

Keysight Technologies

Multi-Coded Waveform Quality
and Code Domain Measurements
for cdma2000®

Technical
Overview



Unlocking Measurement Insights

Introduction

Waveform quality and code domain measurements in TIA/EIA-95-B

Waveform quality is the basic measure of the performance of a CDMA system transmitter. The success of a CDMA system lies in its efficient use of power, and the waveform quality measurement gives the percent of power that correlates to the ideal code.

The figure of merit for waveform quality is known as rho (ρ). Rho indicates how well the CDMA signal's power distribution matches the ideal power distribution. Standards generally specify rho as a percentage, and require a value greater than 0.944 for acceptable performance.

The basic measurement is usually conducted as shown in figure 1. First the mobile station starts transmitting known data on the reverse channel. The test equipment demodulates and decodes the transmitted signal to some level (the level depends on the implementation). The test equipment then re-encodes and mathematically regenerates the signal, thus creating an essentially ideal signal. The actual transmitted signal is compared to this ideal signal, producing the rho measurement. Typically this measurement also produces a number of other measurements such as frequency accuracy, static time offset, amplitude error, phase error and carrier feedthrough.

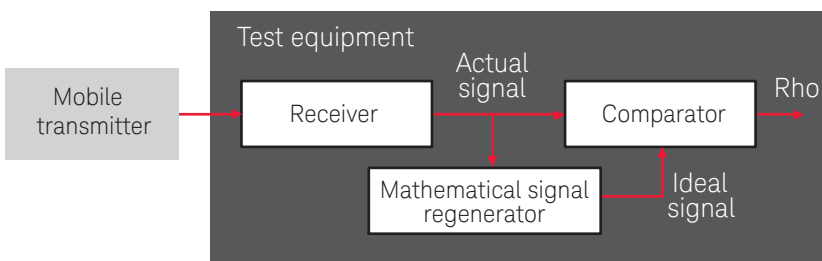


Figure 1. Basic rho measurement

There are two primary methods of measuring waveform quality: test mode rho and traffic channel rho.

Test mode rho is a method that decodes down to the short code. This method is easy to implement, and can be performed while the mobile station is either on a call or in a special test mode. Disadvantages of test mode rho are that it cannot detect hidden coding errors and cannot accurately measure low levels of rho (less than 0.90).

Traffic channel rho can be measured only when a call is active. The signal is decoded down to the input of the 64-ary modulator. By decoding this far we have already recovered most of the original transmitted bits, and have corrected for errors. When it is mathematically regenerated into the ideal signal, it is nearly perfect, and much better than the test mode rho signal. This measurement can measure much lower rho values (about 0.70). This measurement can detect coding errors in the transmitted signal that would otherwise have been missed.

Traffic channel rho is measured on the traffic channel with no other channels active because there is only one channel in the reverse link of IS-95-B.



Figure 2. IS-95 reverse channel coding

For more information about TIA/EIA-95-B waveform quality, see the appendix A: TIA/EIA-95-B waveform quality and correlation.

Code domain measurements for TIA/EIA-95-B are derived from the same data as the rho measurement. These measurements indicate the relative power for each code in the CDMA system.

Waveform quality and code domain measurements for cdma2000

The reverse channel of cdma2000 differs from IS-95's because its new radio configurations always transmit at least two channels, except during a handoff. There can be up to five channels active at once. Refer to figure 3, cdma2000 reverse channel coding, to see how the various reverse channels are combined. The R-pilot and the R-FCH channels are typically transmitted when a call is in progress. The other three channels, R-DCCH, R-DCCH, R-SCH1 and R-SCH2 are optional.

