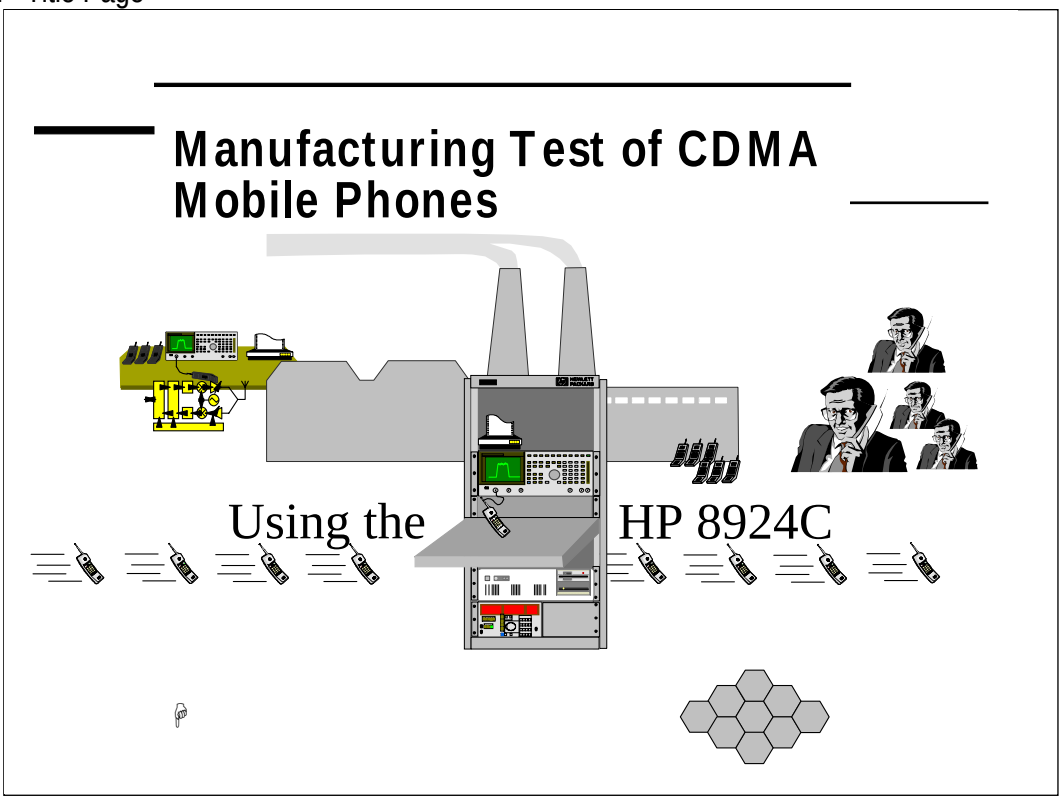
Manufacturing Test of CDMA Phones

Slide #1 - Title Page



The key design goal for the HP 8924C CDMA Mobile Station Test System was efficient manufacturing test of dual mode CDMA/Analog cellular phones. This paper will present a hypothetical cellular production area. It will be presented from the point of view of the manufacturing test engineer. The paper will also present some "best practices" currently in use at Hewlett Packard in the development of our own products.

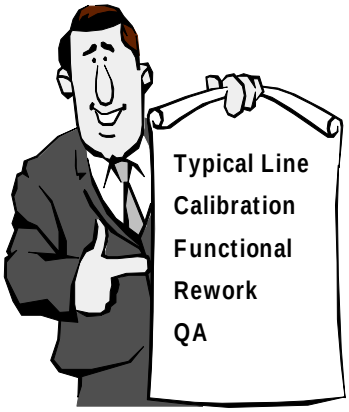
Notes:

Manufacturing Test of CDMA Phones

Slide #2 - Agenda

Agenda

- Typical Line Flow
- Phone Adjustments
- Functional Test
- Rework Station
- Sample/QA Test

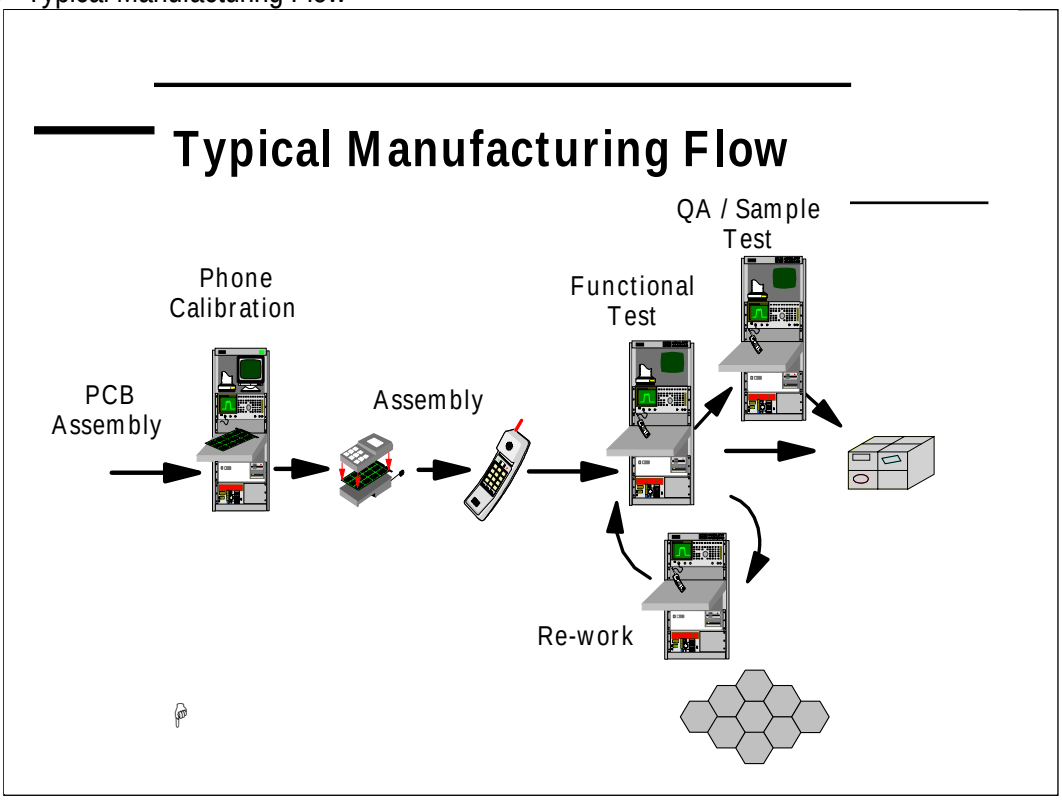


This paper will first show a typical line flow for cellular production, followed by a discussion of the adjustments typically needed for CDMA phones. Adjustments for analog will be discussed as well as those for CDMA, with the emphasis on CDMA. Next, a functional test plan will be presented, along with a structure for reducing the number of data points and the test time. Finally a review of the purpose and function of re-work and sample test stations on the manufacturing floor will be examined. The ideas presented in this paper are generic and apply only in general to CDMA dual mode phone manufacturing. In actual cases, the flow of the manufacturing line and the specific tests performed will vary according to the requirements of that particular phone design.

Notes:

Manufacturing Test of CDMA Phones

Slide #3 - Typical Manufacturing Flow



A typical production line is depicted here. Not shown is the surface mount printed circuit board assembly step. The loaded boards are usually tested in board form. Often this is in fixtures that behave much like the phone housing and enclosures. Calibration is done in this state.

After calibration, the phone is assembled into the final unit, followed by the functional test. Phones that do not pass the functional test are sent to re-work stations for repair. Often there is an additional test station that can be used for two purposes: Quality sampling of phones, and collection of detailed data to support the reduction of data points for the main test station.

