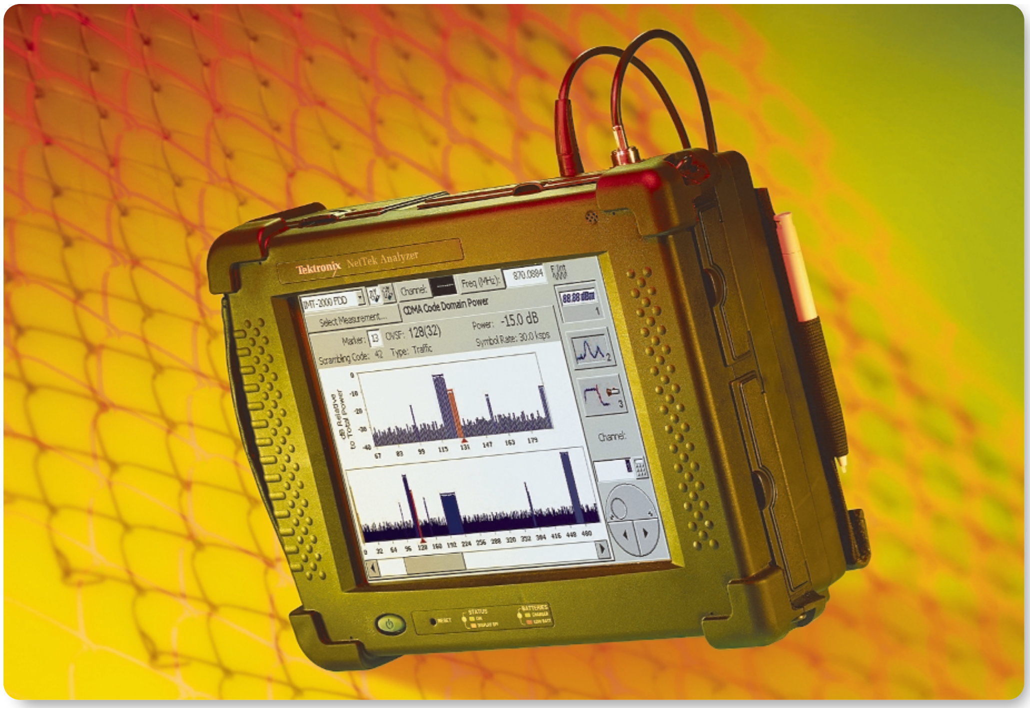
W-CDMA/UMTS Wireless Networks

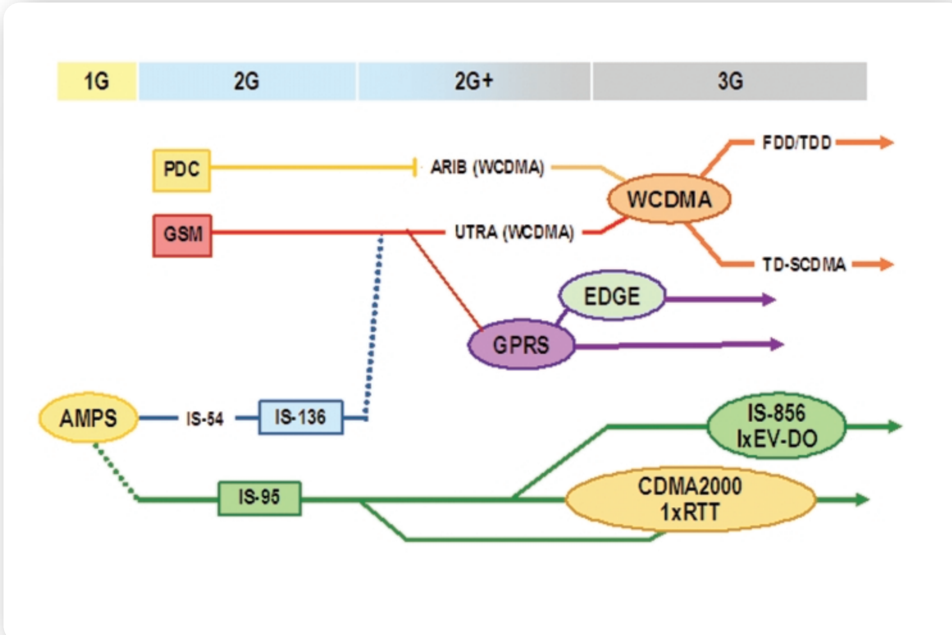


Understanding the Air Interface

This technical brief introduces the reader to W-CDMA/UMTS wireless networks and provide some understanding and insight to the air interface to enable base station/Node B maintenance personnel to effectively maintain them. We begin with a review of the evolution to W-CDMA, followed by a description of the air interface and key RF and code domain parameters. We will then describe some of the testing challenges in W-CDMA and state-of-the-art test tools to ensure that a wireless network meets important QoS goals.

Cellular networks and mobile phone use continues to grow at a rapid pace around the world. A strategic part of the evolution towards third generation (3G) networks, wireless network operators are now putting, or have put, W-CDMA/UMTS networks into commercial service. Cell phone users have come to depend on high quality cellular service to conduct business and stay in contact. With the recent addition of regulations in requiring phone number portability in the United States, and the ongoing competition between wireless service providers worldwide, it has become easy for subscribers to change carriers.

It is essential for wireless network operators to engineer and maintain the cellular network to ensure high Quality of Service (QoS). Dropped calls, non-availability, and poor performance can lead to reduced revenue and customer dissatisfaction, which in turn may lead to fewer customers. At the same time, wireless network operators are focusing on efficiency and increasing revenue, while lowering operating expenses.



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

Evolution to W-CDMA/UMTS

Before the 1980s, the mobile radio communication industry was limited to the armed services, commercial and public organizations using private systems, and marine and aircraft communication. The general public's first introduction to mobile telephones was portable telephones limited to the range of a single base station covering a small geography.

First Generation (1G)

Technical innovations such as automatic switching and reductions in hardware costs, size, and weight led to the first generation (1G) mobile communications systems in the early 1980s. These were based on analog cellular technology. 1G systems have been mainly based on two systems: the American AMPS (Advanced Mobile Phone Service/System) and the Scandinavian NMT system (Nordic Mobile Telephone). Although these systems were incompatible, these analog systems provided important common features:

1. A cellular structure for communication between the base station and mobile.
2. Frequency reuse amongst the cells.
3. Handover between cells as a mobile passes from one to the other.
4. Full duplex *communications*.
5. Roaming across the system.
6. Dedicated control channels for setting up calls.

The transmission quality of these 1G systems left much to be desired and the incompatible systems made cooperation nearly impossible.

Second Generation (2G)

Second generation systems began to appear in the late 1980s.

