Application Note

# Practical Tips on WCDMA Measurements

MT8222A BTS Master™ MS272xB Spectrum Master™

## Introduction

This is a practical Wideband Code Division Multiple Access (WCDMA) measurement procedures note. The objective of this note is to present measurement tips and procedures which will help a field-based network technician or RF engineer conduct Node B measurements on WCDMA access networks.

### *Evolution To WCDMA*

In the mid 1980's a second generation (2G) digital system known as the Global System for Mobile Communications (GSM) was introduced for mobile telephony. It significantly improved speech quality over the older analog-based systems and, as it was an international standard, enabled a single telephone number and mobile phone to be used by consumers around the world. It led to significantly improved connectivity and voice quality, as well as the introduction of a whole slew of new digital services like low-speed data. Proving to be very successful, GSM was officially adopted by the European Telecommunications Standardization Institute (ETSI) in 1991. It is now widely used in over 160 countries worldwide.

The success of GSM spurred the demand for further development in mobile telephony, and put it on an evolutionary path to third generation (3G) technology. Along the way, that development path has included 2G technologies like Time Division Multiple Access (TDMA) and Code Division Multiple Access (CDMA). TDMA is similar in nature to GSM and provides for a tripling of network capacity over the earlier AMPS analog system. In contrast, CDMA is based on the principles of spread spectrum communication. Access to it is provided via a system of digital coding.

In 1997 a 2.5G system called the General Radio Packet Service (GPRS) was introduced to accommodate the growing demand for Internet applications. As opposed to the existing 2G systems, it offered higher data rates and Quality of Service (QoS) features for mobile users by dynamically allocating multiple channels. GPRS installs a packet switch network on top of the existing circuit switch network of GSM, without altering the radio interface.

In 1999, the International Telecommunications Union (ITU) began evaluating and accepting proposals for 3G protocols in an effort to coordinate worldwide migration to 3G mobile networks. These proposals were known as International Mobile Telecommunication 2000 (IMT-2000). One of the most important IMT-2000 proposals to emerge was Universal Telecommunications Services (UMTS).

While GPRS is considered the first step in enhancing the GSM core network in preparation for EDGE and 3G, WCDMA is a 3G technology according to the 3GPP standard (Figure 1). It is the digital access system for the UMTS network and is today considered one of the world's leading 3G wireless standards.

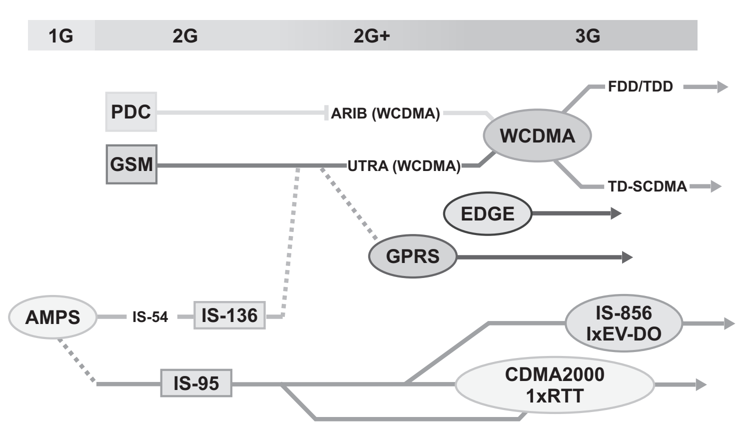


***Figure 1.*** *Evolution of cellular technologies.*

## *Understanding WCDMA*

WCDMA is an approved 3G technology which increases data transmission rates via the Code Division Multiplexing air interface, rather than the Time Division Multiplexing air interface of GSM systems. It supports very high-speed multimedia services such as full-motion video, Internet access and video conferencing. It can also easily handle bandwidth-intensive applications such as data and image transmission via the Internet.

