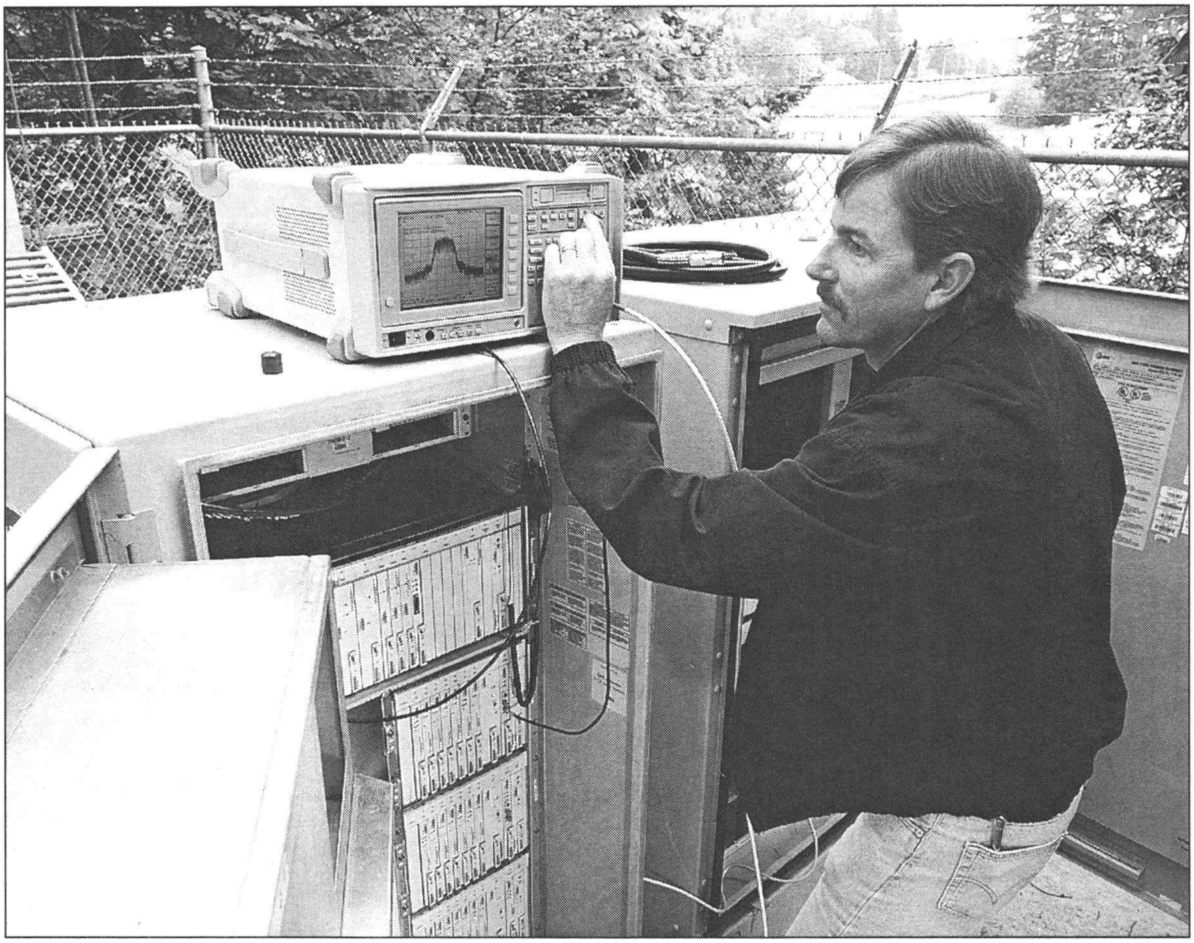
Tektronix

CDMA Base Station Testing Basics



When public wireless telephony was first introduced, it was based on analog principles. In recent years, the industry has been rapidly shifting to digital communications standards. This shift has resulted in smaller handsets, enhanced services, and higher network capacity.

Along with these benefits, digital systems change the knowledge requirements for operating and maintaining a network. The standards, measurements, and equipment have changed. But the challenge is still the same – to provide quality service to subscribers.

This guide provides an overview of CDMA base station testing and provides examples of the required measurements to help meet this challenge.

CDMA Base Station Testing Basics

Introduction

The public wireless telephony business has seen a number of significant changes throughout its fifteen-year life. The commercial popularity of wireless telephone service was proven by the success of early, analog systems such as Advanced Mobile Phone Service (AMPS), Total Access Communication Service (TACS), and Nordic Mobile Telephone (NMT). In recent years, the industry has been rapidly shifting from analog to digital communications standards. These digital systems allow for smaller handsets, enhanced services, and higher network capacities.

While these newer digital services bring a number of benefits, they also significantly change the knowledge requirements for operating and maintaining a network. Analog systems use terms such as signal-to-noise ratio and harmonic levels to quantify how well a base station is performing on a network. In today's digital systems, these familiar concepts are often mixed or replaced with concepts such as Tau Offset, Spectrum Due to Modulation, and Waveform Quality.

This application note will help "ease the transition" from analog to digital systems, and particularly the transition to Code Division Multiple Access, or CDMA, digital systems. Those who will find this application note most useful include RF technicians and engineers tasked with building or maintaining CDMA base station equipment. We'll begin with a brief overview of analog and digital multiplexing methods. This is followed by a review of key CDMA principals, and then a discussion of the various types of testing tools required to verify system performance. The rest of the note is devoted to providing a summary of key measurements required to verify the performance of a CDMA base station.

Contents:

Access Methods for Wireless Communications

The first analog systems for wireless phones used a Frequency Division Multiple Access (FDMA) system. In analog FDMA systems, the user occupies one frequency channel for transmit (30 kHz bandwidth for Advanced Mobile Phone Service – AMPS) and one for receive for the duration of a phone call. These transmit/receive channels are unavailable for further use until a call has been completed. During peak hours, many subscribers are unable to access the system which results in lost revenue for a network operator, and frustration for a user.

As digital processing power has increased, Time Division Multiple Access (TDMA) and Code Division Multiple Access (CDMA) have become viable alternatives to FDMA. TDMA systems improve system capacity by further subdividing a given frequency channel bandwidth into time slots. In such a system, the user's speech is converted to a digital bit stream that can be more easily manipulated and compressed. This compression allows more conversations to occupy the same space. Hence, a 30 kHz frequency bandwidth can be divided into three time slots with a user being allocated a particular time slot (North American Digital Cellular – NADC). In this way, multiple users can share the same duplex pair simultaneously. Popular systems using a TDMA approach include IS-136 and GSM.

A CDMA system uses a much broader bandwidth than either FDMA or TDMA systems (see Figure 1). Instead of dividing users by frequency or time, each user is given a unique code. When the correct code is applied to the received transmission, the desired conversation of a particular user can be found. In a CDMA system, multiple users' signals can occupy the same RF frequency at the same time. The layer of unique user codes is the method for segmenting users in this system.