GSM. The first digital cellular protocol and system was GSM (Global System for Mobile Communication). GSM became popular very quickly, because it provided improved speech quality with a uniform international standard, a single telephone number and mobile phone could be used around the world. The standardization work started by the CCITT and continued by ETSI, led to the GSM standard in 1991. GSM has continued to evolve and add additional features and capabilities. GSM is now used in over 160 countries with over 350 million subscribers worldwide. GSM was estimated to represent 63% of the overall cellular market at the end of 2001.

GSM uses TDMA (Time Division Multiple Access) in its air interface standard. GSM systems in Europe operate in 900 and 1800 MHz bands. GSM in the United States operates in the 800 MHz (cellular) and 1900 MHz Personal Communications Services (PCS) bands. GSM also uses GMSK (Gaussian Modulated Shift Keying) on the RF air interface.

TDMA. In the early 1990s, other digital cellular systems similar to GSM were implemented. TDMA IS-136 (Interim Standard-136), which is still being used today, was introduced in 1994 in the United States. This was an easy transition from AMPS to TDMA IS-136, resulting in a tripling of network capacity. PDC (Personal Digital Cellular) is a TDMA variant that was developed uniquely in Japan.

CDMA, IS-95A. Code Division Multiple Access (CDMA) is a cellular technology that uses the principle of spread-spectrum communications. Access to the system is provided via a system of digital coding, rather than TDMA. The original

CDMA standard for mobile networks was completed in 1993, and is called Interim Standard 95A (IS-95A). CDMA IS-95 systems, also referred to as cdmaOne, have ten times the capacity of 1G AMPS and supports up to 22 voice channels and data rates of up to 14.4 kbps, interspersed in a 1.25 MHz frequency band. In CDMA, all users share the same RF bandwidth at the same time and are distinguished from each other only by spreading codes.

Interim Step to 3G, 2.5G

In order to accommodate the growing demand for Internet applications, it was found that the circuit-switched infrastructure needed to migrate to a packet-switched infrastructure.

GPRS. With initial release in 1997, General Radio Packet Service (GPRS) was specified to create a sound foundation for packet switching in GSM networks. GPRS offers higher data rates for mobile users. It installs a packet switch network on top of the existing circuit switch network of GSM, without altering the radio interface. Higher data rates could be offered to users by dynamically allocating multiple channels. GPRS is the first step in enhancing the GSM core network in preparation for UMTS (Universal Mobile Telecommunications Services). GPRS also introduces important QoS features.

CDMA, IS-95B. New development and a second round of revisions produced the TIA/EIA IS-95B standard. This now gave subscribers new packet-switched data services at speeds up to 64 kbps in addition to the existing voice services.

Third Generation (3G)

In an effort to coordinate worldwide migration to 3G mobile networks, the ITU (International Telecommunications Union) evaluated and accepted 17 different proposals as IMT-2000 (International Mobile Telecommunication 2000) standards in 1999. The most important IMT-2000 proposals were UMTS (Universal Mobile Telecommunication System), cdma2000 (as the IS-95 successor), and EDGE. TS-CDMA (Time Synchronous CDMA) is a 3G specification that is being considered in China. The ITU defines a 3G network as one that provides improved system capacity and spectrum efficiency compared to 2G systems. A 3G network supports data services at transmission rates greater than 144 kbps in mobile (moving) environments and greater than 2 Mbps in fixed (indoor) environments.

EDGE. EDGE (Enhanced Data rates for Global Evolution) was standardized in 1999 and is an enhancement to the radio interface, employing 8-PSK (Phase Shift Keying) modulation (GPRS uses GMSK/Gaussian Minimum Shift Keying). EDGE employs Link Quality Control procedures that are used to select the optimal channel-coding scheme based upon the quality of the radio link in order to provide the maximum data rate. In practice, EDGE is deployed in conjunction with GPRS and is also referred to as EGPRS (Enhanced General Radio Packet Service).

CDMA2000. The cdma2000 specifications and architecture include several implementations that an operator can select to best serve as a transition strategy based on competitive issues, existing infrastructures, costs, and other variables. CDMA2000 is being introduced in three phases. The first phase, CDMA2000 1XRTT (Radio Transmission Technology at one multiple the current North American CDMA chip rate of 1,228,800 chips/second) increases the number of codes from 64 (earlier IS-95 rate) to 128. The second phase includes CDMA200 1XEV-DV (1 x Evolution to Data Voice) and 1XEV-DO (1 x Evolution to Data Optimized), which further increase the data rates.

W-CDMA. W-CDMA (Wideband Code Division Multiple Access) defines the air interface access of the UMTS network. Unlike GSM and GPRS, which uses time division multiple access and frequency division multiple access, W-CDMA allows all users to transmit at the same time and to share the same RF carrier. Further, W-CDMA uses a wider bandwidth (5 MHz) as compared to CDMA IS-95 systems (1.25 MHz). As well, W-CDMA base stations do not require being in system-wide time synchronization, nor do they depend on a GPS (Global Positioning System) signal.

W-CDMA has two modes; FDD (Frequency Division Duplex) mode using separate frequencies for uplink and downlink, and TDD (Time Division Duplex) with uplink and downlink carried in alternating bursts on a single frequency. FDD is being deployed at this time and is usually referred to as W-CDMA. For this discussion, W-CDMA and UMTS will be used interchangeably. W-CDMA is also sometimes referred to as IMT-2000 FDD. The access technology, W-CDMA, is termed UTRA (UMTS Terrestrial Radio Access). The UMTS specifications refer to mobile cell phones or mobile devices as UE (User Equipment) and a W-CDMA base station as Node B. The terms Node B and base station will be used interchangeably.

Early W-CDMA specifications and field trials, such as ARIB in Japan (Association for Radio Industry and Business) and the Universal Mobile Telephone System (UMTS) in Europe, have been harmonized under the supervision of the Third Generation Partnership Project (3GPP). The 3GPP is made up of worldwide standards bodies from around the world.

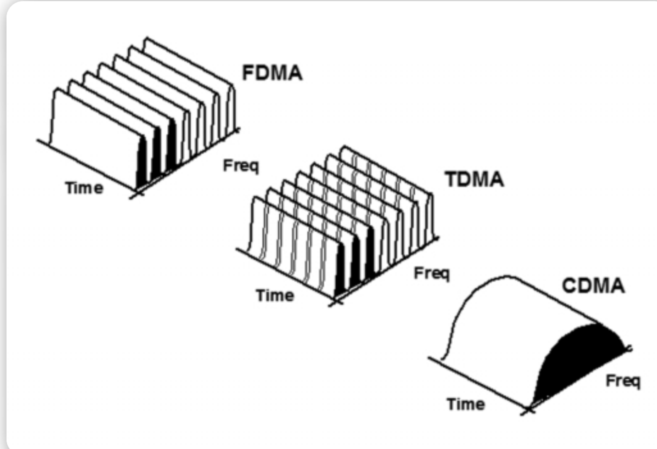
The Basics of W-CDMA

This section will review the technology and concepts of W-CDMA from the air access interface perspective.