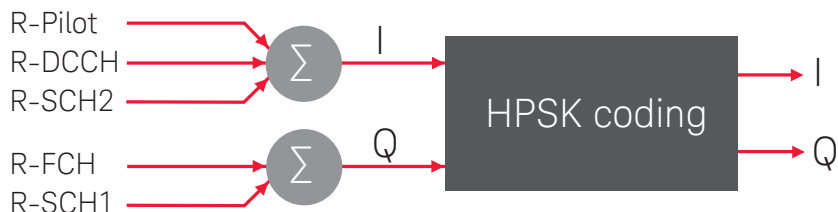


Figure 3: cdma2000 reverse channel coding

Since there are multiple channels transmitted on the reverse link in a cdma2000 system, it seems impossible to measure waveform quality like the IS-95 does on an active call. There is, however, one very short period of time in TIA/EIA-98-D in which only the pilot channel is transmitting. During a handoff, the pilot is the only channel transmitting during the preamble, so it is technically possible to measure IS-95 style waveform quality of the pilot signal. This is called test mode rho and is the measurement described in the TIA/EIA-98-D standard.

Because traffic channel rho and test mode rho are defined only for a single coded channel, cdma2000 system manufacturers cannot have the full confidence in the tested signal that they once had in IS-95. Additionally, when multiple channels are transmitted, the crest factor of the mobile station is increased. Increased crest factor makes it harder to design output amplifiers that are sufficiently linear and low noise.

A waveform quality measurement that works while multiple codes are active would greatly increase design confidence. Keysight Technologies, Inc. has developed a multi-coded rho measurement that restores the ability to test the whole signal. This measurement is similar to traffic channel rho, but can be used while the signal is normally transmitting.

The E1962B test application of the Keysight 8960 series test set measures both the test mode rho and the multi-coded rho.

Multi-coded rho and code domain measurements with the E1962B test application

Keysight's multi-coded rho measurement returns numeric values for rho, frequency error, timing error, carrier feedthrough, phase error, magnitude error, and Error Vector Magnitude (EVM). Waveform quality measurements made on mobile stations operating in radio configuration 1 and 2, are traffic channel rho measurements. Waveform quality measurements made on mobile stations operating in radio configurations 3, 4, and 5 are multi-coded rho, and are unique to the test set. Test mode rho is also available in this test set. This combination of three waveform quality measurements offers the best measure of performance for cdma2000 systems.

How is a multi-coded waveform quality measurement made?

The multi-coded rho technique must decode the HPSK complex scrambling after I/Q demodulation. Since the HPSK scrambling is based on the long code information, the measurement must have this information in order to demodulate the signal. Therefore, the test set and the mobile station must exchange long code information. Once the HPSK scrambling is decoded, the multi-coded rho technique then de-spreads the I and Q channels with every possible Walsh code to determine what channels are active. Once each active channel is found, the data is used to generate an ideal reference signal for each channel. These reference signals are summed with the appropriate gain factors to create an overall ideal channel. Then, like the IS-95 method, this ideal signal is compared with the received signal to determine the overall rho.

Waveform quality measurement display

Waveform quality is shown in figure 4, cdma2000 multi-coded waveform quality. The E1962B test application displays the waveform quality measurement first, and code domain power is selected as a different view. Note that waveform quality and code domain displays are different ways of viewing the data from a single measurement. It is not necessary to repeat the measurement every time a new view is selected.

| Measurement/Instrument Screen | | | | | | |
|-------------------------------|---------------------|-------------------|---------------------------------|---|------------------|--------------|
| Control | Waveform Quality | | | | Call Parms | |
| WaveformQuality Setup ▾ | Rho 0.992 | | Frequency Error 20 Hz | | Cell Power | -55.00 |
| Change View | Time Error: 0.00 us | | Carrier Feedthrough: 0.00 | | dBm/1.23 MHz | |
| | Phase Error: 0.00 ° | | Magnitude Error: 0.00 % | | Cell Band | US PCS |
| | EVM: 0.00 % | | Continuous | | Channel | 525 |
| Swap Window Positions | | | | | Protocol Rev | 6 (IS-2000) |
| | | | | | Radio Config | (Fud3, Rvs3) |
| | | | | | RF Gen Freq Ctrl | Auto |
| | Background | IS-2000 Test Mode | Sys Type: IS-2000 | | | |
| 1 of 2 | | IntRef | Offset | L | 1 of 2 | |

Figure 4. cdma2000 multi-coded waveform quality

How is a multi-coded code domain power measurement made?