WCDMA is a direct spreading technology, it spreads its transmissions over a wide, 5 MHz, carrier and can carry both voice and data simultaneously. It features a peak data rate of 384 kbps, a peak network downlink speed of 2 Mbps and average user throughputs (for file downloads) of 220-320 kbps. In addition, WCDMA boasts increased capacity over EDGE for high-bandwidth applications and features which include, among other things, enhanced security, QoS, multimedia support, and reduced latency (Table 1).

| **Parameters** | **WCDMA** |
|---|---|
| Bandwidth | 5 MHz |
| Chip Rate | 3.84 Mcps |
| Power Control Frequency | 1500 Hz up/down |
| Base Station Synchronization | Not needed |
| Cell Search | 3-step approach via primary, secondary search code and CPICH |
| Downlink Pilot | CDM common (CPICH)<br>TDM dedicated (bits in DPCH) |
| User Separation | CDM/TDM (shared channel) |
| 2G Interoperability | GSM-UMTS handover (Multi-mode terminals) |

***Table 1.*** *System performance fo WCDMA*

**WCDMA networks offer a number of significant benefits. They are:**

- High bandwidth and low latency which contributes significantly to a higher-quality user experience and in turn increases data revenue and improves customer satisfaction.
- Support for a wide array of new and emerging multimedia services.
- Considered the most cost-effective means of adding significant capacity for both voice and data services.
- Far better integration of RF components in the base station as compared to any other radio or mobile technology. A WCDMA base station cabinet has several times the RF capacity of GSM cabinets.
- Extreme flexibility in allocating capacity to offer the optimal QoS for different traffic types.

To date, WCDMA has been adopted for 3G use as specified in the 3GPP standard by ETSI in Europe, and as an ITU standard under the name “IMT-2000 direct spread.” NTT DoCoMo launched the first WCDMA service in 2001 and now has millions of subscribers. WCDMA (BTS) is also the 3G technology of choice for many GSM/GPRS operators, with dozens currently in trials. More than 100 GSM/GPRS operators have even licensed new spectrum with the intent to launch WCDMA services in the coming years.

## *WCDMA Basics*

Unlike GSM and GPRS, which rely on the use of the TDMA protocol, WCDMA – like CDMA - allows all users to transmit at the same time and to share the same RF carrier. Each mobile user’s call is uniquely differentiated from other calls by a set of specialized codes added to the transmission.

WCDMA base stations differ from some of the other CDMA systems in that they do not have to be in system-wide time synchronization, nor do they depend on a Global Positioning System (GPS) signal. Instead, they work by transmitting a sync signal along with the downlink signal.

A downlink or forward link is defined as the RF signal transmitted from the base station to the subscriber mobile phone. It consists of the RF channel, scrambling code (one per sector), an orthogonal variable spreading factor (OVSF) channel for signaling (one per call), and one or more OVSF channels for data (Figure 2). It also contains the sync signals (P-SCH and S-SCH), which are independent of OVSF and scrambling codes. The RF signal transmitted from the mobile phone is referred to as the uplink or reverse channel.

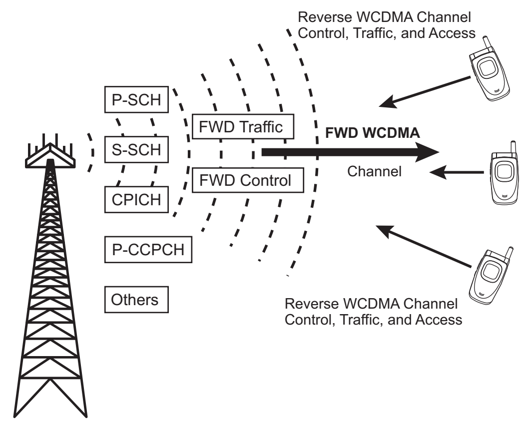


***Figure 2.*** *WCDMA channel structure*

The WCDMA downlink and uplink data streams run at a constant 3.84 Mcps, are divided into time slots and grouped as frames. The frame is the basic unit of data information that the system works with in the coding, interleaving and transmitting processes.

Data transmitted via a WCDMA network – whether digitized voice or actual data – is spread using a code which is running at a 3.84 Mbps code rate. Once the transmitted data is received by the subscriber's mobile receiver, its demodulator/correlator reapplies the code and recovers the original data (Figure 3). The signal received by the mobile is a spread signal together with noise, interference and messages on other code channels in the same RF frequency slot. The interference may emanate from multiple sources including other users in the same cell or from neighboring cells.