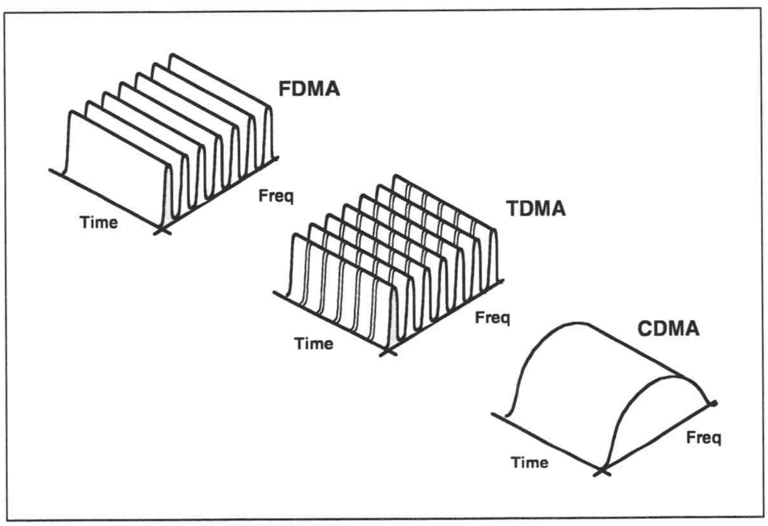


Figure 1. Basic waveform structure of FDMA, TDMA, and CDMA.

Basics of CDMA

What Standards Exist for CDMA? Within the United States, there are two primary standards which dictate the performance characteristics of a CDMA Base Transceiver Station (BTS). At cellular frequencies (approximately 860 to 890 MHz for the transmitter), the Telecommunications Industry Association (TIA) has written Interim Standard 95 (IS-95) for CDMA mobile/base station compatibility. More specifically, Interim Standard 97 (IS-97) outlines the CDMA BTS transmitter and receiver minimum standards.

At Personal Communications Services (PCS) frequencies (1930 to 1990 MHz), the Joint Technical Committee has passed Standard 008 (J-STD-008) for CDMA mobile/base station compatibility. As with IS-95, another standards document (J-STD-019) outlines the CDMA BTS transmitter and receiver minimum standards. The performance requirements are very similar between IS-97 and J-STD-019.

What are Walsh Codes? A "Walsh code" is the term used for the codes that separate the individual conversations being transmitted from a base station on the same CDMA RF carrier. This code uniquely identifies each of the forward traffic channels and "spreads" the data being sent in each channel so that the data lengths for each channel match. There are 64 possible Walsh codes, with each code being 64 bits long.

How does this compare with other access methods? In analog cellular systems such as AMPS, individual users occupy their assigned frequency; each user has a unique transmit and receive frequency. In digital TDMA systems, individual users occupy the correct time slot on a given frequency; each user has a unique period of time for receiving the transmission from the base station. In CDMA, individual users can only be recognized by demodulating the RF signal, since each user is identified by one of the 64 available Walsh codes.

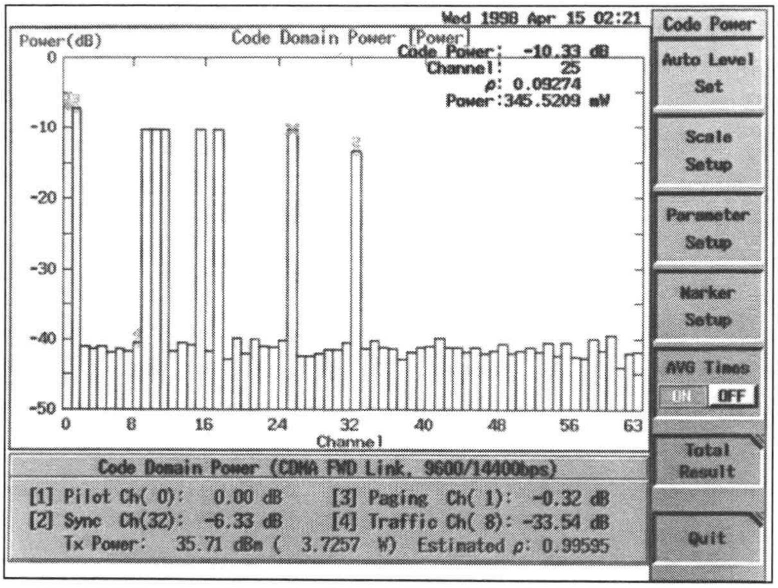


Figure 2. Code Domain Power.

Therefore, many of the measurements we will discuss depend upon looking at a CDMA signal in the "Code Domain." Code domain power, for instance, is a graph of the power levels in each of the 64 Walsh codes. In Figure 2, the power is graphed on the vertical axis, and the 64 Walsh codes (Channels 0 to 63) are displayed on the horizontal axis. In this example, codes 0, 1, 9, 10, 11, 15, 17, 25, and 32 are carrying traffic or system data of some sort.

What Are Pilot, Paging, Sync, and Traffic Channels? Pilot, paging, sync, and traffic channels are all types of forward link channels – logical channels sent from a base station to a mobile phone. Pilot, paging, and sync channels refer to three kinds of "overhead," or system channels. The ***pilot*** signal is usually the strongest of the 64 Walsh channels, and is always on Walsh code 0. The pilot serves almost the same purpose as a lighthouse; it continuously repeats a very simple signal at a high power level so that mobile phones can easily find the base station.

Paging channels can be on one or more of Walsh codes 1 to 7. These channels contain system information that a mobile uses to access and communicate on the network. The synchronization, or ***sync***, channel is always found on Walsh code 32. This channel contains information on the CDMA network's system time and paging channels. Finally, a ***traffic*** channel is a forward link channel being used for a conversation or data transmission from a user.

What is a Chip? The term "chip" is used in CDMA to avoid confusion with a "bit." A bit represents the digital data element being generated from a conversation or transmission. As stated earlier, user data is "spread" before being transmitted at RF in CDMA. A "chip" represents the smallest digital element after spreading. Within CDMA, 128 chips equal one bit.

What is a PN Offset? The abbreviation "PN" stands for pseudo-random noise sequence. This is a long bit sequence that, when viewed over a given period of time, appears to be random. The entire sequence, however, is specified and repeats over a given length of time.

There's more than one layer of coding that occurs in a CDMA network. The PN offset plays a key role in one of these layers, and allows a phone to separate one base station from another. Each base station in a CDMA network may transmit on the same frequency. Furthermore, each base station uses the same group of 64 Walsh codes for pilot, paging, sync, and forward traffic channels. Therefore, another layer of coding is required so that a mobile can detect one base station from another.

The short code is 32,768 chips long, and therefore repeats once every 0.027 seconds. This code sequence is exclusive or'd with the data for each of the forward channel types (pilot, paging, sync, and traffic) described above. Within this 32,768 chip sequence, 512 points in the sequence, or offsets, have been chosen. Each base station in a CDMA network applies the same PN sequence to the forward link data; however, each base station uses a ***different*** PN offset from neighboring base stations. As a result, each base station can be identified from its neighbor by its unique PN offset. In practice, unique PN offsets are assigned to each sector of a base station, so individual sectors can be identified from the received base station signal.

