Application Note

GC7105A Base Station Analyzer

WCDMA Measurement Hints

Introduction

This document provides measurement hints of the Base Station Analyzer GC7105A for WCDMA code domain analysis and helps improve the measurement accuracy using the instrument's Tx analyzer feature for modulated signal analysis. You may increase the accuracy of your data by using more than one of the hints in your test setup and measurements.

Background

The GC7105A is a Base Station Analyzer for installation and maintenance of modern wireless communication systems. It combines the functionality of spectrum analysis, cable and antenna analysis, power meter, and modulation analysis, including:

- cdmaOne/cdma2000
- EVDO
- GSM/GPRS/EDGE
- WCDMA/HSDPA
- TD-SCDMA

The modulation measurement suite of the Base Station Analyzer provides not only RF parametric analysis but also modulation parametric analysis of modern wireless communication systems. Built-in wireless standard test procedures allow users to test each of the following items with a single button action.

cdmaOne/cdma2000 Analyzer

- CDMA Channel Power / Multi-channel Power
- CDMA Adjacent Channel Power
- CDMA Spectrum Emission Mask
- CDMA Code Domain Power
- Frequency Error Time Offset
- Waveform Quality
- PN Search

EVDO Analyzer

- EVDO Channel Power / Multi-channel Power
- EVDO Adjacent Channel Power
- EVDO Spectrum Emission Mask
- EVDO Code Domain Power
- Frequency Error Time Offset
- Waveform Quality
- PN Search

WCDMA/HSDPA Analyzer

- WCDMA Channel Power
- Multi-channel Power
- Adjacent Channel Leakage Power Ration (ACLR)
- WCDMA Spurious Emission Mask
- WCDMA Occupied Bandwidth
- WCDMA Code Domain Error Vector Magnitude (EVM)
- Peak Coded Domain Error (PCDE)
- Auto Scramble Search

GenComm

GSM/GPRS/EDGE Analyzer:

- RMS Phase Error
- Peak Phase Error
- Power vs. Time (Frame, Slot)
- Frequency Error
- TSC Code
- IQ Origin Offset
- Occupied BW

TD-SCDMA Analyzer:

- TD-SCDMA Channel Power
- Adjacent Channel Leakage Power Ration (ACLR)
- Spurious Emission Mask
- Occupied BW
- Code Domain Error
- Power vs. Time (Frame, Slot and Mask)
- Timing Offset
- Frequency Error
- IQ Origin Offset

This document focused on the WCDMA measurements and the conformance with the WCDMA standard 3GPP TS 25.141.

WCDMA Measurements

Transmitter test

WCDMA is a direct sequence spread-spectrum CDMA signaling method that achieves higher speeds and supports more users using wider RF bandwidths, typically from 5 to 20 MHz.

WCDMA uses correlative codes to distinguish one user from another. Frequency division is still used, as is done with Frequency Division Multiple Access (FDMA) and Time Division Multiple Access (TDMA), but in a much larger bandwidth such as 5 MHz or greater. An initial baseband data rate is spread to a transmitted bit rate of 3.840 Mcps, which is also called chip rate or spread data rate.

Even though cdma2000 and WCDMA systems are based on a similar CDMA technology, they are significantly different. The main differences are:

- The SR (3.84Mcps for WCDMA versus 1.2288 Mcps for cdma2000 SR1)
- The synchronization and BTS identification methodology (WCDMA does not use global positioning system, GPS)

There are five generic measurements available under WCDMA measurement in Tx Analyzer mode:

- Channel Power
- Occupied Bandwidth
- Adjacent Channel power Leakage Ratio(ACLR)
- Spectrum Emission Mask (SEM)
- Code Domain Power

The GC7105A supports following class WCDMA bands:

- Band I (2100 General) : 2100MHz ~ 2170MHz
- Band II (1900 General and Additional) : 1930MHz ~ 1990MHz
- Band IV (1700 General and Additional) : 2100MHz ~ 2155MHz
- Band V (850 General and Additional) : 869MHz ~ 894MHz

Channel Power

Measuring the power in a WCDMA signal on a spectrum analyzer involves several measurement considerations. Traditional spectrum analyzers were designed to measure CW signals with known and predictable amplitude distributions. However, a WCDMA signal is noise-like, with a varying amplitude distribution based on the Walsh-Code channel combinations and the power is limited to a bandwidth of 3.84 MHz.