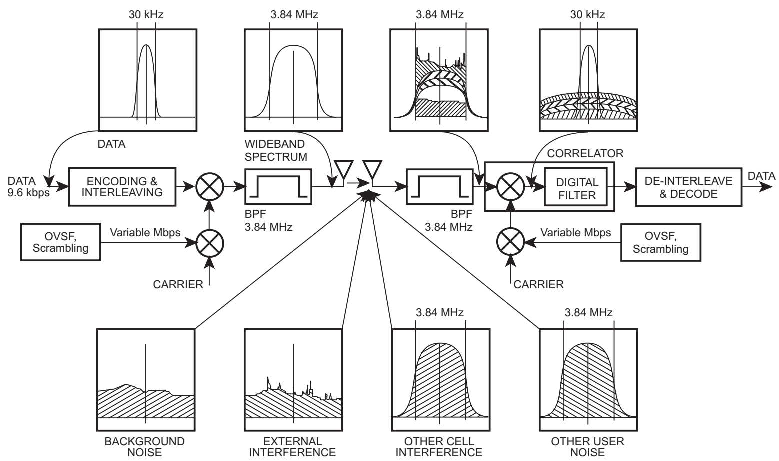


***Figure 3.*** *Signal spreading and correlation in a WCDMA base station*

WCDMA has two basic modes of operation:

- Frequency Division Duplex (FDD) mode. Here separate frequencies are used for uplink and downlink. FDD is currently being deployed and is usually referred to as WCDMA.
- Time Division Duplex (TDD) mode. In this mode, the uplink and downlink are carried in alternating bursts on a single frequency.

Note that this Application Note focuses on FDD systems only.

One of the important features of a WCDMA system is its highly adaptive radio interface. WCDMA is designed to allow many users to efficiently share the same RF carrier by dynamically reassigning data rates. The spreading factor (SF) may be updated as often as every 10 ms, which in turn, permits the overall data capacity of the system to be used more efficiently.

Some of the key things to remember about WCDMA are:

- In WCDMA, the RF signal from each base station sector is "scrambled" by multiplying the data and voice channels by a unique pseudo-noise code, known as the Scrambling Code. The Scrambling Code is mixed prior to the output of a base station or the output of a subscriber's mobile unit. WCDMA base stations (Node B's) use one of 512 Scrambling Codes to uniquely identify each sector in the network.
- Adjacent base stations use the same RF frequency for spectral efficiency. WCDMA employs a frequency reuse method in which the same frequency is used at every site, with forward links separated from one another by Scrambling Codes.
- WCDMA uses channelization codes, known as OVSF codes or Spreading Codes, to uniquely identify a Dedicated Physical Channel (DPCH) user channel. At the receiver, the received RF signal passes through the correlator, that separates and identifies the code channels (pilot, signaling or user data/voice) of each WCDMA channel it sees. Other spreading code channels are used for the pilot (P-CPICH), signaling, user voice or user data. Higher user data rates can be achieved by shortening the spreading factor, thereby increasing the transmission rate.

Note that the synchronization channels, P-SCH and S-SCH, do not go through the OVSF spreading process. The OVSF codes are orthogonal codes used to separate traffic in a WCDMA signal. Any mobile phone that receives a transmitted data sequence and attempts to demodulate it using the "wrong" orthogonal code, would interpret the information as noise. The noise, when integrated over time, will net to zero. As a result, interfering signals not intended for a given mobile phone are effectively eliminated by signal processing in the mobile phone's receiver. The OVSF codes can be reused by each base station and mobile phone within the same location, since the scrambling codes identify the transmitting device.

*WCDMA Versus GSM*

GSM was the first digital cellular system. It uses TDMA as its air interface standard and Gaussian Modulated Shift Keying (GMSK) on the RF air interface. GSM systems in Europe operate in 900 and 1800 MHz bands, while in the United States they operate in the 800 MHz (cellular) and 1900 MHz Personal Communications Services (PCS) bands.

There are many similarities between WCDMA and GSM systems including the fact that both the GSM Base Station Subsystem (BSS) and the WCDMA Radio Access Network (RAN) provide a radio connection to the handset via the same GSM core network (Figure 4). Both are also based on the principles of a cellular radio system. The GSM Base Station Controller (BSC) corresponds to the WCDMA Radio Network Controller (RNC), while the GSM Radio Base Station (RBS) corresponds to the WCDMA RBS.