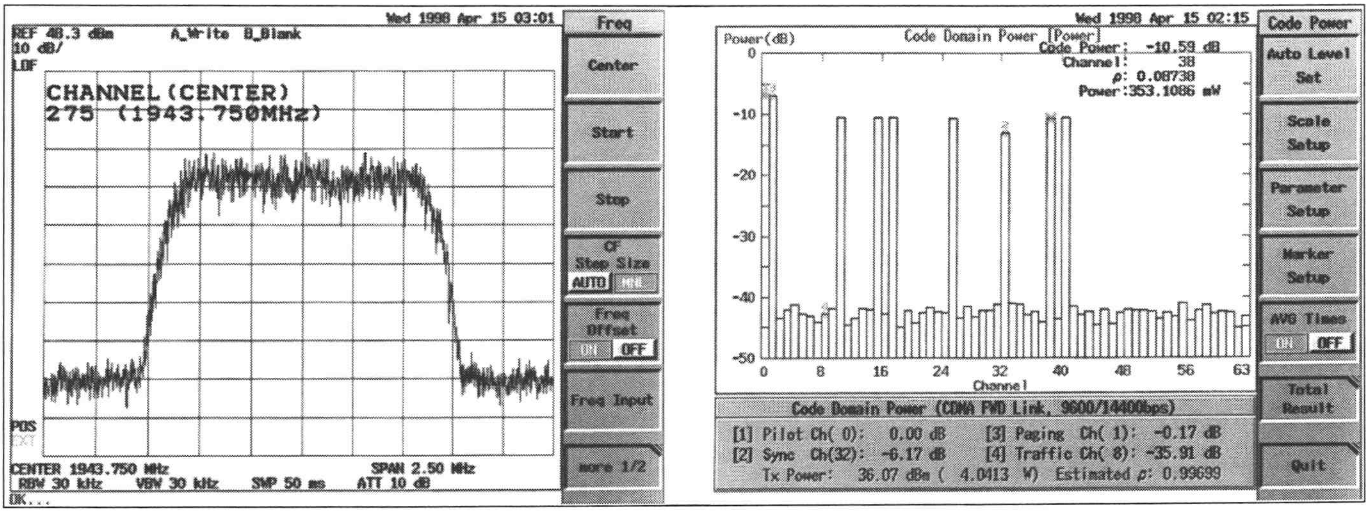


Figure 3. CDMA transmission in frequency domain (left) and code domain (right).

What Does a CDMA Transmission Look Like? Figure 3 shows what a typical CDMA BTS transmission looks like in both the frequency and code domains. The data from the system as well as users is coded, spread, and combined for transmission. This is then modulated onto an RF carrier, with a channel bandwidth of 1.2288 MHz. The code domain picture at right is simply the demodulated data from the frequency domain picture at left.

CDMA RF Testing Tools

What Kinds of Tools are Required? Both IS-97 and J-STD-019 specify certain types of measurement tools to be used in checking the RF performance of a CDMA BTS. These tools include a spectrum analyzer, a CW signal generator, a power meter, an Additive White Gaussian Noise generator (AWGN), a mobile station simulator, and a waveform-quality code-domain power measurement device. Of course, some of these tools are likely to be used more frequently than others. Furthermore, test equipment vendors have worked to combine many of these functions into the same package.

Table 1 lists the common types of tools, and some measurements made with each tool.

Why Are All of These TX Tools Necessary? Each of the instruments listed in Table 1 is well suited for making certain types of measurements. The complex nature of a CDMA signal necessitates the use of these different tools.

Table 1. CDMA Test Equipment

Measurement Device	Sample Applications
Waveform Analyzer	Waveform quality of transmitter (Tx) Frequency error (Tx) Pilot time tolerance (Tx) Code domain power (Tx)
Spectrum Analyzer	In-band spurious emissions (Tx) Out-of-band spurious emissions (Tx) General RF interference checks
Power Meter	Base station total output power (Tx)
CW, CDMA, AWGN Generator	Receiver (Rx) sensitivity Rx dynamic range Rx Single tone desensitization

POWER METERS:

A power meter has the ability to make very accurate, repeatable measurements of total output power from a base station. It has the additional benefits of being portable and relatively easy to use. Unfortunately, however, the power meter alone may not catch many CDMA BTS problems.

Two power meters testing separate base stations could easily show comparable results. While there may be a slight difference in the readings, there doesn't appear to be any difference that would indicate a severe malfunction. Yet, one of these base stations may be in an area experiencing dropped calls, while the other is not.

There are a number of possible causes for this poor RF performance. Additional tools are required, however, to systematically find the problem and identify a solution. For example, no single base station (or sector of a base station) may be the cause of this network disturbance. Instead, an external source – perhaps a competing provider "leaking" into unassigned spectrum, or even a lower frequency RF signal with severe harmonic or filter problems – may be interfering with the signal. In such a case, a spectrum analyzer is required to pinpoint the nature of the interference.

SPECTRUM ANALYZERS:

A spectrum analyzer functions like a "frequency selective" power meter. That is, a spectrum analyzer displays a graph of power levels on the vertical axis versus frequency on the horizontal axis. While a power meter may be more accurate in finding absolute power levels over a range of frequencies, a spectrum analyzer allows the user to more accurately determine which frequencies have high power levels.

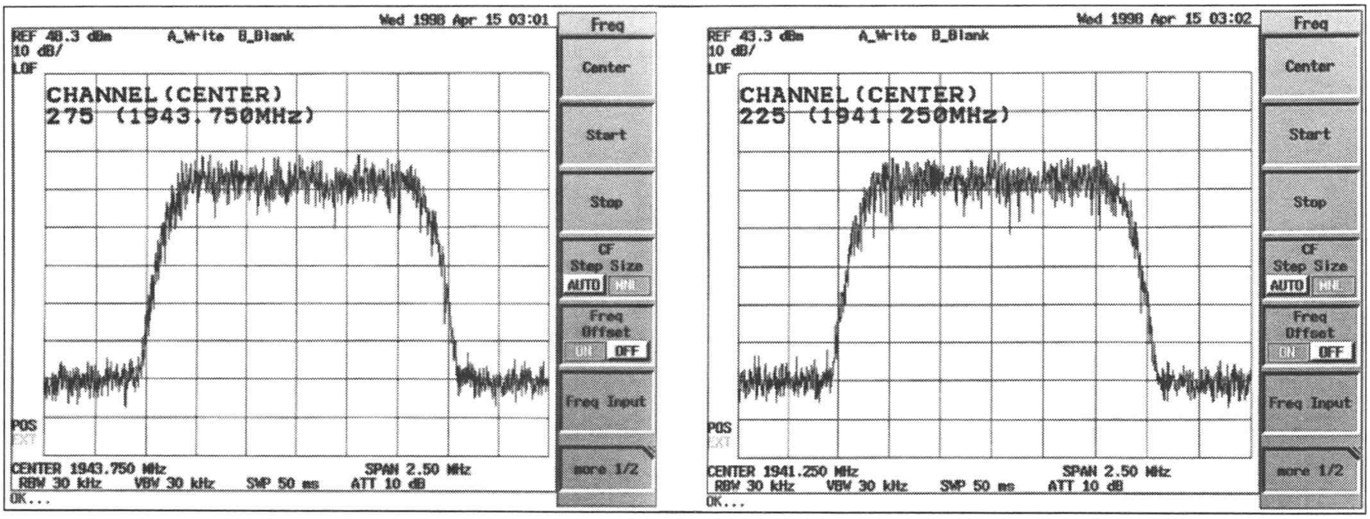


Figure 4. CDMA spectrum images. Which site is healthy?

A spectrum analyzer can therefore help troubleshoot problems such as interference and spurious signals being transmitted from a base station. As with the power meter example, additional test equipment is required to fully diagnose a base station. Figure 4 shows two images from the R3465 CDMA BTS Tester, which includes a full-function spectrum analyzer.

Again, neither image would seem to indicate a severe problem with the sector of the base station being analyzed. The base station on the left, however, could be missing a sync channel, and therefore would not hold up a call. The fact that neither a power meter nor a spectrum analyzer can reliably find this kind of a CDMA modulation problem is the reason for the third major type of test equipment: a CDMA Waveform Analyzer.