Notes:

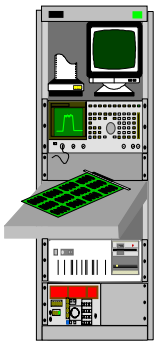
Manufacturing Test of CDMA Phones

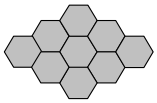
Slide #4 - Calibration for CDMA

Calibration for CDMA

- **Frequency Accuracy**
- **Received Power**
- **Transmit Power**
- **Analog Performance**

Phone Calibration





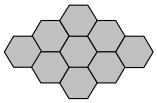
Calibration is performed in two main areas: frequency and power. Power calibration includes the accuracy of both the transmitter and the receiver. If the CDMA phone is dual mode, then traditional FM style calibration functions will also be performed.

Notes:

Slide #5 - Frequency Accuracy

Frequency Accuracy

- Must be Derived from Incoming Signal for CDMA (Pilot Channel)
- Accuracy - Relative to Input
  - +/- 300 Hz for AMPS
  - +/- 150 Hz for PCS
- Crystal Derived for Analog
- Typically implemented as a VCXO (voltage controlled crystal oscillator), feedback generated from Rx in digital, fixed tune voltage for analog

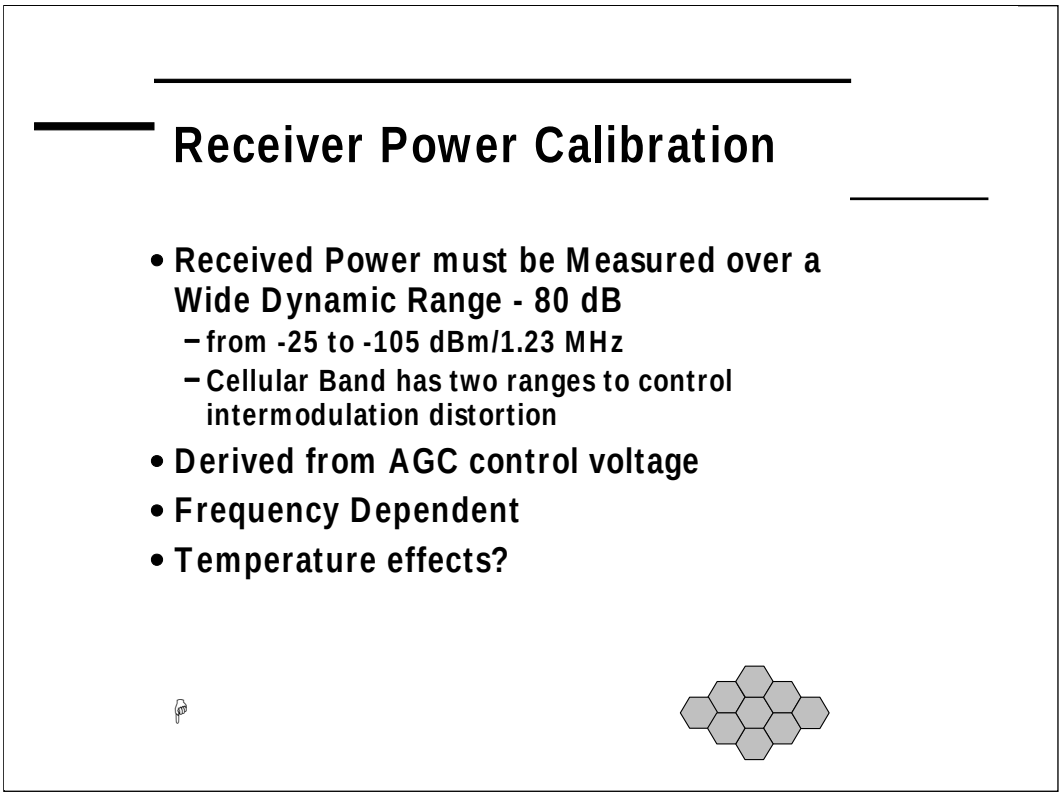


Frequency Accuracy of a phone in CDMA mode is derived from the incoming signal. The specification is much tighter in PCS due to the higher Doppler frequencies encountered in the PCS band. The tighter spec is to allow for a similar accuracy at the IF in the phone.

In analog mode, the frequency accuracy is derived from a crystal controlled oscillator. Usually, this is the same circuitry used for the CDMA reference but is tuned with a fixed voltage rather than with feedback.

Notes:

Slide #6 - Receiver Power Calibration

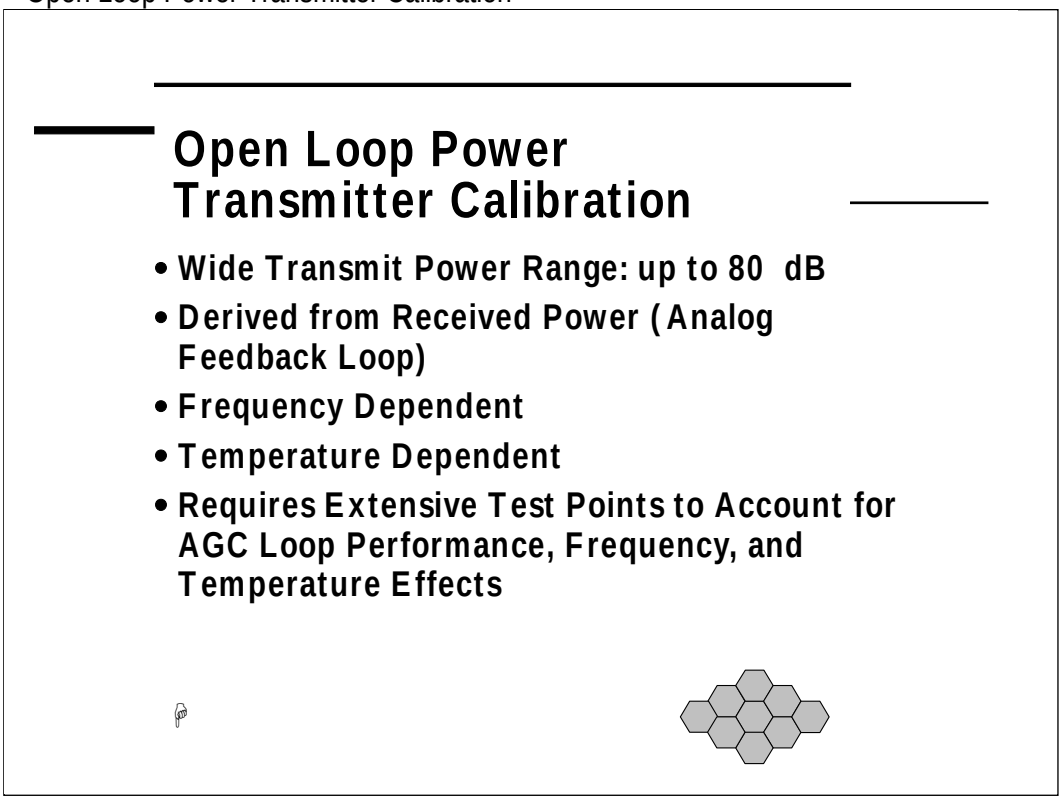


The receiver power calibration is critical for proper CDMA operation. It is compounded by the fact that CDMA has two distinct ranges of input power. This will be shown in more detail in a few slides. The input power can range from -25 dBm to -105 dBm for CDMA. This input value must be measured by the phone and used as a basis for the transmit power. This is called open loop power control.

This measurement cannot be made with a diode detector because the power levels are too low. Typically this is measured by monitoring the feedback voltage of the AGC amplifier in the phone. The operating conditions for a phone include wide variations in temperature, as well as long-term aging effects. These factors must be included in the design and calibration functions.

Notes:

Slide #7 - Open Loop Power Transmitter Calibration



The transmitter power range is much higher for CDMA than for analog. CDMA requires about 80 dB dynamic range for the transmitter power. This is from -50 dBm to the power limit specified for the class of phone. A handheld phone is required to deliver at least +23 dBm, while bag phones or car mount phones will be higher.

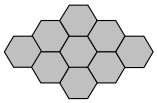
The received power forms a linear reference for open loop power control. The specification for the transmit accuracy based on the input level is +/- 9 dB (must meet) and +/- 6 dB (should meet). Feedback from the base station (closed loop power control) moves the output power away from the open loop set point in 1 dB steps.