As mentioned earlier, when multi-coded rho is measured, code domain results can also be displayed. Using the data collected in the latest waveform quality measurement, the test set displays graphical views of waveform quality in the code domain. Mobile station channelization consists of Walsh coded data transmitted on the I (in-phase) and Q (quadrature-phase) channels. Code domain power measurements reveal how signal energy is distributed throughout the Walsh code set. Code domain power measurements are displayed in figure 5, cdma2000 multi-coded code domain power display. The top line of each graph represents the total power in the received signal (I+Q), following the IS-98-D specification.

These I and Q graphs display the total power in each code channel of a CDMA channel. Active channels show up as dark bars and inactive channels are displayed as light bars. Pass/fail limits can be set for power in inactive channels. Inactive channels should be at least 23 dB below the total output power.

Code domain power plus noise

These I and Q graphs display the signal power in each code channel along with the noise component. Noise is displayed as the light portion of the bar and signal power is displayed as the dark portion.

On the horizontal axis of each graph is a set of labels identifying the Walsh code number for each bar. The order of the Walsh codes is not sequential because of the mathematical expression chosen to derive the orthogonal codes. The order of the Walsh codes in each graph allows grouping of shorter Walsh codes with their longer related codes. This results in contiguous blocks of bars. This is also known as “bit reversed” Walsh code sequences.

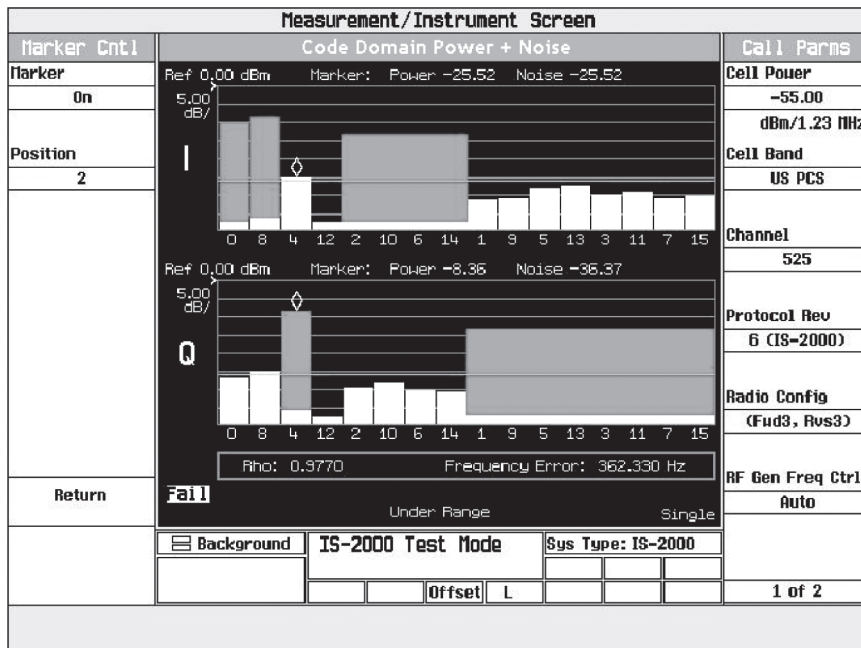


Figure 5. cdma2000 multi-coded code domain power display

For example, the very wide dark bar in the Q channel is comprised of codes 1, 9, 5, 13, 3, 11, 7, and 15. The number of codes used indicates that the mobile station is transmitting with a two bit Walsh code, and we know that this is the R-SCH1. By using the two bit Walsh code, we see that it is using half of the available Walsh codes, and therefore we also know that it is transmitting in its highest bandwidth. This corresponds to the 153 kbps data rate. See appendix B: Walsh code tree, to see how half the codes are being used.

Look at code 4 in the Q channel. This is the R-FCH channel. This particular display is showing both the signal and the noise component. You can see how much noise is being transmitted in the traffic channel.