CDMA ANALYZERS AND SIGNAL SOURCES:

The waveform analyzer tunes to the transmit frequency of the base station sector and then demodulates the signal. This demodulation process allows the waveform analyzer to verify the performance of the individual Walsh codes of the base station sector. As a result of the digital transmission characteristics of a CDMA signal, only an instrument that demodulates the digital RF transmission can perform these measurements. Additionally, the analyzer can determine the timing, phase, and frequency error of the base station. This tool therefore rounds out the measurement capabilities of a power meter and spectrum analyzer, and allows for comprehensive performance checks on the transmitters within the base station.

Often, the waveform analyzer works together with a signal source, or mobile simulator, to send a known CDMA RF signal to the receivers of a base station. The base station, or the switch that controls the base station, can then compare the known signal inserted into the sector to the received signal, and verify the performance of the receiver.

Obviously, each tool provides useful diagnostic capabilities. Fortunately, modern test equipment usually combines two or more of the above types of measuring capabilities within a single package, making it easier to accurately diagnose RF problems in a CDMA network.

Common CDMA Base Station Measurements

Following is a detailed description of the key transmitter and receiver measurements for maintaining a CDMA base station. These tests are called out in the following standards: IS-97 for U.S. Cellular and J-STD-019 for U.S. PCS CDMA systems.

Transmitter Frequency Error

Standards: IS-97 10.1.2 — J-STD-019 4.1.2

What is Being Measured?

This measurement determines the difference between the actual transmitted carrier frequency of a base station sector and the specified frequency. If a transmitted signal is slightly "off-center" from a designated frequency, some of the energy of the signal will be ignored by a properly aligned receiver and may interfere with neighboring transmissions.

How is Frequency Error Measured?

This measurement requires the test equipment to demodulate the CDMA signal. The test set determines the change in phase of the CDMA signal versus time; the slope of the resulting curve is the frequency error of the signal. In the standards, this test is defined as part of the "waveform quality" measurements, meaning that the measurement should be performed on a pilot-only signal. In practice, however, a CDMA signal with multiple active Walsh codes can be input to the test equipment.

What is the Specified Limit?

Both IS-97 and J-STD-019 specify a frequency error less than $+5 \times 10^{-8}$ (0.05 ppm) of the frequency assignment. This translates to approximately 45 Hz error for cellular and 90 Hz for PCS frequencies.

Pilot Time Tolerance

Standards: IS-97 10.3.1.1 — J-STD-019 4.3.1.1

What is Being Measured?

The difference between the transmitted start of the PN sequence of the pilot Walsh code and an external trigger event is measured to determine the Pilot Time Tolerance (see Figure 5). This measurement ensures that any given sector of a base station is "tracking" with the network's CDMA system time. Deviation from this network-wide timing could ultimately result in dropped calls since the faulty base station timing would not match the timing on the remainder of base stations.

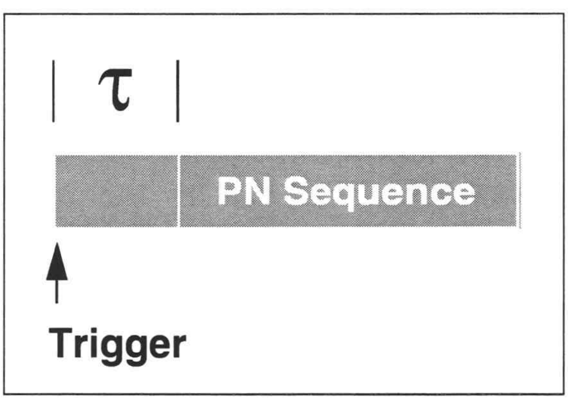


Figure 5. Pilot time tolerance.

How is Pilot Time Tolerance Measured?

The test set demodulates the transmitter output from the base station in order to determine the start of the pilot PN sequence. In addition, the test set uses an even second clock signal (available on all base stations) as the external trigger reference. Taking into account the programmed PN offset, the test set then calculates the difference between the time of the trigger and the time of the Pilot PN sequence, and reports that difference.

As with transmitter frequency error, this measurement should "officially" be made on a Pilot-only transmission from a base station. However, since this requires taking the base station off-line, most test equipment solutions are able to provide a pilot time-alignment error on a mixed signal with paging, sync, and traffic Walsh codes also active.

What is the Specified Limit?

Both IS-97 and J-STD-019 specify that the pilot time-alignment error must be less than 10 μs. Both specifications also state that the value should be less than 3 μs.

Pilot Channel to Code Channel Time Tolerance

Standards: IS-97 10.3.1.2 J-STD-019 4.3.1.2

What is Being Measured?

In the previous measurement, the timing error between a known reference (the even second clock) and the start of the Pilot PN sequence was calculated. There still exists, however, timing differences between each of the rest of the forward channels (sync, paging, and traffic) and the pilot channel. This measurement reports the timing error between the transmitted pilot signal and the other transmitted Walsh codes. A high timing error between the pilot and the rest of the forward channels can affect the system capacity.

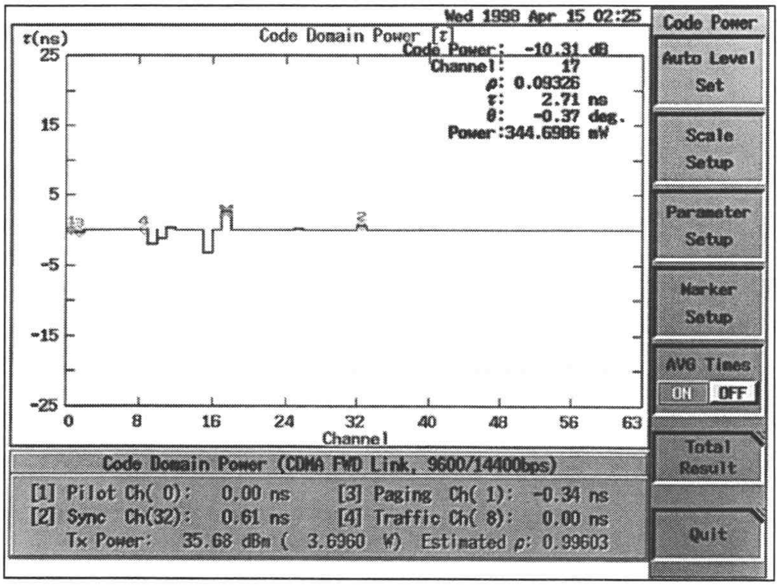


Figure 6. Pilot to code time tolerance.

How is Pilot to Code Time Tolerance Measured?

The test set demodulates the transmitter output from the base station in order to measure the 64 forward link Walsh code channels. The difference between the timing of the beginning of the pilot channel and the rest of the Walsh codes is then measured (see Figure 6).

For this test, both IS-97 and J-STD-019 suggest a nominal test model: a "standard" configuration of the transmitted base station signal. This model is composed of the forward-link Walsh codes shown in Table 2.

What is the Specified Limit?

Both IS-97 and J-STD-019 specify that the pilot channel to code channel time error must not exceed ±50 ns for any one code.

Table 2. Nominal Testing Model (from IS-97 and J-STD-019)

Code Type	Number of Channels	Power (dB)	Comments
Pilot	1	–7.0	Code channel 0
Sync	1	–13.3	Code channel 32, always 1/8 rate
Paging	1	–7.3	Code channel 1, full rate only
Traffic	6	–10.3	Variable code channel assignments; full rate only

Pilot Channel to Code Channel Phase Tolerance

Standards:	IS-97	J-STD-019
	10.3.1.3	4.3.1.3

What is Being Measured?

