Time Division Multiple Access) technology.

In the US there are significant driving factors that are pushing the development of GAIT mobiles. Cingular, the company formed by the combination of the Southwestern Bell and Bell South wireless groups, and AT&T are the two predominant TDMA carriers in the US. These operators either own or are moving to GSM technology and want to promote the ability to use one mobile on both GSM and TDMA networks while also allowing for overseas roaming.

Cingular's network features both GSM and TDMA technologies with the core technology being TDMA. They have also stated that they are going to deploy GPRS (General Packet Radio Service) and EDGE (Enhanced Data for GSM Evolution) data services. With the two operations coming together, there has been a driving force to combine the two technologies to allow the operator to provide "seamless" coverage for their customers without forcing them to a competitor's network.

AT&T Wireless has a similar, although slightly different situation. While Cingular is faced with the tasks of integrating existing systems and future GSM based data services, AT&T is developing an entirely new GSM network to support their new direction into GSM/GPRS/EDGE technologies. Their requirement is similar, however, in that they need to provide "seamless" coverage for their customer base as well. By capturing the customer on their networks, the operators retain customer revenue and boost customer satisfaction thereby reducing customer turn over.

What is GAIT Phase One?

GAIT Phase One is the integration of both TDMA and GSM voice and data technology into one handset with the ability to select and operate on either a TDMA or GSM network. TDMA capabilities offer the ability to roam on AMPS (Advanced Mobile Phone Service) networks, since this is an integral part of the ANSI-136 feature set.

GAIT technology is being developed by the GSM ANSI-136 Interoperability Team headed by Cameron Coursey of Cingular. This group operates under the banner of the TDMA users' group known as the Universal Wireless Communications Consortium and the GSM Alliance.

The GAIT Phase One phone will provide the ability for the user to select and then use either a GSM or TDMA network as determined by the operator. In this first rendition, GAIT mobiles will also allow roaming on other networks as defined by agreements between the user's operator and other wireless service providers. GAIT mobiles will not allow intra-system hand-offs or hand-overs. Simply stated, the mobile will know who its primary operator is and based off an internal look up table, called the NSDB (Network Selection Database), the mobile will know whether to go to either a TDMA or GSM network. This will be based on a number of parameters programmed into the mobiles NSDB which resides on the revised SIM (Subscriber Identity Module) card adopted for the GAIT mobile.

An additional feature of GAIT mobiles will allow the user to send and receive SMS messages using a feature called GHOST (GSM Hosted SMS Teleservices). More on that feature later.

So what do we test on a GAIT mobile?

Testing a GAIT mobile is really like testing separate GSM and TDMA handsets. There is some additional GAIT related testing that is required, but that is limited to just a few specific tests. Let's look at the RF (Radio Frequency) performance side first.

RF Parametric Testing of GAIT Mobiles

As with any mobile phone, the requirements for testing the RF parametrics are still valid. However, with the GAIT phone, you are required to test for both the GSM and TDMA RF performance, depending on how in-depth your testing requirements are. For review, let's look at the two technologies and the typical associated RF performance test parameters.

GSM MOBILE RF TEST PARAMETERS

Transmitter Parameters:

Power Level: This test measures the mobile transmitter power output level while the mobile is in conversation on the TCH (Traffic Channel (GSM)). The pass limits are different for different power levels. The limits for each test are determined by the different power levels and classes for GSM 900, 1800 and 1900 performance.

RMS Phase Error: This test checks the accuracy of the phase modulation of the transmitter in the Mobile Under Test. It is made on the useful part (information or data) of the burst and is usually averaged over a predetermined number of bursts.

Peak Phase Error: This test again checks the modulation accuracy of the transmitter in the mobile under test. It is made on the useful part of the burst over a predetermined number of bursts. This is the worst case measurement of the phase error.

Frequency Error: A test of the stability of the mobile's transmitter to keep on frequency.

Bit Timing: This test checks the accuracy of the mobile's transmission timing.

Power Profile Conformance: The ability of the mobile to control ramping power, power over time and shut down power within a defined power-time profile mask. See figure 1.0 for example.

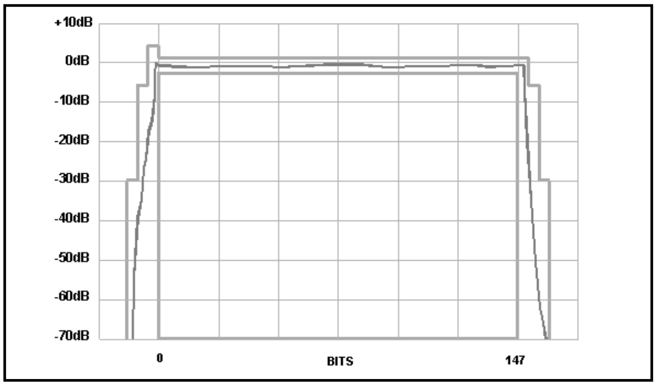

Figure 1.0 - GSM Power Burst Profile - Normal Burst

Receiver Parameters:

BER1 (Bit Error Rate): This test checks the mobile receiver's bit error rate for Class 1 bits (which are subject to error correction by the mobile).

BER2: This test checks the mobile receiver's bit error rate for Class 2 bits (which are not error corrected).

RBER1b (Residual Bit Error Rate): This test checks the mobile receiver's residual bit error rate for Class 1b bits, that is, the bit error rate in those frames that have not been erased by the mobile.

RBER2: This test checks the mobile receiver's residual bit error rate for Class 2 bits (which are not error corrected).

FER (Frame Erasure Rate): This is the measurement of the percentage of speech frames that are so badly corrupted that they fail their Class 1 parity check and are erased.