For this reason using a marker to measure the power in a signal displayed on a spectrum analyzer is not an accurate method for a WCDMA signal. A marker measurement in the spectrum analyzer reads the power in its resolution bandwidth. Therefore power in narrowband signals can be read directly from the marker. However the WCDMA power is distributed over a 3.84 MHz bandwidth requiring a power integration measurement such as channel power.

There is about 21 dB difference between a marker readout on spectrum analyzer mode and a channel power measurement in WCDMA. This difference is due to the bandwidth considered in each methodology.

For example, the power measurement in spectrum analyzer mode, of a CDMA peak detected at -30 dBm with 30 kHz RBW setting, where power is converted into a channel power with 3.84 MHz, then the power difference will be:

$$\text{Power difference between Channel Power and Marker Power} = 10\log\left(\frac{Bandwidth}{RBW}\right)dB$$

$$10\log\left(\frac{3.84\ MHz}{30\ kHz}\right) = 21.07\ dB$$

Comparing the results, the channel power measured with 3.84 MHz bandwidth equals to the marker point reading in spectrum mode of +21.07 dB. Therefore, if the marker point is -30 dBm in spectrum mode, then the channel power should be around -8.93 dBm (-30 dBm + 21.07 dB = -8.93 dBm).

The following diagram shows the differences between CW and Channel power measurements.

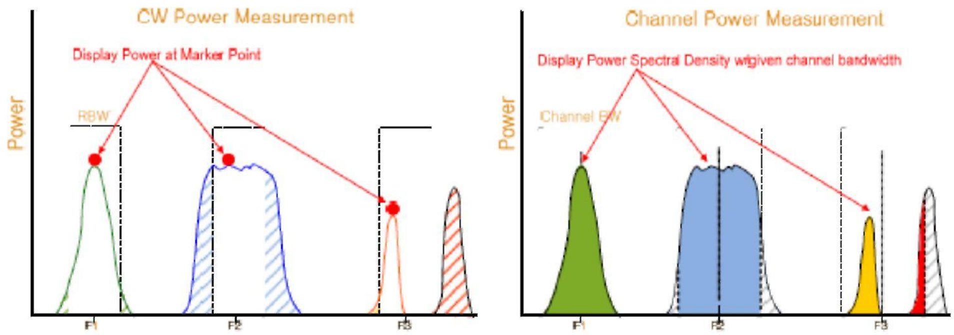


Figure 1 – Power view difference between CW and channel power

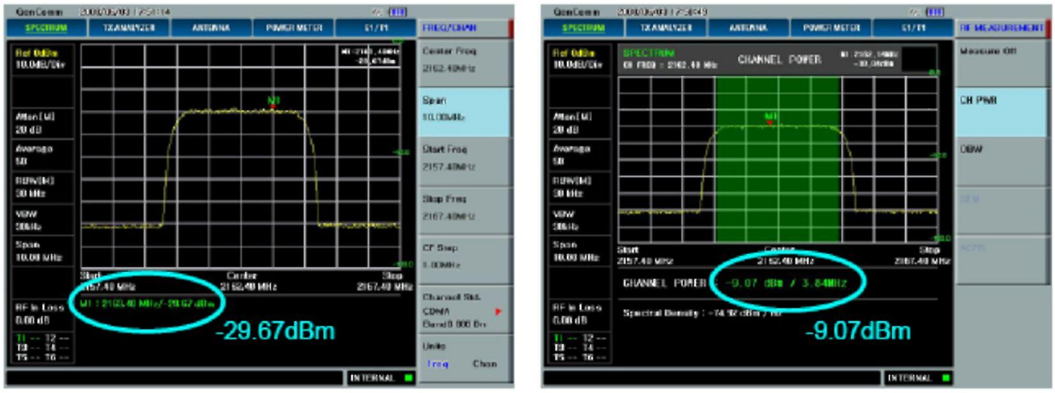


Figure 2 – Power readings from marker point (30 kHz) vs. channel power (3.84 MHz)

The channel power measurement shows the total transmitted power within the channel integration bandwidth, 3.84 MHz and the power spectral density (PSD) in dBm/Hz.