Notes:

Slide #8 - Maximum TX Power Calibration

Maximum TX Power Calibration

- **Maximum Power Must be Set very Accurately**
  - **Sets Coverage Limit for Base Station**
  - **Affects Battery Life**
- **Requires Test Bus Control of Closed Loop Power Control Gain**
- **Test Equipment Requirements**
  - **Absolute Accuracy of +/- 0.25 dB**
  - **Accuracy Maintained on CDMA signal (CW power meter will not work!)**
  - **Fast Measurement Capability**



The maximum level is adjusted to very tight limits, typically at +23.5 dBm for a handheld phone (0.5 dB above the minimum power). Too little power will not meet the system design requirements for the reverse link. This will cause the phone to perform poorly in fringe areas. Too much power will use up excessive current from the battery and shorten the talk time.

Setting the proper maximum transmit power on a CDMA phone in a test mode requires that the phone's test bus provide external control of the phone's closed loop gain. The maximum power condition requires a received signal level of -104 dBm/1.23 MHz and that the phone be commanded to set its closed loop power gain to the maximum level.

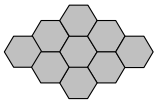
To achieve such a tight margin on the maximum power requires that the test equipment have state-of-the-art absolute power measurement accuracy. This accuracy must be maintained on CDMA modulated signals. Many of the new, high performance power meters on the market offer high accuracy and very high measurement speed. However, these products can only achieve this performance on CW signals. The HP 8924C's average power meter meets these requirements and provides the fast measurement times needed to maintain efficiency.

Notes:

Slide #9 - Key Performance Areas for Test Equipment

Key Performance Areas for Test Equipment

- Accurate Timebase
- Accurate CDMA Source
- Low Glitch Energy Source Attenuator
- Wide Dynamic Range CDMA Channel Power Meter
- Fast Channel Power Measurements:
  - The RX and TX Open Loop Power Calibration Forms the Bulk of the Calibration Test Time for CDMA phones!



One of the key requirements for test equipment in the CDMA calibration station is high frequency accuracy. This translates to having a high accuracy timebase in the test set so that the RF source provided to the phone will be inside the very tight frequency range of the phones. The HP 8924C comes *standard* with a high accuracy oven timebase (+/- 0.1 ppm per year).

Level accuracy is also critical to the proper calibration of open loop power. In addition, the CDMA source of the test set must have a low-switching transients to achieve the fastest measurement throughput. Since the phones are running in open loop power mode, switching transients will require extra settling time to achieve the nominal steady state level. The HP 8924C has a low-glitch electronic attenuator to meet this requirement. When used with the HP 83236B PCS Interface, the HP 8924C offers an attenuator hold mode that locks the mechanical attenuator in the PCS Interface and uses the HP 8924C's electronic attenuator to meet this requirement.

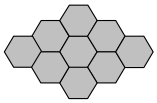
To achieve fast throughput on the many required power measurements, the test set must have a fast, accurate power meter. The HP 8924C's channel power measurement provides over two readings a second from below -50 dBM/1.23 MHz to +30 dBM/1.23 MHz.

Notes:

Slide #10 - Manufacturing Approach to CDMA Phone Calibration

Manufacturing Approach to CDMA Phone Calibration

- Receiver Power, Transmit Power, and Frequency Calibrations done Simultaneously
- Uses a Test Mode: no Call Setup Required
- Full Automation - Test Station Programming
- Statistical Data Collection - Used to find Correlation Between Test Points to Eventually Reduce Test Points
- Statistical Approach to Max Power Setting - Curve fit vs frequency



The design of the manufacturing process for a new phone should be jointly owned by manufacturing and R&D. Both organizations should have common objectives of minimal test time and smooth introduction to the marketplace. Process development engineers should be working early with the R&D project members to meet the required goals. In this hypothetical case, this paper has chosen to define attributes of a test mode that must be designed into the phone.

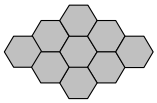
Ideally, the targeted process will be tried on early phones and the process and the phone both modified to improve throughput. It should be noted that the calibration process is very specific to the actual design. Because of the hypothetical nature of this paper, no test times can be presented. The calibration times can be much longer than the RF parametric tests.

Notes:

Slide #11 - Power Calibration Test Mode

Power Calibration Test Mode

- **Test Mode Functionality:**
  - **Phone Measures Received CDMA Signal Level**
  - **Open Loop Power Control is Active in the Phone**
  - **Closed Loop Power is Disabled in the Phone**
  - **Phone Transmits a Continuous CDMA Signal**
- **HP 8924C Measures TX Power over 80 dB Range**
- **For Max Power Calibration, the Test Bus Adjusts Closed Loop Gain to Maximum**
- **System Controller Generates Calibration Data and Sends it to the Phone**
- **Phone Stores it in Internal Nonvolatile Memory**



To efficiently perform the many power calibration test points requires a special test mode that is built into the firmware of the phone. This test mode must be activated via a command sent from the system controller to the phone over its serial test bus. The functions of this test mode are as follows: the phone will actively receive a CDMA signal from the test set that provides a Pilot, Sync Paging, and OCNS channels. The phone must time align to the received Pilot signal and then begin transmitting a continuous CDMA signal back to the test set (access probe preamble). Open loop power control must be fully active in this test mode and closed loop power bit reception must be disabled.

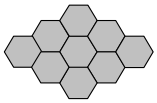
The test set will then receive the signal from the phone and measure the received level. The phone also must send the received signal level to the system controller. The system controller can then compute the received level calibration factor and the transmit level calibration factor for the given sent signal level. This data is then sent via the serial test bus to the phone where it is stored in nonvolatile memory. This process is repeated over the 80 dB range of open loop power. This process may also be repeated across frequency if required by the phone's design.

Notes:

Slide #12 - Test Bus Requirements

Test Bus Requirements

- **Serial Bidirection Bus on the Phone**
- **Functionality:**
  - **Send:**
    - ✓ **Phone in Service**
    - ✓ **Received RX Level**
  - **Receive:**
    - ✓ **Calibration Data**
    - ✓ **Keypad Simulation (Phone Call)**
    - ✓ **Closed Loop Power On/Off**
    - ✓ **Closed Loop Power Gain Control**
    - ✓ **Activate Test Modes**