ANSI-136 (TDMA) MOBILE RF TEST PARAMETERS

Transmitter Parameters:

Power Level: This test measures the mobile transmitter power output level while the mobile is in conversation on the DTC (Digital Traffic Channel). The pass limits are different for different power levels. The limits for each test are determined by the different power levels and classes for TDMA 800 and 1900 performance.

Error Vector Magnitude: This test checks the modulation accuracy of the transmitter in the mobile under test. It is derived from the plot of the symbol on an I/Q quadrant map to determine the magnitude of the error vector. See figure 2.0.

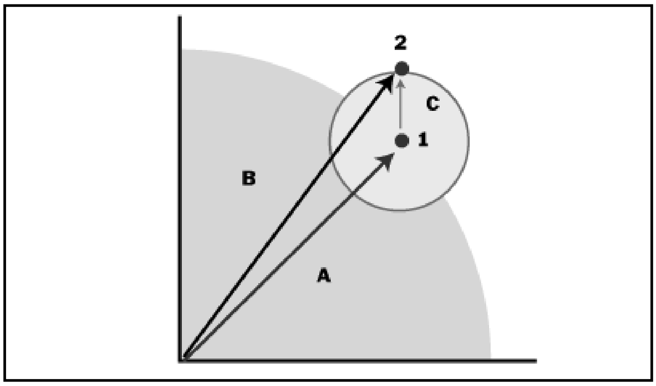

Figure 2.0 - EVM (Error Vector Magnitude) where vector "A" is the optimal path and "B" is the actual path. The EVM (vector "C") is measured from the ideal point (1) to the actual landing point (2) of the symbol and is expressed as the ratio of C to A.

Frequency Error: A test of the stability of the mobile's transmitter to keep on frequency.

Adjacent Channel Power: This tests the mobile transmitters spectral performance by measuring transmitted power in the adjacent, alternate and second alternate channels (offset 30 kHz, 60 kHz and 90 kHz from the center frequency). See figure 3.0.

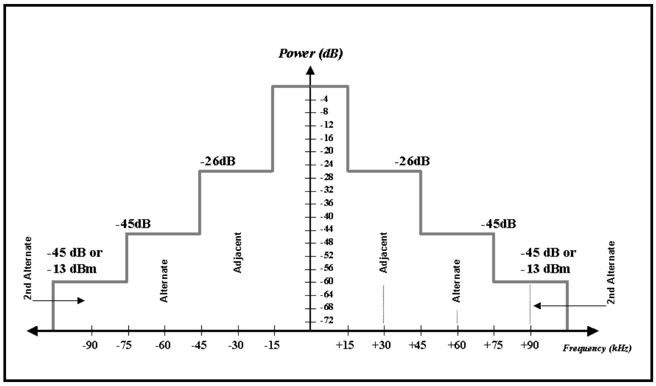

Figure 3.0 - Adjacent Channel Power Mask for TDMA ANSI-136 30 kHz channels for mobile phone digital modulation

Receiver Parameters:

BER: This test checks the mobile receiver's bit error rate using a pseudo-random bit stream looped back through the mobile's transceiver or, as an alternative method, using the actual reported BER from the phone at a low signal level, typically -110 dBm.

Depending on the type of testing required the testing requirements and accuracy will vary. In an engineering operation, you will do both GSM and TDMA full RF parametric analysis. In a service environment, that could change to just a simplified test to troubleshoot the RF circuitry. The level of functionality and accuracy is dependent upon your specific need.

Protocol Testing - what's changed?

Protocol testing is an important part of the mobile phone test process, especially if you are in the verification and validation business for the testing of new mobile phone types. GSM and TDMA protocol test systems have been around for quite a while and for the purposes of this review, we won't go into the vast amounts of protocol testing required.

But, what's changed for GAIT mobile testing? In testing a GAIT mobile you need to add two different tests to the conventional TDMA or GSM protocol tests. These tests are:

1. Test of the Network Selection Database or NSDB. The network selection algorithm determines the mobile's ability to locate and select the proper network for that phones primary operator. For example, if you are a Cingular customer, your GAIT phone would want to stay on a Cingular network. This is good for Cingular since they control the quality of the call and it is good for you since you won't have to pay additional roaming charges by using some other operator’s network. As a test professional, you will want to test the network selection algorithms for proper functioning.

2. GSM Hosted SMS Teleservice. Also known as GHOST. The GAIT mobiles use GSM SMS for messaging and over-the-air programming in both GSM and TDMA modes. In TDMA mode, the GSM SMS PDU (Protocol Data Unit) as defined in GSM 03.40 is tunneled across the ANSI-136 air interface. Therefore, the mobile has to be able to process a standard GSM SMS message while operating in both types of networks.

GAIT Modes

Before going forward, let's define the different modes in which a GAIT mobile operates. These modes are simply operating states that the mobile may operate in, depending upon the type of home network. There are four different modes for the GAIT mobile as defined below:

GSM Native Mode: This is where the mobile is homed to a GSM network and is operating on a GSM network. In this mode, the mobile is able to perform standard GSM type functions including SMS and Data services (circuit switched at 9600 or 14400 bps and packet switched service if it is offered).

ANSI-136 Native Mode: This is where the mobile is homed to an ANSI-136 network and is operating on an ANSI-136 network. In this mode, the mobile is able to perform standard ANSI-136 functions including text messaging using GHOST SMS and Data services (circuit switched at 9600 bps).

GSM Foreign Mode: This is where the mobile is homed to an ANSI-136 network but is operating on a GSM network. At this time, the GSM portion of the phone is operational and the network's Interworking and Interoperability Function (IIF) handles the call delivery and SMS routing from the ANSI-136 network to the serving GSM network.