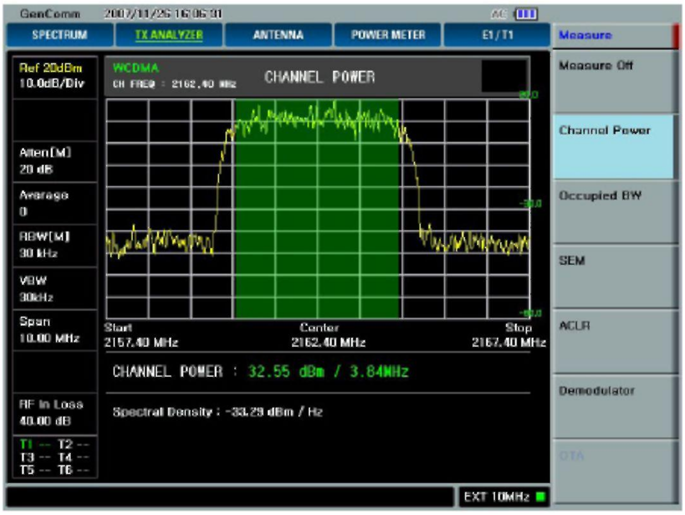


Figure 3 – WCDMA channel power measurement (3.84 MHz bandwidth)

Occupied Bandwidth

The 3GPP TS 25.141 specification requires an occupied bandwidth (OBW) of a transmitted WCDMA signal to be less than 5 MHz, where occupied bandwidth is defined as the bandwidth containing 99% of the total channel power.

In this measurement, the total power of the displayed span is measured. Then the power is measured inward from the right and left extremes until 0.5% of the power is accounted for each of the upper and lower part of the span and the calculated difference is the occupied bandwidth.

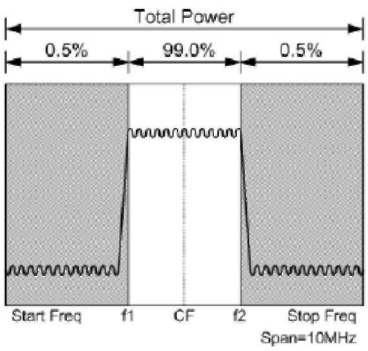


Figure 4 – OBW Measurement

The spectrum shape can give useful qualitative insight into transmitter operation. Any distortions to the WCDMA spectrum shape can indicate problems. For example, "the shoulders" on either side of the spectrum indicate spectral re-growth and intermodulation. Rounding or sloping of the top can indicate a filter shape problems.

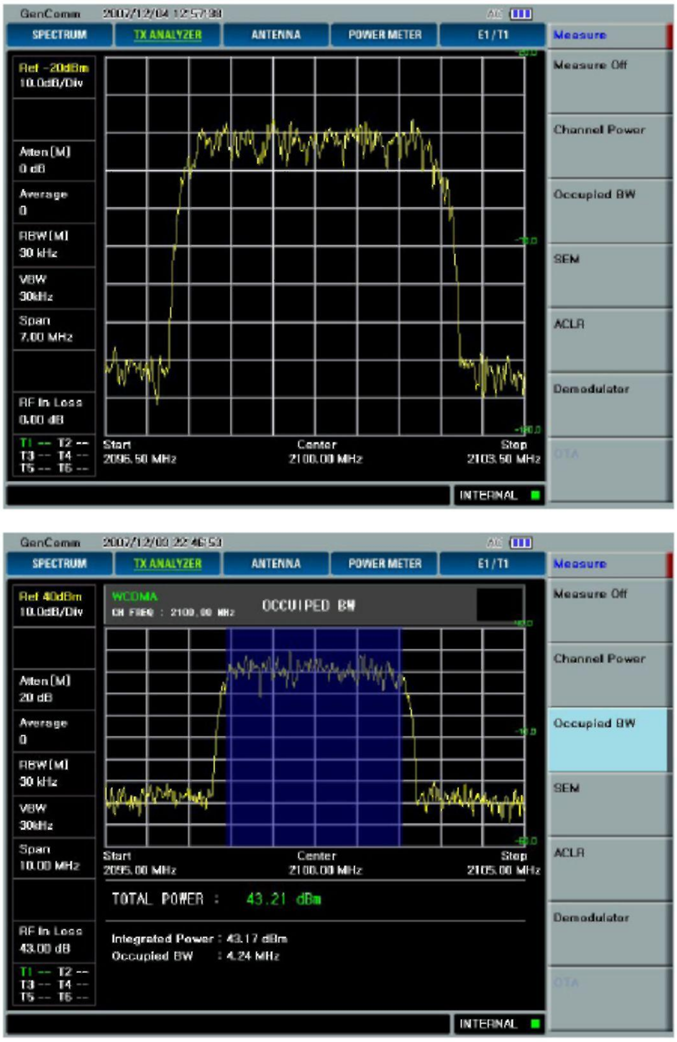


Figure 5 – Typical WCDMA occupied bandwidth measurement

Waveform Quality (rho)