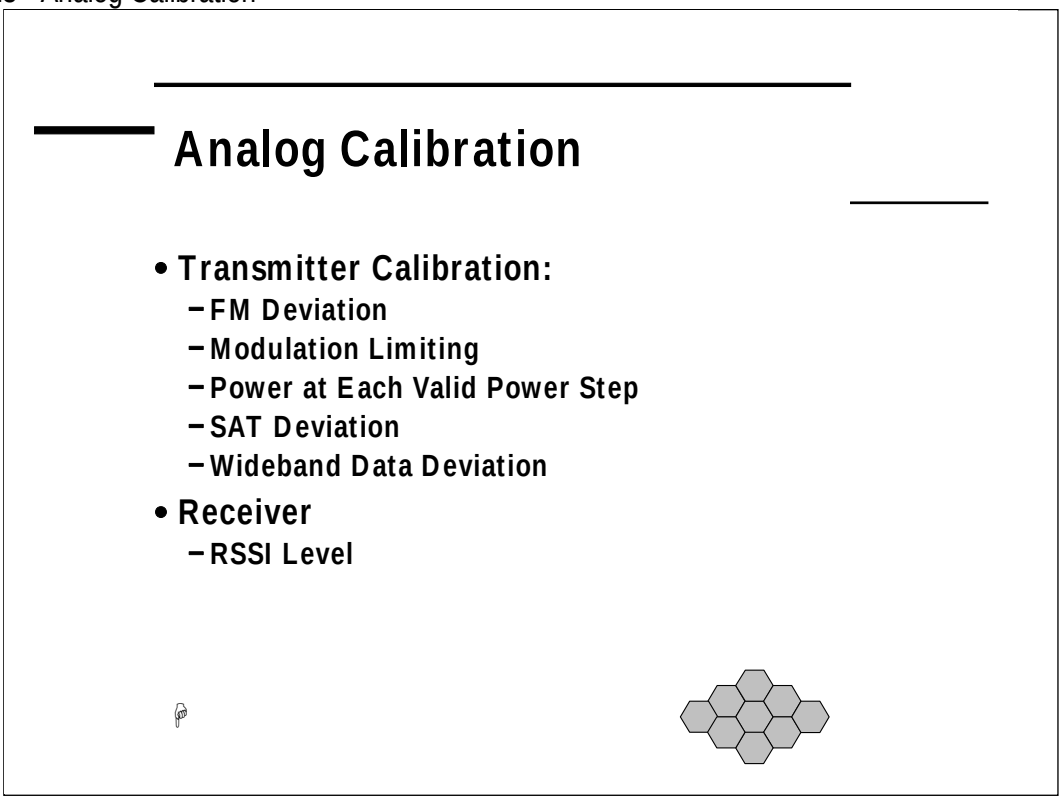


Several previous slides have spoken about the phone's test bus. This bus is a necessary requirement for efficient manufacturing. This bus not only allows activating special test mode require din the manufacturing process, but also allows automated programming the phone. A typically a test bus is a bi-directional serial interface that allows the phone to communicate with the test system controller. The functions required by this hypothetical production line are as follows. The phone must be able to send the received signal level to the system controller as part of the open loop calibration. The phone must also be able to send a message to the system controller when it has acquired CDMA service (more on this in the next slides).

The test bus must also support the reception of calibration data, programming data and special commands for selecting test modes. Some of these test modes include the one described for open loop power calibration, keypad simulation for placing phone calls, turning closed loop power off and setting the closed loop power gain for the maximum power calibration.

Notes:

Slide #13 - Analog Calibration



If the CDMA phone under test also supports analog operation, the test station must able support FM analog type measurements. A number of key analog parameters are typically adjusted at the calibration station. FM parameters are typically controlled by DACs in modern phones. Parameters such as FM deviation, modulation limiting, SAT FM deviation and wideband data deviation must be measured tuned to the proper values. Once generated, the system controller sends the DAC settings to the phone via the test bus for storage in nonvolatile memory. Most analog cellular system support a number of discrete Tx power levels. These must also be adjusted with the corresponding calibration factors sent to the phone for storage.

For analog mode operation few Rx calibration parameters are generated. The most common calibrated Rx parameter is RSSI level.

Notes:

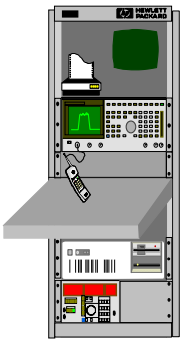
Manufacturing Test of CDMA Phones

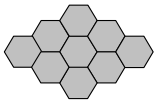
Slide #14 - CDMA Functional Test

CDMA Functional Test

- Verifies Performance to Specifications
- Does not Test Firmware
- Starts with Conservative Testing
  - Many Test Points
- Provides Performance Data Base
  - Used for Test Point Reduction
  - Also Used to Modify Test Conditions and Processes

Functional Test



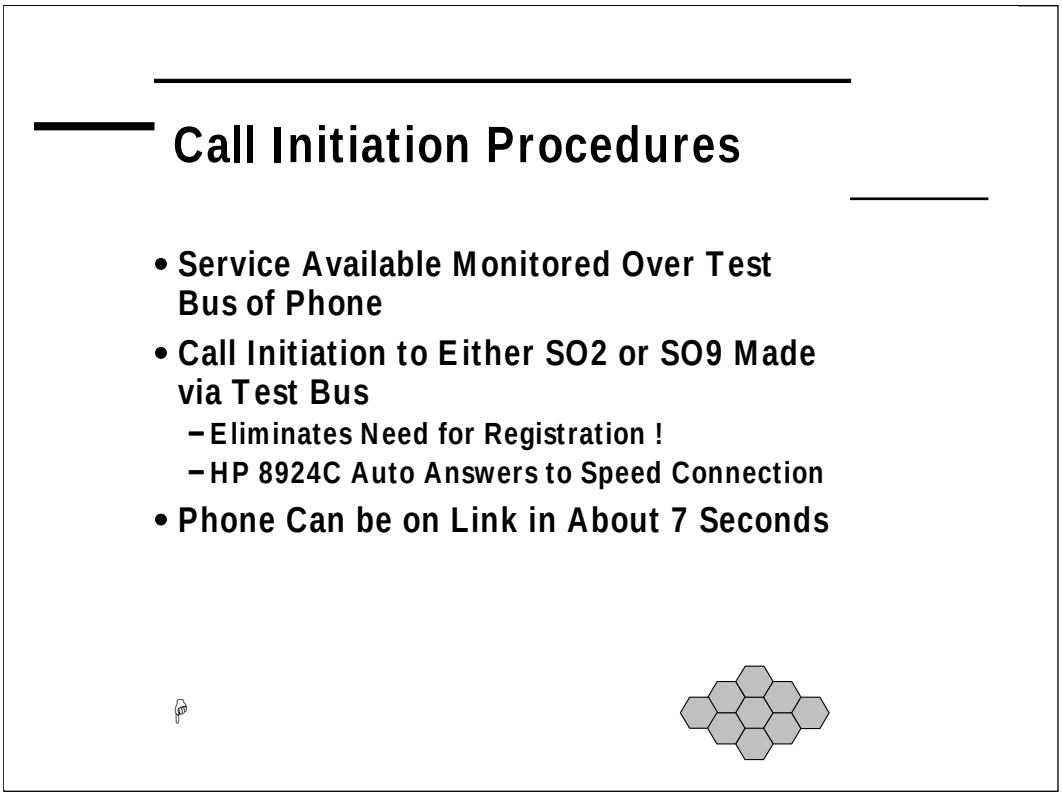


Functional test is a measurement of the RF parameters of the phone. This set of tests is made while on a true link; the test equipment must act like a real base station. In general, this type of testing does not add any value to the phone, it simply confirms that this copy of the design meets the design goals.

A feature of automated manufacturing test is that data can be collected that can be used to modify the test process. Initially, many test points are included, taking much more time than desirable, but generating a good data base of performance.

Notes:

Slide #15 - Call Initiation Procedures



Making the initial link can take substantial time for CDMA. This can be minimized by taking advantage of calling procedures defined in the standard, IS-95 or J-STD-008. A phone must register with the base station before a link can be made. Most registration procedures take about ten seconds to complete. This is after the time required for the phone to find the base station and establish timing, a task that typically takes six to eight seconds.

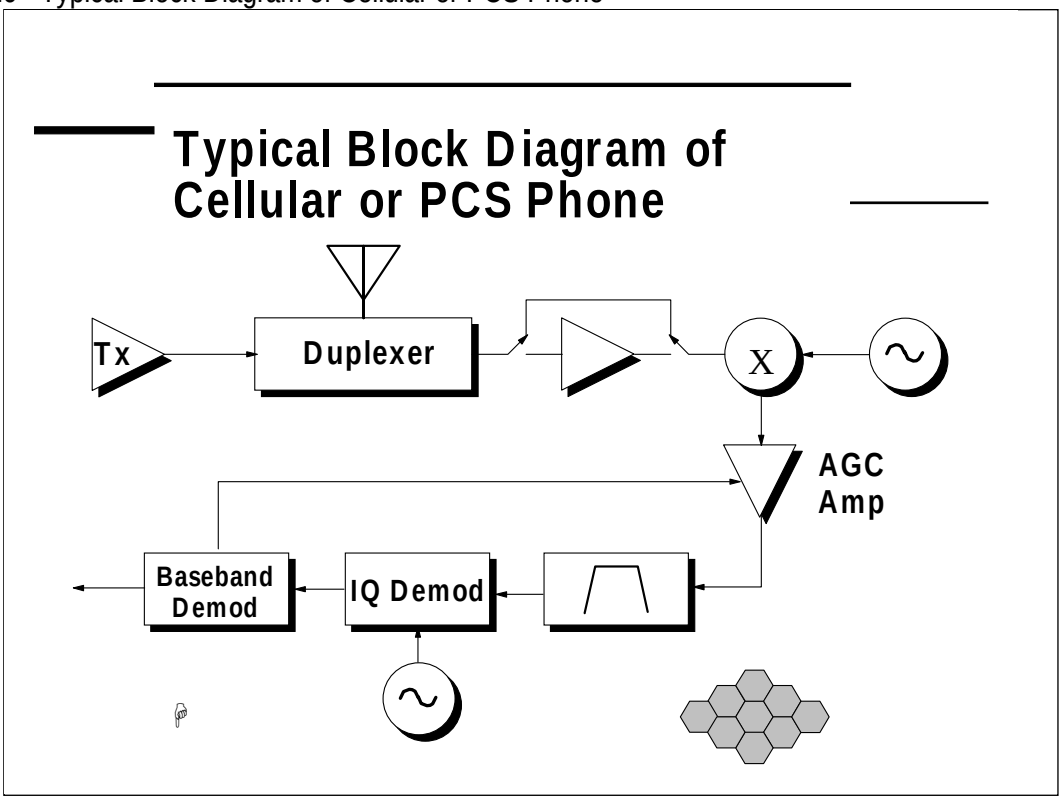
By placing a phone call from the phone to the base station as soon as the timing is established (service is available), a special type of registration, called implicit, is used. The origination message from the phone includes all the registration details.