In the I channel, the pilot is at code 0, the R-DCCH is at code 8, and the R-SCH2 is at codes 2, 10, 6, and 14.

This display gives us great insight to the performance of the mobile station. The horizontal lines across the middle of the I and Q display indicate the maximum limit for the allowed noise. We can see from code 4 in the I channel and code 8 in the Q channel that this mobile station fails the specification in these two channels.

Look at the failed noise channels again, then look at the opposite phase (I or Q). Note that both noise channels that failed have corresponding active channels in the other phase. For the mobile station, this means that there are either phase modulation errors or frequency modulation errors. Since I and Q are supposed to be exactly 90° apart to maintain orthogonality, any phase or frequency error causes the 90° separation to change. This shifts power from I to Q or from Q to I, resulting in the code domain display shown. Amplitude or compression errors can cause noise in the active channel to go up.

Input signal requirements for waveform quality and code domain measurements with the E1962B

The waveform quality measurement meets or exceeds specifications when the following requirements are met:

The frequency of the signal being measured must be in the ranges of approximately 412 MHz to 483 MHz, 800 MHz to 960 MHz or 1.7 GHz to 2.0 GHz, and within 100 kHz of the expected frequency.

The signal level into the test set's RF IN/OUT connector must be in the range of -25 dBm/1.23 MHz to +37 dBm/1.23 MHz, and within 9 dBm of the expected input power to meet specifications. This measurement works to -50 dBm/1.23 MHz, with reduced performance.

Conclusion

The multi-coded waveform quality measurement shows the information necessary to make a useful evaluation of the modulation of a mobile station's transmitter. The multiple displays, including the code domain representation, allow for fast diagnosis of design problems. The waveform quality measurement itself is more convenient and useful because it can be measured throughout the whole signal.

Appendix A: TIA/EIA-95-B waveform quality and correlation

The processing gain of CDMA (error correction codes plus spreading codes) makes the CDMA system very tolerant of transmission errors. What would appear as large errors in the transmitted signal of any other cellular system, are normal for a properly operating CDMA mobile station. Traditional tests that examine modulation quality (error vector magnitude) and receiver performance (bit-error-rate) do not provide meaningful insight into a CDMA mobile station's performance. For transmitter measurements, this leads to a new measurement specific to the CDMA modulation format: waveform quality. Finally, the fact that CDMA is designed to operate with high levels of interference also drives new measurements that must duplicate the normal interference levels experienced by a CDMA mobile station.

The figure of merit specified in IS-98-A for the quality of an OQPSK modulated transmission from a CDMA mobile station is called " ρ " (Greek letter rho). The ρ measurement is also referred to as the power correlation coefficient. The concept of the ρ measurement is fairly simple. Although the CDMA system is designed to operate with high levels of interference, the ultimate capacity of any given cell is limited by the total interference (number of active users). For adjacent cells that are equally loaded, this limit is about 21 callers per cell or sector. If any mobile station's transmitter is not properly encoding each user's data into the required code, some of the transmitted power will appear as increased noise to other users. The ρ measurement computes the power of a CDMA transmitted signal that correlates to the desired code. Thus, ρ gives an indication of the increased interference that will be caused by modulation errors in a CDMA transmitter. A ρ value of 1.00 indicates that all of the transmitted power correlates with the ideal transmission code. The specified performance level that a CDMA mobile station must meet is 0.944 indicating that 94.4% of the transmitted energy correctly correlates into the ideal code. At this level of ρ performance, the increased noise to other users caused by a CDMA transmitter will be an additional 0.25 dB.