Rho is one of the key modulation quality metrics, along with EVM and code domain power. Rho is the ratio of the correlated power in a multi coded channel to the total signal power. This measurement takes into account all possible error mechanisms in the entire transmission chain including: baseband filtering, I/Q modulation anomalies, filter amplitude, phase deviation, and power amplifier distortions. This provides an overall indication of the performance level of the transmitter.

$$\rho = Correlated\ power/Total\ power$$

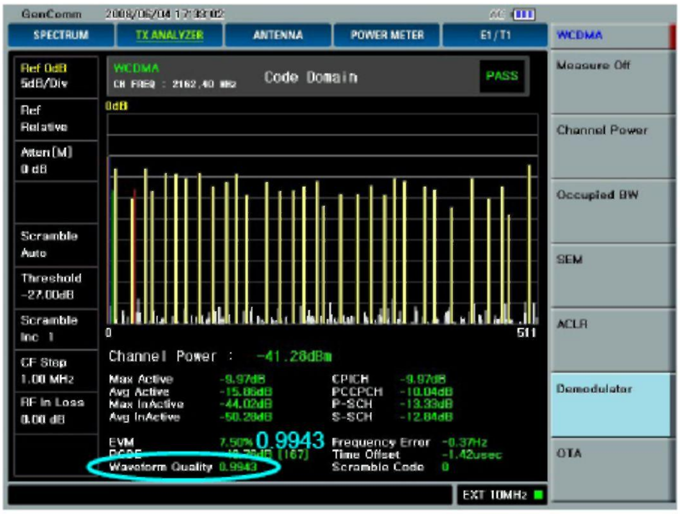


Figure 6 –Waveform quality is measured on the demodulator

Code Domain Analysis

Code domain power is an analysis of a signal power distribution across the defined coded channels, normalized to the total signal power. To analyze the composite waveform, each channel is decoded and determines the correlation coefficient factor for each code. In WCDMA, the measurement is complicated by the fact that the length of the OVSF (Orthogonal Variable Spreading Factor) code, or SF (Spreading Factor), varies to accommodate the different data rates.

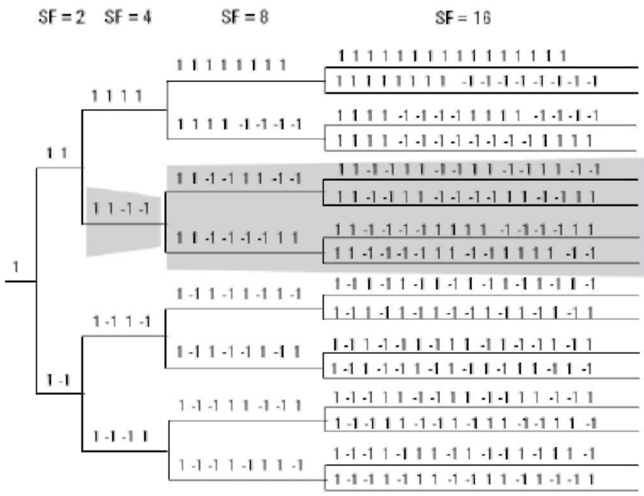


Figure 7 – Hadamard generation of Walsh codes and spreading factor

In terms of code capacity, channels with higher data rates (lower SFs) occupy more code space. For example, W(4)1 occupies two times more code space than W(8)2 and four times more code space than W(16)4. Once the channels are decoded, the power in each code channel is determined. Since the code domain measurements de-spread and descramble the WCDMA signal into its physical channels, the number of active channels of various symbol rates can be observed.

Error vector magnitude (EVM) is defined in 3GPP conformance tests for both downlink and uplink signals. EVM is a common modulation quality metric widely used in digital communications.

Modulation accuracy is measured with the EVM of the multi-code channel signal detecting spreading or scrambling errors, identifying certain problems between baseband and RF sections, and analyzing errors that cause high interference in the signal.

The 3GPP 25.104 specification defines EVM as the square root of the ratio of the mean error vector power to the mean reference power, where EVM shall not be worse than 17.5% for QPSK modulated signals and 12.5% for 16-QAM modulated signals.

In 3GPP WCDMA, two optional control channels are provided: secondary common control physical channel (S-CCPCH) and paging indicator channel (PICH). These two channels have different spreading codes and spreading factors. For this reason, the GC7105A is capable to identify these two channels as S-CCPCH and PICH when they are enabled, note that the default setting is disabled.