Overview – The RF Interface

In older analog FDMA systems, the user occupies one frequency channel for transmit (30 kHz bandwidth for AMPS) and one for receive for the duration of a phone call. These transmit and receive channels are busy 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 increased frustration for a user.

TDMA systems improve on this capacity issue by further subdividing a given bandwidth into time slots. For example, in the NADC (North American Digital Cellular) system, a 30 kHz frequency bandwidth can be divided into three time slots with a user being allocated a particular time slot. In this way, multiple users can use the same duplex pair simultaneously.

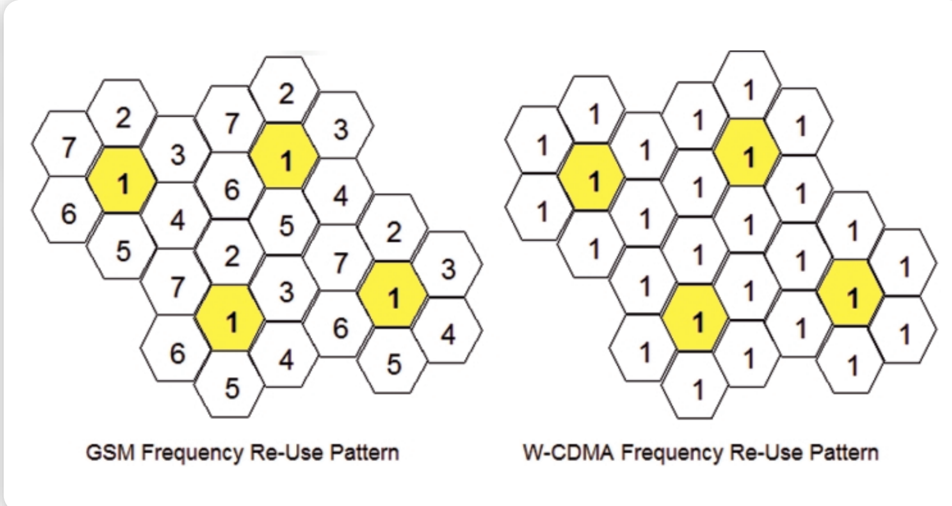


▶ **Figure 2.** *Comparison of multiple access schemes.*

CDMA and W-CDMA systems use a much broader bandwidth than either FDMA or TDMA systems. Instead of dividing users up by frequency or time, they are divided into codes, specific data streams assigned to particular users. All users transmit at the same time and multiple users share the same frequency carrier. Each mobile user is uniquely identified by a specialized code and frequency.

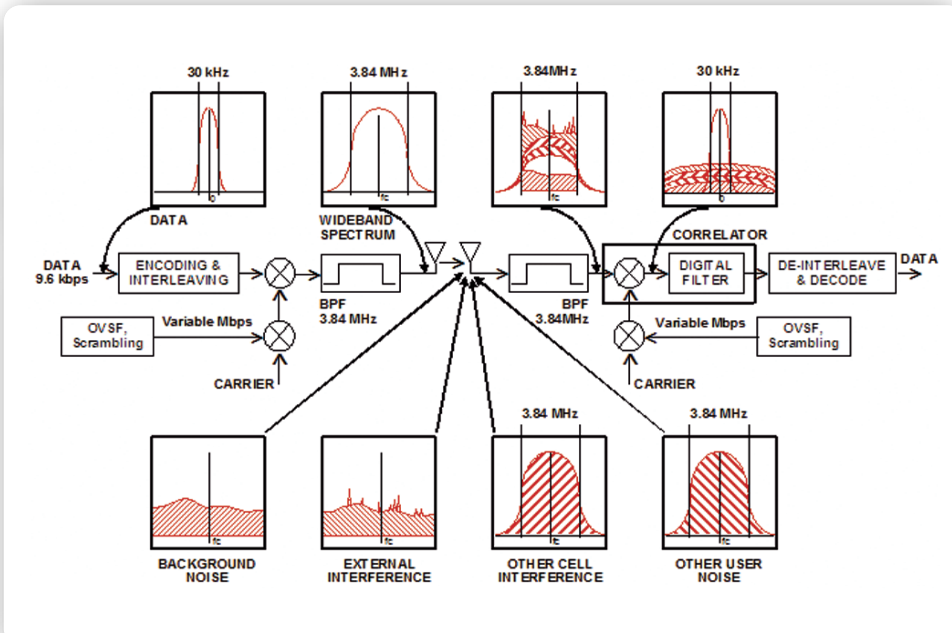
Frequency reuse. Traditional cellular systems (FDMA or TDMA) have a frequency reuse method where frequencies are only duplicated within a certain pattern. This reduces the likelihood of interference between two neighboring cell sites that are both using the same channel. CDMA and

W-CDMA take a much different approach in that the same frequency is used at every site (Figure 3). In the case of CDMA, forward links are separated from each other not by frequencies, but by Pseudo Noise (PN) Offsets. In the case of W-CDMA, forward links are separated from each other by Scrambling Codes.



▶ **Figure 3.** *Comparison of frequency reuse; GSM and W-CDMA.*

W-CDMA signal spreading and correlation. Unlike TDMA signals, W-CDMA signals use all available bandwidth for each RF channel. Code channel separation is accomplished by digitally coding individual channels, not by frequency separation. A particular subscriber's receiver looks for the unique code assigned to it and the rest of the channels are indistinguishable from noise. Each channel is uniquely identified by the carrier frequency and the code.



▶ **Figure 4.** *Signal spreading and correlation in W-CDMA base station.*

W-CDMA specifications allow 3.84 MHz for a signal bandwidth. In the example in Figure 4, we start with a user data rate of 9.6 kbps per channel. This data could be either digitized voice or actual data. At a rate of 9.6 kbps, the data would normally need approximately 10 kHz of spectrum. The data is then "spread" using a code which is running at 3.84 Mbps code rate. The resulting spread bits are called chips and the resulting transmitted spread rate is expressed as 3.84 Mcps for W-CDMA. This is comparable to a bandwidth of 3.84 MHz.