Much like the code domain timing tolerance, this measurement reveals the phase error between the pilot code channel and the rest of the code channels. A high phase error between the pilot and any of the rest of the forward channels can result in impaired reception by the mobile.

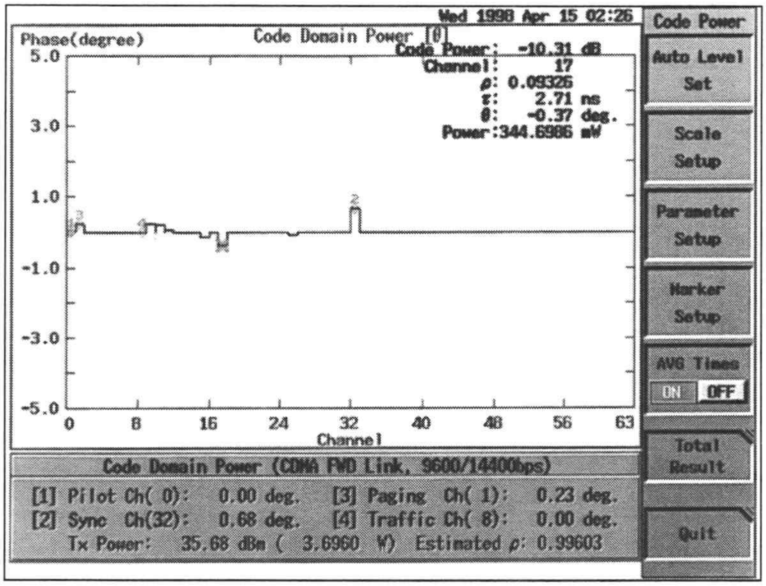


Figure 7. Code domain phase tolerance.

How is Pilot to Code Phase Tolerance Measured?

The test set demodulates the transmitter output from the base station in order to measure the 64 forward link Walsh code channels. The difference between the phase of the pilot channel signal and the rest of the Walsh codes is then measured (see Figure 7).

For this test, both IS-97 and J-STD-019 suggest the same nominal test model described above.

What is the Specified Limit?

Both IS-97 and J-STD-019 specify that the pilot channel to code channel phase error must not exceed ±0.05 radian for any one code.

Waveform Quality (rho)

Standards:

	IS-97	J-STD-019
	10.3.2	4.3.2

What is Being Measured?

Waveform quality, often referred to as rho (ρ), is perhaps the most common measurement for CDMA systems. Rho is a correlation constant, representing how closely the transmitted CDMA signal's power matches the ideal power distribution for a CDMA signal (see Figure 8).

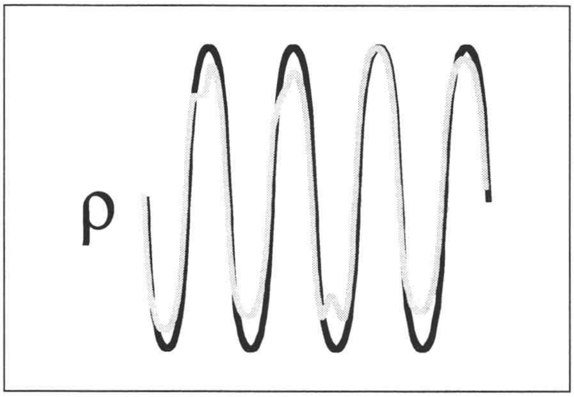


Figure 8. Waveform quality measurement (the darker trace represents the ideal signal).

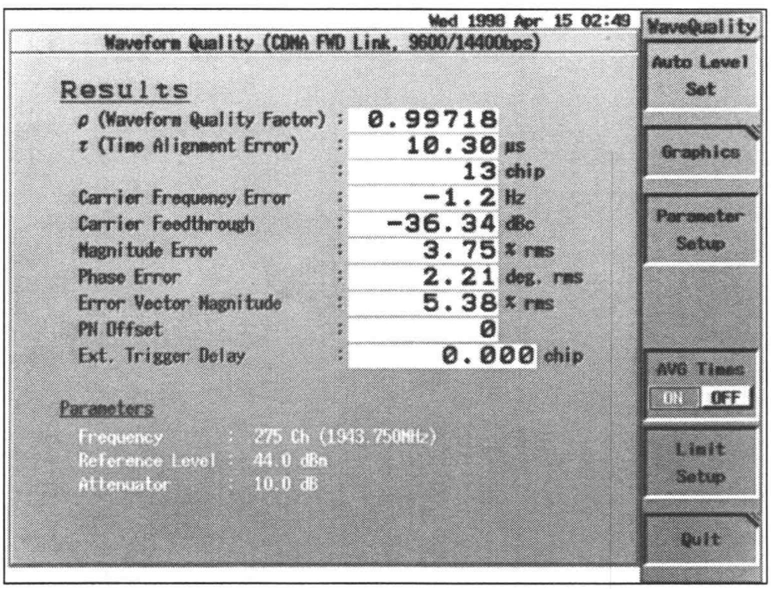


Figure 9. Waveform quality result example.

An easy way to remember rho is to think of the tested CDMA signal power distribution as the numerator of a fraction and the ideal CDMA signal as the denominator. As a result, a waveform quality constant of 1.0 would represent a perfectly correlated CDMA signal. This measure is a good tool for judging the modulation quality of the transmitted CDMA signal.

Note: Waveform quality measurements do not include effects from the frequency and pilot timing errors discussed previously.

How is Waveform Quality Measured?

The test set must demodulate the transmitter output from the base station in order to derive a value for waveform quality. The fraction of power received at certain "decision" points in the CDMA transmission is compared to the ideal power values. Both IS-97 and J-STD-019 dictate that this measurement is to be made on a Pilot-only forward link signal. Furthermore, the test is to be made over a sample period of at least 1280 chips (see Figure 9).

In practice, a pilot-only transmission from a base station implies that the base station has been removed from service. Most test equipment vendors now supply an "estimated rho" capability, allowing rho to be derived in the presence of multiple Walsh codes. This capability therefore allows an approximate rho value to be calculated without taking down a sector of the base station.

What is the Specified Limit?

Both IS-97 and J-STD-019 specify that the waveform quality constant be greater than 0.912.

Total Power

Standards:	IS-97	J-STD-019
	10.4.1	4.4.1

What is Being Measured?

This measurement verifies the total output power from the base station or the appropriate sector of the base station (see Figure 10).

How can Total Power be Measured?

The unique qualities of a CDMA signal make power measurements less straightforward than with other communications systems. The CDMA signal has the appearance of a "noise-like" signal spread over 1.23 MHz bandwidth. In actuality, however, a CDMA signal can have much higher peak-to-average power ratios than a noise signal.

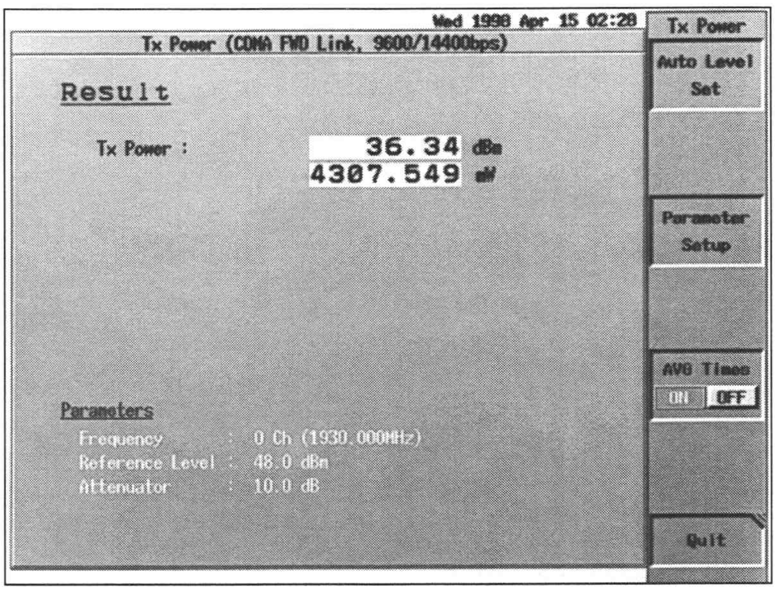


Figure 10. CDMA transmitter power measurement.