The GC7105A displays decoded Walsh codes in different colors,

- Common pilot channel (CPICH) Orange
- Primary common control physical channel (P-CCPCH) Blue
- Secondary common control physical channel (S-CCPCH) Yellow-Green
- Paging indicator channel (PICH) Red

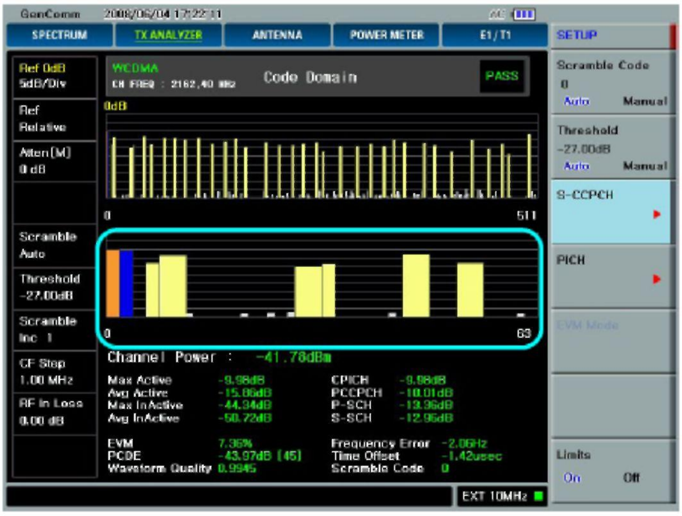


Figure 8 – Code domain analysis (S-CCPCH, PICH are disabled)

In the code domain power display, the wider bars represent codes with low SF which occupy more code space. Notice that the primary synchronization channel (P-SCH) and secondary synchronization channel (S-SCH) are not assigned spread codes and therefore do not appear in the code domain power display. So, the GC7105A displays only the relative power information and does not have a bar representation of these two channels.

If you use the frequency reference provided by the base station, keep in mind that the frequency error measurement will only measure the relative error to the base station reference signal and not to an absolute frequency and time. You will not be able to determine if the base station frequency is aligned with other base stations. Alternatively the use of a GPS receiver provides an independent reference, and the frequency error measurement can determine if the base station has a frequency offset.

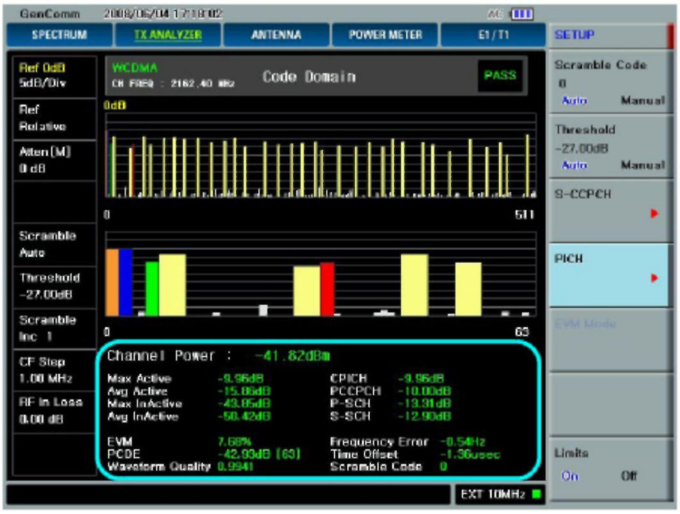


Figure 9 – Code domain analysis (S-CCPCH, PICH are enabled)

- **Max Active**
  The highest value of active channel among Walsh code channels except W(0)64, W(1)64, and W(32)64. Active threshold: Any code channels below this power level are considered inactive (or noise), and any code channels exceeding this power level are considered to be potentially active traffic channels (Factory Set: -27 dB).
- **Average Active**
  The sum of traffic channel power divided by the number of traffic channels.
- **Max Inactive**
  Indicates that the highest level among all the Inactive channels or channels whose level is below threshold (default -27 dB).
- **Average Inactive**
  The sum of uncorrelated Walsh channel power divided by the number of inactive channels.
- **CPICH**
  The Common Pilot Channel (CPICH) is a downlink channel used to provide the timing and frequency reference to the mobile. It helps the mobile to estimate the quality of the wireless channel on a given communication link. This channel carries no information and it uses a fixed data rate of 30 kbits/s. It carries one of the predefined code sequences.