ANSI-136 Foreign Mode: This is where a GSM native subscriber is accessing an ANSI-136 network. Again, routing of calls and SMS is handled by the network's Interworking and Interoperability Function.

Testing the NSDB - what's involved?

So what is involved in testing the Network Selection Database? Network selection is the mobile's ability to acquire the correct network and to obtain the best service in a given geographic area. The mobile looks at the stored information on the SIM card, as defined by the home service provider, for the information to determine which networks the phone can access. This can include GSM, ANSI-136 and AMPS networks. For GAIT mobiles, the network selection algorithm is a combination of the ANSI-136 Intelligent Roaming Algorithm and GSM's network selection algorithm.

Tables 1 and 2 show the service provider categories for ANSI-136/AMPS and GSM networks, respectively. In ANSI-136, the Home service provider is defined by the Home SID (System Identity) or SOC (System Operator Code). Partner, Favored and Forbidden service providers are defined by SID and SOC lists that are part of the Intelligent Roaming Database. If the SID or SOC of a network is not included in any of these databases, then it is considered a Neutral service provider. In GSM, the Home service provider is defined by the MCC (Mobile Country Code) and MNC (Mobile Network Code) that are part of the mobile station's IMSI (International Mobile Subscriber Identity). A Preferred GSM service provider is defined as one whose MCC/MNC combinations are stored in a Preferred PLMN (Public Land Mobile Network) List. Similarly, a Forbidden GSM service provider is defined as one whose MCC/MNC combinations are stored in a Forbidden PLMN List. A Neutral GSM service provider is one whose MCC/MNC is not part of the mobile's IMSI or one of the PLMN Lists.

Service Provider Category	***Action Taken***
Home	Select Immediately, no background triggered scanning
Partner	No background triggered scanning
Favored	Select Best Available, use background scanning for selection of better Service Provider
Neutral	Use background scanning for selection of a better Service Provider
Forbidden	Emergency Calls only

Table 1 - ANSI-136 Intelligent Roaming Service Provider Categories

Service Provider Category	***Action Taken***
Home	Select Immediately
Preferred	Select Best Available, use background scanning for selection of better Service Provider
Forbidden	Emergency Calls only

Table 2 - GSM Network Selection Service Provider Categories

Table 3 shows the priority used by the GAIT mobile station to obtain service on different networks, based on a PPI (Protocol Priority Indicator) setting. For example, if the PPI indicates ANSI-136 Preferred then the mobile station follows the priority shown in the left-hand column when searching for service. Suppose that the GAIT mobile station scans for service and determines that there are two networks available for selection, an ANSI-136 Neutral system and a GSM Neutral system. If the PPI is set to ANSI-136 Preferred, then the mobile selects the ANSI-136 Neutral system. Conversely, if the PPI is set to GSM Preferred, then the mobile selects the GSM Neutral system.

ANSI-136/GSM (ANSI-136 Preferred)	***GSM/ANSI-136 (GSM Preferred)***
ANSI-136 Home	GSM Home
ANSI-136 Partner	ANSI-136 Home
GSM Home	ANSI-136 Partner
ANSI-136 Favored	GSM Preferred
GSM Preferred	ANSI-136 Favored
ANSI-136 Neutral	GSM Neutral
GSM Neutral	ANSI-136 Neutral
ANSI-136 Forbidden	GSM Forbidden
GSM Forbidden	ANSI-136 Forbidden

Table 3 - Combined GAIT Network Selection Process

For AMPS and ANSI-136 operation, the mobile looks at the SID and the SOC broadcast on the network's DCCH (Digital Control Channel) (Analog Control Channel (ACC) for AMPS networks). For GSM operation, the mobile looks at the MCC and MNC found on the GSM network's BCCH (Broadcast Control Channel). Depending on how the NSDB is configured and the corresponding signal quality of the base station's DCCH or BCCH, the mobile will determine what is the best network to access.

A test solution for GAIT should offer 800 MHz and 1900 MHz operation for ANSI-136 and 800 MHz, 900 MHz, 1800 MHz and 1900 MHZ GSM operation. (800 MHz will be required with the upcoming GSM deployments in the US.) It should offer the ability to select all channels within these bands and set the channel at a particular power level. It should also provide the ability to select and set SID and SOC information for ANSI-136 operation and MCC and MNC (3 digit for North American operation) for GSM.

Putting together the Test System

The test system will require the use of the IFR 2935 GSM Test Head and the IFR 1900-5 CSA TDMA test system along with a computer system. The computer system will require two com ports, one to control each of the instruments. In addition, the system will need to be running Windows 98, 2000 or NT 4.0. Connect the 2935 using a RS-232 Null Modem cable and the 1900-5 using a standard RS-232 cable.

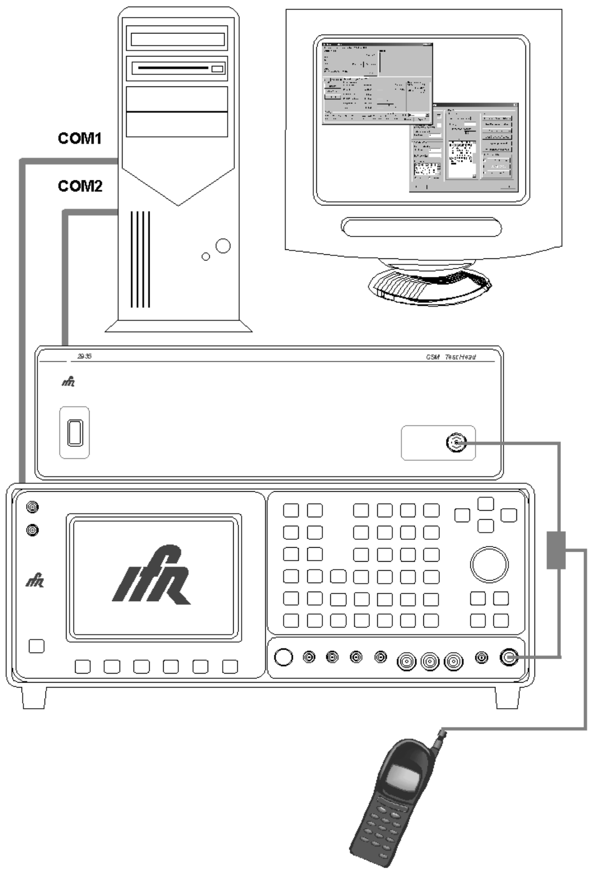

Figure 3.1 shows the system configuration

Setting Up a GSM Test Process

Figures 4.0 through 4.3 show how the IFR 2935 GSM test system can be set up to test the various parameters we've discussed so far. Figure 4.0 shows the initial setups for power measurements, frequency error, timing error and phase error measurements. Figure 4.1 shows band selection, control and traffic channel setup, timeslot designation, power level settings, timing advanced settings and RF generator level. In addition, the ability to set RF Cable Gain and Loss is very important for accurate power measurements. Additional test parameters are shown for registration time out and protocol time out (loss of communications).

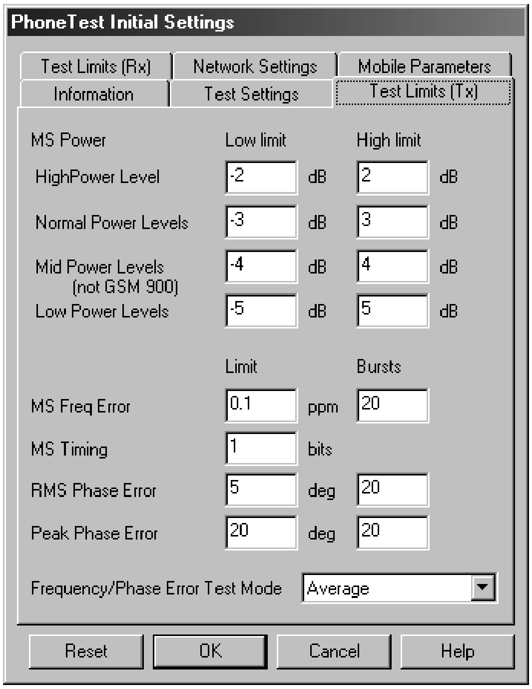

Figure 4.0 - GSM Parametric Test Setup

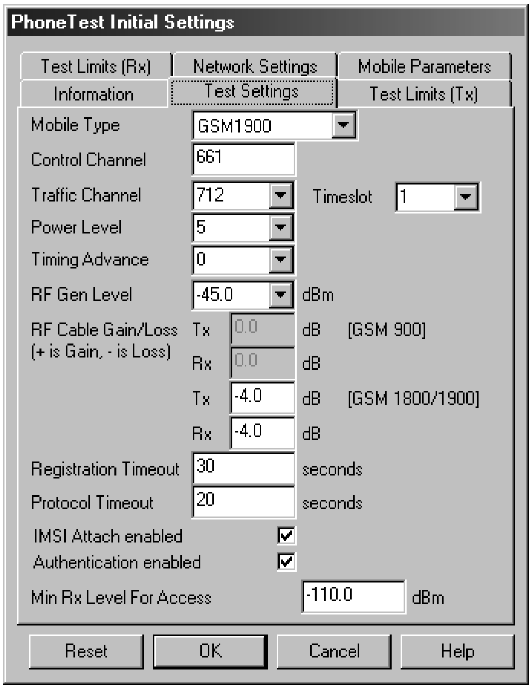

Figure 4.1 - Additional GSM Test Setup

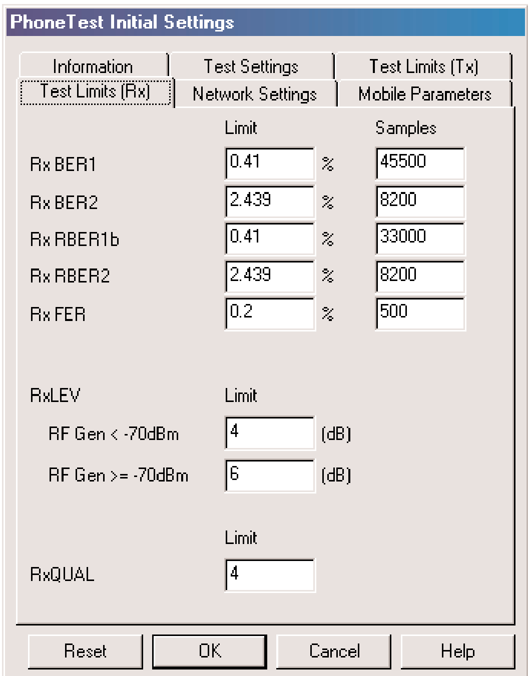

Figure 4.2 - GSM Receiver BER/FER Test SetUp

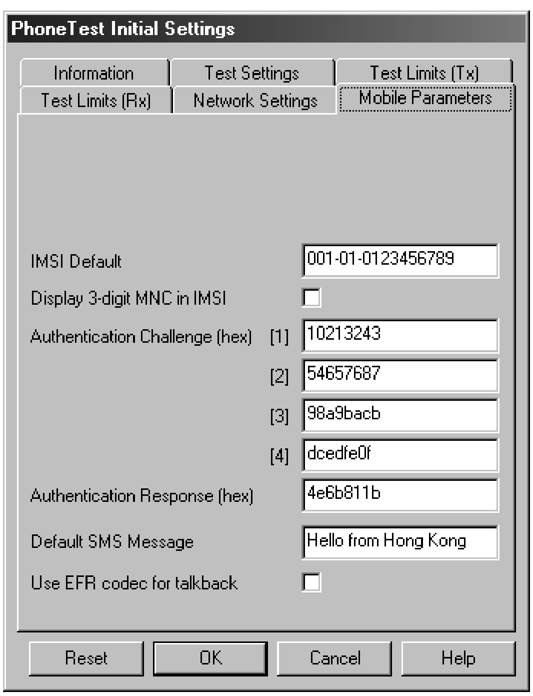

Figure 4.3 - GSM Network Selection SetUp using MCC and MNC

Figure 4.2 shows the setup limits and samples for the various BER tests for GSM testing, along with the FER test parameters. The RxLEV is the mobile's measurement of signal level it is receiving and RxQUAL is the phone's evaluation of the signal received expressed in a numeric response that gives a relative indication of the quality of the signal.

Figure 4.3 shows the network setup parameters for the mobile country code, the mobile network code and additional network parameters. Also, the MNC should be able to handle the 3 digit MNC that is used on the North American GSM networks, not just the two digit MNC used in the rest of the world. This capability is critical to testing GAIT mobiles.

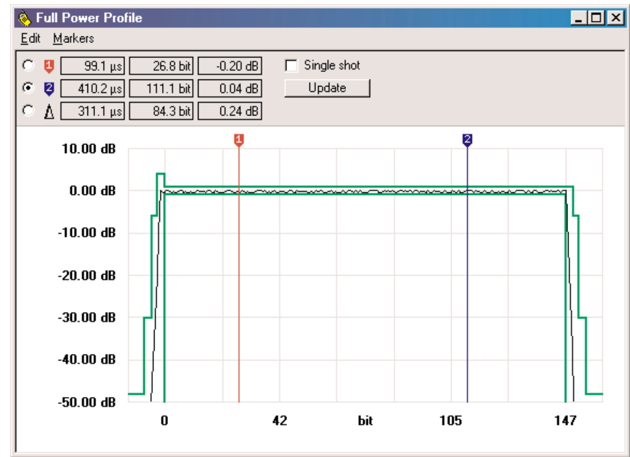

Figure 4.4 - GSM Full Power Profile

Figure 4.4 shows the burst profile for measuring the GSM power burst to ensure that it meets the specification. Markers are nice to allow for timing measurements within the burst profile. Figure 4.5 shows how these capabilities are displayed for easy reference of the mobile's performance.

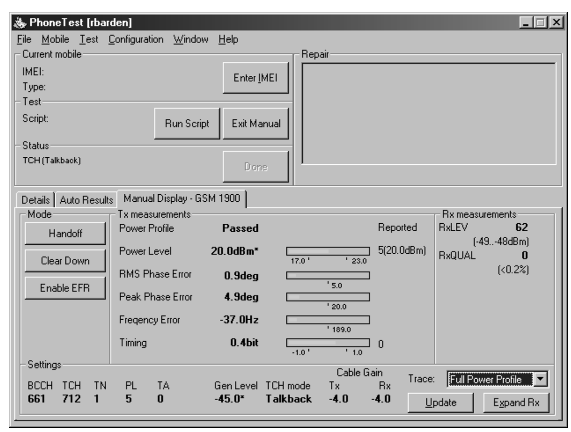

Figure 4.5 - IFR 2935 GSM Test Display

Setting Up an ANSI-136 Test Process

Setting up an ANSI-136 test is very similar to the GSM test for parametric tests. Figure 5.0 shows the GAIT Phone Test parametric display for ANSI-136 phones. As you can see, you can test EVM, Power, Frequency Error and Origin Offset, along with different time slots, power levels and timing advance. You also have the ability to perform multiple hand-off tests, both in band and across band. Figure 5.1 shows the Adjacent Channel Power Mask for ANSI-136 digital power measurements.

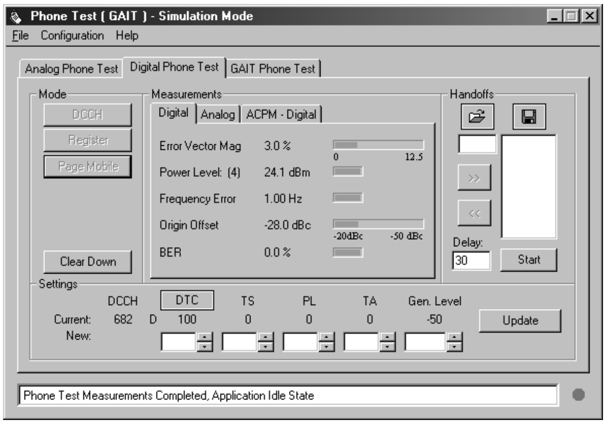

Figure 5.0 - Digital ANSI-136 parametric measurements

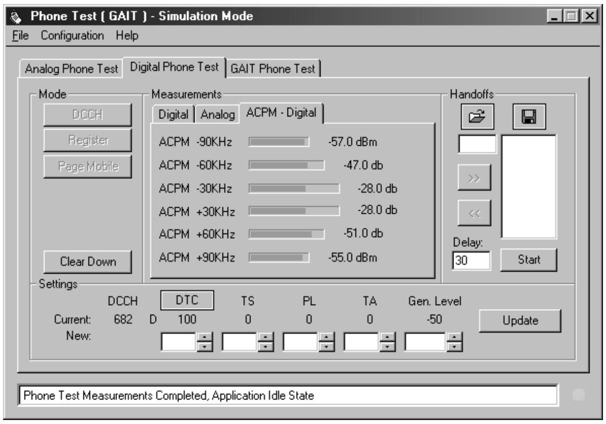

Figure 5.1 - Adjacent Channel Power Measurements (ACPM)

Figures 5.2 and 5.3 show the setup parameters for both the analog and digital settings. The SID and SOC parameters are what the NSDB uses for selection of the proper network. In addition, you have the ability to select Analog Control Channel number (ACC) and Digital Control Channel number (DCCH). In the digital mode, you have the ability to select either the 800 MHz cellular band or the 1900 MHz PCS band. RF levels can also be set.

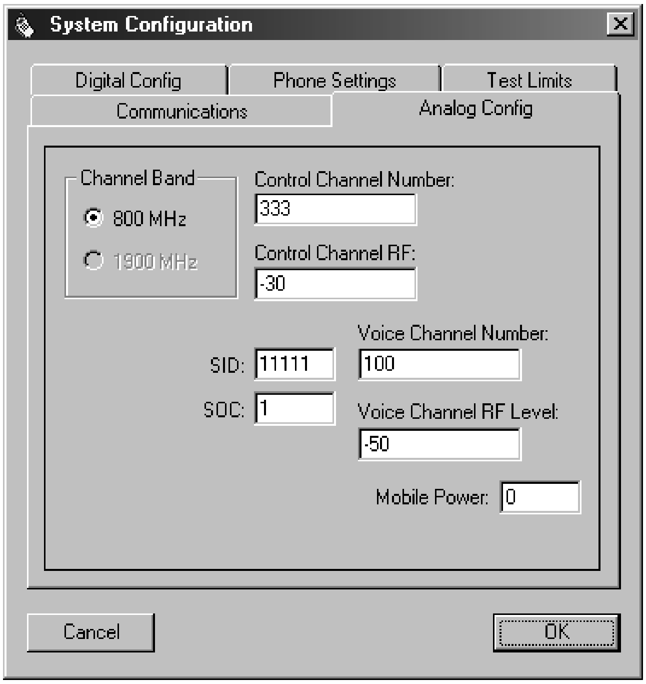

Figure 5.2 - Analog Set Up Configuration

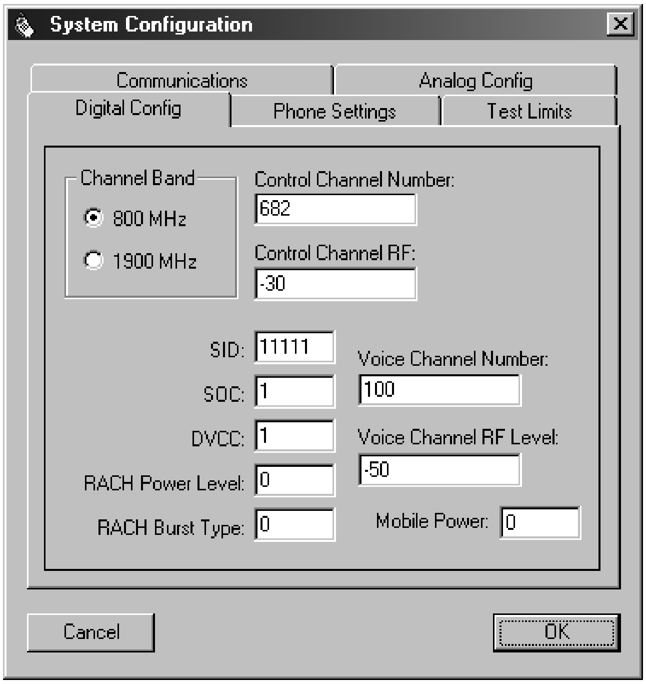

Figure 5.3 - ANSI-136 Digital SetUp Configuration

Testing GHOST

Testing GHOST functionality in a mobile requires the ability to simulate network functions. The GSM Hosted SMS Teleservice function is standardized on the GSM SMS Protocol Data Unit (PDU) as specified in GSM 03.40. Handling this PDU is the primary concern of testing the SMS functionality of the mobile.

Figure 6.0 shows how a mobile terminated GHOST message is generated from the network IIF through the ANSI-41D network (the mobile network that supports TDMA) and onto the ANSI-136 air interface for delivery from the base station to the GAIT mobile. Of course, this is for a mobile that is operating in an ANSI-136 Native Mode or ANSI-136 Foreign Mode. A mobile operating in a GSM Native Mode or GSM Foreign Mode would just use the standard GSM SMS delivery procedures.

As you can see, the network has built a SMDPP (Short Message Delivery Point to Point) message that incorporates the GSM SMS PDU in the form of SMS Bearer Data. The source of this bearer data can be another GAIT mobile, a GSM mobile or an ANSI-136 mobile.

This information is mapped onto a R-Data (Relay Data) message where the mandatory (M) information elements are set and optional (O) information elements are enabled as the network operator chooses. The mandatory information elements are required for minimum functionality to deliver the R-Data Unit. Optional information elements can be enabled that allow for additional information to be presented such as the originating user's address.

The R-Data message payload is the R-Data Unit, which includes the higher-layer-protocol identifier (HLPI) and the HLPDU (Higher-layer-protocol data unit) which is the GMS SMS PDU.

The higher layer protocol identifier contains information about the R-Data Unit, in this case showing that the Teleservice Type Indicator is set to one designating it as a carrier specific teleservice (versus a standardized teleservice). The TSAR (Teleservice Segmentation and Reassembly) bit is enabled for either a single R-Data message or multiple R-Data messages (0 or 1). In addition, the message is indicated as a GHOST message through the use of the Teleservice Protocol Identifier Subfield which is set to 00 0011.

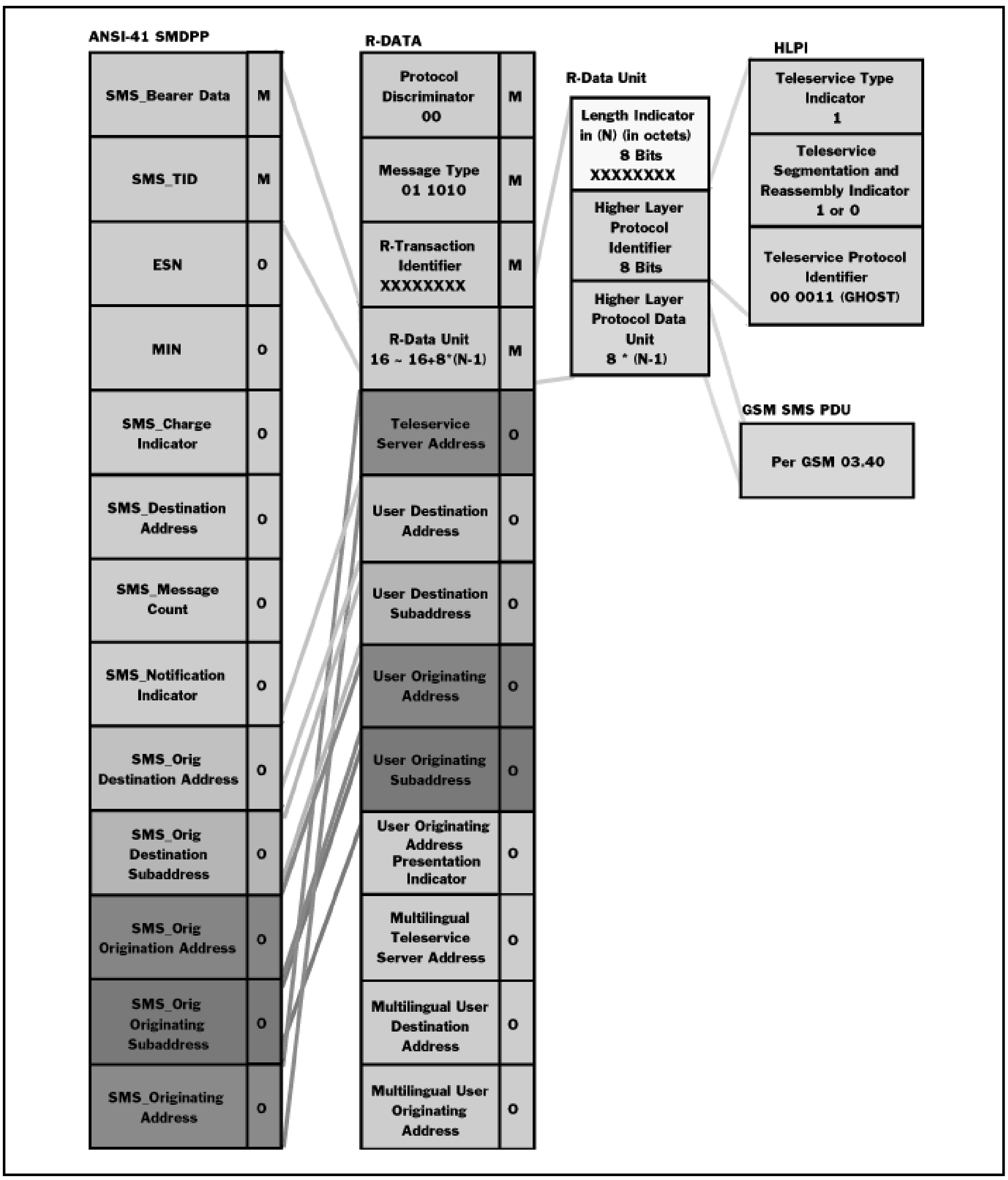

Figure 6.0 - GHOST Message Mapping for a Mobile Terminated GHOST SMS message (courtesy of the GAIT Standards Group)

For mobile terminated GAIT GHOST testing, a comprehensive test system should allow you to select the ANSI-136 R-Data message information elements and set them to the proper values for GAIT support. It should also allow you to monitor a mobile originated call and log the information coming from the mobile. Figure 7.0 shows a test system screen for handling GAIT GHOST SMS messaging.

The system allows the ability to receive and send GHOST messages through the R-Data message on both the DCCH and DTC. The system will automatically determine if the mobile is camped on a DCCH or on a DTC and handle the messages appropriately. Interoperability with the 2935 Phone Test system allows the user to send and capture GSM messages easily from the 2935.

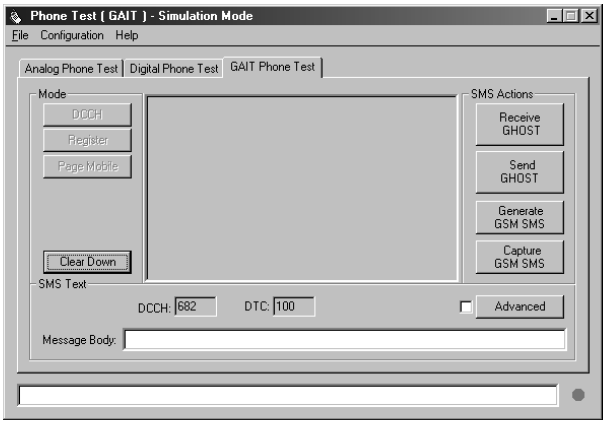

Figure 7.0 - GAIT GHOST Testing Example

Figure 7.1 shows some of the advanced features for GAIT testing. To properly set the various information elements and parameters associated with a GHOST message, the user needs to be able to select and manipulate each of the Higher Layer Protocol Identifiers and the GSM SMS PDU. The R-Data Unit contains the HLP Identifier data from the HPLI (Higher Layer Protocol Identifier) elements and has a specific length in octets that is automatically calculated. This system then builds the R-Data Unit based on the selected parameters.

The message-type mandatory information element is definable as are the Optional R-Data elements that can be configured directly by selecting a pop-up window that allows additional parameters to be set.

After the GSM SMS PDU, HLPI and R-Data mandatory and optional information elements are defined, the system then builds an entire R-Data message for transport to the phone. Conversely, the system will also decode an R-Data message and display the appropriate parameters.

This particular test system offers the user three ways to build a HLPDU (GSM SMS PDU).

1. By loading a predetermined GSM SMS PDU formatted file.
2. By using a default PDU based on a SMS message received from the 2935.
3. By creating a new PDU based on your input.

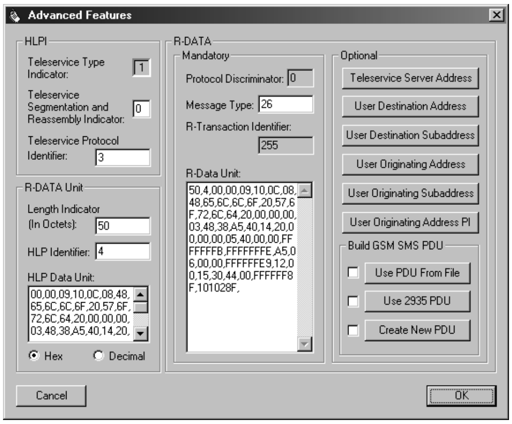

Figure 7.1 - Setting the GHOST HLPI and R-Data Message Parameters

Creating a new GSM SMS PDU

To create a new GSM SMS PDU, select the "Create New PDU" button (See Figure 7.2). The next screen that comes up is the screen used in formatting the SMS PDU. Formatting the GSM SMS PDU is important in that the GAIT test specification requires the testing of different PDU contents. For more information, see the GAIT document, GAIT-T-H-1-1-4-0.doc.

The GSM SMS PDU is formatted according to GSM 03.40. The main parameters of the PDU are as follows:

SMS PDU Information Element	*Value*	*Description*
TP-MTI	User Defined	Message Type Indicator - SMS Deliver "00" is default for GAIT.
TP-MMS	User Defined	More Messages to Send - GAIT Default is "0" - More messages are waiting. "1" means no more messages are waiting.
TP-RP	User Defined	Reply Path - GAIT Default is "0" - Parameter is not set in this SMS Deliver. "1" means the return path parameter is set in this SMS Deliver.
TP-UDHI	User Defined	User Data Header Indicator - GAIT Default is "0". The TP-UD field contains only the short message. "1" means the beginning of the TP-UD field contains a header in addition to the short message.
TP-SRI	User Defined	Status Report Indicator - "0" means a status report will not be returned to the SME. "1" means a status report will be returned to the SME.
TP-OA	User Defined	Originating Address, International Number, E.164 format.
TP-PID	User Defined	Protocol Identifier - "0000 0000" Default. Using the PID of "0111 1111" enables sim data download, in conjunction with the DCS being set to 8 bit data.
TP-DCS	User Defined	Data Coding Scheme: a. Default Alphabet, Class 0 (1111 0000) or 240 b. Default Alphabet, Class 1 (1111 0001) or 241 c. Default Alphabet, Class 2 (1111 0010) or 242 d. 8 Bit Data, Class 2 (1111 0110) or 246
TP-SCTS	User Defined	Service Center Time Stamp.
TP-UDL	Auto Calculation	User Data Length - Auto Calculated based on message length.
TP-UD	User Defined	User Data .

Defining a GSM SMS PDU

The GAIT Phone Test Suite will map this file into a HLPDU data field and then send it out as a GHOST message to a mobile operating in the ANSI-136 Native or Foreign mode when the Send GHOST button is selected on the main GAIT Phone Test tab.

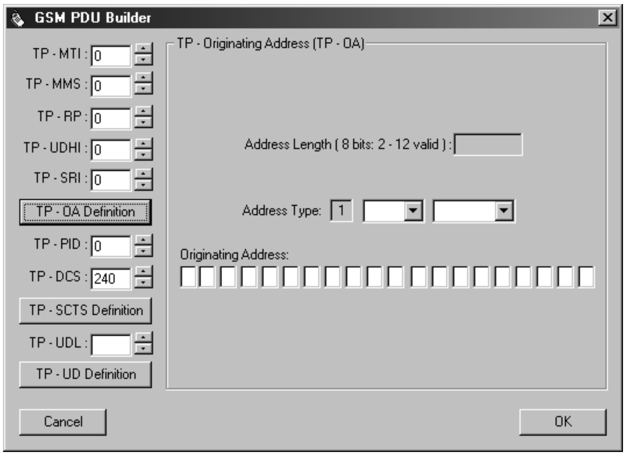

Figure 7.2 - Setting the GSM SMS PDU Parameters

Other GAIT Tests, emergency calls

Other tests associated with the GAIT mobile should include the ability to make an emergency call internationally without requiring registration of the mobile on the network, especially when the phone is on a forbidden network.

Opening the GATE to the future of GAIT - Phase One + and beyond

Since the world of wireless communication continues to turn, there will undoubtedly be more features added to the GAIT mobile. Phase One + will add GPRS capability to the mobile for faster data rates.

Cameron Coursey, head of the GAIT Standards Group says it well, "The TDMA and GSM networks offer complimentary performance features that will play an important part in the delivery of quality wireless services to our customers. The GAIT mobile will act as a bridge to bring these two world class technologies together to provide true international world phone capabilities and its benefits to operators and users alike."

Where we go from here is only limited to our imagination as we take another step closer to a true "world phone."