Total power can be measured with either a power meter, or a piece of test equipment which has a "power meter like" measurement function. For CDMA, a power meter using a thermal power head provides accurate measurements of the power transmitted in the spread-spectrum signal.

Spectrum analyzers can also be used to make this measurement. The common method of measurement is to sum the power measurements across the 1.23 MHz wide CDMA bandwidth. Most spectrum analyzers, however, have power detectors appropriate for CW signals instead of CDMA signals. As a result, power measurements can be 9 dB or more in error, with the error depending upon which Walsh codes are active.

Many CDMA BTS testers now provide accuracy similar to a thermal power meter. Usually, a DSP measurement is made, with the tester completing an RMS calculation based upon a number of samples. As an example, the R3463 and R3465 CDMA BTS Testers have a CDMA power measurement accuracy of ±0.8 dBm, with each instrument offering typical accuracy of ±0.2 dB after calibration.

Both IS-97 and J-STD-019 specify a base station signal configuration of pilot, paging, sync, and six traffic channels active for this measurement. This configuration matches the model expressed in Table 2.

What is the Specified Limit?

IS-97 and J-STD-019 specify that the total power shall remain within +2 dB and –4 dB of the specified base station (or sector) power.

Pilot Power

Standards:

	IS-97	J-STD-019
	10.4.3	4.4.3

What is Being Measured?

The test equipment measures the ratio of power in the pilot Walsh code to the total CDMA channel power transmitted (see Figure 11).

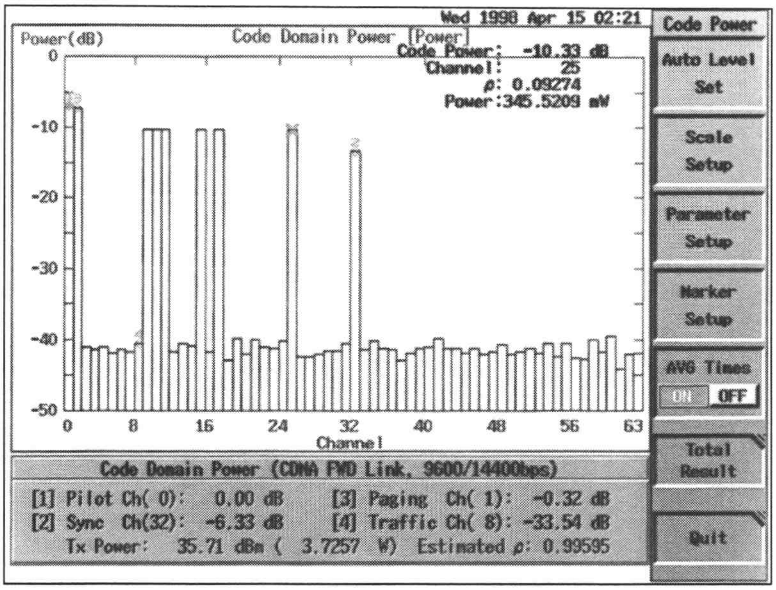


Figure 11. Code domain power showing power on Pilot and Walsh codes. Pilot power is measured directly by placing a marker on Channel 0.

How is Pilot Power Measured?

In order to measure the pilot power, the test equipment must be able to demodulate the signal and analyze power levels in the code domain. That is, the test gear must be capable of finding the power for each of the 64 forward link Walsh codes. Then, the ratio of the power in the pilot channel is compared to the CDMA Tx power, and the result is expressed in dB.

For either U.S. cellular or PCS systems, pilot power is evaluated with a mixed signal: a combination of Pilot, Sync, Paging, and six traffic channels. The same model expressed in Table 2 is used for this measurement. A pilot power level that deviates substantially from desired values can affect the coverage characteristics of the network.

What is the Specified Limit?

IS-97 and J-STD-019 specify that the pilot power shall remain within ±0.5 dB of the BTS sector configuration value.

Code Domain Power

Standards: IS-97 10.4.4 J-STD-019 4.4.4

Standards:	IS-97	J-STD-019
	10.4.4	4.4.4

What is Being Measured?

The test equipment measures the ratio of power in each of the forward link Walsh codes to the total CDMA channel power transmitted. This information is displayed in either a bar graph format, for visual verification, or as a tabular summary to more accurately monitor performance.

Figure 12 shows a graph of the Code Domain along with the accompanying Code Domain Power table.

How is Code Domain Power Measured?

As described in the pilot power measurement, the test equipment must be able to demodulate the signal and analyze power levels in the code domain. For this test, the ratio of the power in each Walsh code is compared to the CDMA Tx power, and the result is expressed in dB. For convenience, some code domain analyzers also produce results for each code in absolute power units, such as dBm or Watts. In many cases, this allows for a faster verification of code domain performance against known, absolute, power levels (see Figure 12).

For either U.S. cellular or PCS systems, code domain power is verified with the base station sector producing a mixed signal: a combination of Pilot, Sync, Paging, and six traffic channels (refer to Table 2). The tested power levels in these Walsh codes can then be compared against the desired values. Furthermore, the level of the inactive Walsh codes (those forward codes not supporting an overhead or traffic signal) can be compared against the standard. A base station's ability to accurately control the power in individual Walsh codes is a necessity in order to handle multiple users with varying RF losses between the base station and the phone and to ensure interference-free transmissions.

What is the Specified Limit?

IS-97 (U.S. Cellular) and J-STD-019 (U.S. PCS specify that the code domain power in each inactive Walsh code shall be 27 dB or more below the total CDMA output power.

In addition, many system problems such as carrier feedthrough or modulation imbalance can be detected by an increase in the inactive Walsh code power levels.