- **PCCPCH**
  The primary common control physical channel (P-CCPCH) is used to carry broadcast information for the cell site. This information has to be read by the mobile before it attempts to access the system.
  The P-CCPCH has the following important properties:
  i. P-CCPCH does not apply power control. Just like CPICH, and P-CCPCH needs to be heard over the entire Cell it is always broadcast at a fixed power.
  ii. The rate of the P-CCPCH has to be kept relatively low. Any increase in the data rate would also demand an increase in power. Since the P-CCPCH is broadcasted over the entire cell a substantial increase in its power would have a negative effect on the system's capacity.
- **P-SCH**
  To aid mobile synchronization to the network, each base station also transmits the Synchronization Channel (SCH). SCH is used for system detection and acquisition. The P-SCH is used for the system detection. The code used for P-SCH is the same for every cell site in the system. The actual code is 256 chips long and it is repeated at every time slot of the radio frame. Since the time slot is 2560 chips long, P-SCH occupies only 1/10 of the time slot.
- **S-SCH**
  The S-SCH is used to help the mobile acquire frame synchronization with the serving cell. The S-SCH is used by the base station as a pointer to a group of 8 primary scrambling codes; it helps the mobile to determine the scrambling code used for the CPICH at the site. Unlike the P-SCH which repeats the same code word sequence every time slot, the code used by the S-SCH starts repeating only after 15 slots (i.e. the repetition is on the frame level).
- **EVM**
  EVM measures signal quality specified as a percent of noise to an ideal signal. It is the difference between the measured waveform and the theoretical modulated waveform (the error vector). The 3GPP standard requires the EVM not to exceed 17.5% for normal WCDMA (defined as Test Models 1 and 4).
- **PCDE**
  PCDE is the maximum value for the code domain error for all codes (both active and inactive). In WCDMA or WCDMA with HSDPA, specifically to address the possibility of uneven error power distribution, the EVM measurement is supplemented with PCDE.
  The 3GPP standard requires the PCDE not to exceed -33 dB at a spreading factor of 256, but the conformance test adds in a test tolerance of 1 dB. This gives a conformance limit for peak code domain error of -32 dB at a spreading factor of 256.
- **Waveform Quality**
  Rho is one of the key modulation quality metrics, along with EVM and code domain power. It is the ratio of the correlated power in a multi coded channel to the total signal power. This measurement takes into account all possible error mechanisms in the entire transmission chain including: baseband filtering, I/Q modulation anomalies, filter amplitude, phase deviation, and power amplifier distortions. This provides an overall indication of the performance level of the transmitter.
- **Frequency Error**
  To ensure that each WCDMA transmitter is on its frequency and not interfering with other WCDMA channels, the 3GPP 25.104 standard specify very tight frequency error performance, known as frequency tolerance (± 0.05 ppm).
  To accurately measure the frequency error, the test equipment must have access to the reference frequency from the GPS receiver.
- **Time Offset**
  The time offset measurement compares the time of the signal to the offset from the even-second clock (base station, or GPS time). This is the only transmitter test that requires the even-second clock signal from the base station. Other transmitter tests can be performed without this connection.

- **Scramble Code**
  Variable spreading with channelization codes assures the orthogonality between channels that belong to the same site. WCDMA mobile receives signals from multiple base stations, and all of these signals share the same spectrum and are present at the same time, every base station is assigned scrambling codes that make its signal unique relative to the signals of other base stations in the area. By using the appropriate scrambling code, a mobile can separate the signal coming from the base station of interest from signals of other base stations in the area On the uplink, the scrambling codes are used to distinguish the signals from different mobiles as well as a mean to provide the encryption and privacy.

OTA (Over-the-Air) Measurement

The Base Station Analyzer provides over the air measurements for a quick performance characterization of the WCDMA signal at a specific location. This function is especially useful in testing areas with reception problems or cell sites which are not easily accessible or physical connection is not available.

The following is the measurement screen of over the air measurement. Note that the instrument must have access to the reference frequency from the GPS receiver to get more accurate measurement result.

Figure 10 – Over-the-air measurement

- **SC Scanner**
  WCDMA mobile receives signals from multiple base stations, and that all of these signals share the same spectrum and are present at the same time, every base station is assigned scrambling codes that make its signal unique relative to the signals of other base stations in the area.
- **Multi-path Profile**
  Multipath profile the amount of power, of the dominant pilot signal, that is dispersed outside the main correlation peak due to multipath echoes (expressed in dB). Ideally, this value should be very small. multipath profile is the result of portions of the original broadcast signal arriving at the receiving antenna out of phase with the main power of the original signal. This can be caused by the signal being reflected off objects, such as buildings, or being refracted through the atmosphere differently from the main signal. Note that the multipath profile is only valid to Over the Air measurements. It does not apply to transmitter measurements.