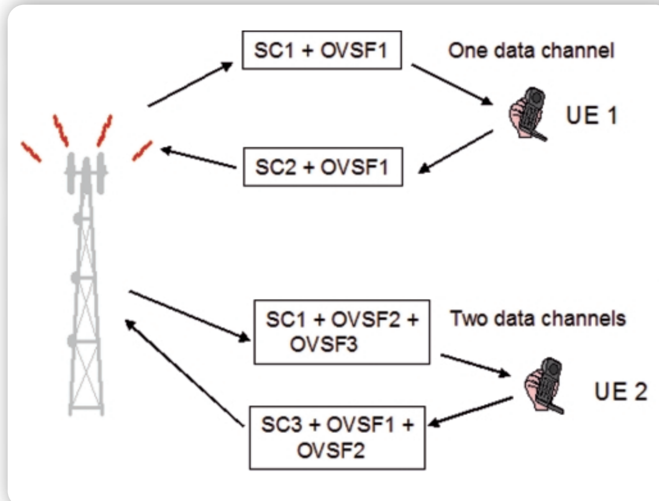
The subscriber mobile receiver will see this spread signal together with noise, interference, and messages on other code channels in the same RF frequency slot. The interference can come from other users in the same cell and interference from neighboring cells. The receiver's demodulator/correlator then reapplies the code and recovers the original data signal.

Channels and codes. In W-CDMA, each user channel is uniquely identified by a code, which is a combination of a scrambling code and an OVSF (orthogonal variable spreading factor) code (Figure 5).

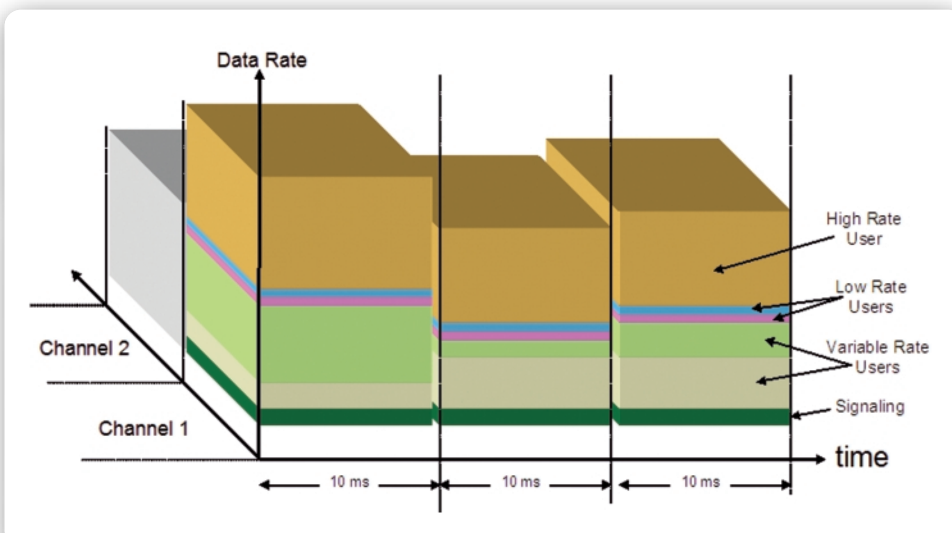
The scrambling code is mixed prior to the output of a base station or the output of a subscriber's mobile unit. The scrambling code is unique for each device and allows the recipient to identify the device from others.

Each base station sector is identified by a unique scrambling code and may also be transmitting multiple code channels (other mobile users) at the same time. Each of these channels is first uniquely multiplied by an OVSF code. Note, however, that the synchronization channels, P-SCH and S-SCH, do not go through the OVSF spreading process (Figure 9). The OVSF codes are orthogonal codes used to separate traffic in a W-CDMA signal (see ***Orthogonal Coding, Spreading, and Correlation***, next page). W-CDMA uses a variable length code (4 to 512 chips). The length of spreading code is also known as the spreading factor. 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. This is an important property of orthogonal codes used in W-CDMA systems. Interfering signals not intended for a given mobile phone will be 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. Scrambling codes are not orthogonal and therefore can be a source of interference.

An important feature of W-CDMA systems is a radio interface that is highly adaptive. W-CDMA is designed to allow many users to efficiently share the same RF carrier by dynamically reassigning data rates. The SF (spreading factor) may be updated as often as every 10 ms. This permits the overall data capacity of the system to be used more efficiently. Figure 6 illustrates the dynamic nature of the radio interface as the data rates of various users change.



▶ **Figure 5.** *W-CDMA scrambling code and OVSF assignments.*

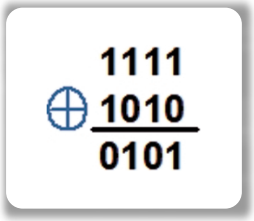


▶ **Figure 6.** *W-CDMA/UMTS adaptive radio interface.*

Orthogonal Coding, Spreading, and Correlation

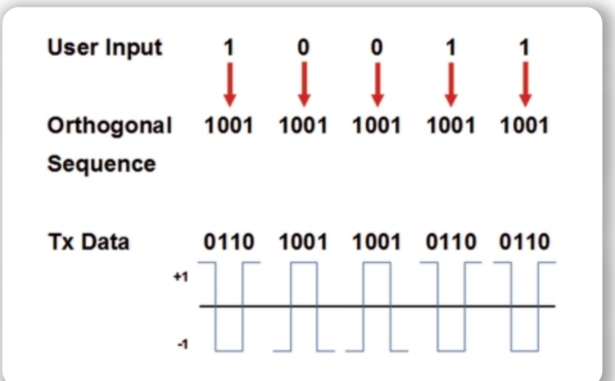
Coding

Two binary sequences of equal length are defined as being orthogonal if the result of passing them through an exclusive-OR operation, results in an equal number of 1's and 0's.



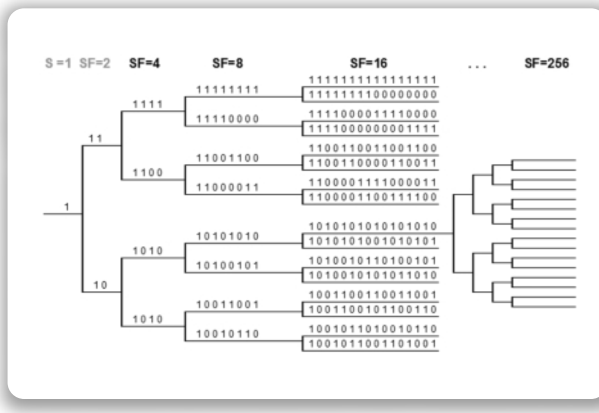
When data streams that are first exclusive-OR'd with orthogonal codes and then merged, they can later be separated.