A phone must be able of making this call from a test port, and service negotiation of one of the loopback service options during origination must be supported. Not all phones can do this. A link can be made in about seven seconds, which is less than half the time of waiting for registration and then paging the phone.

Notes:

Manufacturing Test of CDMA Phones

Slide #16 - Typical Block Diagram of Cellular or PCS Phone



Different tests have been designed to test different aspects of the phone. This block diagram, typical of the receiver section of a cellular phone, illustrates the many elements that may affect test. The preamp is shown with a bypass switch. When the amp is in, the noise figure of the phone is minimized, typically at about 8 dB. This is set by a combination of loss in the duplexer and noise figure of the preamp. Intermodulation distortion can be tested both with the preamp in and out. The performance of both the preamp and the mixer determine performance here. Generally, the IF filter will determine performance of alternate channel rejection.

Most manufacturers do not test performance of intermodulation distortion or alternate channel tests. The test system needed to make these measurements is much more complex than a test system that only makes in-channel tests.

Notes:

Slide #17 - What Should be Tested Rx

What Should be Tested - Rx

- **Do Test**
  - **Sensitivity**
  - **FER in AWGN**
  - **Use Data Loopback Mode SO2 or SO9**
- **Don't Test**
  - **Fading Tests**
  - **Single Tone Desensitization**
  - **Two Tone Intermodulation Distortion**
  - **Cannot Use Test Modes**

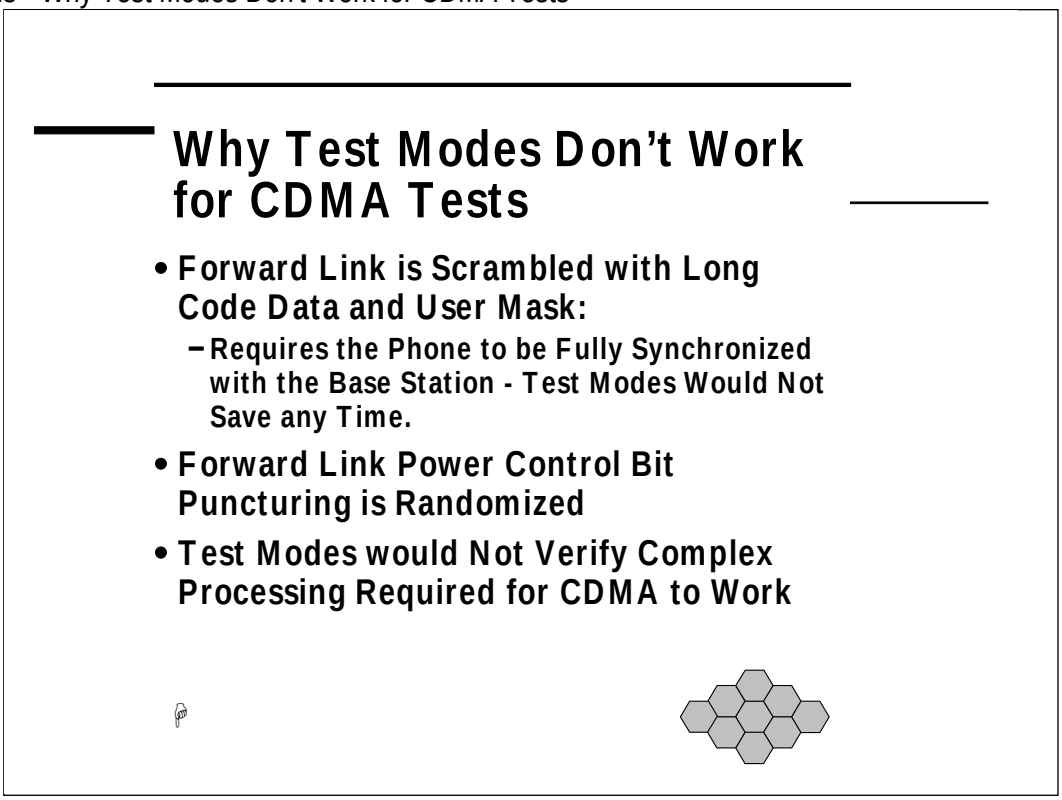
Here's a list of what should be tested for the receiver. As mentioned previously, only in-channel tests will be performed. Characterization of a large sample of prototype units should be measured to justify this; these tests would probably be included in the QA test system. The receiver test require using a data loopback call either service option 002 for rate set one phones or service option 009 for rate set two phones.

Faded tests would only be done in R&D; they would not be included anywhere in manufacturing. The interfering tests, such as single tone desensitization and two tone intermodulation distortion should only be sampled tested on the manufacturing floor. Remember, test modes provide no speed advantage for CDMA receiver tests.

Notes:

Manufacturing Test of CDMA Phones

Slide #18 - Why Test Modes Don't Work for CDMA Tests



Test modes provide no advantage when testing Rx functionality of CDMA phones and provide no method to verify the complex signaling used in the CDMA system. Since CDMA phones must be fully synchronized with a base station to decode a received signal, test modes provide no speed advantage while requiring a large effort to create the test modes.

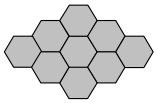
In CDMA, the forward link sent by the base station to the phone is scrambled with the long code and the user's 42-bit long code mask. To decode this signal, a CDMA phone must acquire service, decode the Sync Channel data and read the Paging channel information In addition, the timing of closed loop power control bits is set by the long code. A test mode would require getting this information into the phone via the test bus and some means of sending the RF timebase to the phone. Such connections are typically not available and as a consequence, no production line in operation today uses such test modes.

Notes:

Slide #19 - What Should Be Tested - Tx

What Should be Tested - Tx

- **Do Test**
  - **Waveform Quality**
  - **Frequency**
  - **Max Power**
  - **Full Call Processing Required**
- **Don't Test**
  - **Emissions**
  - **Timing of Power Control Functions**
  - **Open Loop Power Control - It is Tested during Calibration**



The test list for the transmitter includes the waveform quality set which includes frequency accuracy and timing, and power. Emissions should be sample tested on the manufacturing floor. The design should have been fully qualified so that emission testing on every phone it not required. Since the Rx tests will require full synchronization and call processing, the Tx tests should be made under the same condition to minimize test time.

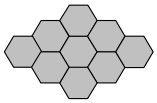
The time response of power changes is a design characterization that should only be needed in R&D. The open loop power performance of the phone is important, but it is assumed that the calibration process has verified the needed performance.