- **Code Domain**
  Channels with high correlation factors are determined to be active channels and are indicated as such on the display. Once the channels are decoded, the analyzer determines the power in each channel relative to the total signal power.
  This measurement helps to verify that each code channel is operating at its proper level and helps to identify problems throughout the transmitter design from the coding to the RF section. System imperfections, such as amplifier non-linearity, will present themselves as an undesired distribution of power in the code domain.
- **Channel Power (dBm)**
  The channel power measurement measures the channel power within a specified bandwidth (default of 3.84 MHz).
- **CPICH Power (dBm)**
  The CPICH power is the total power in the dominant pilot signal, expressed in dBm.
- **Latitude, Longitude, Altitude, Satellites Information**
  If GPS antenna is supplied and locked to GPS, then the information will be displayed on the bottom of the screen.

Spectrum Emissions Measurement

The Spectrum Emission Mask (SEM) measurement includes the in-band and out-of-band spurious emissions. As it applies to WCDMA, this is the power contained in a specified frequency bandwidth, at certain offsets, relative to the total carrier's power. It may also be expressed as a ratio of power spectral densities between the carrier and the specified offset frequency band. It provides useful figures-of-merit for the spectral re-growth and emissions produced by components and circuit blocks, without the rigor of performing a full SEM measurement.

The SEM measures spurious signal levels in up to five pairs of offsets or regional frequencies and relates them to the carrier's power. The reference channel integration bandwidth method is used to measure the carrier channel power and the offsets or regional power. When *offset* is selected, SEM measurements are made relative to the carrier channel frequency bandwidth. When *region* is selected, absolute SEM measurements are made, specifying the start and stop RF frequencies. In this process, the reference channel integration bandwidth is analyzed using the automatically defined resolution bandwidth, which is narrower than the channel bandwidth. The results are displayed both as relative power in dBc, and as absolute power in dBm.

The spectrum emission mask displays the selected signal and the mask as defined in the 3GPP specification. The mask varies depending upon the level of the input signal. The GC7105A will indicate if the signal is within the specified limits by displaying PASS or FAIL. The emission mask is also displayed in a table list with different frequency ranges and whether the signal is within those frequency offset range.

The 3GPP TS 25.104 specifies four masks depending upon the base station output power. The mask will be automatically set based on the output power categories in the instrument.

- **P ≥ 43 dBm**

Frequency offset Δf	Minimum requirement	Bandwidth
2.515 MHz ≤ f_offset < 2.715 MHz	-14 dBm	30 kHz
2.715 MHz ≤ f_offset < 3.515 MHz	-14 dBm -15x(f_offset- 2.715) dB	30 kHz
3.515 MHz ≤ f_offset < 4.0 MHz	-26 dBm	30 kHz
4.0 MHz ≤ f_offset < f_offset_{max}	-13 dBm	1 MHz

- **39 ≤ P < 43 dBm**

Frequency offset Δf	Minimum requirement	Bandwidth
2.515 MHz ≤ f_offset < 2.715 MHz	-14 dBm	30 kHz
2.715 MHz ≤ f_offset < 3.515 MHz	-14dBm -15x(f_offset- 2.715) dB	30 kHz
3.515 MHz ≤ f_offset < 4.0 MHz	-26 dBm	30 kHz
4.0 MHz ≤ f_offset < 8.0 MHz	-13 dBm	1 MHz
8.0 MHz ≤ f_offset < f_offset_{max}	P -56 dB	1 MHz

- **31 ≤ P < 39 dBm**

Frequency offset Δf	Minimum requirement	Bandwidth
2.515 MHz ≤ f_offset < 2.715 MHz	P-53 dB	30 kHz
2.715 MHz ≤ f_offset < 3.515 MHz	P-53dB -15x(f_offset- 2.715) dB	30 kHz
3.515 MHz ≤ f_offset < 4.0 MHz	P-65 dB	30 kHz
4.0 MHz ≤ f_offset < 8.0 MHz	P-52 dB	1 MHz
8.0M Hz ≤ f_offset < f_offset_{max}	P-56 dB	1 MHz