Spreading



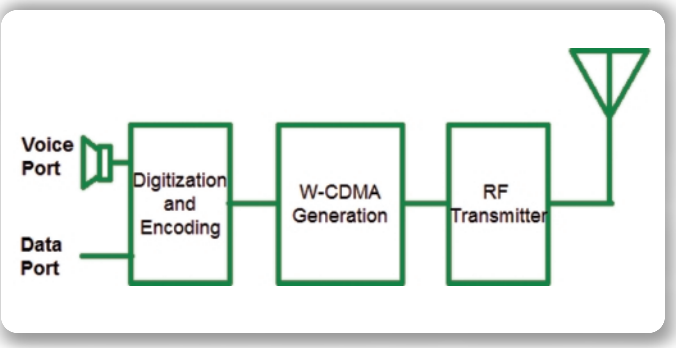
Orthogonal codes can be used to "spread" a user data sequence, such as digitized voice or actual data.

In this example, each binary "1" has become a string of "0110" and every transmitted "0" becomes the inverse, "1001". Orthogonal codes used in W-CDMA vary in length from 4 to 512 bits. The 1s and 0s of the resultant data stream from the exclusive-OR process are called "chips". W-CDMA systems have a fixed chip rate of 3.84 Mcps (mega chips per second). The length of the code is called the spreading factor (SF). The diagram below shows the SF out to 256. Longer codes provide a more robust system; however, the individual user channel data rate is lower. Engineering design considerations trade off between robustness and capacity.

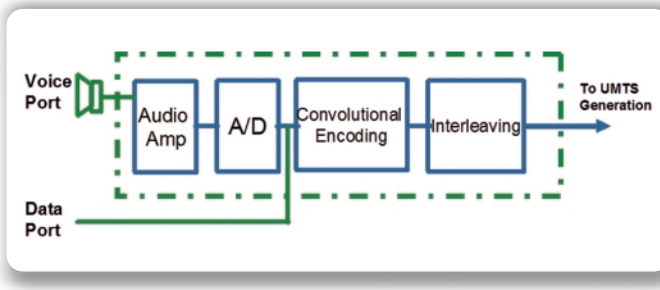


Decoding, Correlation

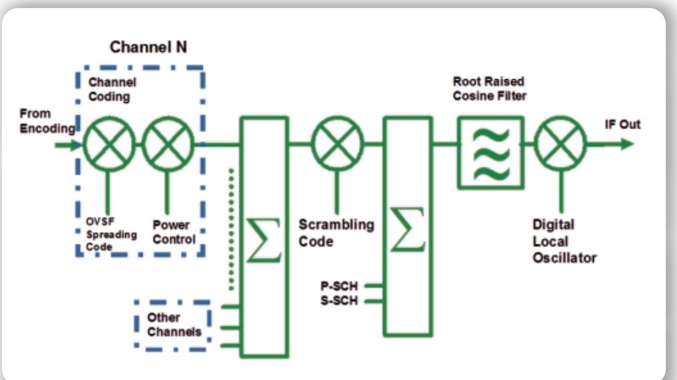
In order to recover the received user data, the same orthogonal code must be used at the receive end and together, passed through a correlation and data recovery process.



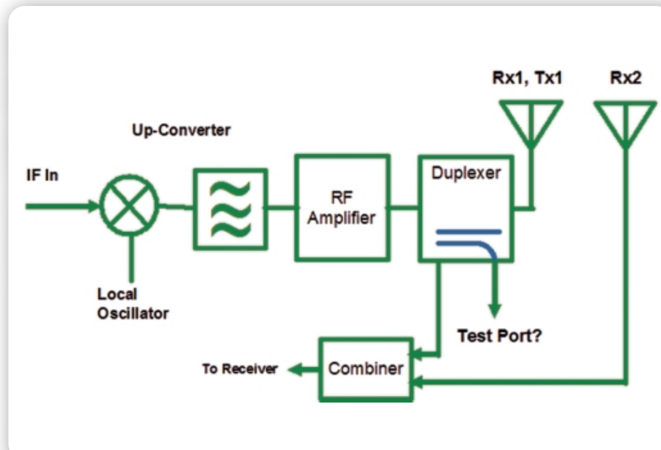
▶ **Figure 7.** *Block diagram of W-CDMA base station transmit.*



▶ **Figure 8.** *Digitization and encoding functional block of W-CDMA base station.*



▶ **Figure 9.** *W-CDMA/UMTS generation block of W-CDMA base station.*

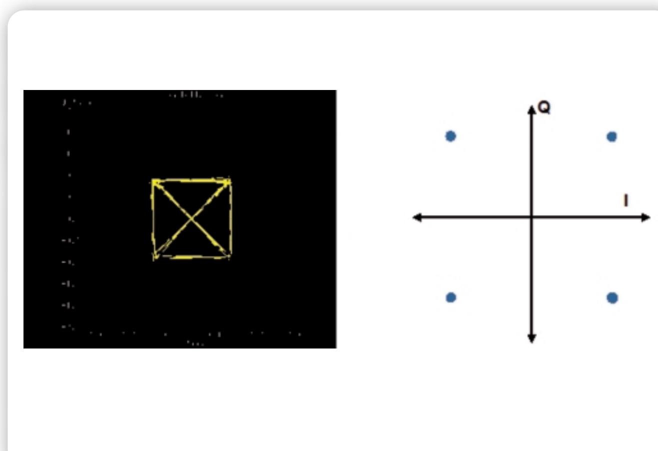


▶ **Figure 10.** *RF transmitter block of W-CDMA base station.*

RF downlink and uplink. It is useful to understand the functional blocks and signal flow of the W-CDMA base station transmitter (Figures 7 to 10). The RF signal transmitted from the base station to the subscriber mobile phone is referred to as the downlink or forward link. It consists of the RF channel, scrambling code (one per sector), an OVSF channel for signaling (one per call), and one or more OVSF channels for data. It also contains the sync signals (P-SCH and S-SCH), which are added after the OVSF codes and before the scrambling codes. The RF signal transmitted from the mobile phone is referred to as the uplink or reverse channel.