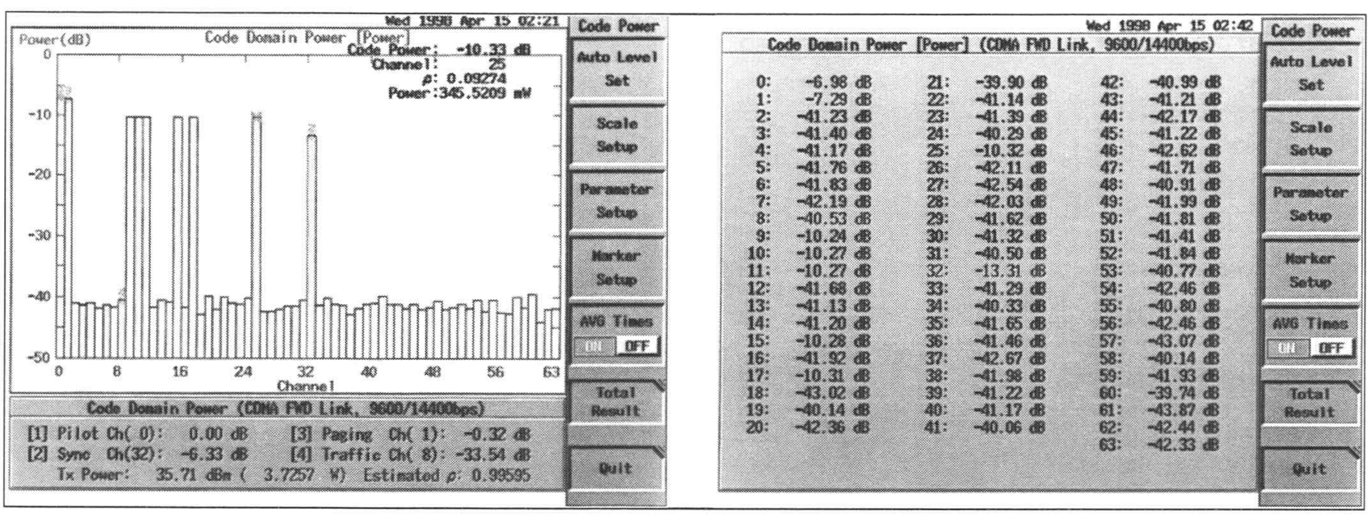


Figure 12. Code Domain Power graph (left) with the accompanying Code Domain Power table (right).

Conducted In-Band Spurious Emissions

Standards:	IS-97	J-STD-019
	10.5.1	4.5.1

What is Being Measured?

The test equipment measures the frequency spectrum covering the entire transmit band and checks for any spurious signals originating in the base station equipment.

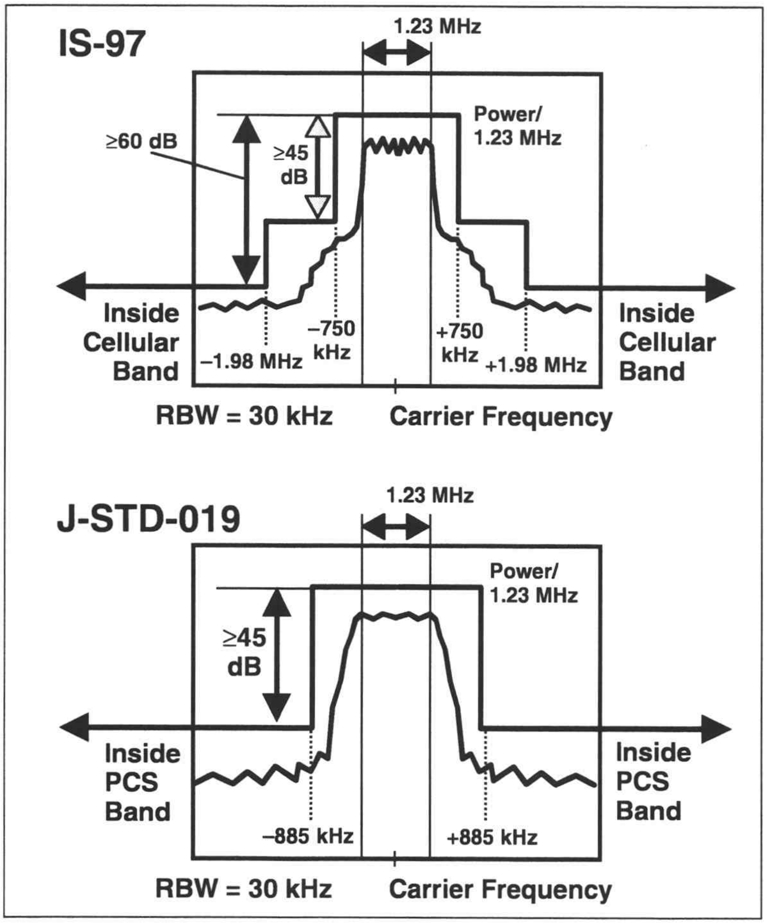


Figure 13. In-band specifications.

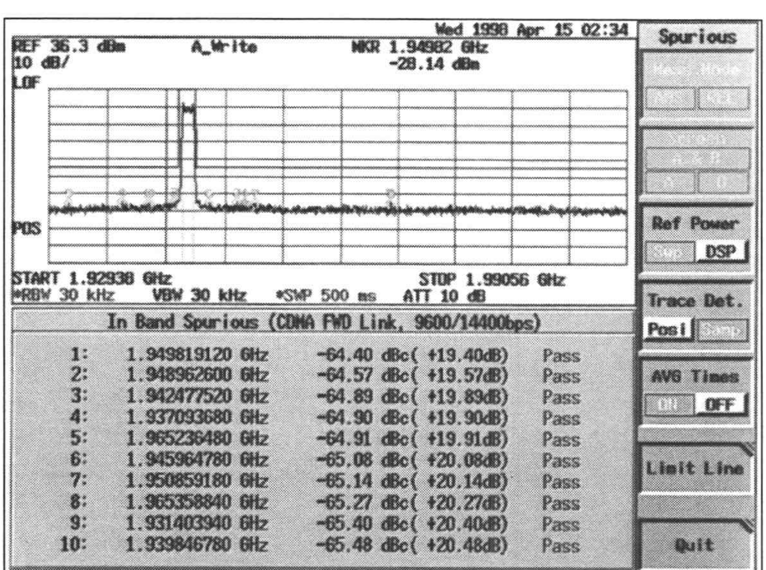


Figure 14. Typical in-band measurement.

How are In-Band Spurious Emissions Measured?

This measurement is easily made with a spectrum analyzer, or with a CDMA BTS Tester that includes a spectrum analyzer. The analyzer connects to the RF output port of the base station. For this test, the base station should be set to transmit the nine-code test model described in Table 2.

The CDMA power level at the RF output port is then measured and used as a reference for the spurious levels to be detected. In general, each standard specifies a unique passing level for spurs. These levels are described as a "mask," with power levels paired with frequency offsets from the center of the transmit frequency. Any signal peak that falls above the mask and within the transmit band is then judged to be a spurious signal in excess of the specification. Additionally, both IS-97 and J-STD-019 specify that the spectrum analyzer use a 30 kHz resolution bandwidth setting when performing sweeps for spurious signals.

The purpose of this measurement is to ensure that the base station's transmitters are not producing interference within the transmit band.

What is the Specified Limit?

IS-97 specifies the following performance for In-Band (869 to 894 MHz) Spurious:

- For frequency offsets between 750 kHz and 1.98 MHz from the center of the transmitted CDMA signal, spurious emissions shall be at least –45 dBc. In this case, dBc refers to dB relative to the carrier power of the CDMA signal.
- For frequency offsets greater than 1.98 MHz from the center of the transmitted signal, spurious emissions shall be at least –60 dBc.

J-STD-019 specifies the following performance for In-Band (1930 to 1990 MHz) Spurious:

- For frequency offsets greater than 885 kHz from the center of the transmitted signal, spurious emissions shall be at least –45 dBc. Again, dBc refers to dB relative to the carrier power of the CDMA signal.

Figure 13 outlines the above standards. Admittedly, these masks can appear confusing, and certainly less than straightforward to evaluate. Fortunately, many test equipment manufacturers have included automated routines for In-Band Spurious measurements. Figure 14 is an example of one such measurement from the R3465 CDMA BTS Tester.

Conducted Out-Band Spurious Emissions

Standards:	IS-97	J-STD-019
	10.5.1	4.5.1

What is Being Measured?

The test equipment measures the frequency spectrum covering the areas adjacent to the transmit band and checks for any spurious signals originating in the base station equipment.