- **P < 31 dBm**

Frequency offset Δf	Minimum requirement	Bandwidth
2.515 MHz ≤ f_offset < 2.715 MHz	-22 dBm	30 kHz
2.715 MHz ≤ f_offset < 3.515 MHz	-22dBm -15x(f_offset- 2.715) dB	30 kHz
3.515 MHz ≤ f_offset < 4.0 MHz	-34 dBm 3	0 kHz
4.0 MHz ≤ f_offset < 8.0 MHz	-21 dBm	1 MHz
8.0 MHz ≤ f_offset < f_offset_{max}	-25 dBm	1 MHz

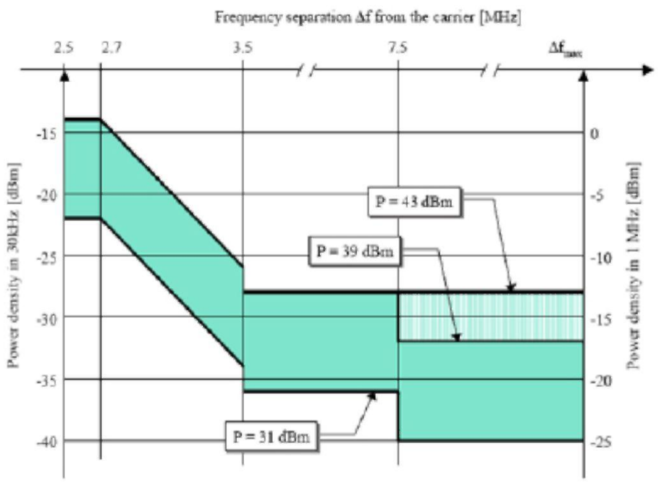


Figure 11 – Spurious Emission Test Limit & Illustrative Diagram (3GPP TS 25.104)

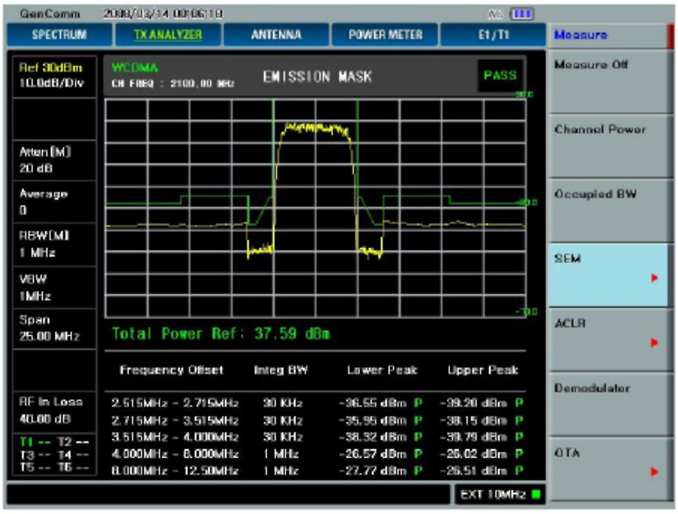


Figure 12 – Spurious emission mask measurement

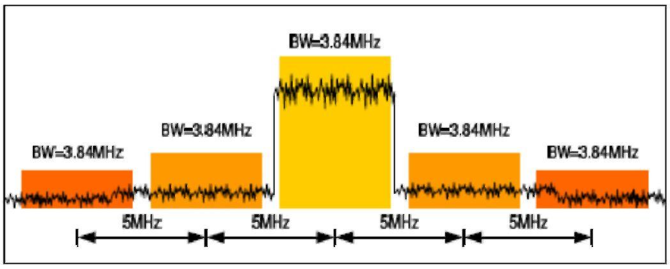
- **Total Power:** Channel power measurement value.

Adjacent Channel Leakage power Ratio (ACLR)

The adjacent channel power ratio (ACPR), designated by the 3GPP WCDMA specifications is the adjacent channel leakage power ratio (ACLR), and measures the power contained in a specified frequency channel bandwidth relative to the total carrier power. It may also be expressed as a ratio of power spectral densities between the carrier and the specified offset frequency band.

ACLR combines both in-band and out-of-band specifications to provide useful figures-of-merit for spectral regrowth and emissions produced by components and circuit blocks without the rigor of performing a full SEM measurement.

The specification for measuring ACLR requires a comparison of the power in the RF channel to the power at several offsets. The following is the ACLR specification.



Frequency offset	Maximum level	Bandwidth
5 MHz	> 45 dBc	3.84 MHz
10 MHz	> 50 dBc	3.84 MHz

Figure 13 – ACLR specification (3GPP TS 25.104)

Figure 14 – ACLR measurement