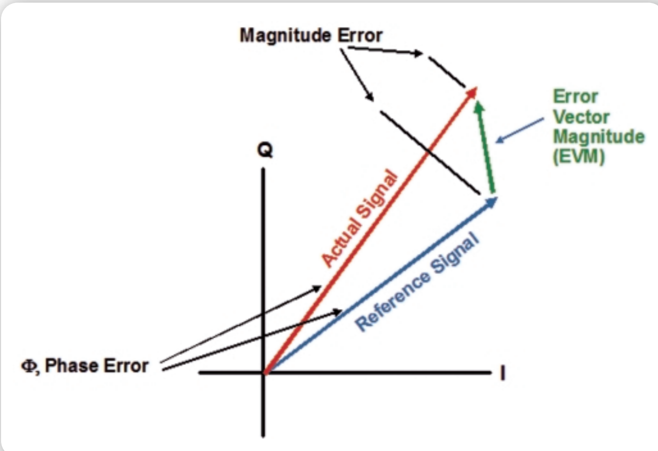
Signal quality

The transmitted RF signal from the Node B is a complex QAM (Quadrature Amplitude Modulated) type of signal. An example of a constellation display of QPSK (Quadrature Phase Shift Keying) and a corresponding I-Q diagram illustrate that the symbols represented by the modulated RF signal need to be demodulated and decoded within discrete decision points in the constellation in order to be error free (Figure 11). Increasing degradation of received RF signal, due to impairments such as interference or noise, will spread the points out

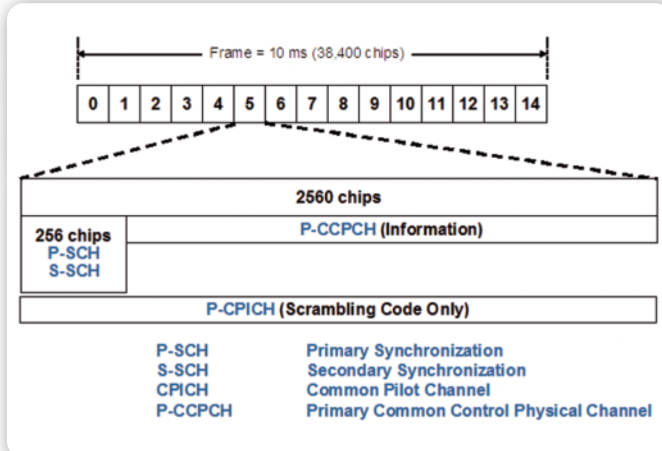


▶ **Figure 11.** *A QPSK constellation display and I-Q modulation plane showing idealized decision points.*

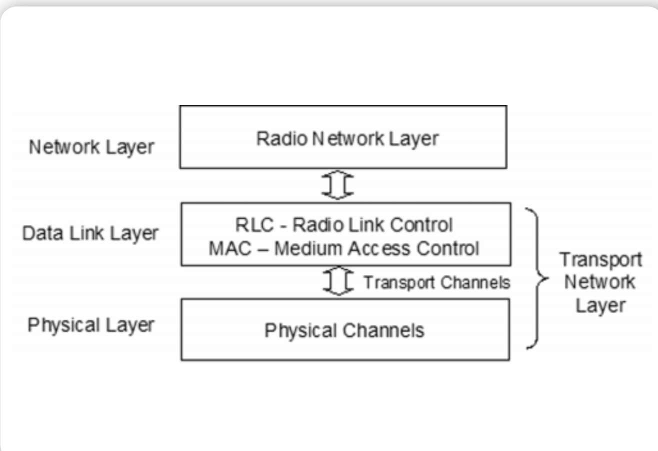
until errors begin to occur. At the base station transmitter, modulation accuracy of the transmitter or distortion along the RF path may cause the points to spread. EVM (Error Vector Magnitude) is a measurement which evaluates the signal quality. EVM is computed from the vector difference between the actual received signal and a



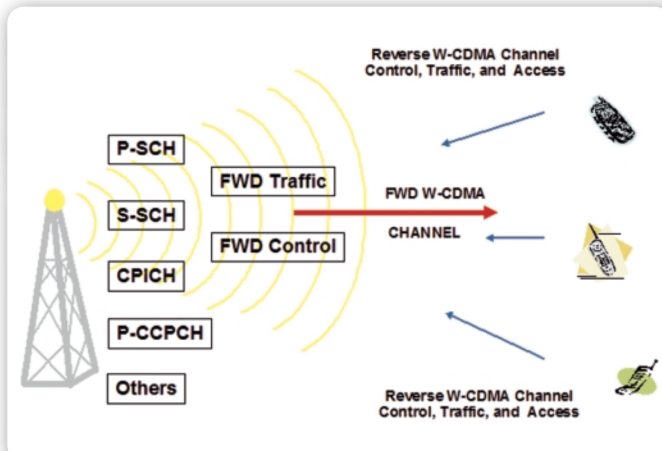
▶ **Figure 12.** *EVM measurement concept.*



▶ **Figure 13.** *The W-CDMA downlink frame and timeslot composition.*



▶ **Figure 14.** *The W-CDMA protocol description of the lower three layers.*



▶ **Figure 15.** *W-CDMA channel structure.*

calculated, ideal reference signal (Figure 12). The W-CDMA standards specify EVM tolerances.

Protocol

The W-CDMA downlink and uplink data streams are running at a constant 3.84 Mcps and 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 (Figure 13).

The W-CDMA system is described in the specifications in terms of the OSI (Open System Interconnection) seven layer mode (Figure 14).

The physical layer, layer 1, maps the transport channels onto the physical channels and provides the necessary RF functionality for the system to operate properly. The RF functionality includes power control, data channel rate matching, time synchronization, and handoff controls. The data link layer, layer 2, maps the logical channels to the transport channels (media access control) and provides the radio link control functionality such as error correction, flow control, error detection and recovery, etc. The physical layer and the data link layer make up the transport network layer.

The radio network layer, layer 3, provides the functionality for connecting services from the network to the mobile phone. In this discussion, we will only address the physical channels contained in the RF signal. An in-depth discussion of the higher protocol layers can be found in Tektronix technology primer, "***UMTS Protocols and Protocol Testing***", publication number 2FW-14251-1.

Downlink/forward link. The downlink or forward physical channels consist of forward traffic channels, pilot, paging, and sync channels (Figure 15).

The important downlink/forward physical channels are described below;

P-CPICH	Primary Common Pilot Channel (Pilot & Broadcast) Transmits scrambling code only, provides phase reference for other channels, used for Node B signal strength measurement by UE
P-SCH	Primary Synchronization Channel (Sync) Provides first step in recovering timing information, provides timeslot sync
S-SCH	Secondary Synchronization Channel (Sync) Provides second step in recovering timing information, provides first scrambling code clue to UE, provides frame sync
P-CCPCH	Primary Common Control Physical Channel (Pilot & Broadcast) Transmits broadcast information to all UE
DPDCH/DPCCH	Dedicated Physical data and control channels. Carries the user data and user (layer 3) signaling.
AICH	Acquisition Indication Channel Acknowledges access request from UE
PICH	Paging Indication Channel Alerts UE to a page
PDSCH	Physical Downlink Shared Channel Used to broadcast packet data to multiple UEs

Uplink/reverse link. The RF uplink, or reverse link, has a slightly different frame structure. In W-CDMA cellular systems, the base station must precisely control the transmit power of the mobile phones for optimum capacity. Each uplink frame has power control bits in each time slot and this permits the power control to occur. The uplink or reverse physical channels consist of reverse traffic channels and access channels.