How are Out-Band Spurious Emissions Measured?

The Out-Band Spurious measurement methodology is similar to that for In-Band Spurious. Again, the measurement is easily made with a spectrum analyzer, or with a CDMA BTS Tester that includes a spectrum analyzer. The analyzer connects to the RF output port of the base station. For this test, the base station should be set to transmit the nine-code test model described in Table 2.

The CDMA power level at the RF output port is then measured and used as a reference for the spurious levels to be detected. A search is then made for any signal peak that falls above the mask or above certain absolute limits for signal power.

The purpose of this measurement is to ensure that the base station's transmitters are not producing interference damaging to other users outside the transmit band.

What is the Specified Limit?

IS-97 specifies the following performance for Out-Band Spurious:

- Frequency range to be measured is from either 1 MHz or the lowest frequency generated within the base station, whichever is lower, up to the transmit band for cellular. Likewise, frequencies are checked from the top end of the transmit band to the tenth harmonic of the transmit frequency.
- Levels are measured against pre-defined, local standards (such as the FCC regulations for the U.S.).

J-STD-019 specifies the following performance for Out-Band Spurious:

- Frequency range to be measured is from either 1 MHz or the lowest frequency generated within the base station, whichever is lower, up to the transmit band for cellular. Likewise, frequencies are checked from the top end of the transmit band to the tenth harmonic of the transmit frequency.

  Note: For receiver conducted spurious measurements at the RF input port, the spectrum is checked to at least 6 GHz.
- The spurious emissions are to be less than or equal to –13 dBm, or –80 dBc, whichever is larger. Typically, –13 dBm is the larger value and is therefore used for this check.
- J-STD-019 also specifies that the spectrum analyzer should use a resolution bandwidth of 1 MHz for these measurements. There is, however, an exception for a small portion of the spectrum located directly adjacent to the transmit frequency block, where a narrower resolution bandwidth filter setting can be used.

Receiver Sensitivity and Dynamic Range Measurements

Standards:

	IS-97	J-STD-019
	9.4.1-2	3.4.1-2

What is Being Measured?

The previous tests have all measured various performance characteristics of the base station transmitters. There are also a number of tests that verify the performance of the base station receivers. In general, these tests check the ability of the base station receiver to accurately recover transmitted signals. There are a number of receiver measurements that can be made on a base station, including receiver sensitivity, dynamic range, and single-tone desensitization. This document will focus on two of the more common receiver measurements: receiver sensitivity and dynamic range.

For receiver sensitivity, the receiver's ability to recover low-level signals is verified. For receiver dynamic range, the ability to capture higher-level signals is tested. The results of receiver sensitivity and dynamic range help to quantify the ability of the base station to accurately recover signals from mobiles at very low and high power levels. Some of the other receiver measurements help to judge the receiver's ability to accurately recover signals in the presence of different types of interference. Low performance in any of these areas contributes to poor call quality.

How are Receiver Sensitivity and Dynamic Range Measured?

Most digital wireless communication systems rely upon a bit-error rate measurement in order to verify receiver performance. A known data pattern signal is injected into the base station at a given power level. The received signal data is then compared to the known transmitted data, and an error rate is calculated. Usually, the standards documents list an acceptable level of errors for any given test condition.

These receiver tests can, however, require the switch to place the base station into a testing mode. Many of the transmitter measurements can be performed locally at the base station, using a test port to insure uninterrupted base station operation. However, receiver tests may take more time and may need to be performed during a pre-defined maintenance window for the site.

First, the test equipment must be able to generate a reverse link (mobile phone) CDMA signal that can be injected into the base station receivers. Second, the equipment must be able to transmit a pre-defined, or user-defined, set of data that can later be checked for errors. Finally, the equipment should be able to inject these signals at a variety of signal levels, matching the standards' requirements.

What is the Specified Limit?

RECEIVER SENSITIVITY:

IS-97 specifies the following performance for receiver sensitivity:

- The transmitted power level from the test equipment injected at the RF input port that yields a calculated frame erasure rate (FER) of 1.0% or less (with a statistical confidence of 95%) with the following conditions:
  - Power ≤–117 dBm
  - Additive White Gaussian Noise (AWGN) generators off
  - Random data transmitted
  - Full rate transmission

J-STD-019 specifies the following performance for receiver sensitivity:

- The transmitted power level from the test equipment injected at the RF input port that yields a calculated frame erasure rate (FER) of 1.0% or less (with a statistical confidence of 95%) with the following conditions:
  - Power ≤–119 dBm
  - AWGN generators off
  - Random data transmitted
  - Full rate transmission

RECEIVER DYNAMIC RANGE:

Receiver dynamic range is reported as a set of power levels through which the base station is able to maintain an FER threshold level. The lower power level is usually determined by the sensitivity measurement described above. The higher power level is the highest power level at which the base station can still meet the FER threshold level. When determining the higher value, the CDMA test signal is to also include AWGN.

IS-97 and J-STD-019 specify:

- Full rate transmission
- Noise power spectral density of –65 dBm/ 1.23 MHz or greater
- Signal level (Eb/No) of 10 dB ±1 dB
- Random data transmitted
- Full rate transmission
- Calculated FER ≤1.0%

Summary of CDMA Base Station Measurements

Measurement	IS-97 Standard	J-STD-019 Standard	Page Reference
• **Transmitter Frequency Error**	<+5 x 10^{-8} (0.05 ppm)	<+5 x 10^{-8} (0.05 ppm)	6
• **Pilot Time Tolerance**	Alignment error must be <10 µs Should be <3 µs	Alignment error must be <10 µs Should be <3 µs	6
• **Pilot Channel to Code Channel Time Tolerance**	≤±50 ns for any one code	≤±50 ns for any one code	7
• **Pilot Channel to Code Channel Phase Tolerance**	≤±0.05 radian for any one code	≤±0.05 radian for any one code	8
• **Waveform Quality (rho)**	>0.912	>0.912	9
• **Total Power**	+2 to –4 dB	+2 to –4 dB	10
• **Pilot Power**	Within ±0.5 dB	Within ±0.5 dB	11
• **Code Domain Power**	≥27 dB below total output power	≥27 dB below total output power	12
• **Conducted In-Band Spurious Emissions**	750 kHz to 1.98 MHz: ≥–45 dBc >1.98 MHz: ≥–60 dBc	>885 kHz: ≥–45 dBc	13
• **Conducted Out-Band Spurious Emissions**	Please refer to text	Please refer to text	14
• **Receiver Sensitivity**	FER ≤1% for power ≤–117 dBm	FER ≤1% for power ≤–119 dBm	15
• **Receiver Dynamic Range**	FER ≤1% for output of –65 dBm/1.23 MHz	FER ≤1% for output of –65 dBm/1.23 MHz	15

References

Standards referenced in this document:

- **ANSI J-STD-019**, Recommended Minimum Performance Requirements for 1.8 to 2.0 GHz Code Division Multiple Access (CDMA) Base Stations
- **TIA/EIA/IS-97**, Recommended Minimum Performance Standards for Base Stations Supporting Dual-Mode Wideband Spread Spectrum Cellular Mobile Stations

Other literature:

- **R3465/63 CDMA Data Sheet** – 2HA-11565-0
- **R3465/R3463 Series Quick Guide** – 2HA-11941-0
- **R3465/R3463 CDMA BTS Testing Overview** – 2HA-12005-0
- **CDMA BTS Measurement Quick Start Manual** – 2HA-11940-0

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