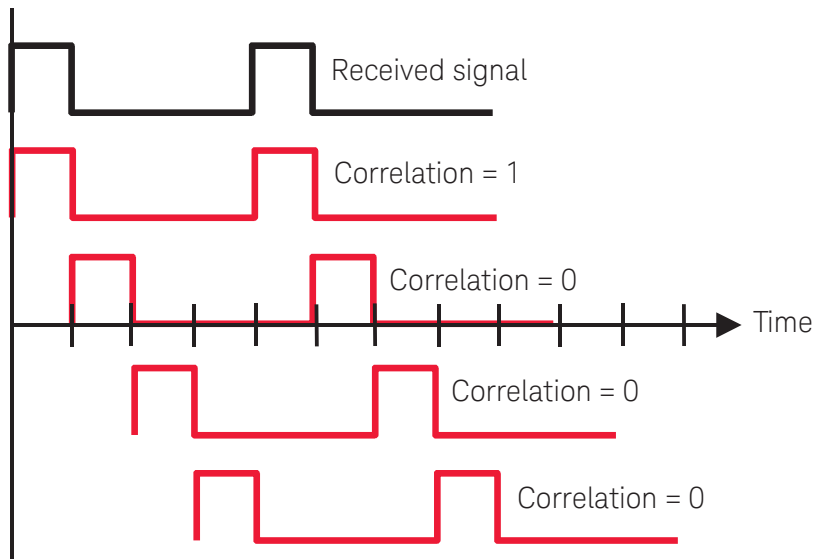


Figure 6. Correlation timing

Correlation

Correlation is the key enabling concept for direct sequence CDMA systems. Correlation is a measure of how well a given signal spread with a digital code, matches a desired code. In the following example, a digital sequence is received and then compared to the desired code. This comparison takes place over a range of different times. When time aligned, the correlation is 1, indicating that an exact match occurred between the received signal and the desired signal. At other times the correlation is near zero, especially if the digital codes used to spread the waveform are designed properly. It is the fact that we can correlate to signals that enables direct spread CDMA to function.

Appendix B: Walsh code tree

The R-SCH1 can have a variable data rate. The desired data rate determines how many Walsh codes will be used. The higher the data rate, the more codes needed. For the highest data rate, a two bit Walsh code is used. When the Walsh code is just two bits wide, it uses all of the codes further along the tree (see figure 7, Walsh code tree). When translated to the code domain display in the E1962B test application (see figure 5, cdma2000 multi-coded domain power display), the higher data rates are shown by contiguous bars. So by just looking at the code domain display, you can determine the data rate of the R-SCH1.

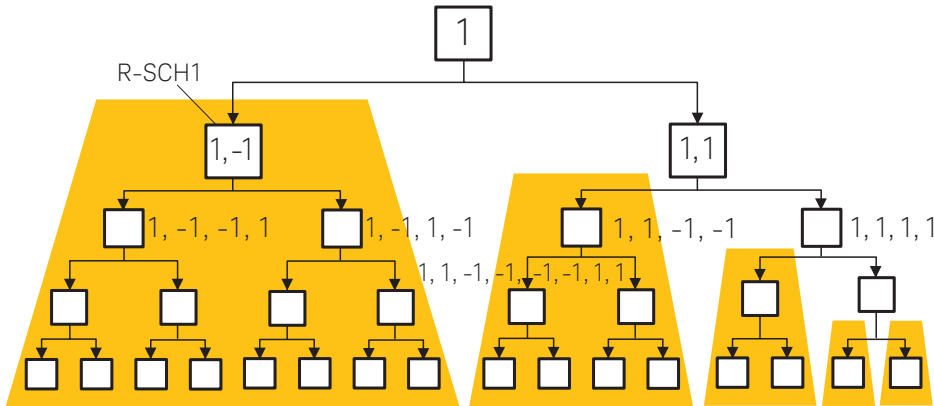


Figure 7. Walsh code tree

| Acronym list | |
|--------------|--------------------------------------|
| R-FCH | Reverse Fundamental Channel |
| R-DCCH | Reverse Digital Control Channel |
| R-SCH1 | Reverse Supplemental Channel 1 |
| R-SCH2 | Reverse Supplemental Channel 2 |
| R-Pilot | Reverse Pilot Channel |
| HPSK | Hybrid Phase Shift Keying |
| OQPSK | Offset Quadrature Phase Shift Keying |

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