Notes:

Slide #20 - Phase 1 - Initial Test List

Phase 1 - Initial Test List

- At Five Frequencies Across Band
- At Each Frequency, Measure
  - ✓ Min and Max Power
  - ✓ Waveform Quality at Max Power
  - ✓ Frequency and Timing Accuracy
  - ✓ FER in AWGN - at all Rates, One Rate Set
  - ✓ Sensitivity
- Hard Handoff Executed to Change Frequencies
- Test Time per Phone is 7.7 Minutes
- *All times Were Measured Using HP 83217A Software Running on an External Controller*



When the first manufacturing runs are started, a conservative approach is taken. Min and Max power are included, as well as the full suite of tests in AWGN as listed in IS-98 or J-STD-018. A hard handoff is used to change the phone to new frequencies for test.

Test times were measured using the HP 83217A automation software, but running it on an external controller rather than in I-Basic inside the HP 8924C. Test times for customized test systems should easily be faster than the testing done by the HP 83217A general purpose software.

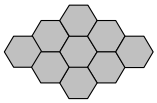
Test time for this large list of test points is 7.7 minutes per phone. This time is very high, but is indicative of the number of data points, being more of a characterization than a functional test.

Notes:

Slide #21 - Phase 2 - Test Point Reduction

Phase 2 -Test Point Reduction

- **Eliminate Min Power at all but One Frequency**
- **Eliminate FER in AWGN at all but One Frequency**
- **Test Time per Phone Reduces from 7.7 Minutes to 3.7 Minutes**



After enough phones have been measured to provide a database, a reduction of test points can be made. In this hypothetical case, the data indicates that the minimum power can be tested at one frequency, and that the FER test in AWGN can only be tested at one frequency. This assumes that the phone design has been shown to be repeatable. The following slide illustrates this point.

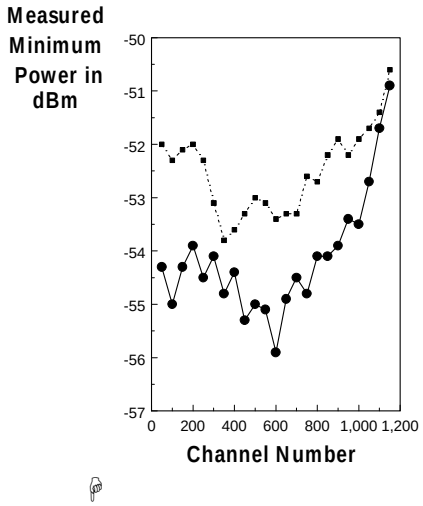
The reduction in number of test cases cuts the test time per phone substantially, to 3.7 minutes.

Notes:

Manufacturing Test of CDMA Phones

Slide #22 - Justification for First Test Point Reduction

Needed Justification for First Test Point Reduction

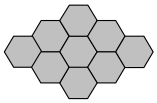


For Minimum Power:

- Minimum Power Plot vs Channel Average for Many Phones
- Worst for Many Phones
  - ✓ Test at Channel 1100

For FER with AWGN:

- Realization that FER in AWGN is Frequency Independent



The database can provide justification for the reduction of test points. For the minimum power test, the average of many phones is plotted as a function of frequency. Also shown is the worst case measurement of many phones. It may be interesting to plot a 3 or 4 sigma line from the average, as well.

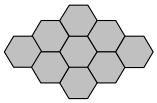
The AWGN test really only needs to be done at one frequency because it should be independent of frequency. The frequency dependent elements of the receiver are noise figure, and max power handling capability. The AWGN tests are performed about 45 dB above the noise floor, and 30 dB below the max input power of the phones.

Notes:

Slide #23 - Phase 3 - Process Improvement

Phase 3 - Process Improvement

- **Utilize Concurrent Measurement Capability of HP 8924C**
  - **Measure Max Power, Waveform Quality at Same Time as FER measurement of Sensitivity**
  - **Matches the Test Efficiency of Separate RX and TX Test Stations in a Single Test Station**
- **Test Time per Phone is Reduced from 3.7 minutes to 2.7 minutes**

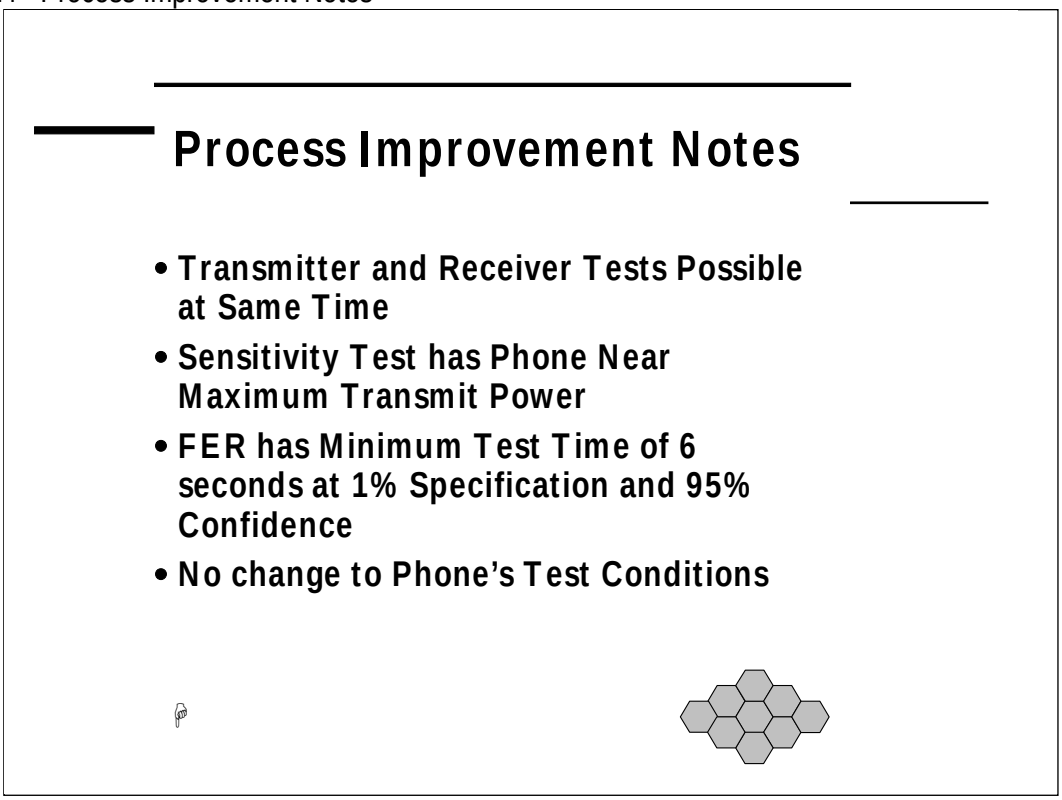


At this point, a change is made that changes the test sequence in a manner that will be more efficient on the HP 8924C. One of the key speed enhancements of the HP 8924C is its capability to simultaneous perform CDMA receiver and transmitter tests. The test process will not be changed at all. While the sensitivity test is running, maximum power and Tx waveform quality will be measured. These tests can be performed while frames are being counted to verify FER performance. This capability of the HP 8924C allows it to match or even exceed the test throughput of having separate Tx and Rx test stations. Only one call setup is required, and then both measurements can be made at the same time.

Now the test time is reduced by a minute, to 2.7 minutes per phone.

Notes:

Slide #24 - Process Improvement Notes



The HP 8924C has the capability of concurrent transmitter and receiver testing. The FER test takes a minimum of 6 seconds for 95% confidence of meeting a 1% FER specification. This minimum test time will increase if any error are detected in the test. One key to fast FER testing is to have sufficient test margin in the phone. This will ensure a minimum of receiver test time for CDMA phones. The test conditions at this time have the phone near maximum power, as well.

The max power test will send all UP power control bits to the phone, measure the power and measure the waveform quality, and return to wait until the end of the FER test.

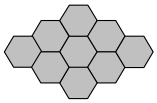
This reduction in test time is the result of more capable test equipment, not by reducing any test points.