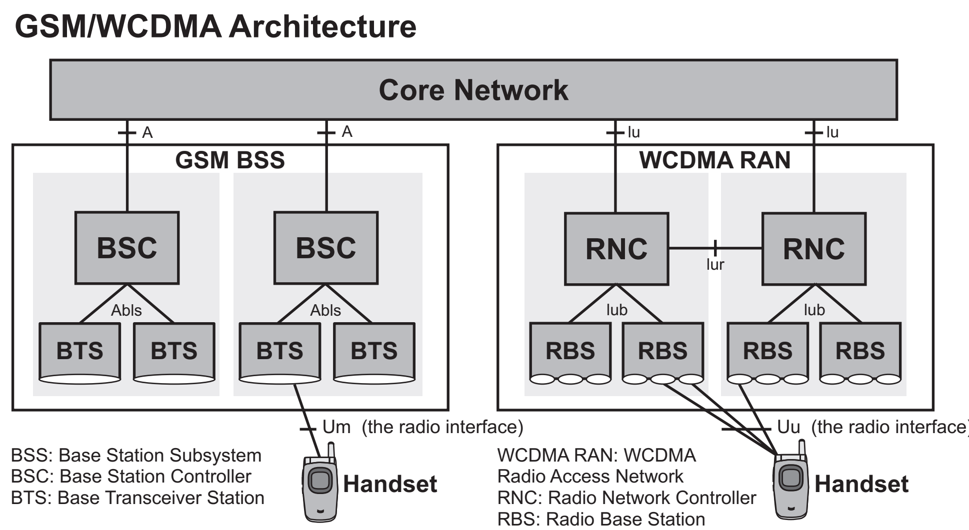


***Figure 4.*** *Although GSM and WCDMA are different technologies, they both share the same core network.*

The significant differences between the two standards, apart from the lack of an interface between the GSM BSCs and an insufficiently specified GSM Abis-interface to provide multi-vendor operability, include the following:

- GSM uses TDMA technology with a lot of radio functionality based on managing the timeslots. WCDMA systems use CDMA technology in which both the hardware and control functions are different.
- GSM was created with voice as the primary application. WCDMA includes support for voice, high-speed packet data and multimedia applications.
- The underlying WCDMA air interface is much more performance sensitive and its operation shares many more similarities with its rival CDMA2000 than its predecessor GSM. To achieve link-level performance gains over GSM's equalization and frequency hopping techniques, WCDMA uses rake receiver technology for diversity gain.
- WCDMA employs a fast power control scheme — 1500 Hz on both the up and downlink — to deal with CDMA's inherent near-far interference issues. GSM, which features a hard capacity due to its fixed frequency reuse scheme, employs a very slow (2 Hz) power control scheme.

## Understanding WCDMA Measurements

Proper characterization of complex WCDMA signals requires field technicians to measure many different types of parameters. The WCDMA measurements that can be made with BTS Master include:

- **Carrier Frequency**
  Carrier frequency is defined as the selected transmitter operating center frequency, entered by the user or calculated from the signal standard, and channel number, entered by the user.
- **Carrier Feedthrough**
  Carrier Feedthrough measures the amount of unmodulated signal that is leaking through the transmitter and is displayed in the Code Domain Power display. The WCDMA 3GPP specification does not specify Carrier Feedthrough measurement.
- **Code Domain Power (CDP)**
  CDP displays how much of the power is in each code channel (Figure 5). Power is normalized to the total power, so if a code reads –10dB, it means that the code is one tenth of the channel power. Colors are applied according to the following:

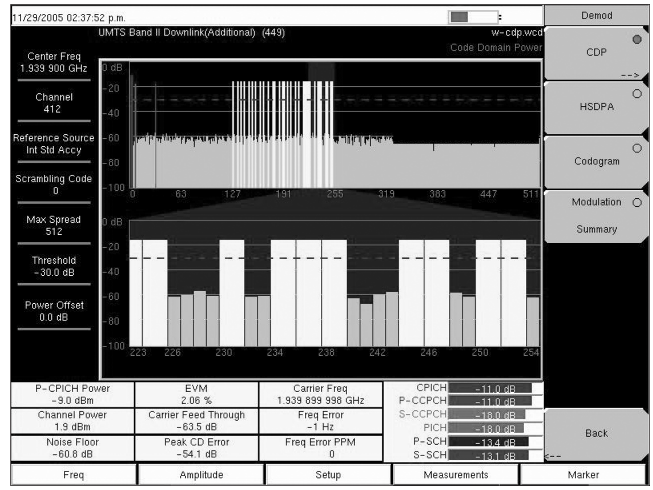


***Figure 5.*** *CDP display example.*

| Parameter | Description | Color | Viewable on Display |
|---|---|---|---|
| CPICH | Common Pilot Channel | Red | All CDP views |
| P-CCPCH | Primary Common Control Physical Channel | Magenta | All CDP views |
| S-CCPCH | Secondary Common Control Physical Channel | Cyan | All CDP views |
| PICH | Paging Indicator Channel | Green | All CDP views |
| P-SCH | Primary Sync Channel | Navy Blue | Control Channels |
| S-SCH | Secondary Sync Channel | Blue | Control Channels |
| Traffic | WCDMA Traffic | Yellow | All CDP views |
| Noise | Noise | Grey | All CDP views |

***Table 2.*** *Parameters description table*

Note that in the WCDMA specification, the P-SCH and S-SCH signals are not assigned spreading codes and therefore do not appear in the CDP display. The P-SCH and S-SCH signals are displayed in the control channel table. They have special non-orthogonal scrambling codes and are on 10% of the time.