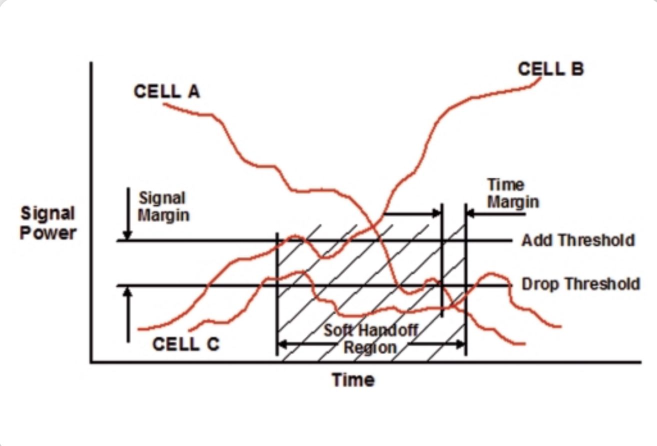
PRACH	Physical random access channel UE requests "random" connection to network
PCHPC	Physical common Packet Channel Provides packet data transport
DPDCH/DPCCH	Dedicated Physical Data/Control Channel User's digitized voice and data channels and user (layer 3) signaling

Procedures in W-CDMA

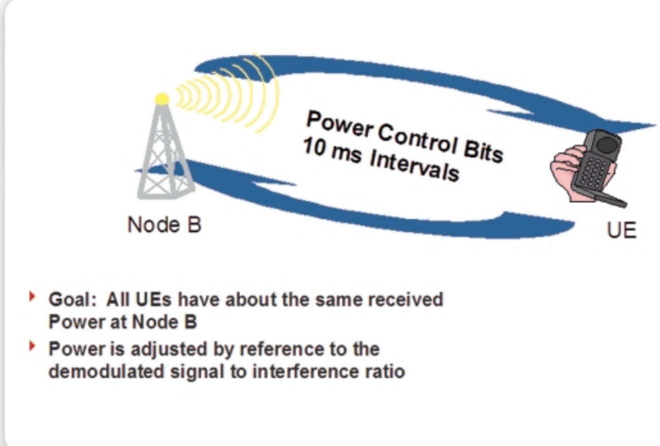
There are several procedures in W-CDMA that are useful to understand in order to be able to effectively troubleshoot and maintain base stations. These include how a mobile device places a call, how a mobile device moves from one base station to another in a handoff, power control, and multi-path signal handling.

Call processing and UE registration process. When a subscriber wishes to make a mobile call, the UE will have gone through the following RF signal acquisition and registration process in order to locate and connect to the nearest base station.

1. The UE correlates and finds the P-SCH (Primary Sync Channel) which provides system timing and timeslot synchronization information.
2. The UE then finds the S-SCH (Secondary Sync Channel) which provides frame timing and provides the sector's scrambling code group (first step to identifying the scrambling code).
3. The UE finds P-CPICH (Primary Common Pilot Channel) which provides the scrambling code and accurate phase and timing information.
4. The UE finds P-CCPCH (Primary Common Control Physical Channel) which contains information broadcast to all UEs and provides UE rules for access attempt.
5. The UE starts an access attempt using PRACH (Physical Random Access Channel). This involves using the scrambling code of the target sector or Node B and selecting a time slot at random. The UE starts at a low transmit power, repeating at higher and higher powers until a response (AICH) is received. The UE may also be changing time slots while searching for a signal acquisition.
6. The UE receives a response from the Node B on AICH, Acknowledge Access channel, when the Node B detects the PRACH.
7. The UE now exchanges layer 2 and layer 3 information to set up the voice or data call, to maintain the call, and to terminate the call.
8. During the call, power levels and data rates can be changed at every time slot boundary. Time slots are 10 ms wide.



▶ **Figure 16.** *Soft handover behavior.*



▶ **Figure 17.** *Power control.*

Handovers. W-CDMA systems have several methods to hand over communications from one cell site to another, depending on the proximity to neighboring Node Bs, environmental variables, etc. These handovers are called hard, soft, and softer.

Hard handover

A hard handover involves the transfer of a mobile from one W-CDMA cell system on one RF to another W-CDMA cell system on a different RF or perhaps to a GMS cell system. Hard handovers are characterized by the potential of failure. There is no feedback mechanism and no way to recover from a faulty handover.

Soft handover

A soft handover occurs on the same W-CDMA channel between two different cell sites. In a soft handover, the mobile can establish simultaneous communication with several base stations and is always decoding information from the multiple cells. A mobile is able to measure signal strength from multiple pilots and determine which adjacent cells have sufficient strength to use for call processing. The mobile (UE) measures the signal to interference ratio (SIR) of pilots and the receive signal code power (RSCP). As a mobile travels between two cells, it signals to the network that it has found a new pilot. The network tells the new cell site to allocate a traffic channel for the mobile. This will continue until one cell is too weak to use. At that point, the mobile sends a handover completion message on the reverse traffic channel and begins to exclusively use the new cell site (Figure 16). The soft handover procedure ensures that a mobile is always in constant communications with a cell.

In addition, W-CDMA does not rely on global timing synchronization. The W-CDMA has methods defined for the mobile phone to measure the received frame timing differential between Node Bs and provide this to the network control. The network control is then able to make frame timing adjustments from one Node B to another so that the mobile (UE) is able to make the soft handover.

Softer handover

A softer handover is one that occurs between two sectors of the same Node B. The signals received within the Node B are combined and sent to the network.

Power control. In order to maximize the capacity of W-CDMA systems, it is important to control the signal level of each mobile so that its signal arrives at the cell site with minimum required signal-to-noise ratio (Figure 17). If the signal is too low, the bit error rate increases. If the mobile sends too strong a signal, this will result in an increase of interference to all other mobile users sharing that RF carrier, which causes reduction in cell capacity.

The goal is to have all of the mobiles (UE) to have about the same received power from the Node B. The power is dynamically adjusted by reference to the demodulated signal to interference ratio (SIR). Power control, both open loop and closed loop, is used to maintain the minimum power levels necessary for correctable communications errors while maximizing the capacity of the system.