Notes:

Slide #25 - Phase 4- More Test Process Improvements

Phase 4 - More Test Process Improvements

- Change Sensitivity and AWGN Test to 3% FER from 1% FER
  - Minimum Test Time Goes to 2 Seconds From 6 Seconds per FER Test
  - Requires That the Phone Has Sufficient Test Margin
- Test Only Full Rate
- Test Time per Phone Goes from 2.7 Minutes to 1.6 minutes



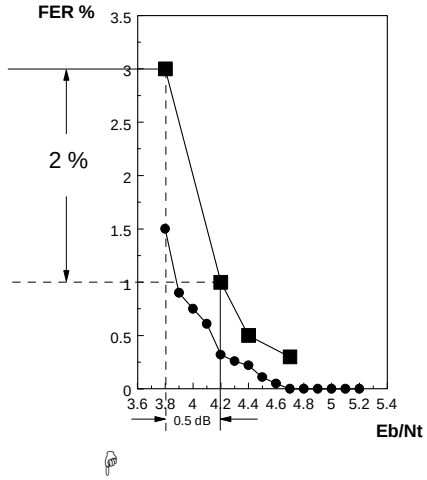
To further reduce test time further, two additional changes are proposed. One is to change the test environment to test to 3% FER limits rather than 1%. The other is to perform the FER test in AWGN at only the full data rate. The following page illustrates why this is feasible.

The test time gets a reduction of one minute, to 1.6 minutes.

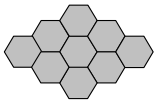
Notes:

Slide #26 - Justification for Change in FER Limits

Needed Justification for Change in FER Limits



- IS-98A Specification Limit
- FER vs Eb/Nt for Many Phones Measured
- Test Conditions Changed by 0.5 dB in Eb/Nt to Test Phone in a More Stringent Environment
- Phone Must Have Margin to Pass at the New Test Conditions



The graph above shows FER as a function of Eb/Nt has been measured on many phones of the same design. These curves have been shown to be very repeatable. The difference in Eb/Nt is 0.5 dB for a FER change from 1% to 3%. The test conditions for the phone will be degraded by 0.5 dB when the 3% testing is performed. The IS-98A test conditions allow for FER with AWGN testing at not only 1% FER, but at 3% and 5%. The benefit of moving to the 3% FER test condition is that the test time is reduced from 6 seconds to 2 seconds! If the phone design has sufficient margin, testing can be done at the 5% FER point to further reduce test time

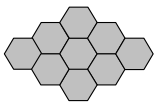
The reduction in the number of test conditions for AWGN can be justified by looking at the data from many phones. The data should be searched for phones that did not pass one of the AWGN conditions on the first try. These phones were routed to the repair station in order to eventually pass. Phones that did not pass initially should be examined to see one data rate were worse than others, and this one be chosen as the test condition.

Notes:

Slide #27 - Phase 5 - Second Data Point Reduction

Phase 5 - Second Data Point Reduction

- Test at Three Frequencies Vs Five
- Optimize Test Code (remove waits)
- Test Time Per Phone is Reduced from 1.6 Minutes to 48 seconds
- Test Suite Includes:
  - Place Call and Measure at Three Frequencies:
    - ✓ Sensitivity
    - ✓ Max. Power
    - ✓ Rho
  - Measure One Frequency:
    - ✓ FER with AWGN
    - ✓ Min. Power



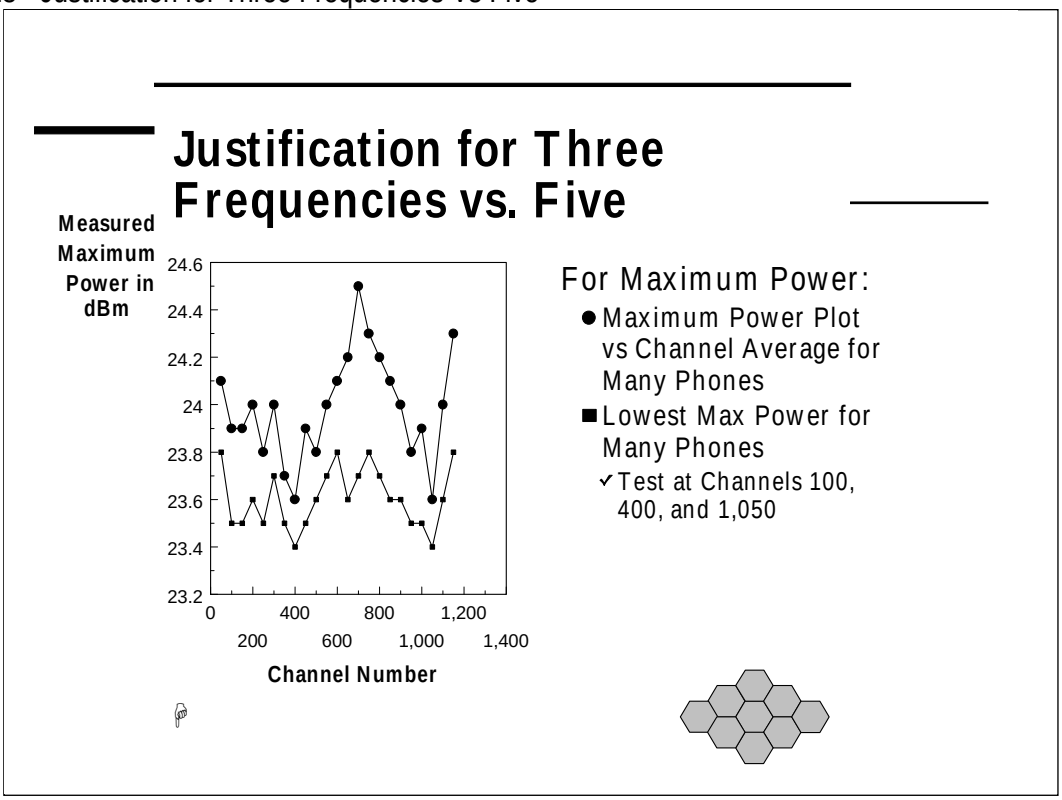
The final change will be to reduce the number of frequencies where tests are performed from five to three. In addition, the test code was optimized for this exact test sequence by removing wait statements that allowed for settling between tests in the general purpose software. It was found that the waits were not needed for this sequence of tests. Similar experiments on any test system can yield significant throughput improvements. These should only be attempted after the production line has established a solid history of consistent performance.

The test time per phone now drops to 48 seconds.

Notes:

Manufacturing Test of CDMA Phones

Slide #28 - Justification for Three Frequencies Vs Five



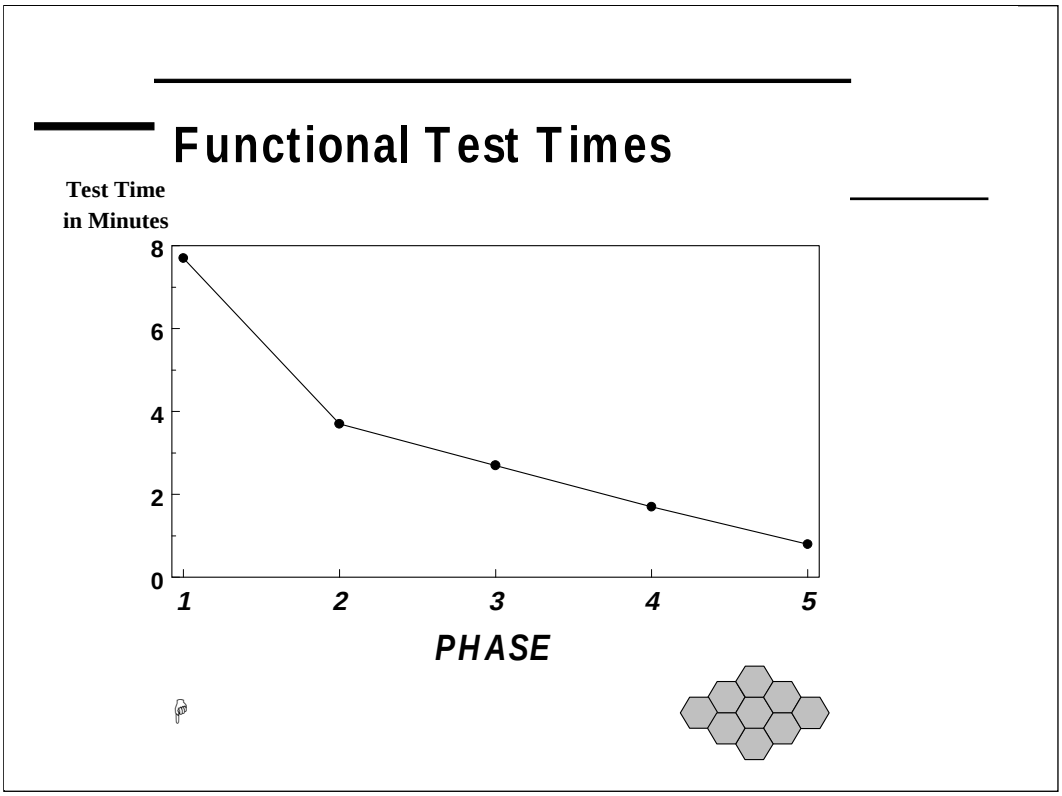
The specification of most concern when changing to only three frequencies is Maximum Power. A plot is shown here of max. power Vs channel for many phones. One line is the average of many phones, and the other is the minimum of the sample. As in the case of minimum power, a plot of 3 or 4 sigma may be of interest, as well. By examining such collected data, we can conclude that for this example, testing at channels 100, 400 and 1050 should catch any samples that do not meet the Maximum Power standard.