- **Channel Power** is the total power transmitted in the 3.84 MHz WCDMA channel specified. Channel power measures the Node B/base station transmitting power across the entire 3.84 MHz WCMDA channel and is measured in units of dBm and Watts. For Over The Air (OTA) measurements, the channel power will vary as the signal path from the Node B transmitter to the BTS Master MT8222A varies.
- **Scrambling Code**
  According to the WCDMA specification, the scrambling code can be from 0 to 511. If the scrambling code is known, its value can be entered and the test set can decode and display the CDP of the signal. If the scrambling code is unknown, BTS Master can be set to auto scrambling (automatically detect the scrambling code) so that the test set can lock on to the strongest code to decode and display the CDP of the signal.
- **Spreading Factor (OVSF Codes)**
  According to the 3GPP standard the spreading factor can vary from 4 to 512. BTS Master can be set to a maximum spreading factor of either 256 or 512, depending upon the network requirements.
- **Frequency Error**
  Frequency error is the difference between the received center frequency and the specified center frequency. This value is tied to the external frequency or when the GPS option is installed it is tied to the internal OCXO oscillator frequency accuracy. It is typically only useful with the GPS option or a good external frequency reference.

- **Codogram**
  When codogram is selected the screen displays the changes in code power levels over time.
- **Noise Floor**
  The average power of the unused scrambling codes, displayed in CDP and OTA measurement displays.
- **Threshold**
  The active channel threshold power level can be set to indicate which code channels are considered active. Any code channels exceeding this power level are considered active traffic channels. Any code channels below this power level are considered inactive (or noise). A horizontal red line on the screen represents the threshold level. BTS Master can set this level automatically based on the received signal. The user can also opt to manually enter a value in the threshold setup menu.
- **Occupied Bandwidth** is the total integrated power occupied in a given signal bandwidth.
- **Error Vector Magnitude (EVM)** is the ratio, in percent, of the difference between the reference waveform and the measured waveform. EVM metrics are used to measure the modulation quality of a transmitter. The 3GPP standard requires the EVM not to exceed 17.5%.
- **Symbol EVM (@EVM)** is defined as the EVM for a single code channel.
- **Peak to Average Power** is the ratio of the peak power and the RMS power of the signal calculated over one frame interval and is measured in units of dB.
- **Peak Code Domain Error (PCDE)** takes the noise and projects the maximum impact it will have on all OVSF codes. PCDE is the maximum value for the code domain error for all codes (both active and inactive). Note that in the 3GPP standard, to address the possibility of uneven error power distribution in WCDMA, the EVM measurement has been supplemented with PCDE. The 3GPP standard requires the PCDE not to exceed –33 dB at a spreading factor of 256.
- **Ec** is a measurement of chip energy for CPICH.
- **Ec/Io** is the value of the pilot power compared to the total channel power.
- **Pilot Dominance** is the strength of the strongest pilot compared to the next strongest pilot from different base stations or from different sectors of the same base station. This value should be >10 dB to make good measurements.
- **Total Power** is the sum of all the scrambling codes; also called Io. It is measured in units of dBm.
- **CPICH Abs Power** is the absolute power of the common pilot channel power measured in units of dBm.
- **P-CCPCH Abs Power** is the absolute Primary Common Control Physical Channel power measured in units of dBm.
- **S-CCPCH Abs Power** is the absolute Primary Common Control Physical Channel power measured in units of dBm.
- **P-SCH Abs Power** is the absolute Primary Sync Channel power measured in units of dBm.
- **S-SCH Abs Power** is the absolute Secondary Sync Channel Power measured in units of dBm.
- **PICH** is the Paging Indicator Channel Power.

## Making WCDMA Measurements

The Anritsu BTS Master MT8222A can measure WCDMA performance in one of two ways, either:

- Over The Air (OTA) with an antenna.
- Via Direct Connection of BTS Master to any Node B/WCDMA base station.