Table 1: Field Maintenance Measurements Summary

Parameter	Measurement	Significance
RF Output Power	RF Channel Power	In-service indicator of health of Node B and power budget
RF Output Power	Peak/Average Ratio	Indicates amount of margin in transmitter (headroom). Lack of headroom may be due to distortion, which reduces cell capacity
RF Power – Intermodulation	ACLR (Adjacent Channel Leakage Ratio)	Indicator of carrier leakage into adjacent channels. Decreases call capacity
RF Power – Interference	Spectrogram, Signal Strength, Noise Floor	Analysis of intermittent interfering RF signals
RF Frequency	Frequency and Error	Finding transmitter faults & mis-configurations
RF Frequency	Occupied Bandwidth	Excessive bandwidth contributes to noise in other RF carriers, lowering system call capacity
Pilot Code Power	Pilot and Sync Channel Power	Pilot power is very important, sets coverage of base station, affecting user's perception of network quality
Channel Power	Code Channel Power, Codogram	Indicator of user utilization. Improperly set, will cause loss of call capacity
Signal Quality	EVM (Error Vector Magnitude)	Degradation in quality contributes to lower data rates, dropped calls and lower system capacity
Scrambling Code Power	Scrambling Code Analyzer	Identifies neighboring cell sites that are interfering, causing dropped calls, excess handovers, etc.

Multi-path fading. Unlike other digital systems, W-CDMA systems have designed mechanisms to enhance signal reception when multi-path environments or other RF signal impairments may occur. The mobile phone's receiver has three parallel correlators or rake receivers, and the base station has four rake receivers. These rake receivers track individual signal paths independently, adjust for time offsets, sum the resultants, and then demodulate the resultant signal.

Measurement Issues and Challenges

The challenge of the network operations manager is to deliver high Quality of Service consistently and cost effectively. QoS, as experienced by the mobile phone user, is evaluated on the basis of parameters such as dropped calls, blocked calls, lack of signal, and slow data throughput. Implementing a regular proactive maintenance strategy is important in ensuring high QoS.

In-the-field measurements of base station transmitted RF signals and other, possibly interfering, RF signals, provide much of the basic information needed to evaluate Quality of Service. To ensure that the W-CDMA system is running within specification, it is necessary to measure the various RF and code-domain signals that have been discussed.

A summary of key field maintenance measurements and the base station transmitter parameters being measured to ensure the ongoing Quality of Service of a cellular system are described in Table 1.

Overview of the NetTek

The Tektronix NetTek YBT250 field transmitter and interference tester is optimized to provide the right set of tests for field maintenance technicians and RF engineers to maintain and troubleshoot base station/Node B transmitters. A series of basic Pass/Fail tests summarizes Node B performance and pinpoints problems. In addition, in-depth tests are a great help for those more difficult problems. Measurements can be made by either connecting the analyzer directly to the base station or by making over-the-air (OTA) measurements. OTA measurements evaluate received signals for unwanted interference and conduct first level performance checks.

The Tektronix NetTek YBT250, option IN1 Interference Analyst is a superb tool for identifying and locating sources of interference. A detailed analysis and application study can be found in Tektronix application notes, "***Hunting for Sources of Interference in Mobile Networks***", publication number 2GW-14759-0, and "***Fundamentals of Interference in Mobile Networks***", publication number 2GW-14758-0.

In addition to the RF and demodulation testing, the Tektronix NetTek YBA250 BTS Antenna and Transmission Line Analyzer provides the tools necessary for fast identification and easy location of base station antenna and transmission line trouble.

The package is designed to be rugged, modular, and easy-to-use. It is purpose-built specifically for the base station technician and field RF engineers. Traditional, larger, dedicated test instrumentation is too costly, too heavy, and too complicated to use in practical applications in the field. The Tektronix NetTek is a comprehensive one "toolbox" approach needed for RF transmitter maintenance, with specific measurements for W-CDMA/UMTS, CDMA, GSM, TDMA, and analog systems.

Conclusion

In the field measurements of the Node B transmitted RF signal and the surrounding environment provide information to evaluate QoS. These tests can be performed by using full-scale compliance test sets or coverage area testers. These are often too complex and time consuming for routine field work or involve dedicated drive vehicles and highly skilled test personnel. An integrated field portable test tool that has the appropriate measurements and can be operated by base station maintenance personnel provides a cost effective solution.

Quality of Service, as experienced by the mobile phone user, is evaluated on the basis of parameters such as dropped calls, blocked calls, lack of signal, and slow data throughput. In-the-field measurements of base station transmitted RF signals and other, possibly interfering, RF signals, provide much of the basic information needed to evaluate Quality of Service. Traditionally, these tests have been performed either by complex compliance testers, which can be difficult to use, or very simple testers, such as area testers, which can spot some problems, but are not so useful when it is time to fix the problems.

A better alternative would be a test set designed for field conditions with just the right set of tools, or measurements, to get the job done quickly. This tester would combine measurements normally acquired from several discrete, conventional instruments into a "Tool Box" containing the commonly used measurements for W-CDMA base stations/Node Bs.

In this technical brief, we have reviewed W-CDMA/UMTS wireless networks and the air interface of W-CDMA base stations. We looked at the evolving cellular technologies from an RF perspective. We then described some of the testing challenges and finished with a consideration of ideal field maintenance test tools for W-CDMA base station technicians.

Appendix

Abbreviation List

3GPP	Third-Generation Partnership Project
AMPS	Advanced Mobile Phone Service
ARIB	Association for Radio Industry and Business (Japan)
CCITT	Committee Consultative International Telephone and Telegraph
EIA	Electronic Industries Alliance
EMI	Electro-Magnetic Interference
ETSI	European Telecommunications Standardization Institute
EVM	Error Vector Magnitude
FDD	Frequency Division Duplex
FDMA	Frequency Division Multiple Access
GMSK	Gaussian Minimum Shift Keying
GPRS	General Packet Radio Service
GPS	Global Positioning System
GSM	Global System for Mobile Communications
IMT-2000	International Mobile Telecommunication 2000
IS	Interim Standard
ITU	International Telecommunications Union
NADC	North America Digital Cellular
NMT	Nordic Mobile Telephone
PCS	Personal Communications Service
PDC	Personal Digital Cellular (Japan)
OTA	Over-The-Air
OVSF	Orthogonal Variable Spreading Factor
QAM	Quadrature Amplitude Modulation
QoS	Quality of Service
QPSK	Quadrature Phase Shift Keying
P-CPICH	Primary Common Pilot Channel
P-CCPCH	Primary Common Control Physical Channel
P-SCH	Primary Sync Channel
RSCP	Receive Signal Code Power
S-SCH	Secondary Sync Channel
SCA	Scrambling Code Analyzer
SF	Spreading Factor
SIR	Signal to Interference Ratio
TIA	Telecommunications Industry Association
TDD	Time Division Duplex
TDMA	Time Division Multiple Access
TS-CDMA	Time Synchronous Code Division Multiple Access
UE	User Equipment
UMTS	Universal Mobile Telephone System (Europe)
UTRA	UMTS Terrestrial Radio Access
W-CDMA	Wideband Code Division Multiple Access

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