It is quite possible that the data for this could be generated in the calibration station, rather than the final test or QA test station.

Notes:

Manufacturing Test of CDMA Phones

Slide #29 - Functional Test Times



The test times for functional test have been reduced by a factor of almost 10! The initial test list was very detailed, while the final test list was very focused. Substantial improvements were made by using the concurrent measurement capability of the HP 8924C.

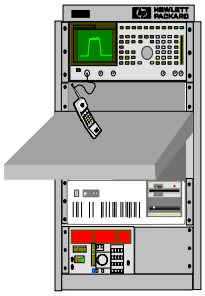
Notes:

Slide #30 - CDMA Re-Work Test

CDMA Re-Work Test

- **Failed Phones go to the Re-Work Area**
- **Technicians Isolate Problems Based on Functional Test Results**
- **To achieve Good Process Control:**
  - **Must use the Same Test Equipment as the Functional Test Station**
  - **Fixed Problems Must be Entered into Database to Provide Process Feedback**
- **If the Phone Cannot be Fixed Quickly (<15 minutes), the Phone is Scrapped**

Re-Work Test



If phones fail any test points on the functional test station (or sometimes called the final test station), these are routed to the re-work test benches. Skilled technicians who are familiar with the phone's characteristics operate these stations. The goal of the re-work station is to quickly identify and repair the problem in a minimum of time. Each phone arrives at the re-work station with the test results from the functional test station. Based on these results and the technician's knowledge of the phone's design, the technicians use the re-work test equipment to repair the phone.

To maintain process control, the test equipment used at the re-work station should be the same as that used in the calibration and functional test stations. If different test equipment is used, discrepancies arise that waste time trying to determine if it is a test equipment problem or a phone problem. This places additional requirement on the test set. The HP 8924C meets this requirement by providing not only excellent automated speed and performance for the calibration and functional test stations, but the most comprehensive and flexible user interface for the re-work station.

Phone that cannot be fixed quickly are scrapped.

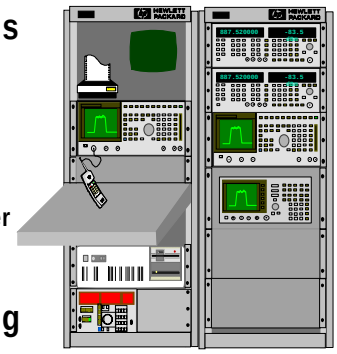
Notes:

Slide #31 - QA/Sample Test Purpose

QA / Sample Test Purpose

- Used to Verify Process Control
- More Extensive Testing that is Similar to the Original Phone Qualification Test
- Includes:
  - ✓ Intermodulation Tests
  - ✓ Time Response of Open Loop Power
  - ✓ Spurious Tests
  - ✓ Idle Handoff Tests
- More Complete IS-98A Testing

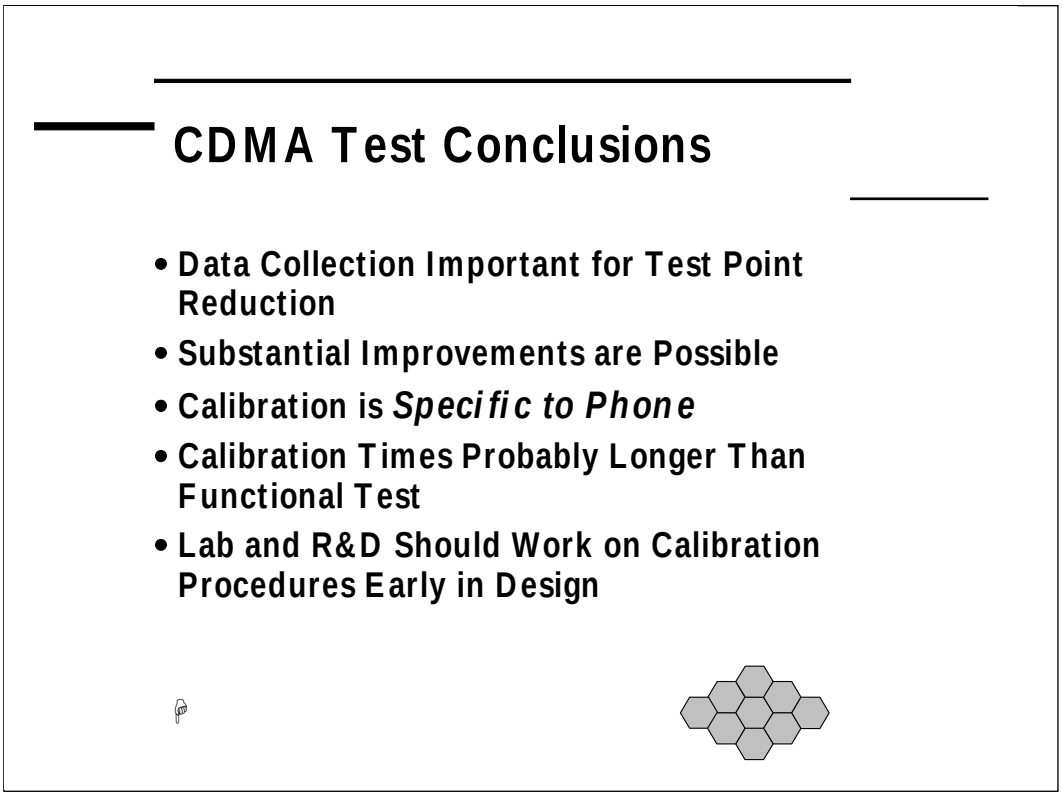
QA / Sample Test



The final station of this hypothetical production line is the QA or sample test station. This automated test station performs more thorough testing on a small sample of phones that have completed the entire manufacturing process. The purpose of this test station is to check quality to verify that the production line is maintaining good process control. Before entering manufacturing, the phone design was fully verified to meet all specifications. The sample test system is similar to the test system used to do this original qualification testing. The additional tests that are performed by the sample test station include: intermodulation tests (requiring one or two additional RF sources to provide interfering CW signals), time response of open loop power, spurious testing (requiring a full function spectrum analyzer) and idle handoff tests (requiring a second HP 8924C).

Notes:

Slide #32 - CDMA Test Conclusions



The key points of this paper are as follows:

- Collection of Good data is needed to reduce the number of test points.
- Substantial test time improvements are possible.
- Calibration will be specific to the phone's design.
- The CDMA calibration process will probably take more time than final test.
- Manufacturing and R&D should be working together to optimize phone design and process design.

Remember that the key is to learn the behavior of your phone's design. By gaining knowledge of its average performance, you can use these techniques to improve test time without reducing quality. Sample testing can provide a periodic check that your processes are still under control.

Notes: