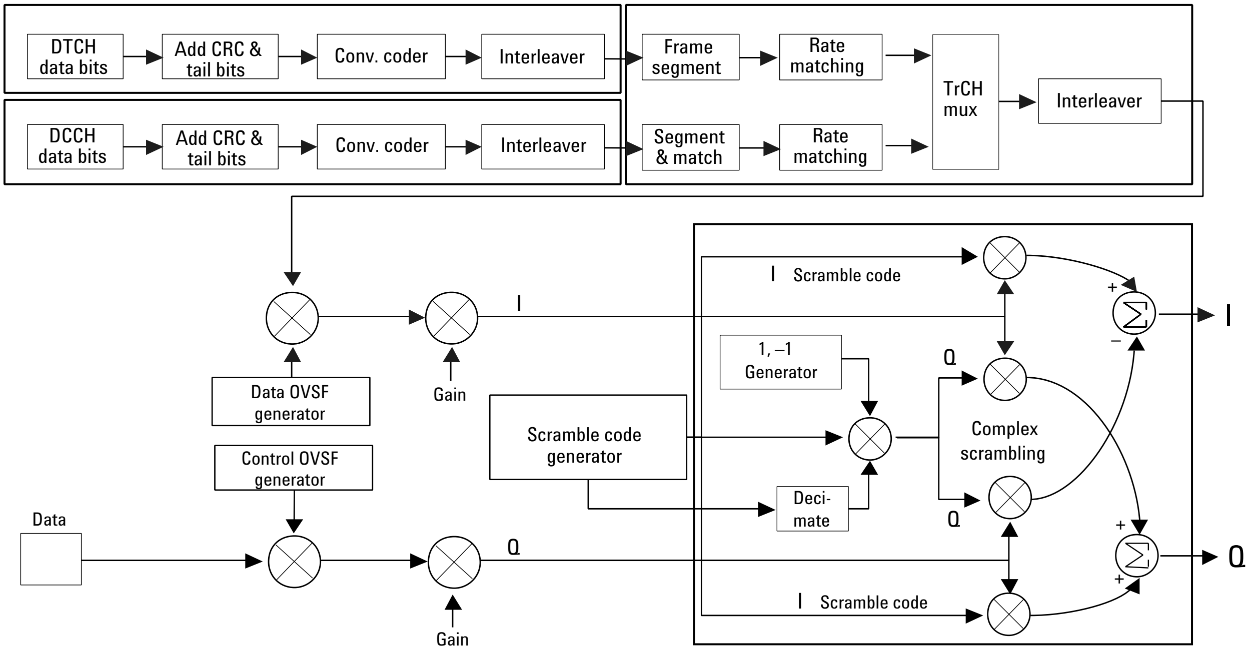
Agilent
Designing and Testing 3GPP W-CDMA User Equipment

Application Note 1356



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Introduction

W-CDMA is one of the leading wideband digital cellular technologies that will be used for the third generation (3G) cellular market.

The earlier Japanese W-CDMA trial system and the European Universal Mobile Telephone System (UMTS) have both served as a foundation for the workings of this harmonized W-CDMA system, under the supervision of the Third-Generation Partnership Project (3GPP). The 3GPP organizational partners are the European Telecommunications Standard Institute (ETSI), the Japanese Association of Radio Industries and Businesses (ARIB), the Japanese Telecommunication Technology Committee (TTC), the Korean Telecommunications Technology Association (TTA), and the American Standards Committee T1 Telecommunications. The harmonized system is sometimes referred to as 3GPP W-CDMA, to distinguish it from earlier wideband CDMA versions.

The W-CDMA system will employ wideband CDMA in both frequency division duplex (FDD) and time division duplex (TDD) modes. To limit its scope, this application note focuses on the FDD mode of W-CDMA, although most of the content is applicable to both modes. Whenever the term W-CDMA is used throughout the application note it is in reference to the 3GPP (release 99) specifications for W-CDMA FDD mode.

This application note focuses on the physical layer (layer 1) aspects of W-CDMA user equipment (UE)[1]. It consists of

- A brief overview of W-CDMA technology

- A discussion of design issues and measurement concepts related to the technology that are important for the W-CDMA UE air interface because of the differences between W-CDMA and its second generation (2G) predecessors (specifically, Global System for Mobile Communication (GSM) and Personal Digital Cellular (PDC)). This section will provide you with an understanding of why these measurements are important and how you can use them to characterize and troubleshoot your design. These measurements can be useful throughout the development of the UE. This section can also be used as background information for conformance and manufacturing testing.

- A list of Agilent Technologies' solutions for the physical layer of W-CDMA UE design and test

You can find further information about 3G technologies at the following URL: **http://www.agilent.com/find/3G**

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[1] The W-CDMA specifications use the term UE to refer to mobile phones, wireless computing devices, or other devices that provide wireless access to the W-CDMA system.

1 Basic Concepts of W-CDMA

W-CDMA is designed to allow many users to efficiently share the same RF carrier by dynamically reassigning data rates and link budget to precisely match the demand of each user in the system. Unlike some 2G and 3G CDMA systems, W-CDMA does not require an external time synchronization source such as the global positioning system (GPS) **[1]**.

1.1 Code division multiple access

As its name implies, W-CDMA is a code division multiple access (CDMA) system. As opposed to time division multiple access (TDMA), in CDMA, all users transmit at the same time. Frequency divisions are still used, but at a much larger bandwidth. In addition, multiple users share the same frequency carrier. Each user's signal uses a unique code that appears to be noise to all except the correct receiver. Therefore, the term *channel* describes a combination of carrier frequency and code. Correlation techniques allow a receiver to decode one signal among many that are transmitted on the same carrier at the same time. Figure 1 shows a simplified version of the transmission and reception processes for a CDMA system. Although this example uses W-CDMA data rate and bandwidth parameters, the basic processes are the same for all CDMA systems. One difference between W-CDMA and the existing 2G CDMA system (IS-95) is that W-CDMA uses a wider bandwidth (3.84 MHz, as opposed to 1.23 MHz for IS-95).

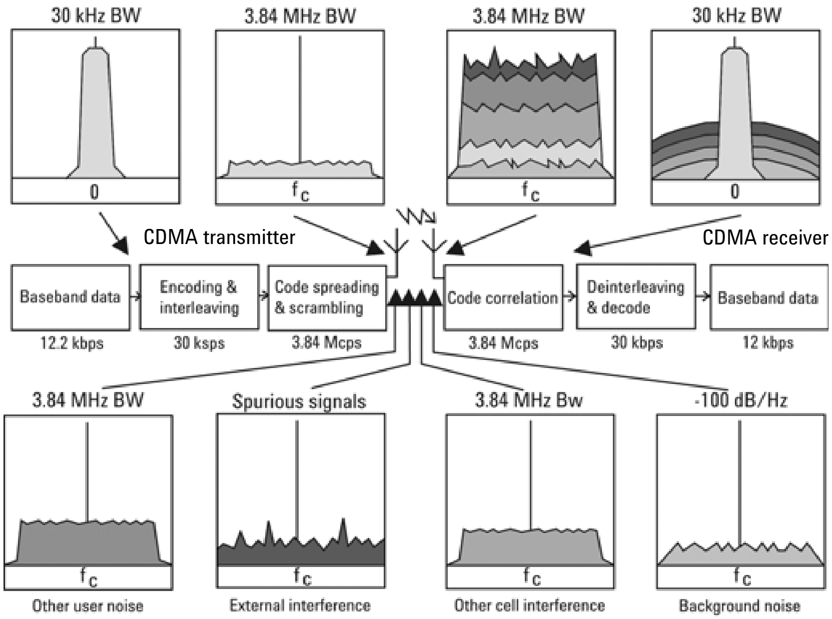

Figure 1. CDMA transmission and reception processes

In the above example, the W-CDMA system starts with a narrowband signal at a data rate of 12.2 kbps. In reality, this data rate is variable, up to 2 Mbps. After coding and interleaving, the resulting symbol rate in this example is 30 ksps. This is spread with the use of specialized codes to a bandwidth of 3.84 MHz. The final spread bits are called chips, and the final spread rate is defined in terms of chips per second (3.84 Mcps for W-CDMA). The ratio of the spread data rate (3.84 Mcps) to the encoded data rate (30 ksps in this case) is called the spreading gain. The ratio of the spread data rate to the initial data rate (12.2 kbps in this case) is called the processing gain (overall coding gain). In CDMA systems the spreading gain is a big contributor to the processing gain. The processing gain allows the receiver's correlator to extract the desired signal from the noise. When transmitted, a CDMA signal experiences high levels of interference, dominated by the signals of other CDMA users. This takes two forms, interference from other users in the same cell and interference from adjacent cells. The total interference also includes background noise and other spurious signals. When the signal is received, the correlator recovers the desired signal and rejects the interference. This is possible because the interference sources are uncorrelated to each channel's unique code. In W-CDMA, the unique code for each channel is a combination of the scrambling code and the orthogonal variable spreading factor (OVSF) code, which are described in the following sections.

1.2 Base transceiver station and user equipment identification

As in other CDMA systems, in W-CDMA each base transceiver station (BTS) output signal is "scrambled" by multiplying all of its data channels by a unique pseudo-noise (PN) code, referred to in the W-CDMA specification as a scrambling code. The UE receiver can distinguish one BTS from another by correlating the received signal spectrum with a scrambling code that is identical to that used in the desired BTS. Similarly, each UE output signal is scrambled with a unique scrambling code that allows the BTS receiver to discern one UE from another. The scrambling codes are applied at a fixed rate of 3.840 Mcps. The scrambling codes are not orthogonal, therefore, some interference can exist between two UEs.

1.3 Data channelization

Beside distinguishing which transmitter is being listened to, a CDMA receiver must further distinguish between the various channels originating from that transmitter. For example, a BTS will transmit unique channels to many mobile users, and each UE receiver must distinguish each of its own channels from all the other channels transmitted by the BTS. In W-CDMA, this function is provided by the channelization codes, also known as OVSF codes.

OVSF codes are orthogonal codes similar to the Walsh codes used in IS-95 and cdma2000. Each channel originating from a W-CDMA BTS or UE is multiplied by a different OVSF code[1]. In IS-95, Walsh codes are fixed at 64 chips in length; in W-CDMA, the length of these codes, also known as the spreading factor (SF), can be configured from 4 to 512 chips, with the resulting downlink (DL) symbol rate being equal to the system chip rate of 3.84 Mcps divided by the SF. For example a SF of four corresponds to a symbol rate of 960 ksps.

The entire set of OVSF codes is identical for each UE and BTS. The scrambling code allows OVSF code reuse among UE and BTS within the same geographic location. Therefore, it is the combination of OVSF and scrambling codes that provides a unique communication channel between a UE and BTS.

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1. The synchronization channels are an exception to this, as described later.

The W-CDMA radio link between the BTS and UE must support multiple simultaneous data channels. For example, a 3G connection may include bi-directional voice, video, packet data, and background signaling messages, each representing a unique data channel within a single frequency carrier.

Figure 2 illustrates a W-CDMA system with two BTS and four UEs. The scrambling code (SC) provides a unique identity to each UE and each BTS. The OVSF code allocations provide a unique identity to each channel conveyed by a UE or BTS within one cell. For example SC_2 identifies BTS 2, and SC_6 identifies UE 4. BTS 2 uses $OVSF_4$ and $OVSF_5$ to send voice and signaling information to UE 4. This UE uses $OVSF_1$ and $OVSF_2$ to send voice and signaling information back to BTS 2. Note that other BTSs and UEs also use the same OVSF codes ($OVSF_1$ and $OVSF_2$). This is not a problem since the scrambling codes decorrelate the re-used OVSF codes.

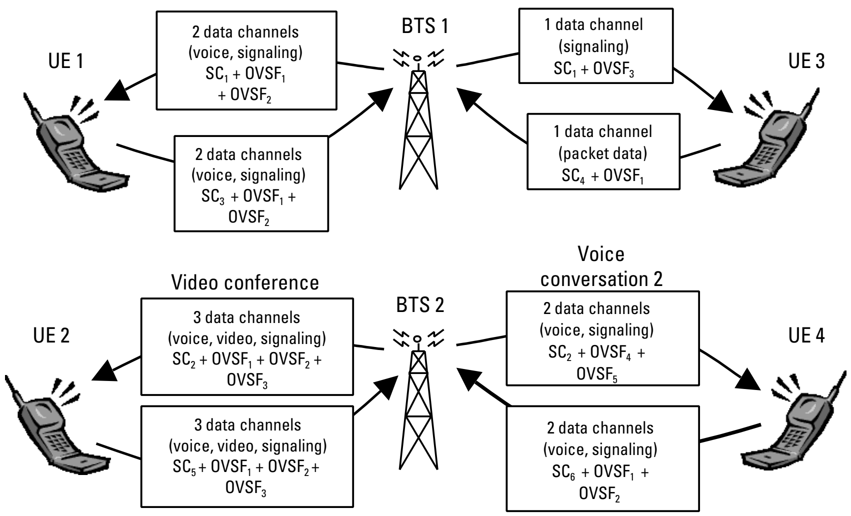


Figure 2. W-CDMA code allocations

The combination of OVSF codes and scrambling codes provide the signal spreading, and therefore, the spreading gain needed for the receiver correlators to pull the desired signal out of the noise. The SF determines the degree of spreading gain. For high data rate signals, the SF and spreading gain are lower. For the same level of interference, the amplitude for high data rate channels must be higher, in order for all channels to maintain equal energy-per-bit-to-noise ratio (E_b/N_o).

SFs may be reassigned as often as every 10 ms. This allows the W-CDMA network to dynamically reassign bandwidth that would otherwise be wasted. In effect, the total data capacity within W-CDMA can be allocated in a more efficient manner as compared with 2G CDMA systems (IS-95) that use fixed-length orthogonal codes.

1.4 Slots, frames, and power control

All W-CDMA uplink (UL) and DL data channels are segmented into time slots and frames. A slot is 666.667 µsec in length, equal in duration to 2560 chips of the system chip rate. Fifteen of these time slots are concatenated to form a 10 ms frame (Figure 3). The frame is the fundamental unit of time associated with channel coding and interleaving processes. However, certain time-critical information, such as power control bits, are transmitted in every time slot. This facilitates UE power control updates at a rate of 1500 adjustments per second to optimize cell capacity.

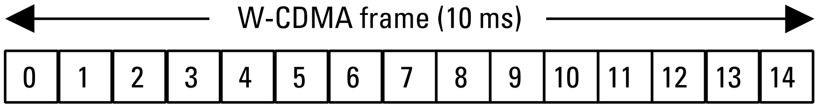


Figure 3. W-CDMA slot and frame structure

In any cellular CDMA system, the BTS must precisely control the transmit power of the UEs at a rate sufficient to optimize the link budget. This is referred to as UL power control. The goal is to balance the power received at the BTS from all UEs within a few dB, which is essential to optimizing the UL spread spectrum link budget. Unlike IS-95, the UE sends power control bits to the BTS at the same rate, and the BTS responds by adjusting the power of the data channels that are intended for the respective UE. This is referred to as DL power control.

1.5 Protocol structure

The protocol structure of the W-CDMA system closely follows the industry standard open system interconnection (OSI) model. Figure 4 shows the three bottom layers.

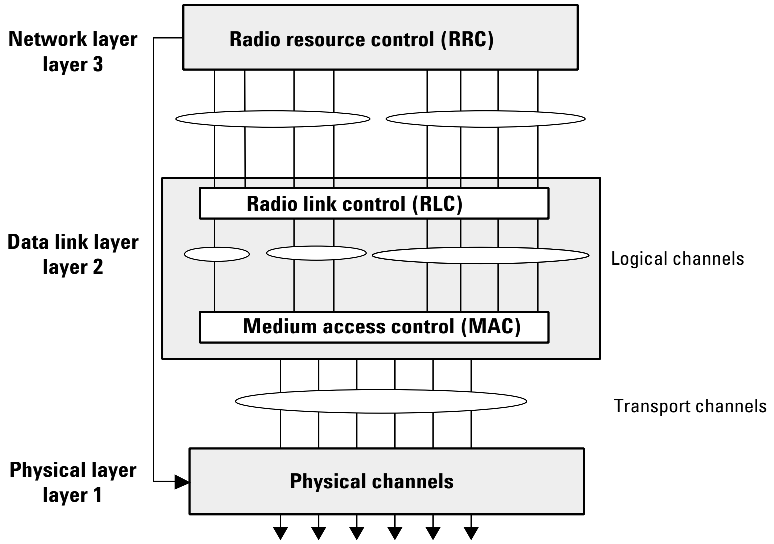


Figure 4. W-CDMA protocol structure

The network layer (layer 3) is based heavily on GSM standards. It is responsible for connecting services from the network to UE. The data link layer (layer 2) is composed of two main functional blocks: the radio link control (RLC) and medium access control (MAC) blocks **[3]**. The RLC block is responsible for the transfer of user data, error correction, flow control, protocol error detection and recovery, and ciphering. The MAC function at layer 2 is responsible for mapping between logical channels and transport channels (see following section). This includes providing for the multiplexing/de-multiplexing of various logical channels onto the same transport channel. The physical layer (layer 1) maps the transport channels onto the physical channels and performs all of the RF functions necessary to make the system work. These functions include operations such as frequency and time synchronization, rate matching, spreading and modulation, power control, and soft handoff. This application note focuses on layer 1 and refers to layer 2 briefly when appropriate. For more information on layer 2 refer to **[3]** and **[4]**. See **[5]** for information on layer 3. See **[6]** for more information on the protocol architecture.

1.6 Logical, transport, and physical channels

Logical channels are the information content, which will ultimately be transmitted over the physical channels. Logical channels include the Broadcast Control Channel (BCCH), the Paging Control Channel (PCCH), the Common Control Channel (CCCH), and Dedicated Control and Traffic Channels (DCCH, DTCH).

W-CDMA introduces the concept of transport channels to support sharing physical resources between multiple services. Each service, such as data, fax, voice, or signaling, is routed into different transport channels by the upper signaling layers. These services may have different data rates and error control mechanisms. The transport channels are then multiplexed as required prior to transmission via one or more physical channels. High data rate services or a combination of lower rate transport channels may be multiplexed into several physical channels. This flexibility allows numerous transport channels (services) of varying data rates to be efficiently allocated to physical channels. By multiplexing these transport channels efficiently, system capacity is optimized. For example, if the aggregate data rate of three transport channels exceeds the maximum of a single physical channel, then the data can be routed to two lower rate physical channels that closely match the total required data rate. Transport channels include the Broadcast Channel (BCH), the Paging Channel (PCH), the Forward Access Channel (FACH), the Dedicated Channel (DCH) and the Random Access Channel (RACH). **[7]**

The W-CDMA DL is composed of a number of physical channels. The most important DL physical channels are the Common Pilot Channel (CPICH), the Primary Common Control Physical Channel (P-CCPCH), the Secondary Common Control Physical Channel (S-CCPCH), and the Dedicated Physical Data and Control Channels (DPDCH/DPCCH). The UL consists of a Physical Random Access Channel (PRACH), a Physical Common Packet Channel (PCPCH), and Dedicated Physical Data and Control Channels (DPDCH/DPCCH). These channels are described in the following sections.

Figure 5 shows an example of channel mapping for the DL. When a UE is in the idle mode, the BTS sends dedicated signaling information from the DCCH logical channel through the FACH transport channel. This maps the information onto the S-CCPCH physical channel for transmission to a UE. When the UE is in the dedicated connection mode, the same signaling information is routed through the DCH transport channel. This maps the information onto the DPDCH/DPCCH physical channel for transmission to the UE.

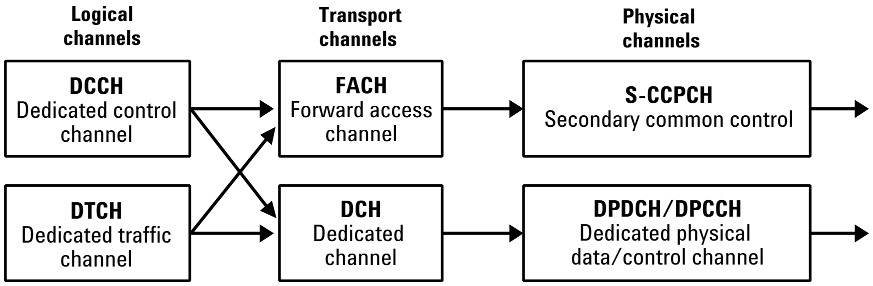


Figure 5. Example of logical, transport, and physical channel mapping (DL)

1.7 Downlink physical channels

Figure 6 shows the slot and frame structure for the CPICH, P-CCPCH and SCH.

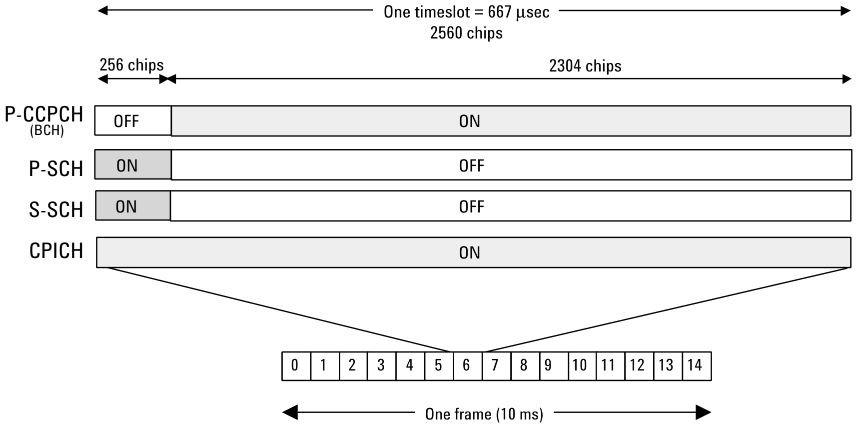


Figure 6. CPICH, P-CCPCH and SCH slot and frame structure

The CPICH is a continuous loop broadcast of the BTS scrambling code. As described earlier, the scrambling code provides identification of the BTS transmission. The UE uses the CPICH as a coherent reference for precise measurement of the BTS time reference, as well as to determine the signal strength of surrounding BTS before and during cell site handover. Since no additional spreading is applied to this signal, it is quite easy for the UE to acquire a lock to this reference. This must occur before any other channels can be received.

The P-CCPCH is time multiplexed with an important channel used by the UE during system acquisition, the Synchronization Channel (SCH). This carries two sub-channels, the Primary Synchronization Channel (P-SCH) and Secondary Synchronization Channel (S-SCH). These channels consist of two codes known as Primary Synchronization Code (PSC) and Secondary Synchronization Code (SSC). The PSC is a fixed 256-chip code broadcast by all W-CDMA BTS. During initial acquisition, the UE uses the PSC to determine if a W-CDMA BTS is present and establish the slot boundary timing of the BS. The SSC represents a group, called a code group, of 16 sub-codes, each with a length of 256 chips. The BTS transmits these codes in an established order, one SSC sub-code in each time slot of a frame. When a UE decodes 15 consecutive SSC transmissions, it can determine the BTS frame boundary timing, as well as derive information that will aid in the identification of the BTS scrambling code (see chapter 2). The SCH is transmitted during the first 256 chips of each time slot while the P-CCPCH is off (Figure 6). During the remaining 2304 chips of each slot the P-CCPCH is transmitted, which contains 18 bits of broadcast data (Broadcast

Transport Channel (BCH) information) at a rate of 15 kbps. Since the cell's broadcast parameters message will require more than 18 bits, the broadcast information may span several frames.

The Dedicated Physical Channel (DPCH) carries all the user data and user signaling, as well as physical channel control bits for the slot format and the UE inner loop power control. The DPCH consists of the DPDCH and the DPCCH (Figure 7). The user's digitized voice and/or digital data, along with layer 3 signaling data, are carried on the DPDCH. The user data and signaling data are individually treated with error protection coding and interleaving, then multiplexed together to form the DPDCH. The DPDCH is then multiplexed with the DPCCH, which contains the Transmit Power Control (TPC) bits (to control the UE transmit power), Transport Format Combination Indicator (TFCI) bits (indicates the slot format and data rate), and embedded Pilot bits (short synchronization patterns embedded within each slot).

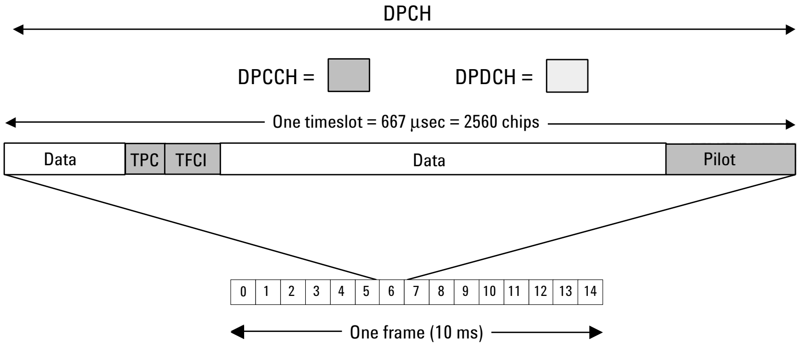


Figure 7. DPCH (DPDCH/DPCCH) slot and frame structure

Other DL channels include the Secondary Common Control Physical Channel (S-CCPCH), used to transmit pages and signaling to idling UEs; the Acquisition Indication Channel (AICH), used to acknowledge UE access requests; a Paging Indication Channel (PICH), used to alert the UE of a forthcoming page message; a Physical Downlink Shared Channel (PDSCH), used to dish out packet data to a number of UEs; and additional DPDCHs to increase DL data throughput for a single UE.

1.8 Uplink physical channels

The PRACH carries the RACH transport channel, which is used by the UE to request connection to the network as well as for intermittent services such as low duty cycle packet data. PRACH transmissions begin with a short preamble pattern that alerts the BTS of the forthcoming PRACH access message. The preamble consists of a complex signature and a scrambling code. The signature is a series of 16 bits that is repeated 256 times within a single preamble **[9]**. All BTS use the same 16 signatures. The BTS tells each UE which signature to use and then uses the signature to determine which UE it is communicating with. The scrambling code is used by the BTS to determine that the PRACH transmission is intended for that BTS. It can also allow the BTS to determine the access class of the UE. Access class is a means of establishing priority of access for different UE or different service types. In general, the preamble transmission can be initiated at any random instant and is therefore subject to collisions with other users. In this case, the UE will retransmit the preamble using different time access slots until acknowledgment is received.

The message part is transmitted as part of the PRACH after the UE receives acknowledgment from the BTS on the DL AICH. It consists of two parts: a control part and a data part. These two parts are transmitted in parallel. Figure 8 shows the message part structure. The control part carries the pilot and TFCI bits. The data part consists only of data bits that contain the information the UE wants to send to the network. The message part uses the same scrambling code used in the preamble.

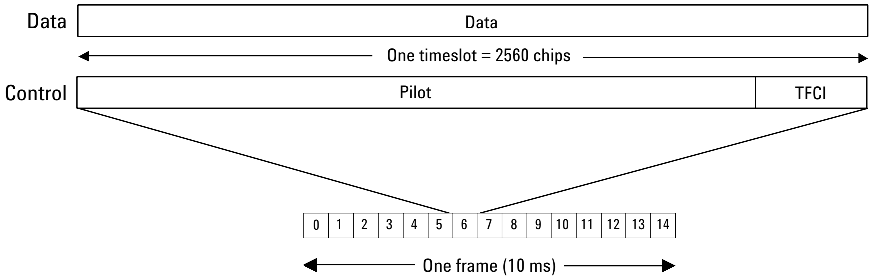


Figure 8. Structure of the message part in the PRACH

The PCPCH carries the CPCH transport channel and it is used for UL packet data transmission. The CPCH is an efficient way to send UL packet data since it requires fewer system resources as compared with a dedicated data channel. It is a random access channel and uses access procedures similar to the RACH. Since a packet transmission may span several frames, it is necessary for the BTS to control the PCPCH transmit power. After the CPCH access attempt is successfully acknowledged, the UE begins transmitting and the BTS responds with power control bits. Once the transmit power is stabilized, the UE will commence transmission of a multi-frame packet.

The UL DPDCH/DPCCH carries the user's digitized voice and data channels along with layer 3 signaling data. The payload data and signaling data (DPDCH) are transmitted on the "I" path of the QPSK modulator; the power control, pilot, and other overhead bits (DPCCH) are transmitted on the "Q" path. Figure 9 shows the slot structure of a DPDCH and a DPCCH. Multiple DPDCHs may be transmitted. In this case they are consecutively assigned to either the I or Q paths. Each channel is spread by an OVSF code and its amplitude can be individually adjusted. Before modulation, the composite spread signal is scrambled with a special function that minimizes the signal transitions across the origin of the IQ plane and the 0° phase shift transitions. This improves the peak-to-average power ratio of the signal **[8]**.

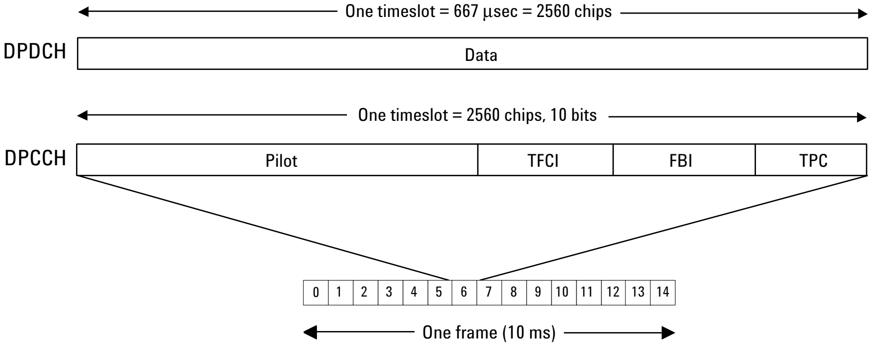


Figure 9. Uplink slot structure of a DPDCH and a DPCCH

1.9 Transport format detection

The number of possible arrangements of the W-CDMA air interface numbers in the millions. For any given connection only a small subset of these are needed. To make operation practical, that subset, known as the Transport Format Combination Set (TFCS), is communicated from the network to the UE at the time of connection setup. The TFCS includes all of the allowable Transport Formats (TF) and the associated data capacity for each of the channels that can be present in the link, and all of the allowable Transport Format Combinations (TFC) for the link. The Network's Radio Resource Control (RRC) entity provides this information to its lower layers. The UE's RRC entity does the same for its lower layers upon receiving the TFCS from the network.

Once this information is shared between the two, the transmitter can use it, along with the demands for transmission capacity from higher layers, to decide which channels shall be present and how each channel will be arranged in the radio frame. Likewise the receiver can use it to determine which channels are present and how to recover each channel that is present.

The W-CDMA system provides two methods to make this determination. The first of these is the inclusion of a Transport Format Combination Indicator (TFCI) in each radio frame. The second is Blind Transport Format Detection (BTFD).

When TFCI is used, the transmitting side determines which Transport Format Combination it will use. It then includes the TFCI, which is an index to the list of allowable combinations in the TFCS, in the control portion of the DPCH. The receiver always knows how to recover the TFCI, which it then uses to determine which channels to try to recover and how to decode each one.

When BTFD is used, the receiver must try every allowable TFC in the TFCS to determine which one results in the least errors.

1.10 Downlink DPDCH/DPCCH coding and air interface

Figure 10 shows an example of the coding, spreading, and scrambling for the DPCH. In this example, a 12.2 kbps voice service is carried on a DTCH logical channel that uses 20 ms frames. After channel coding, the DTCH is coded with a 1/3 rate convolutional encoder. In this example, the data is then punctured (rate matching) and interleaved. At this point, the DTCH is segmented into 10-ms frames to match the physical channel frame rate. The DCCH logical channel carries a 2.5 kbps data stream on a 40 ms frame structure. The DCCH is coded in the same manner as the DTCH. Frame segmentation for the DCCH involves splitting the data into four 10-ms segments to match the physical channel frame rate. The DTCH and DCCH are multiplexed together to form the Coded Composite Transport Channel (CCTrCH). The CCTrCH is interleaved and mapped onto a DPDCH running at 42 kbps.

In this example, the DPCCH is running at a rate of 18 kbps. The DPDCH and DPCCH are time multiplexed together (DPCH) to form a 60 kbps stream. This stream is converted into separate I and Q channels with a symbol rate of 30 ksps for each channel. The DPCH is spread with an OVSF code with spread factor equal to 128 (to reach the desired 3.84 Mcps), which differentiates the signal from others within the cell or sector. After that process, it is complex scrambled with a code that identifies each cell or sector. The resulting I and Q signals are then filtered with a root-raised cosine (RRC) filter of a = 0.22 and used to modulate the RF carrier (not shown in the figure).

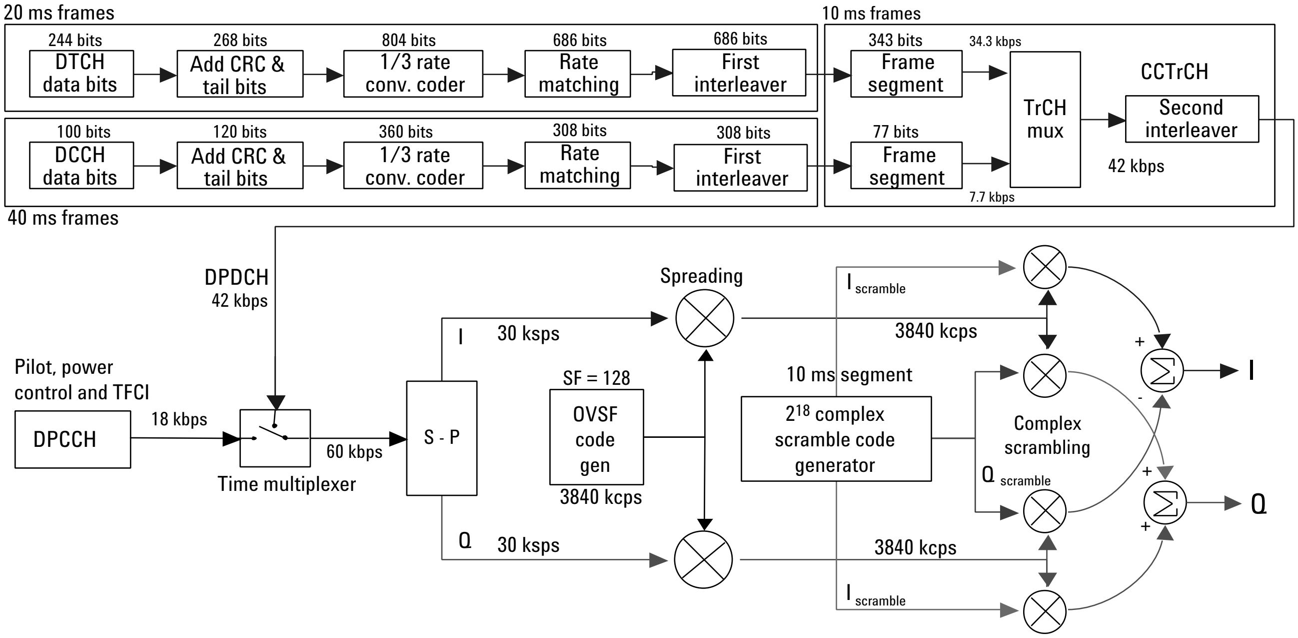


Figure 10. Downlink DPDCH/DPCCH coding, spreading, and scrambling. (For an alternative description, refer to [2], [9], and [10])

1.11 Uplink DPDCH/DPCCH coding and air interface

The spreading and scrambling used on the UL DPDCH/DPCCH differ from the DL in two key areas: I/Q multiplexing and hybrid phase shift keying (HPSK) scrambling (instead of complex scrambling). Figure 11 shows an example of the coding and air interface for an UL DPDCH and DPCCH. In this example, the logical DTCH carries a 12.2 kbps voice channel and the logical DCCH carries a 2.5 kbps signaling channel. Each of these logical channels is channel coded, convolutionally coded, and interleaved. The DTCH uses 20-ms frames. At the frame segmentation point, the DTCH is split into two parts to conform with the physical layer's 10-ms frame structure. The DCCH, which operates with 40-ms frames, is split into four parts so that each signaling frame is spread over four 10-ms radio frames. These channels are then punctured (rate matching) and multiplexed prior to spreading. The multiplexed data at this point is called the Coded Composite Transport Channel (CCTrCH). After a second interleaving, the CCTrCH is mapped onto a DPDCH running at 60 kbps. The DPDCH is spread with an OVSF code with spread factor equal to 64 in order to reach the desired 3.84 Mcps. After gain scaling (to adjust the transmission power for the variable spreading factor), the spread DPDCH is applied to the I channel.

The data rate for the UL DPCCH is always 15 kbps. The DPCCH data is spread with an OVSF code with SF = 256 to reach the 3.84 Mcps rate and is gain scaled in this example to be –6 dB relative to the DPDCH. The DPCCH is then applied to the Q channel. If additional DPDCHs were present they would be assigned to I or Q and spread with the appropriate OVSF code. Before modulation, the composite spread signal is scrambled with a special complex function that limits the signal transitions across the origin of the IQ plane and the 0° phase shift transitions. This improves its peak-to-average power ratio. This function can be considered a variation of regular complex scrambling and is commonly known as HPSK, although this term is not mentioned in the 3GPP specifications. The scrambling generator produces two random sequences (referenced in the 3GPP specifications as $C_{long,1}$ and $C_{long,2}$, if long scrambling sequences are used **[9]**). The second sequence is decimated, multiplied by the function {1,-1} and by the first sequence, and applied to the Q path of the complex scrambler. The first sequence is applied to the I path of the complex scrambler. For a more detailed description of HPSK please refer to **[8]**.

The resulting I and Q signals are then filtered with an RRC filter (α = 0.22) and used to modulate the RF carrier (not shown in the figure).

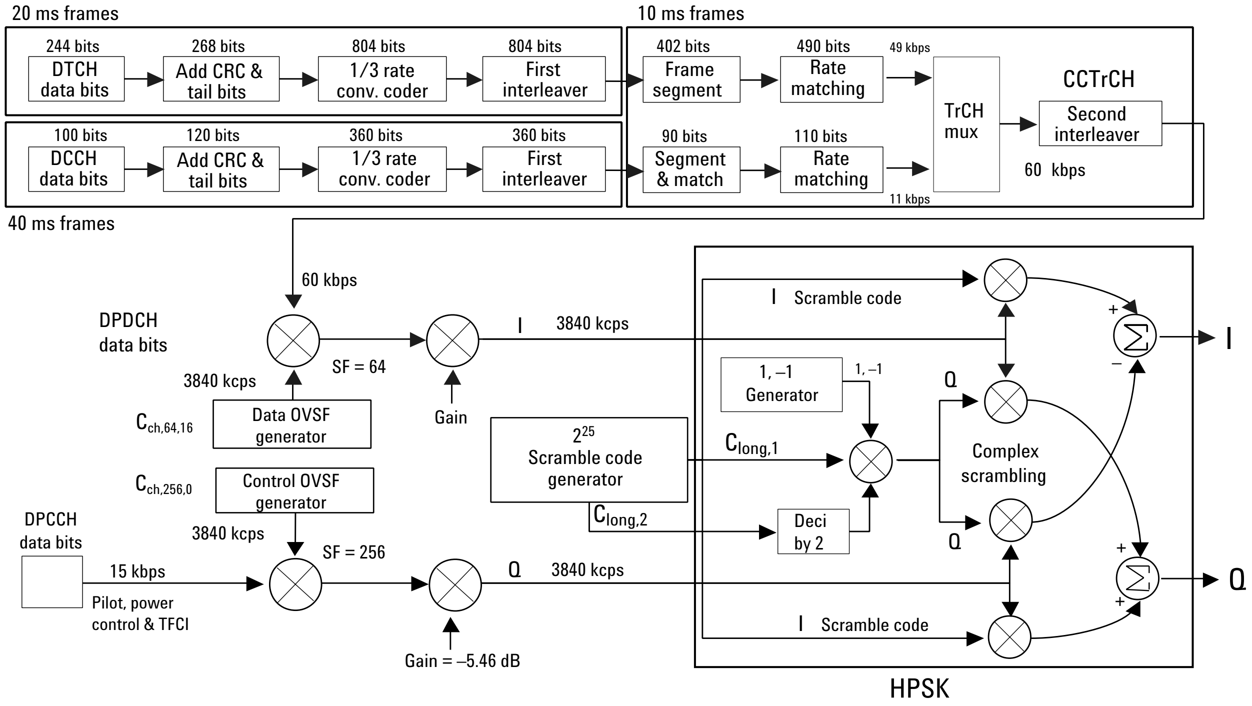


Figure 11. Uplink DPCH/DPCCH coding, spreading, and scrambling. (For an alternative description, refer to [2], [9], and [10])

1.12 Reference measurement channels

In order to avoid ambiguity and inconsistency across different equipment suppliers, the 3GPP specifications define the UL and DL channel configurations to use for UE transmitter and receiver conformance testing, respectively **[12]**. These configurations are called reference measurement channels. There are four DL reference measurement channels and five UL reference measurement channels. All of them consist of a DPDCH and a DPCCH. The main difference between the four DL or five UL reference measurement channels is the information bit rate for the DTCH logical channel (12.2 kbps, 64 kbps, 144 kbps, and 384 kbps). A 768 kbps information bit rate is also available for the UL only.

The data rates in the channel configuration example in Figure 10 correspond to the 12.2 kbps DL reference measurement channel. The data rates in the channel configuration example in Figure 11 correspond to the 12.2 kbps UL reference measurement channel. The 12.2 kbps UL (or DL) reference measurement channel is the test channel configuration specified for most UE transmitter (or receiver) conformance tests. Appendix A provides the complete structure and parameter description for the 12.2 kbps UL and DL reference measurement channels as they appear in the 3GPP specifications **[12]**.

1.13 Compressed mode

Compressed mode allows the BTS and UE to momentarily stop transmitting a particular DPCH. This enables the UE to make signal strength measurements on other frequencies, as would be needed to perform an inter-frequency or inter-system (hard) handover. One to seven slots per frame can be allocated for the UE to perform these measurements. These slots can be in the middle of a single frame or spread over two frames. The portions of the frame where the power is turned off are referred to as Discontinuous Transmission (DTX) in the specifications.

The 3GPP specifications define three different methods to achieve compressed mode:

- Reducing the SF by 2 (shorter OVSF code). The data is transmitted at a higher rate to make room for DTX.
- Reducing the symbol rate by puncturing the output of the error correction encoder to reduce the number of bits per frame to a number that can be carried by the smaller number of symbols available in the compressed radio frame. This method is only used in the DL.
- Higher layer scheduling. The data rate from higher layers in the protocol is limited by restricting the TFCs that can be used and delaying the transmission of some data. This effectively reduces the number of timeslots for user traffic.

For more information on compressed mode refer to **[2]**.

1.14 Asynchronous cell site acquisition

Other CDMA systems use GPS to precisely synchronize the time reference of every BTS. This provides the benefit of simplifying acquisition and inter-cell handover. In particular, the scrambling codes, short PN codes, used by IS-95 BTS are uniquely time-delayed versions of the same code. A time-delayed version of a PN code behaves as if it were a statistically independent code, so each BTS can therefore be distinguished based on a simple time offset measurement rather than a complicated search through multiple codes. Furthermore, soft handover is simplified since the frame timing of every BTS is closely synchronized. This technique, while simplifying UE operation, requires GPS synchronization and code offset planning at the cell sites in order to insure that no PN code can be confused with another after undergoing propagation delay.

One of the W-CDMA design goals was to remove the requirement for GPS synchronization. Without dependence on GPS, the system could potentially be deployed in locations where GPS is not readily available, such as in a basement of a building or in temporary locations. W-CDMA accomplishes this asynchronous cell site operation through the use of several techniques.

First, the scrambling codes in W-CDMA are Gold codes rather than PN codes. In W-CDMA, the Gold codes are unique codes rather than time offsets of the same code. Therefore, precise cell site time synchronization is not required. There are, however, 512 unique Gold codes allocated for cell site separation. The UE must now search through a number of scrambling codes, rather than simply searching through various time offsets of the same code. In order to facilitate this task, the SSC in the S-SCH channel is used to instruct the UE to search through a given set of 64 Gold codes. Each set represents a group of eight scrambling codes (64 x 8 = 512). The UE then tries each of the eight codes within each code group, in an attempt to decode the BCH. The ability to recover the BCH information (system frame number) completes the synchronization process.

1.15 Asynchronous cell site soft handover

In CDMA soft handover, a UE can establish simultaneous communication with several BS. During soft handover the combined signals from each BTS are individually correlated and then combined. As such, communication is possible in situations where an individual signal from a single BTS might otherwise be too weak to support the radio link.

With each W-CDMA BTS operating on an asynchronous clock, soft handover is complicated by the fact that frame timing between BTS is not explicitly coordinated. The UE could therefore have a difficult time combining frames from different BTS. To get around this problem, the W-CDMA UE measures the frame timing differential between the originating BTS and the handover target BTS. The UE reports this frame timing back to the network, which then issues a frame timing adjustment command to the target BTS. The target BTS adjusts the frame timing of the DPDCH/DPCCH channel that is being transmitted so the UE receives the target BTS frames in close time alignment with the corresponding frames from the originating BTS. With this time alignment feature, the UE's rake receiver is able to track the received signals from both BTS.

2 General Design and Measurement Issues

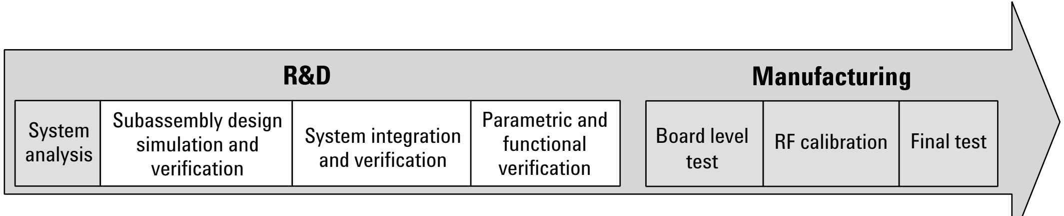


Figure 12. Generic diagram for the R&D and manufacturing phases of a UE

Figure 12 shows a generic diagram for the R&D and manufacturing phases of a UE. This chapter focuses on the development phase of the UE, highlighted in white. However, it does contain general information that may be useful to engineers involved in any area of the UE life cycle.

This chapter provides information about some of the most critical tests required during the UE design and verification. This includes some of the tests in the conformance specifications **[12]**, and other measurements that are required to verify the UEs functionality or to troubleshoot problems in the design. Mention of the corresponding conformance test in the specifications is included when appropriate.

In order to perform the transmitter and receiver conformance tests as required by the specifications, a call must be set up and the UE must be entered into loopback test mode. This implies that a single instrument known as system simulator (SS) is used to send the appropriate stimulus and to measure the response back from the UE. It also implies that all the UE hardware and functionality is available. Depending on the UE design stage, this might or might not be true. For this reason, the test descriptions in the AN do not assume that loopback test mode is used. This means that the tests described in the AN can generally be performed using either one instrument (one-box tester or SS) or two (signal generator and spectrum analyzer or power meter), although in the later case the measurements do not strictly follow the procedures defined in the specifications. Most of the measurements can even be performed in simulation. Refer to Appendix B for a list of the W-CDMA test capabilities available for Agilent's one-box testers (or SS), signal generators, signal analyzers, power meters, and design and simulation software.

2.1 Controlling interference

In CDMA systems, each active user communicates at the same time, on the same frequency. Because each user uses a different spreading code, they look like random interference to each other. The capacity of the system is ultimately determined by the minimum operating signal to interference ratio (SIR) of the receiver. But, whatever the budget is, the number of users that can coexist in one frequency channel depends on the level of interference generated by each user. This is a statistical quantity that depends on many factors, ranging from network topology down to how a user holds his or her phone. As a result, system design has proven to be heavily dependent on detailed simulations.

Two important performance factors that can be specified, measured, and controlled are adjacent channel interference and average power. Power leakage from adjacent channels contributes to the noise floor of the channel. It directly reduces the available margin and hence system capacity. Fast and accurate power control is also critical to the performance of a CDMA system because a user transmitting at higher power than is necessary to achieve a satisfactory error rate, even for a short time, reduces system capacity.

The following sections describe some of the key tests to characterize these RF power performance factors.

2.1.1 Average RF power

Average RF power will probably remain the preferred measurement for manufacturing test, even for sophisticated modulation schemes such as CDMA; but for any modulated signal, average RF power is only part of the picture. In the research and development phase, engineers are interested in peak power, peak to average power ratio (PAR), and, particularly for CDMA, power statistics such as the complementary cumulative distribution function (CCDF)—described later in the chapter. Relatively recently, power meters and analyzers have started to provide these additional measurements.

It is instructive to take a brief look at some of the power meter and sensor design challenges presented by high-bandwidth modulated RF signals. For a more detailed explanation see **[13]**.

The most common sensor technologies used for general use are thermocouple and diode sensors. Thermocouple sensors are heat-based sensors, so they are true averaging detectors regardless of the bandwidth or modulation complexity of the signal. Their dynamic range, however, is limited to 50 dB maximum. They also take longer to settle before measurements are accurate. Therefore, they are not good for pulse (peak power) measurements.

Diode sensors use the square law part of a diode's transfer characteristic as a detector (see Figure 13).

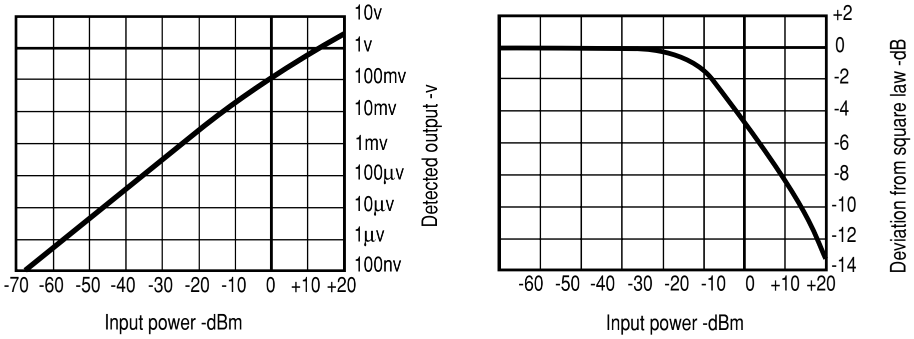


Figure 13. The diode detection characteristic ranges from square law, through a transition region, to linear detection

By employing post-detection correction techniques, the transition and linear parts of the diode's characteristic can also be used for detection. This results in a larger dynamic range, typically 90 dB, from –70 to +20 dBm. However, when the signal is above the square law region (typically –20 dBm), this approach is only accurate for continuous wave (CW) signals.

Alternatively, diode power sensors have recently been developed that achieve a true square law response over the whole dynamic range **[14]**. This alternative ensures accurate average RF power measurement for any bandwidth of signals within the frequency range of the sensor.

The major advantage of the power meter approach is accuracy over a wide dynamic range, down to a few tenths of a dB, provided care is taken while performing the measurement. It also provides measurement traceability to national standards. A potential disadvantage is that, since the power meter makes broadband measurements, you need to make sure that unwanted signals are not included.

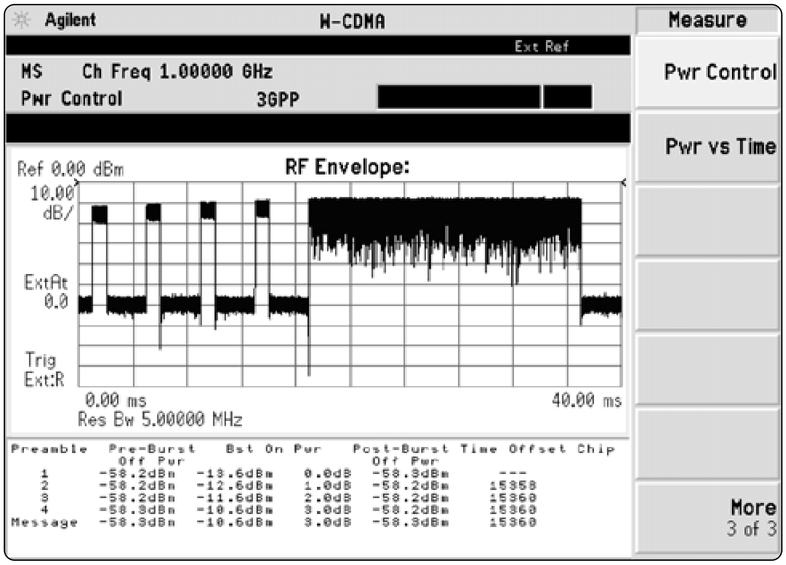
The other solution is to measure average power using a signal analyzer with a channel power measurement. The amplitude accuracy in this case depends on the instrument. For some analyzers, the absolute amplitude accuracy is as low as 0.6 dB (similar to the power meter's accuracy). For others, the accuracy can be more than ±1 dB, though the relative accuracy is usually much better than ±1 dB. An advantage of the analyzer approach is that it often provides a much larger suite of measurements, including modulation quality analysis.

The specification for *5.2 maximum output power* in **[12]** requires the power be measured over a bandwidth of at least (1 + a) times the chip rate and over at least one time slot.

2.1.2 Power control in the uplink

Power control limits the transmitted power level resulting in minimized interference levels and greater system capacity. In the UL, the objective is to optimize the power that each UE transmits to ensure proper communication. An excess error of the power control decreases the system capacity. There are three different power control loops in the UL: outer loop power control, open loop power control, and inner loop power control. Outer loop power control is used by the network to set a signal quality level based on the desired Quality of Service (QoS) **[20]**.

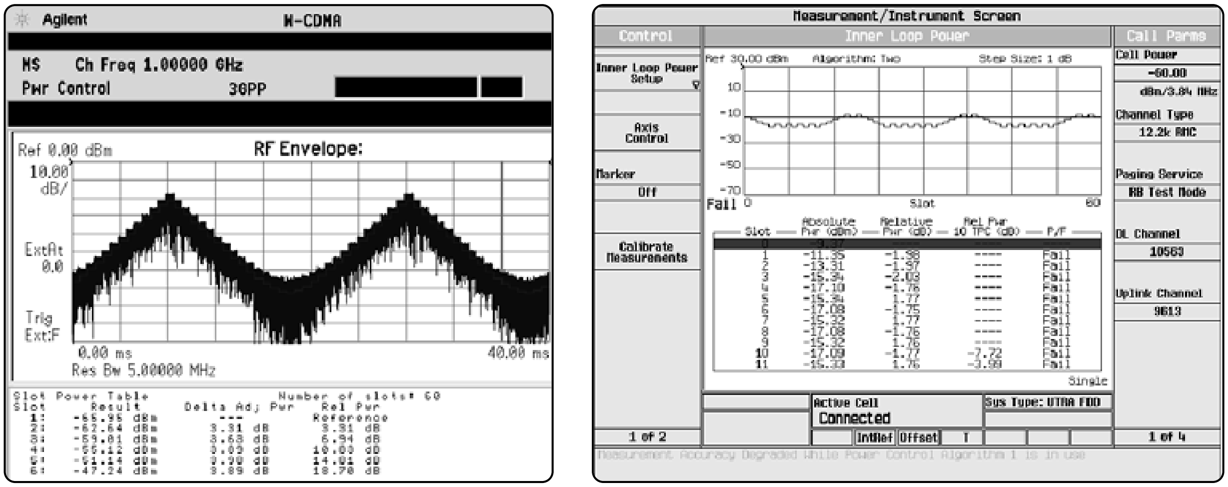
Open loop power control is used only during initial access of the UE to the network or when UL transmission needs to be interrupted; such as, during a hard handoff. The power used for PRACH transmission is adjusted by the UE based on the power measured by the UE on the received signal and the signaled BCCH information from the BTS. The UE open loop power control tolerance must not exceed the values described in the specifications (see *5.4.1 Open loop power control in the uplink* in **[12]**). Figure 14 shows a display of an open loop power control measurement on the PRACH.



Preamble	Pre-Burst Off Pwr	Bst On Pwr		Post-Burst Off Pwr	Time Offset Chip
1	-58.2dBm	-13.6dBm	0.0dB	-58.3dBm	---
2	-58.2dBm	-12.6dBm	1.0dB	-58.2dBm	15358
3	-58.2dBm	-11.6dBm	2.0dB	-58.2dBm	15360
4	-58.3dBm	-10.6dBm	3.0dB	-58.2dBm	15360
Message	-58.3dBm	-10.6dBm	3.0dB	-58.3dBm	15360

Figure 14. Open loop power control measurement

Inner loop power control (also called fast closed loop power control) operates rapidly in real time to maintain the desired signal quality level. Inner loop power control in the UL is used during regular UE transmission. In order to minimize interference, the UE transmitter adjusts its output power in accordance with TPC commands received in the DL. Power control commands are sent at every slot. The UE transmitter must be capable of changing the output power with a step size of 1 dB, 2 dB, or 3 dB (the latter is only used in compressed mode), in the slot immediately after the received TPC command can be derived. The UE inner loop power control size and response must meet the values described in the specifications (see 5.*4.2 Inner loop power control in the uplink* in **[12]**). This test also verifies that the UE derives the received TPC commands correctly. Figure 15 shows two inner loop power control measurement examples.



```
Slot Power Table                     Number of slots: 60
Slot      Result        Delta Adj Pwr      Rel Pwr
                                           Reference
  1:    -65.95 dBm          ---
  2:    -62.64 dBm        3.31 dB           3.31 dB
  3:    -59.01 dBm        3.63 dB           6.94 dB
  4:    -55.12 dBm        3.09 dB          10.83 dB
  5:    -51.14 dBm        3.98 dB          14.81 dB
  6:    -47.24 dBm        3.89 dB          18.70 dB
```

(a)

```
         Absolute    Relative     Rel Pwr
  Slot   Pwr (dBm)   Pwr (dB)   10 TPC (dB)   P/F
    0     -9.37        ----        ----       ----
    1    -11.35       -1.98        ----       Fail
    2    -13.31       -1.97        ----       Fail
    3    -15.34       -2.03        ----       Fail
    4    -17.10       -1.76        ----       Fail
    5    -15.34        1.77        ----       Fail
    6    -17.08       -1.75        ----       Fail
    7    -15.32        1.77        ----       Fail
    8    -17.08       -1.76        ----       Fail
    9    -15.32        1.76        ----       Fail
   10    -17.09       -1.77       -7.72       Fail
   11    -15.33        1.76       -3.99       Fail
```

Measurement Accuracy Degraded While Power Control Algorithm 1 is in use

(b)

Figure 15. Inner loop power control measurement example (a) using a spectrum analyzer (a signal generator was used to provide the power control commands) and (b) using a one-box tester

2.1.3 Adjacent channel interference

Depending on the context, the acronym ACP(R) has been taken to mean either adjacent channel power (ratio), which is a transmitter measurement or adjacent channel protection (ratio), which is a receiver measurement. To resolve this ambiguity, 3GPP has introduced three new terms: adjacent channel leakage power ratio (ACLR), adjacent channel selectivity (ACS), and adjacent channel interference ratio (ACIR).

ACLR is a measure of transmitter performance. It is defined as the ratio of the transmitted power to the power measured after a receiver filter in the adjacent RF channel. This is what was formerly called adjacent channel power ratio.

ACS is a measure of receiver performance. It is defined as the ratio of the receiver filter attenuation on the assigned channel frequency to the receiver filter attenuation on the adjacent channel frequency.

ACIR is a measure of overall system performance. It is defined as the ratio of the total power transmitted from a source (BTS or UE) to the total interference power resulting from both transmitter and receiver imperfections affecting a victim receiver. ACIR is mainly of interest in network simulation where the total amount of interference, rather than the source of the interference, is the primary concern. This is what was formerly called adjacent channel protection ratio.

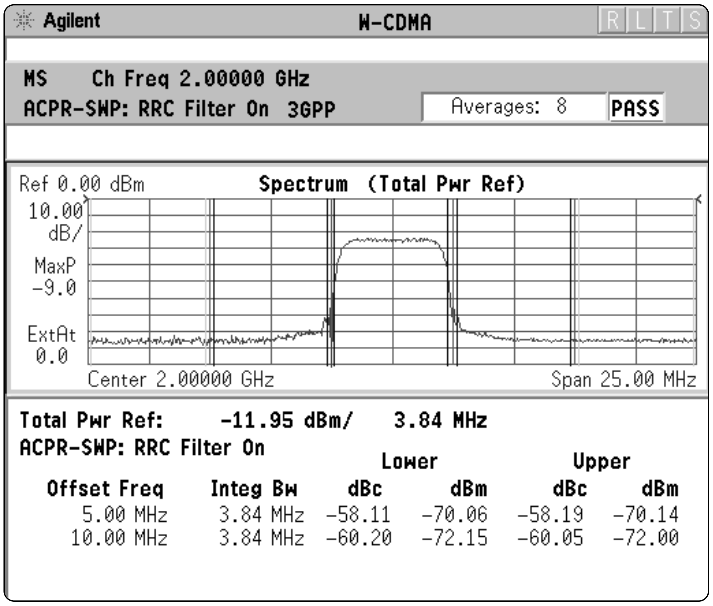
The following equation shows the relationship between ACIR, ACLR, and ACS:

$$\mathrm{ACIR} = \frac{1}{\frac{1}{\mathrm{ACLR}} + \frac{1}{\mathrm{ACS}}}$$

The main source of adjacent channel leakage (ACL) is non-linear effects in the power amplifiers (PA). It directly affects the co-existing performance of systems on adjacent channels. Power leakage is a general noise pollution and degrades performance of the system in the adjacent channel. If sufficiently bad, it causes the so called “near-far” problem, where a UE simply cannot communicate with a far away BTS because of high ACL from a nearby adjacent channel UE. Network planning can address this problem, but the associated costs depend directly on the stringency of the ACLR specification. So, we have conflicting needs. From an equipment design perspective, a relaxed ACLR specification is attractive, whereas from a network planning perspective, low ACL is very desirable.

There has been much discussion of this within the specifications committee. The current values in the 3GPP specifications for the UE are 33 dB (or –50 dBm, whichever represents a lower leakage power) at 5 MHz offset and 43 dB (or –50 dBm, whichever represents a lower leakage power) at 10 MHz offset.

ACLR (or ACPR) is commonly measured using a signal analyzer or measuring receiver. In the measurement, filtering is applied to both the power in the main frequency channel and the power in the adjacent channel. An important factor for ACLR is the specification of the measurement filter, including its bandwidth and shape. Original W-CDMA specifications called for a rectangular filter, but this has now changed to a RRC filter with a –3 dB bandwidth equal to the chip rate **[12]**. This provides an closer indication to real-life performance. However, it requires the measuring instrument to apply precise filter weighting. This may preclude making the measurement with existing spectrum analyzers that do not have W-CDMA ACLR capability, although, in reality, the difference in the measurement result is very small (around 0.1 dB). Figure 16 shows an ACLR measurement for a W-CDMA UE transmitter. The measurement was performed using a vector signal analyzer with the appropriate RRC filter, as specified. (See *5.10 ACLR* in **[12]**.)



```
MS    Ch Freq 2.00000 GHz
ACPR-SWP: RRC Filter On  3GPP          Averages: 8

Total Pwr Ref:      -11.95 dBm/    3.84 MHz
ACPR-SWP: RRC Filter On
                                  Lower             Upper
  Offset Freq     Integ Bw     dBc      dBm      dBc      dBm
     5.00 MHz     3.84 MHz   -58.11   -70.06   -58.19   -70.14
    10.00 MHz     3.84 MHz   -60.20   -72.15   -60.05   -72.00
```

Figure 16. ACLR measurement for W-CDMA UE transmitter using a RRC filter as specified [12]

2.2 Maximizing battery life

ACLR is a key parameter, but why is it a particular challenge to maintain good ACLR performance for a W-CDMA UE?

In mobile communications, battery life is one of the most important characteristics of the handset. The efficiency of the power amplifier is key to maximizing battery life. Gaussian minimum shift keying (GMSK), used in GSM, has the advantage of having a constant amplitude envelope, which allows the use of less expensive, non-linear, class B power amplifiers (PA).

W-CDMA, on the other hand, uses a non-constant amplitude scheme, forcing the use of more expensive, less efficient, linear amplifiers. For W-CDMA, the PAR of the signal is a concern. The PAR is defined as the ratio of the peak envelope power to the average envelope power of a signal. A signal with a high PAR requires more headroom in the amplifier, which makes it less efficient. 2G non-constant amplitude formats, such as π/4 DQPSK (differential quadrature phase shift keying, used in PDC), minimize the PAR by avoiding signal envelope transitions through zero.

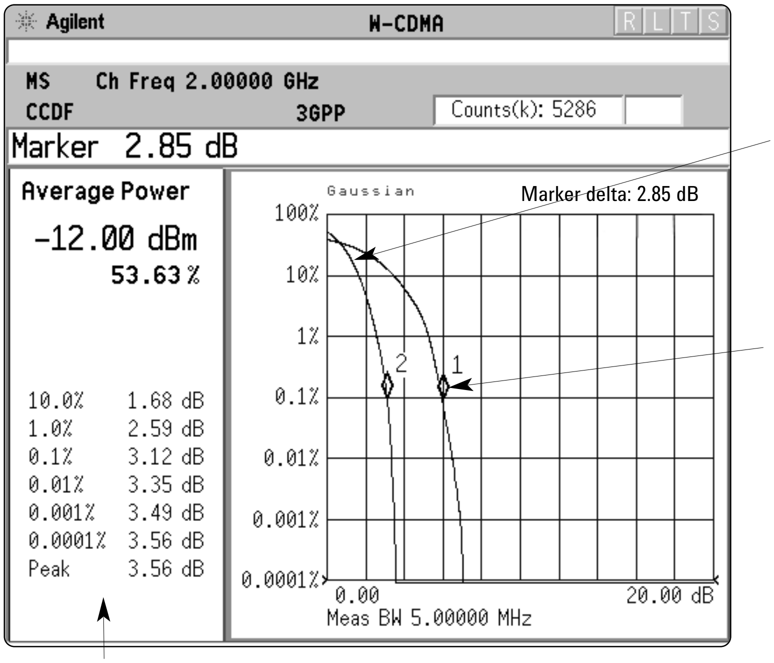
In W-CDMA the UE can transmit multiple channels to accommodate the high data rates. QPSK is used in combination with a spreading/scrambling function (HPSK) to minimize the PAR **[8]**. With this technique, the PAR for the basic configuration (one DPDCH and one DPCCH) is equal or larger than 3.6 dB during 0.1 percent of the time (see Figure 17).

However, even though HPSK reduces the PAR, the PAR still increases as code channels are activated. The worst case scenario would be when five or six channels are required (see code domain power section). Although, it is expected that this will only happen a small percentage of the time, it is still critical.

Both the amplifier designer and the system integrator must make sure that the PA (and other components) can handle the PAR that the signal exhibits for the different data rates, while maintaining a good ACL performance. You can use the complementary cumulative distribution function to help you with this job.

2.2.1 Complementary cumulative distribution function

The complementary cumulative distribution function (CCDF) fully characterizes the power statistics of a signal **[15]**. It provides PAR versus probability. Figure 17 shows the CCDF curves for two UL W-CDMA signals with different channel configurations. For a probability of 0.1 percent, the PAR of the signal with one DPCCH and five DPDCH is 2.85 dB higher than that of the signal with one DPCCH and one DPDCH.



MS Ch Freq 2.00000 GHz

CCDF 3GPP Counts(k): 5286

Marker 2.85 dB

Average Power

-12.00 dBm

53.63 %

10.0%	1.68 dB
1.0%	2.59 dB
0.1%	3.12 dB
0.01%	3.35 dB
0.001%	3.49 dB
0.0001%	3.56 dB
Peak	3.56 dB

W-CDMA UL signal with one DPCCH and one DPDCH

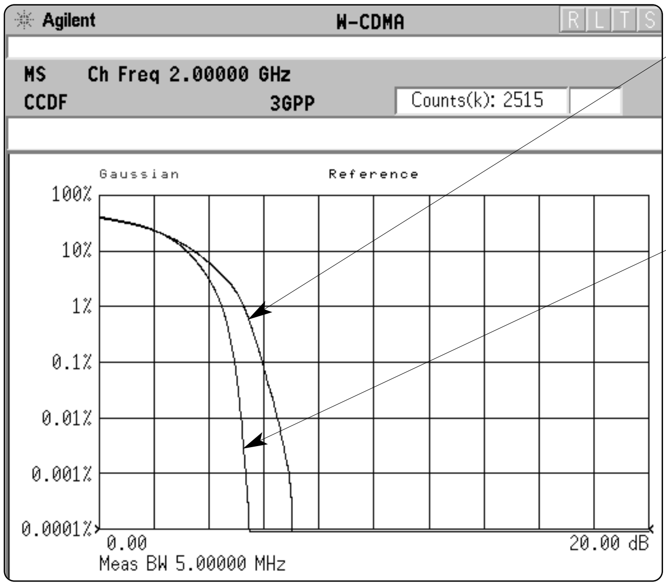
W-CDMA UL signal with one DPCCH and five DPDCH

PAR values for W-CDMA UL signal with one DPCCH and one DPDCH

Figure 17. CCDFs of an UL W-CDMA signal with a DPCCH and a DPDCH and an UL W-CDMA signal with a DPCCH and five DPDCHs

CCDF curves can help you in several situations:

- To determine the headroom required when designing a component **[15]**.
- To confirm the power statistics of a given signal or stimulus. CCDF curves allow you to verify if the stimulus signal provided by another design team is adequate. For example, RF designers can use CCDF curves to verify that the signal provided by the digital signal processing (DSP) section is realistic.
- To confirm that a component design is adequate or to troubleshoot your subsystem or system design, you can make CCDF measurements at several points of a system. For example, if the ACLR of a transmitter is too high, you can make CCDF measurements at the input and output of the PA. If the PA design is correct, the curves will coincide. If the PA compresses the signal, the PAR of the signal is lower at the output of the PA (Figure 18).



Amplifier input:
W-CDMA UL signal with
one DPCCH and five DPCH

Amplifier output:
W-CDMA UL signal with
one DPCCH and five DPDCH
(compressed signal)

Figure 18. CCDFs for a W-CDMA signal with a DPCCH and five DPDCH, with and without compression

2.3 Measuring modulation accuracy

In constant amplitude modulation schemes, such as GMSK, the phase and frequency error are the metrics for modulation quality. However, these metrics are not very effective for non-constant amplitude modulation formats that can also have errors in amplitude.

The accuracy of non-constant amplitude modulation schemes, such as quadrature amplitude modulation (QAM), or quadrature phase shift keying (QPSK), can be assessed very effectively by looking at the constellation of the signal. Signal impairment can be objectively assessed by taking the displacement of each measured symbol from the reference position as an error phasor (or vector), as shown in Figure 19.

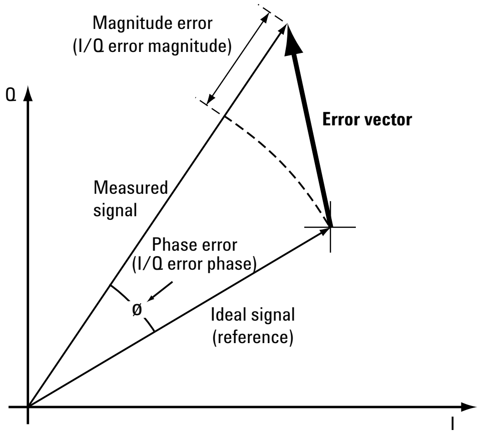


Figure 19. Error vector and related parameters

The reference position is determined from a reference signal that is synthesized by demodulating the data bits from the received signal and then remodulating these bits "perfectly" for a generic QPSK signal, as shown in Figure 20.

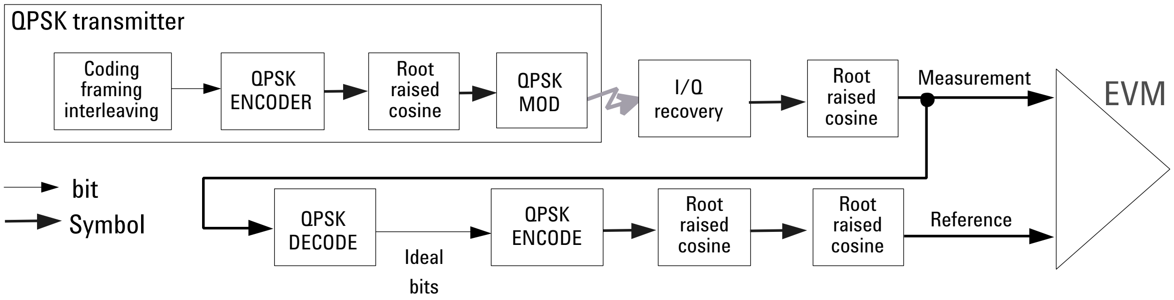


Figure 20. Process to calculate EVM for a generic QPSK signal

The root mean square (RMS) of the error vectors is computed and expressed as a percentage of the square root of the mean power of the ideal signal[1]. This is the error vector magnitude (EVM). EVM is a common modulation quality metric widely used in digital communication systems. (See **[16]** for more information on how to use EVM as a troubleshooting tool.)

When we consider evaluating the modulation accuracy of W-CDMA it becomes evident that this explanation of EVM, while sufficient for ordinary QPSK or QAM, needs further elaboration. Should we measure the EVM at the chip level or at the symbol level? Should we measure EVM for a signal with a single DPDCH channel or with another channel configuration? How do we calculate the reference?

---

1. The actual calculation method of the percentage depends on the specific standard. The EVM may be normalized to the amplitude of the outermost symbol, the square root of the average symbol power, or the square root of the mean power of the ideal signal. In the case of W-CDMA, the specifications require normalization to the square root of the mean power of the ideal signal (see section on Composite EVM).

The following sections explain the differences between the various EVM and other modulation quality measurements that you can perform on a W-CDMA signal and when they should be used. Figures 21, 23, and 30 show the processes to make the different measurements.

2.3.1 QPSK EVM

For a regular QAM or a PSK signal, the ideal symbol points always map onto a few specific locations in the I/Q plane. However, the W-CDMA UL signal can consist of multiple channels that are I/Q multiplexed. This means the bits for each channel are binary phase shift keying (BPSK) encoded[1] for either the I or the Q paths. Several channels can be added to the I and/or the Q paths. The resulting I and Q signals are then spread and scrambled with a special function (HPSK) (see Figure 11).

The complex-valued chip sequence is then filtered with an RRC ($\alpha = 0.22$) filter and the result is applied to the QPSK[2] modulator. The UE transmitter in Figure 21 illustrates this process.

The resulting constellation depends on the physical channel configuration. The constellation typically does not look like QPSK, or any other known constellation, except for some very specific channel configurations. For example, a signal with a single DPDCH (or a single DPCCH) does map onto a QPSK constellation. A signal with a DPDCH and a DPCCH at the same amplitude level maps onto a 45°–rotated QPSK constellation, as shown in Figure 22. Because the receiver does not care about the absolute phase rotation, it effectively sees a QPSK constellation.

You can use a regular QPSK EVM measurement to evaluate the modulation quality of the transmitter for a single DPDCH, a single DPDCH, or a signal with both at the same amplitude level. More complex signals cannot be analyzed with this measurement. QPSK EVM compares the measured chip signal at the RF with an ideal QPSK reference (see Figure 21).

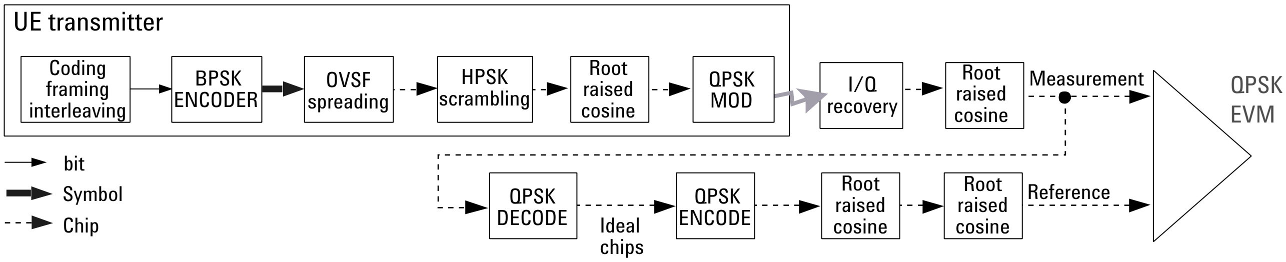


Figure 21. Process to calculate QPSK EVM for a W-CDMA UL signal

The QPSK EVM measurement does not descramble and despread the signal into symbols and back into chips to calculate the appropriate reference. Therefore, it can detect baseband filtering, modulation, and RF impairments, but does not detect OVSF spreading or HSPK scrambling errors.

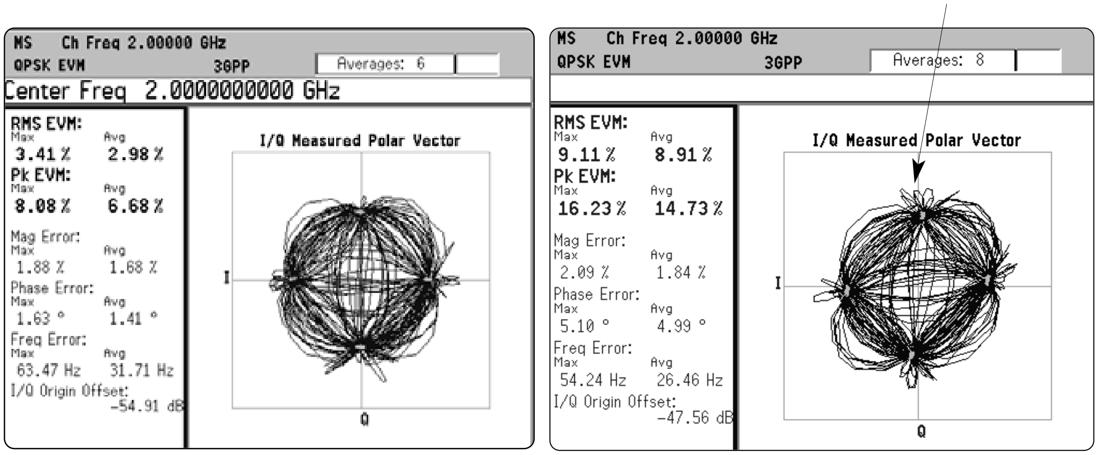
---

[1] BPSK encoding, in this case, refers to the process of mapping the bits for a channel onto the I (or the Q) path in serial. This means that the bits for a channel are directly converted into I (or Q) amplitude levels. For example, 1001 would be converted to 1 -1 -1 1.

[2] QPSK modulation, in this case, refers to the up conversion process of modulating the RF carrier with the I/Q baseband signal.

If it is impossible to despread and descramble the signal, the QPSK EVM measurement may be the only choice. In this sense, the QPSK EVM measurement can be useful to RF designers or system integrators to evaluate the modulation quality of the analog section of the transmitter when the spreading or scrambling algorithms are not available or do not work properly. For example, Figure 22 shows the QPSK EVM measurement and vector diagram for a W-CDMA UL signal (one DPDCH and a DPCCH at the same power level) with and without an I/Q quadrature error.

I/Q quadrature error causes
constellation distortion



```
MS    Ch Freq 2.00000 GHz
QPSK EVM              3GPP      Averages: 6
Center Freq  2.0000000000 GHz
RMS EVM:
Max        Avg
 3.41 %     2.98 %
Pk EVM:
Max        Avg
 8.08 %     6.68 %
Mag Error:
Max        Avg
 1.88 %     1.68 %
Phase Error:
Max        Avg
 1.63 °     1.41 °
Freq Error:
Max        Avg
 63.47 Hz   31.71 Hz
I/Q Origin Offset:
           -54.91 dB
```

```
MS    Ch Freq 2.00000 GHz
QPSK EVM              3GPP      Averages: 8
RMS EVM:
Max        Avg
 9.11 %     8.91 %
Pk EVM:
Max        Avg
 16.23 %    14.73 %
Mag Error:
Max        Avg
 2.09 %     1.84 %
Phase Error:
Max        Avg
 5.10 °     4.99 °
Freq Error:
Max        Avg
 54.24 Hz   26.46 Hz
I/Q Origin Offset:
           -47.56 dB
```

(a) (b)

Figure 22. Vector diagram and QPSK EVM measurement for an UL W-CDMA signal (one DPDCH and one DPCCH at the same amplitude level). (a) Transmitter without any impairment. (b) Transmitter with an I/Q quadrature error

Depending on the nature of the error, you can use the vector diagram, the error vector versus time or frequency, the magnitude error versus time, or the phase error versus time to troubleshoot it. For example, most I/Q impairments (such as the I/Q quadrature error in Figure 22) can be easily recognized by looking at the vector diagram. In-channel spurious signals can be detected by analyzing the error vector spectrum **[16]**.

2.3.2 Composite EVM

Although measuring EVM for a signal with a single DPDCH (or a DPDCH and a DPCCH) may be useful, in general, we are interested in the overall modulation quality of the transmitter for any channel configuration. The constellation of this signal will vary depending on its channel configuration. The measurement of choice in this case is the composite EVM measurement. It corresponds to the modulation accuracy conformance test specified in the 3GPP specifications **[12]**.

To evaluate the modulation accuracy of a W-CDMA multi-channel UL signal, we again need to synthesize a reference signal. The signal under test is downconverted (the baseband I and Q signals are recovered) and passed through a root raised cosine receiver filter. Active channels are descrambled, despread, and the BPSK is decoded to bits (see Figure 23).

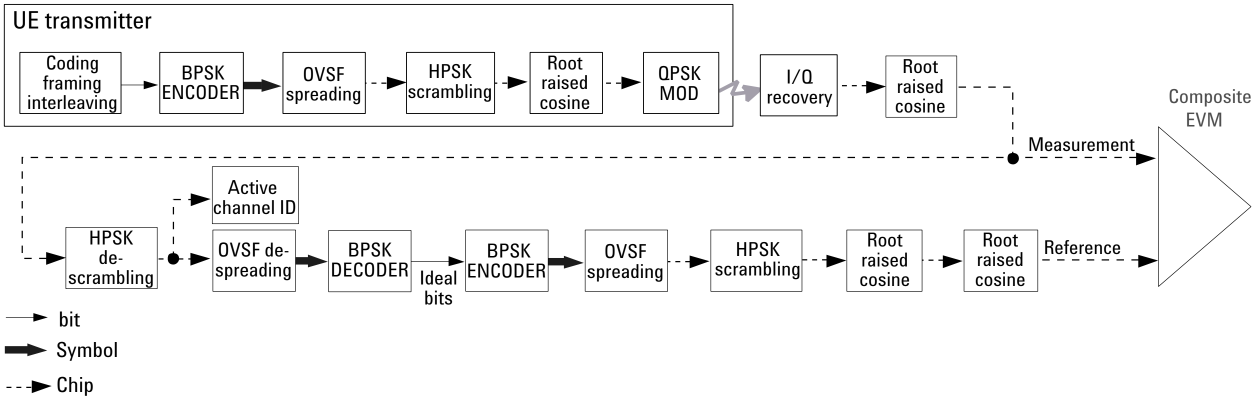


Figure 23. Process to calculate the composite EVM

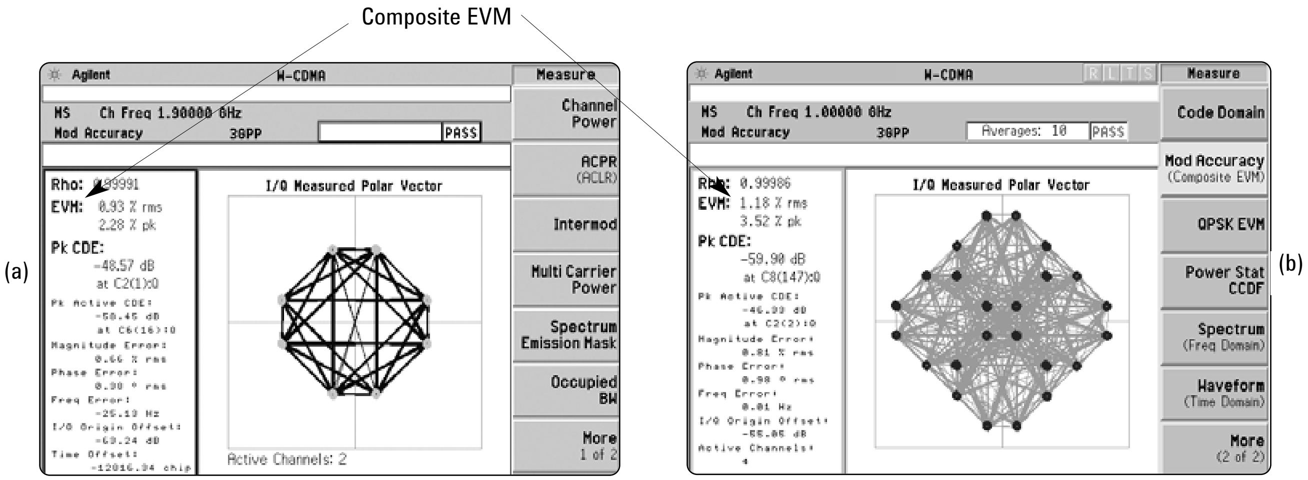
The despread bits are "perfectly" remodulated to produce the required reference signal at the chip level. The reference signal is then subtracted from the measured signal to produce a time record of error phasors. The square root of the ratio of the mean power of the error signal to the mean power of the reference signal is computed and expressed as a percentage EVM.

The composite EVM measurement accounts for all spreading and scrambling problems in the active channels and for all baseband, IF, and RF impairments in the transmitter chain.

A coded signal with the DPCCH and at least one DPDCH is required to make a composite EVM measurement on a W-CDMA UL signal. Otherwise, the analyzer cannot demodulate the signal and calculate the appropriate reference. In this case, you can use QPSK EVM to measure the RF performance for limited channel configurations, as mentioned earlier.

There are several situations were you will want to use the composite EVM measurement (and its related vector diagram, phase error and magnitude error metrics, etc.), instead of a QPSK EVM measurement:

1. **To evaluate the quality of the transmitter for a multi-channel signal.** This is particularly important for RF designers, who need to test the RF section (or components) of the transmitter using realistic signals with correct statistics. In general, the peak-to-average power ratio of the signal increases as the number of channels increases. By measuring modulation quality on a multi-channel signal you can analyze the performance of the RF design for W-CDMA UL signals with different levels of stress (different CCDFs). Evaluating the modulation quality of multi-channel signals is also important for the baseband designers to analyze the performance of multi-board baseband designs. For example, a small timing error in the clock synchronization between channels on different boards can be detected as a decrease in modulation quality. Figure 24a shows the composite EVM and vector diagram for the UL 12.2 kbps reference measurement channel, as required by the modulation accuracy test in the 3GPP specifications **[12]**. Figure 24b shows the composite EVM and vector diagram for a signal with the DPCCH and three DPDCHs.



(a)

MS Ch Freq 1.90000 GHz
Mod Accuracy 3GPP PASS

Rho: 0.99991
EVM: 0.93 % rms
2.28 % pk
Pk CDE:
-48.57 dB
at C2(1):0
Pk Active CDE:
-50.45 dB
at C6(16):0
Magnitude Error:
0.66 % rms
Phase Error:
0.30 ° rms
Freq Error:
-25.13 Hz
I/Q Origin Offset:
-63.24 dB
Time Offset:
-12016.94 chip
Active Channels: 2

(b)

MS Ch Freq 1.00000 GHz
Mod Accuracy 3GPP Averages: 10 PASS

Rho: 0.99986
EVM: 1.18 % rms
3.52 % pk
Pk CDE:
-59.90 dB
at C8(147):0
Pk Active CDE:
-46.93 dB
at C2(2):0
Magnitude Error:
0.81 % rms
Phase Error:
0.98 ° rms
Freq Error:
0.01 Hz
I/Q Origin Offset:
-55.05 dB
Active Channels:
4

Figure 24. Composite EVM and vector diagram for a signal with (a) UL 12.2 kbps reference measurement channel (one DPDCH and a DPCCH), and (b) three DPDCHs and a DPCCH

2. **To detect spreading or scrambling errors.** Depending on the degree of the error, the analyzer may show an intermittent unlock condition or may not be able to lock at all when trying to perform a composite EVM measurement. This is mainly useful to system integrators to determine errors in the spreading and scrambling. If this problem occurs, you can use the QPSK EVM measurement to confirm that the rest of the transmitter is working as expected. If the scrambling or spreading error does not cause an unlock measurement condition, you can use the error vector versus time display to find the problematic chip.

3. **To detect certain problems between the baseband and RF sections.** This is mainly useful for system integrators. You may be able to use QPSK EVM measurement to detect some of these problems. For example, LO instability caused by interference from digital signals can be detected with QPSK EVM. However, the QPSK EVM measurement will not detect problems that require the measurement to synchronize with a bit sequence. For example, I/Q swapped (reversed I and Q) errors will look perfectly normal if a QPSK EVM measurement is used. On the other hand, it will cause an unlock condition when performing a composite EVM measurement.

Composite EVM is useful throughout the development, performance verification, and manufacturing phases of the UE life cycle as a single figure of merit for the composite waveform as a whole. You will also be interested in the code-by-code composition of the multiplex. The primary means of investigating this is to look at the distribution of power in the code domain.

2.3.3 Code domain power

Code domain power is an analysis of the distribution of signal power across the set of code channels, normalized to the total signal power. To analyze the composite waveform, each channel is decoded using a code-correlation algorithm. This algorithm determines the correlation coefficient factor for each code. Once the channels are decoded, the power in each code channel is determined.

In W-CDMA, the measurement is complicated by the fact that the length of the OVSF codes, or SF, varies to accommodate the different data rates. As the user rate increases the bit period becomes shorter. Since the final chip rate is constant, fewer OVSF code chips are accommodated within the bit period—the SF becomes smaller. The SF can be 4, 8, 16, 32, 64, 128, or 256, corresponding to DPDCH bit rates from 960 kbps down to 15 kbps[1].

Seven sets of spreading codes are specified, one set for each SF. The OVSF codes can be allocated using the code tree in Figure 25. Each code is denoted by $C_{ch,SF,n}$. For example, $C_{ch,4,2}$ means channelization code, SF = 4, code number 2.

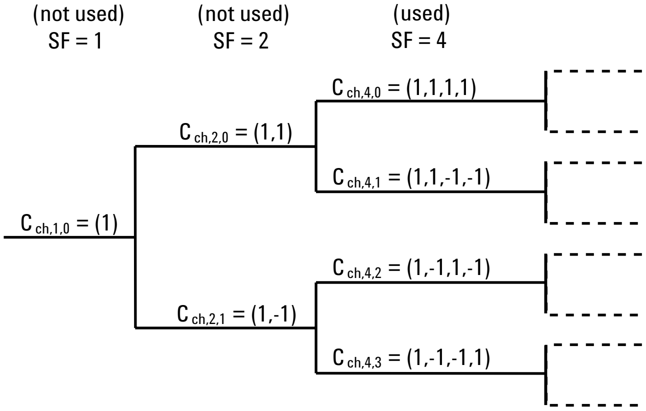


Figure 25. Code tree generation of OVSF codes [3]

In this tree, OVSF codes of a certain SF are obtained by copying the “mother-branch” code of the previous SF and repeating or inverting it. For example, $C_{ch,4,2}$ = (1,-1,1,-1) is obtained by repeating $C_{ch,2,1}$ = (1,-1), while $C_{ch,4,3}$ = (1,-1,-1,1) is obtained by copying $C_{ch,2,1}$ = (1,-1) and inverting it. This code generation technique is known as reverse-bit method.

One of the consequences of using variable SFs is that a shorter code precludes using all longer codes derived from it. Figure 26 illustrates this concept. If a high data rate channel using a code of SF = 4 (1, 1, -1, -1) is selected, all lower data rate channels using longer OVSF codes that start with 1, 1, -1, -1 have to be inactive because they are not orthogonal.

---

[1] The bit rate for the DPCCH is fixed at 15 kbps.

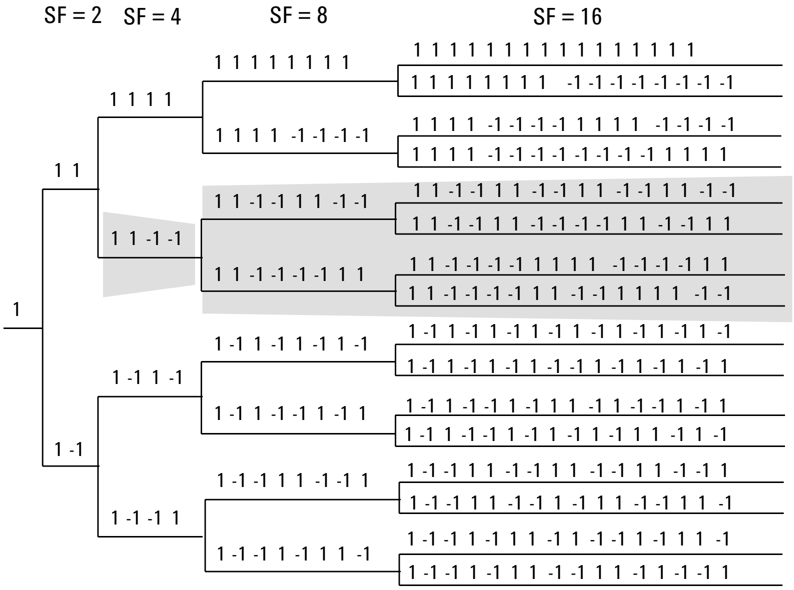


Figure 26. Effects of using variable SFs

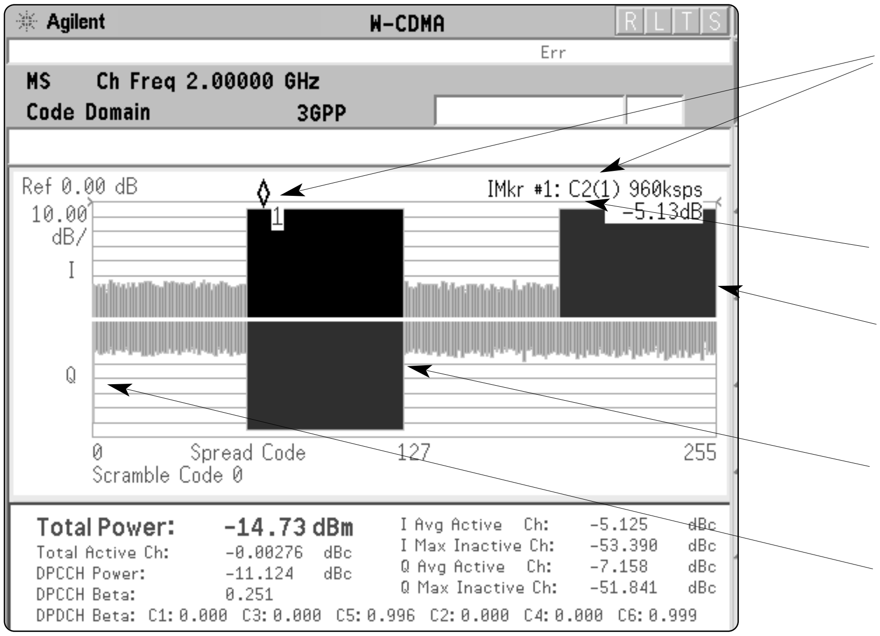
For the UL, as shown earlier, the physical channels are I/Q multiplexed. A special scrambling function (HPSK) is applied to limit the PAR. However, HPSK limits the choice of OVSF codes. In order to benefit from HPSK, the OVSF codes must consist of pairs of consecutive identical chips. For example, $C_{ch,4,1}$ = (1,1,-1,-1) would meet this condition, but $C_{ch,4,2}$ = (1,-1,1,-1) would not **[8]**.

Careful choice of OVSF codes can lead to lower PAR. Exhaustive simulations using CCDF curves (see earlier section) led to the following specifications for the OVSF codes **[9]**:

- The DPCCH is always spread by code $C_{ch,256,0}$ = (1,1,1,1,1,...).
- When only one DPDCH is to be transmitted, it is spread by code $C_{ch,SF,SF/4}$ = (1,1,-1,-1,1,1,-1,-1...).
- When more than one DPDCH is to be transmitted (because of high data rates), all DPDCHs have SFs equal to four. Two DPDCHs can share the same code, since one will be in I and the other one in Q, which makes them orthogonal.
  The channelization codes for the DPDCHs are defined as:
  - $C_{ch,4,1}$ = (1,1,-1,-1) for the first and second DPDCHs
  - $C_{ch,4,3}$ = (1,-1,-1,1) for the third and fourth DPDCHs
  - $C_{ch,4,2}$ = (1,-1,1,-1) for the fifth and sixth DPDCHs

Even though the OVSF codes where selected to maximize the benefits of HPSK, the HPSK requirements will be completely fulfilled only for the first two DPDCHs. The worst case of PAR will be when five or six channels are required to cover the high data rates. It is expected that this will only occur a small percentage of the time. However, this does not make solving the problem easier for the amplifier designer.

In terms of code capacity, channels with higher data rates (lower SF) occupy more code space. For example, $C_{ch,4,1}$ occupies two times more code space than $C_{ch,8,2}$, and four times more code space than $C_{ch,16,4}$. The wider bars in the code domain power display represent codes with low SF that occupy more code space. Figure 27 shows the code domain power display for a signal with a DPCCH and three DPDCHs. The three DPDCH (at 960 kbps, SF = 4) are much wider than the DPCCHs (at 15 kbps, SF = 256). In order to provide this display, the analyzer must be able to identify the SFs of the code channels being measured.



MS Ch Freq 2.00000 GHz
Code Domain 3GPP

IMkr #1: C2(1) 960ksps
-5.13dB

Total Power: -14.73 dBm
Total Active Ch: -0.00276 dBc
DPCCH Power: -11.124 dBc
DPCCH Beta: 0.251
I Avg Active Ch: -5.125 dBc
I Max Inactive Ch: -53.390 dBc
Q Avg Active Ch: -7.158 dBc
Q Max Inactive Ch: -51.841 dBc
DPDCH Beta: C1: 0.000 C3: 0.000 C5: 0.996 C2: 0.000 C4: 0.000 C6: 0.999

The marker provides the power reading and data rate for 1st DPDCH ($C_{ch,4,1}$ in I)

C2 means SF = 2^2 = 4

3rd DPDCH ($C_{ch,4,3}$ in I)

2nd DPDCH ($C_{ch,4,1}$ in Q)

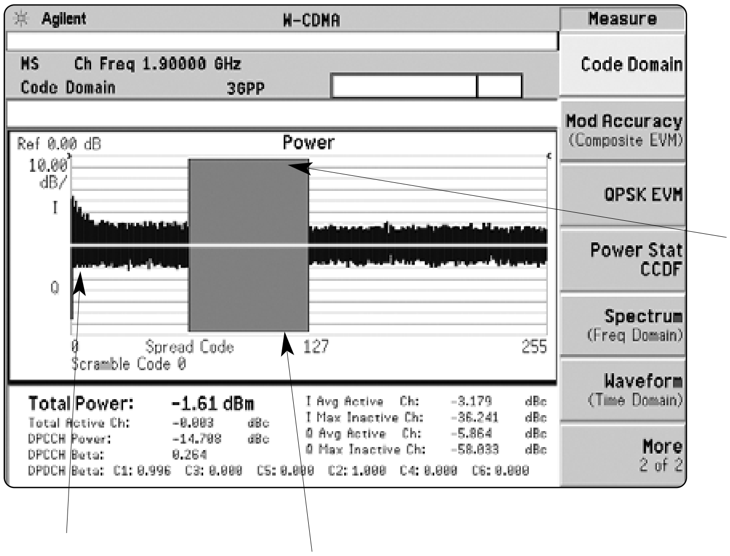
DPCCH ($C_{ch,256,0}$)

Figure 27. Code domain power of W-CDMA UL signal with a DPCCH and three DPDCHs

The code domain power measurement helps you not only verify that each OVSF channel is operating at its proper amplitude, but also identify problems throughout the transmitter design from the coding to the RF section. In particular, the levels of the inactive channels can provide useful information about specific impairments. Ideally, the levels for the inactive channels would be zero. In reality, signal and system imperfections compromise the code orthogonality and result in a certain amount of signal power projecting onto inactive codes. A real signal will also have a certain noise level, which being random, will project more or less evenly onto all codes.

The projection of the error is interesting because it enables you to see how the error power is distributed in the code domain. You want the error power to be evenly distributed throughout the code domain, rather than concentrated in a few codes, to avoid code-dependent channel quality variations.

One possible cause of uneven distribution of error power is LO instability. In essence, energy is lost from the active channels and appears in those channels with codes that are closely related to the active channel codes **[16]**. In the case of OVSF codes, this results in higher code domain noise for channels with code assignments consecutive to the active channel code, whether they are at the same or at a different I/Q path. Figure 28 shows the code domain power display for the UL 768 kpbs reference measurement channel (1 DPCCH and 2 DPDCHs) signal with a phase noise problem.



MS Ch Freq 1.90000 GHz
Code Domain 3GPP

Total Power: -1.61 dBm
Total Active Ch: -0.003 dBc
DPCCH Power: -14.708 dBc
DPCCH Beta: 0.264
DPDCH Beta: C1: 0.996 C3: 0.000 C5: 0.000 C2: 1.000 C4: 0.000 C6: 0.000
I Avg Active Ch: -3.179 dBc
I Max Inactive Ch: -36.241 dBc
Q Avg Active Ch: -5.864 dBc
Q Max Inactive Ch: -58.033 dBc

DPDCH ($C_{ch,4,1}$ in I)

DPCCH ($C_{ch,256,0}$ in Q) DPDCH ($C_{ch,4,1}$ in Q)

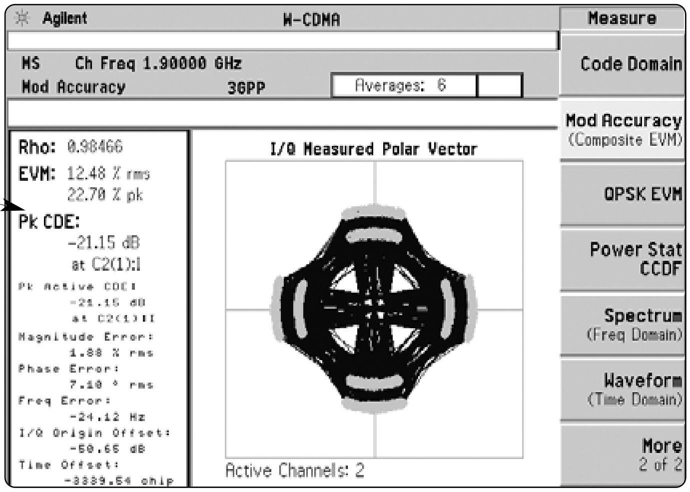
Figure 28. Code domain power measurement for the UL 768 kbps reference measurement model (one DPCCH and two DPDCHs). Signal with high LO instability

2.3.4 Peak code domain error

In W-CDMA, specifically to address the possibility of uneven error power distribution, the composite EVM measurement has been supplemented by another test called peak code domain error that specifies a limit for the error power in any one code.

This test is only required for the UE in which multi-code transmission is provided. The UE must be configured with the UL 768 kbps reference measurement channel (which is the only UL reference measurement channel with two DPDCHs). The error vector power must be projected on each code channel with a SF of 4. The peak code domain error is then calculated from the code that returns the largest error power relative to the composite reference signal. The error must not exceed -15 dB. Figure 29 shows the peak code domain error, in combination with the composite EVM, for the same signal (UL 768 kbps reference measurement channel) with the LO instability problem above. In this case, the peak code domain error falls in an active code channel. The result of the measurement coincides with the peak active code domain error, which calculates the error only in the active code channels.

Peak code domain error and peak active code domain error on channel ($C_{ch,4,1}$in I)



MS Ch Freq 1.90000 GHz
Mod Accuracy 3GPP
Averages: 6

Rho: 0.98466
EVM: 12.48 % rms
22.70 % pk
Pk CDE:
-21.15 dB
at C2(1):I
Pk Active CDE:
-21.15 dB
at C2(1):I
Magnitude Error:
1.88 % rms
Phase Error:
7.10 ° rms
Freq Error:
-24.12 Hz
I/Q Origin Offset:
-50.65 dB
Time Offset:
-3339.54 chip
Active Channels: 2

Figure 29. Peak code domain error and composite EVM display for the UL 768 kbps reference measurement model (one DPCCH and two DPDCHs). Signal with high LO instability

Apart from looking at the code domain power and peak code domain error, it is useful to analyze a specific code channel. The following sections describe some analysis tools and how they can be applied. Figure 30 shows how these measurements are calculated.

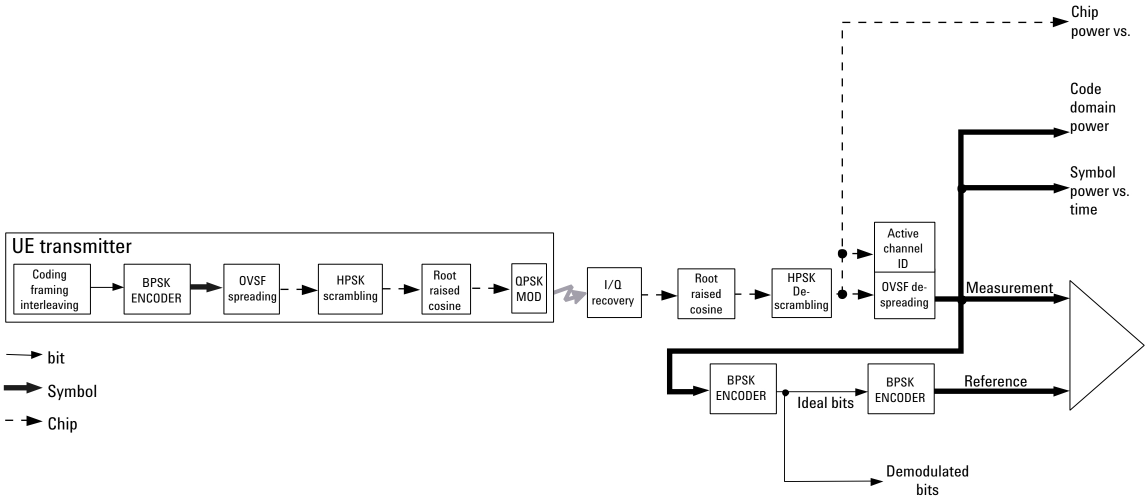


Figure 30. Process to calculate code domain power, symbol EVM, symbol power versus time, chip power versus time, and demodulated bits

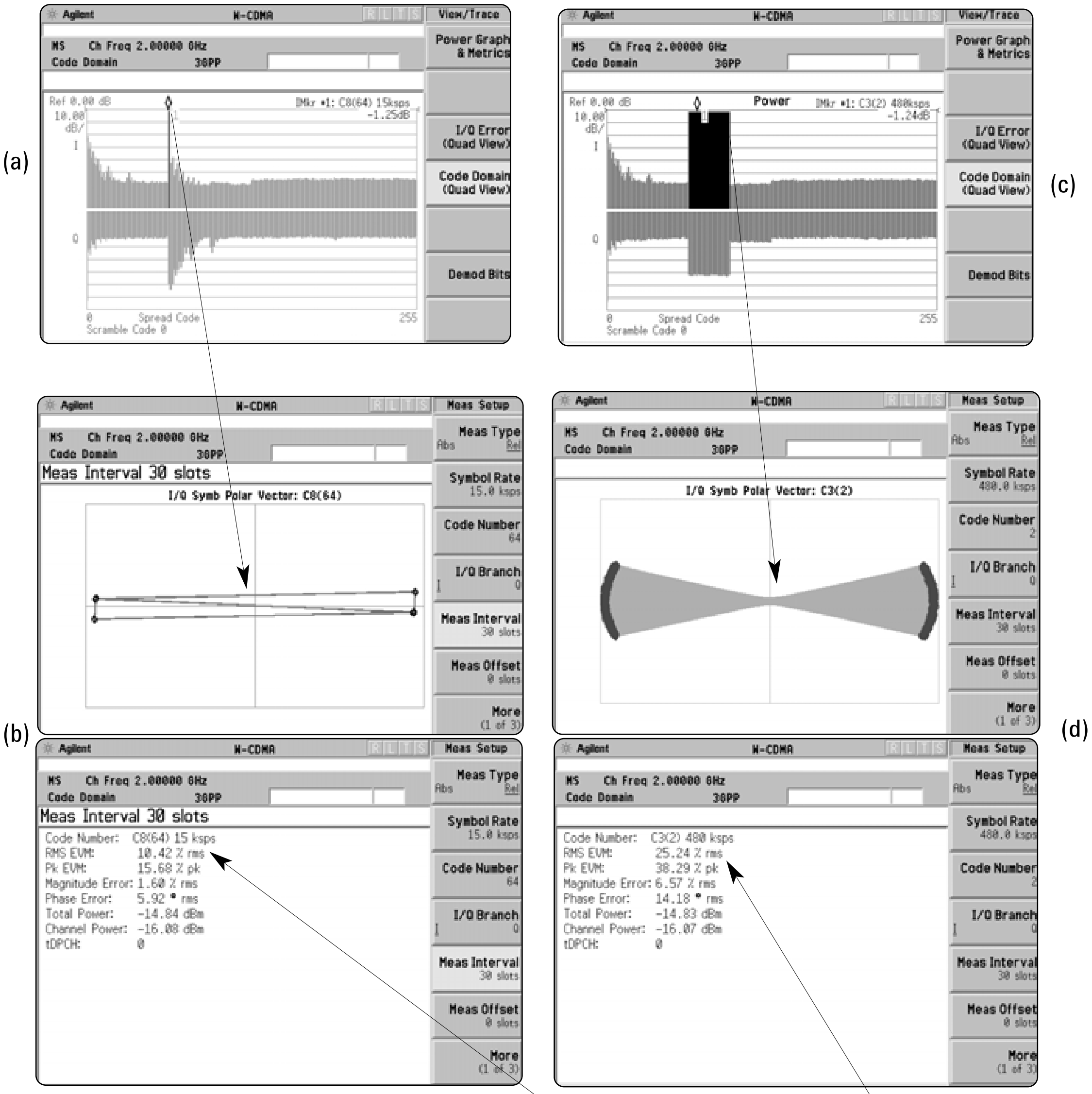
2.3.5 Symbol EVM

By descrambling and despreading the signal you can analyze the constellation and EVM for a specific code channel at the symbol level, even in the presence of multiple codes. The measured signal is HPSK descrambled and despread. The phase trajectory of the ideal symbol reference is then calculated and compared to the trajectory of the measured despread symbols (Figure 30).

An impairment that affects symbol EVM will also affect the composite EVM. For example, an amplifier compression problem will appear both in the composite EVM and in the symbol EVM measurement. However, because of the spreading gain symbol EVM will mute the impairment. So why use symbol EVM?

Symbol EVM provides the bridge between RF and demodulated bits. Since it includes the spreading gain, it provides a measure of modulation quality closer to real-life performance. In this sense, you can think of symbol EVM as the actual quality the user in that channel will experience (similar to the reciprocal of the bit error rate (BER)).

The relationship between symbol EVM and chip EVM depends on the SF. At low SFs (high data rates) chip modulation errors have a significant effect on symbol EVM. But at high SFs, chip modulation errors have little effect on symbol EVM. In this sense, it is particularly useful to baseband digital signal processing (DSP) engineers to evaluate symbol quality and analyze how specific impairments affect the quality of channels at different data rates. For example, Figure 31 shows the symbol EVM for a signal with a high-frequency phase error problem, for a code channel at 15 kbps with SF = 256 ($C_{ch,256,64}$) and a channel at 480 kbps with SF = 8 ($C_{ch,8,2}$). The symbol EVM for the lower data rate channel is much lower than that of the higher data rate channel.



```
Code Number:     C8(64) 15 ksps
RMS EVM:         10.42 % rms
Pk EVM:          15.68 % pk
Magnitude Error: 1.60 % rms
Phase Error:     5.92 ° rms
Total Power:     -14.84 dBm
Channel Power:   -16.08 dBm
tDPCH:           0
```

```
Code Number:     C3(2) 480 ksps
RMS EVM:         25.24 % rms
Pk EVM:          38.29 % pk
Magnitude Error: 6.57 % rms
Phase Error:     14.18 ° rms
Total Power:     -14.83 dBm
Channel Power:   -16.07 dBm
tDPCH:           0
```

Impairment causes higher symbol
EVM error in high data rate channel

Figure 31. (a) Code domain power measurement of a W-CDMA UL signal with the DPCCH and one DPDCH at 15 kbps ($C_{ch,256,64}$) and (b) symbol EVM measurement for the DPDCH at 15 kbps ($C_{ch,256,64}$). (c) Code domain power measurement of a W-CDMA UL signal with the DPCCH and one DPDCH at 480 kbps ($C_{ch,8,2)}$ and (d) symbol EVM measurement for the DPDCH at 480 kbps ($C_{ch,8,2}$)

2.3.6 Symbol power versus time

Analyzing the symbol power for a specific code channel versus time can be particularly useful to monitor the power and response of the UE power control system for different code channels (Figure 32).

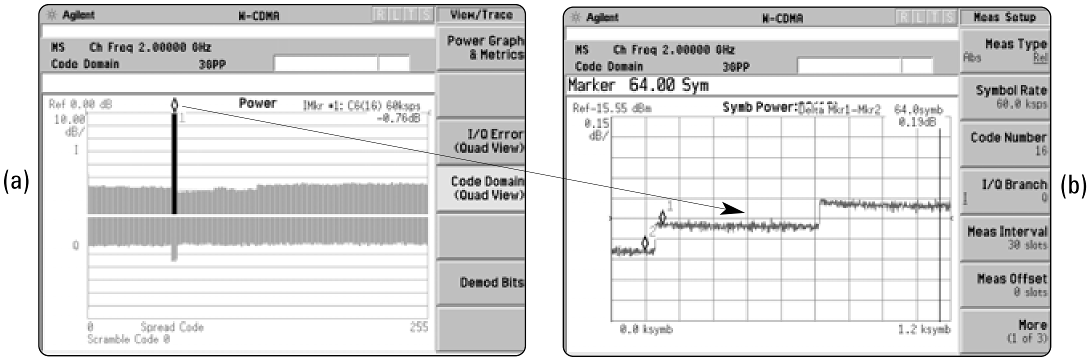
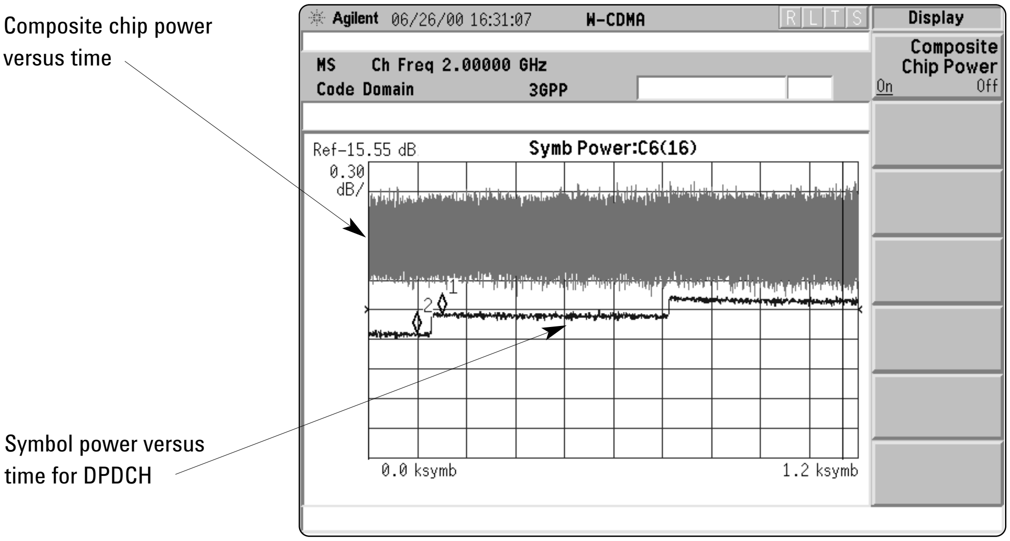


Figure 32. (a) Code domain power measurement of a W-CDMA UL signal with the DPCCH and one DPDCH at 60 kbps ($C_{ch,64,16}$) and (b) symbol EVM measurement for the DPDCH ($C_{ch,64,16}$)

Figure 33 shows the despread symbol power in combination with the composite (total) chip power for an UL signal. Chip power represents the total power of the signal at the chip rate. Analyzing the symbol power for a channel in combination with the total chip power versus time is particularly useful for system integrators to analyze the power amplifier response (ripple) to a power control command.



Composite chip power versus time

Symbol power versus time for DPDCH

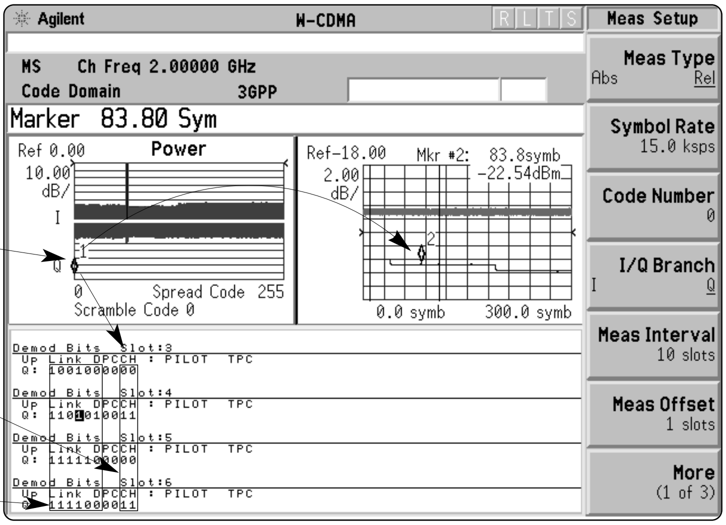
Figure 33. Chip power versus time for a W-CDMA UL signal with the DPCCH and one DPDCH at 60 kbps ($C_{ch,64,16}$), combined with symbol power versus time for the DPDCH ($C_{ch,64,16}$)

2.3.7 Demodulated bits

By obtaining the demodulated bits after HPSK descrambling and despreading for each code channel (I for the DPDCH and Q for the DPCCH, for the basic configuration), the correct bit patterns can be verified. As shown in Table 1, the UL DPCCH can have different slot structures. You can verify if the bits for the different fields (Pilot, TPC, etc.) are correct by using the demodulated bits measurement (Figure 34).

Slot form at #i	Channel bit rate (kbps)	Channel symbol rate (ksps)	SF	Bits/ frame	Bits/ slots	N_{pilot}	N_{TPC}	NT_{FCI}	N_{FBI}	Transmitted slots per radio frame
0	15	15	256	150	10	6	2	2	0	15
0A	15	15	256	150	10	5	2	3	0	10-14
0B	15	15	256	150	10	4	2	4	0	8-9
1	15	15	256	150	10	8	2	0	0	8-15
2	15	15	256	150	10	5	2	2	1	15
2A	15	15	256	150	10	4	2	3	1	10-14
2B	15	15	256	150	10	3	2	4	1	8-9
3	15	15	256	150	10	7	2	0	1	8-15
4	15	15	256	150	10	6	2	0	2	8-15
5	15	15	256	150	10	5	1	2	2	15
5A	15	15	256	150	10	4	1	3	2	10-14
5B	15	15	256	150	10	3	1	4	2	8-9

Table 1. UL DPCCH fields in normal mode and compressed mode [7]



MS Ch Freq 2.00000 GHz

Code Domain 3GPP

Marker 83.80 Sym

Scramble Code 0

Mkr #2: 83.8symb -22.54dBm

Symbol Rate 15.0 ksps

Code Number 0

I/Q Branch Q

Meas Interval 10 slots

Meas Offset 1 slots

```
Demod Bits  Slot:3
 Up Link DPCCH : PILOT  TPC
 Q: 1001000000

Demod Bits  Slot:4
 Up Link DPCCH : PILOT  TPC
 Q: 1101010011

Demod Bits  Slot:5
 Up Link DPCCH : PILOT  TPC
 Q: 1111100000

Demod Bits  Slot:6
 Up Link DPCCH : PILOT  TPC
 Q: 1111000011
```

DPCCH

TPC bits

Pilot bits

Figure 34. Demodulated bits for the DPCCH (slot format 0) of a W-CDMA UL signal with the DPCCH and one DPDCH at 60 kbps ($C_{ch,64,16}$)

Analyzing demodulated bits enables baseband engineers to identify coding and interleaving errors. In many cases, it can help you clarify situations where the BTS and UE are having problems communicating with each other. Analyzing the demodulated bits may verify whether the error is coming from the UE coding and interleaving, or the BTS de-interleaving and decoding process.

2.4 Measuring receiver functionality and performance

In CDMA systems the receiver demodulation process is more complex than in TDMA systems. The UE receiver must use correlation and descrambling algorithms to recover the symbols for the appropriate channel from the signal transmitted by the BTS.

In the case of W-CDMA, the complexity increases by at least an order of magnitude over IS-95. Some key challenging aspects are the UE's synchronization with the BTS and the UE's ability to demodulate channels with different configurations.

The figure of merit in the 3GPP specifications is bit error rate (BER) for receiver characteristics, and block error rate (BLER) for performance requirements. The receiver characteristics tests include reference sensitivity level, ACS, and blocking characteristics. Performance requirement tests analyze the receiver performance for several UL reference measurement channels under specified propagation conditions. Some examples of performance tests are demodulation of DCH in multi-path fading propagation conditions, demodulation of DCH in birth/death propagation conditions. In addition to these, performance requirements also include verification of the receiver's performance for DL compressed mode, DL power control, and BTFD.

This chapter provides an explanation of the differences between BER and BLER. Also included is a description of the appropriate stimulus signals for the receiver characteristics tests. For a detailed description see the specifications **[12]**.

In addition to the conformance tests in the specifications, additional receiver testing is needed to verify the performance and the functionality of different aspects of the receiver design. This chapter also discusses different tests that you can perform to verify the functionality and performance of different aspects of your W-CDMA UE receiver subsystem and system design, and the stimulus signal requirements for these tests.

For a description of the receiver test capabilities of Agilent UE design and test solutions see Appendix B. For general information on troubleshooting digital communications receiver designs refer to **[17]**.

2.4.1 Bit error rate (BER) versus block error rate (BLER)

BER and BLER – or Frame Error Ratio (FER) in IS-95 or cdma2000–are two related methods of measuring the ability of a digital receiver to recover the information in the received signal. The subject of which figure of merit to use has caused considerable debate in the CDMA community. Both measures have value; though for slightly different applications.

BER is defined as the ratio of the bits wrongly received to all data bits sent. The bits are the information bits above the convolutional/turbo decoder (see Figure 35).

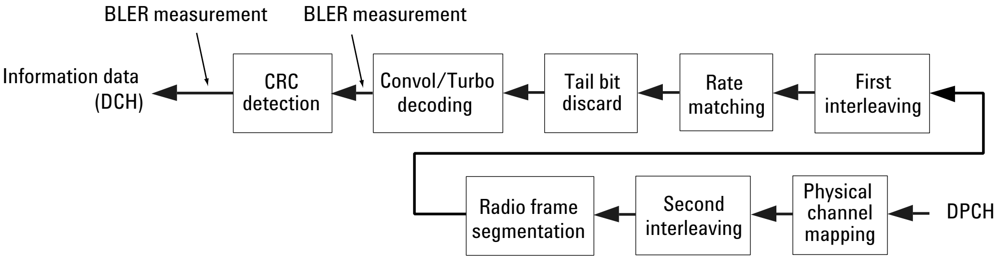


Figure 35. BER and BLER measurements in the DL for a DPCH.

BER is typically used to evaluate receiver RF performance during radio development. During the early stages of W-CDMA technology development, it was also extensively used in system simulation of the W-CDMA reference measurement channels. For these reasons, BER tests remain in the 3GPP specifications, as the figure of merit for the receiver characteristics measurements.

Also in production, a measure that relates directly to the quality of the portions of the device that are likely to vary from unit to unit is required. In a digital communications receiver that is the analog, RF, portion of the receiver. Digital sections, whether codeware or hardware, should not change behavior from unit to unit. The contribution of the RF portion of the receiver to its effectiveness is largely determined by the noise figure (sensitivity) of its front end. When constructing a test for production process control, one desires a measure that offers good sensitivity to the characteristics being tested, and reasonable linearity of response to variations in that characteristic. This allows the process monitor to detect degradations in the process output before they become so bad as to cause significant failures. BER is a more useful measure for this purpose than BLER or FER. BLER is defined as the ratio of the number of erroneous blocks received to the total number of blocks sent. An erroneous block is defined as a Transport Block, the cyclic redundancy check (CRC) of which is wrong. The 3GPP specifications describe two methods to determine BLER. In the first one, the UE estimates the BLER by evaluating the CRC of each transport block associated with the measured transport channel after radio link combination, and reports the BLER back through layer 3 signalling. In the second one, all the data bits and CRC bits are sent back to the system simulator, which calculates the BLER.

CDMA systems, such as cdma2000 and W-CDMA, operate with a large degree of coding gain, which helps the receiver recover information in the presence of noise and interference. When the goal is to estimate or monitor the overall system capacity, this coding gain must be taken into account. In that case, the Block or Frame Error Rate is a more useful measure of the receiver's effectiveness; and thus, of the capacity of the overall system of which the receiver is a part. BLER or FER are important measures when evaluating a new system design or coding and decoding elements for a system. Because it includes more coding gain, BLER will offer a somewhat less gradual slope of measured result versus receiver noise figure than BER. If BLER is used for monitoring process quality the higher coding gain will result in little warning of impending problems; the test results will look very good until the process quality degrades past a threshold, at which point there will suddenly be a substantial number of failures. For this reason, BLER is used during system design evaluation and RF performance conformance testing, but it will probably not be very useful during manufacturing.

2.4.2 Test setup for BER measurements

The basic measurement setup to perform a BER/BLER measurement consists of a system simulator (SS) (or a signal generator acting as a BTS simulator) that sends a fully coded downlink signal to the UE receiver under test. There are different alternatives on how to measure the BER once the UE receiver has recovered the bits. The specifications require the UE to transmit back the bits in the UL. This method is known as loopback test and assumes that the UE transmitter and receiver are fully integrated and functional. The system simulator in this case requires UL receiver capability. Figure 36 shows the basic test setup for this case.

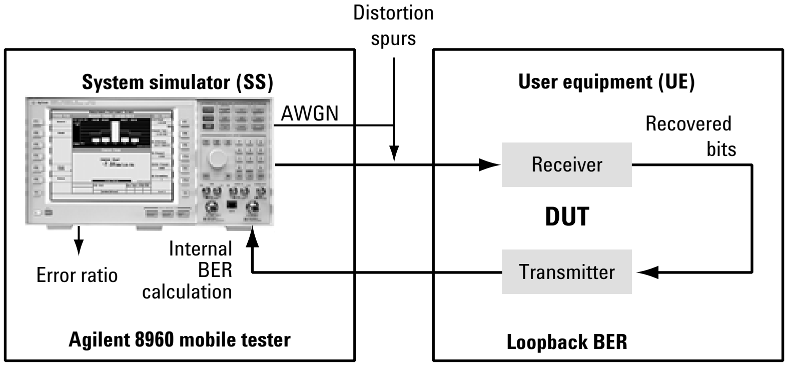


Figure 36. Basic test setup for BER loopback test

However, in earlier stages of the design, when the UE has not been fully designed or integrated, loopback test might not be appropriate. For example, if the designer wants to verify the performance of the receiver, but only the receiver module is available, the baseband bits can be sent back directly to the BTS simulator or to an external PC-based application, which can then calculate the BER/BLER. Figure 37 shows a possible test setup for BER/BLER when loopback test is not possible.

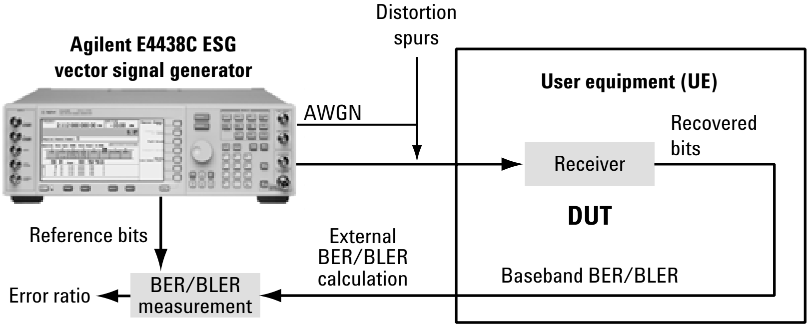


Figure 37. Test setup for BER/BLER using recovered baseband bits

2.4.3 Stimulus signals for receiver characteristics tests

In order to make BER or BLER measurements, the specifications require a fully-coded signal as the stimulus. Most of the receiver characteristics tests (*6.2 and from 6.4 to 6.7* in **[12]**) require a downlink signal with the CPICH, P-CCPCH, SCH, PICH, and a DPCH. The DPCH is the DL 12.2 kbps reference measurement channel. In the case of loopback test, the received signal is sent back to the SS through the UL 12.2 kbps reference measurement channel. Appendix B shows the coding structure and parameters for the UL and DL 12.2 kbps reference measurement channels. A PN9 sequence must be used as the information data for the DTCH (or the DCCH).

In addition to these channels, *6.3 Maximum Input Level* in **[12]** requires a S-CPICH, and an Orthogonal Channel Noise Simulator (OCNS) channel. These channels are also required for most of the performance requirement tests. In real life, the DPCH is transmitted at a low power compared to the total system power. However, this means that multiple channels would be required to perform the receiver tests, which would complicate the measurement. The OCNS solves this problem. The OCNS consists of 16 non-modulated orthogonal channels (each channel uses an OVSF code). It represents other users in the system and therefore its power is specified at a higher level than the DPCH power. The OVSF codes and relative level settings are chosen to simulate a signal with realistic peak-to-average power ratio.

Since *6.8 Spurious Emissions* in **[12]** measures the emissions generated or amplified in the UE's receiver, this test does not measure BER on a DPCH. Therefore, the DL signal for this test consists only of the CPICH, P-CCPCH, SCH, and PICH.

In addition to the wanted signal with the appropriate reference measurement channel, some of the receiver characteristics tests require another signal (or two) to act as interference.

For *6.4 ACS* in **[12]**, the interfering signal is a W-CDMA modulated signal that consists of a P-CCPCH, an SCH, a P-CPICH, a PICH and an OCNS channel (representing 16 DPCHs). The same W-CDMA modulated signal is used as an in-band interferer for *6.5 Blocking Characteristics* in **[12]**, the in-band interferer. The out-of-band interferer for this test is a CW signal, and the narrow-band interferer is a GMSK modulated carrier that follows the structure of GSM signals.

For *6.6 Spurious Response* in **[12]**, the interferer is a CW signal.

6.7 Intermodulation Characteristics in **[12]** requires two interfering signals: a CW signal and either the same W-CDMA modulated interferer described above or a GMSK modulated carrier that follows the structure of GSM signals.

2.4.4 Additive white gaussian noise (AWGN) interferer

Some of the performance requirement tests, such as *7.2 Demodulation in Static Propagation Condition*s require an AWGN interferer. The AWGN interferer must be at least 1.5 times the chip rate wide, so at least 5.76 MHz wide. Having a single instrument generate both the wanted signal and the AWGN interference eliminates the technical issues associated with summing the signals from two different sources to achieve a proper noise ratio. Either the required carrier-to-noise ratio (C/N) or the energy-per-chip-to-noise ratio (Ec/No) for a physical channel, can then be set up directly as required by the specifications. While C/N refers to the ratio between the overall carrier power to the noise power in the bandwidth, the Ec/No is used to set the noise level relative to a single physical channel, so changing the C/N changes the Ec/No and vice versa. Calculations to obtain one from the other are not required if you use an instrument that allows you to directly set up both the C/N and the Ec/No.

2.4.5 Verifying baseband functionality

The conformance tests verify the performance of the whole UE design (baseband and RF). However, additional tests that are not part of the specifications might be necessary to verify the correct functionality of the receiver baseband for different transport or physical layer parameters.

Testing this functionality requires a stimulus source with the flexibility to modify transport layer parameters such as: block size, number of blocks, coding type, Transmission Time Interval (TTI), data type, rate matching attribute, CRC size and physical layer parameters such as the slot format, the OVSF codes, and the scrambling code. Table 2 shows the DL slot structures for the DPCH in normal mode. See **[7]** for the complete table with normal and compressed mode slot formats.

Slot form at #i	Channel bit Rate (kbps)	Channel symbol Rate (ksps)	SF	Bits/ slots	DPDCH Bits/slots		DPCCH Bits/slots			Transmitted slots per radio frame N_{Tr}
					N_{Data1}	N_{Data2}	N_{TPC}	N_{TFCI}	N_{pilot}	
0	15	7.5	512	10	0	4	2	0	4	15
1	15	7.5	512	10	0	2	2	2	4	15
2	30	15	256	20	2	14	2	0	2	15
3	30	15	256	20	2	12	2	2	2	15
4	30	15	256	20	2	12	2	0	4	15
5	30	15	256	20	2	10	2	2	4	15
6	30	15	256	20	2	8	2	0	8	15
7	30	15	256	20	2	6	2	2	8	15
8	60	30	128	40	6	28	2	0	4	15
9	60	30	128	40	6	26	2	2	4	15
10	60	30	128	40	6	24	2	0	8	15
11	60	30	128	40	6	22	2	2	8	15
12	120	60	64	80	12	48	4	8*	8	15
13	240	120	32	160	28	112	4	8*	8	15
14	480	240	16	320	56	232	8	8*	16	15
15	960	480	8	640	120	488	8	8*	16	15
16	1920	960	4	1280	248	1000	8	8*	16	15

Table 2. DL DPDCH and DPCCH fields in normal mode

In addition, baseband functionality must also be verified for different modes of operation or functions. Some examples of this are: compressed mode, and timeslot synchronization testing and searcher testing. The following sections provide more information on these tests.

2.4.6 Verification of compressed mode functionality

There are two different types of DL compressed frames, known as A and B.

Type A maximizes the transmission gap length. The pilot field in the last compressed slot is transmitted while the other slots in the transmission gap are DTX.

Type B optimizes for power control. The TPC field of the first compressed slot and the pilot field of the last compressed slot are transmitted while all other slots in the transmission gap are DTX.

Compressed mode receiver verification requires a stimulus source with the capability to generate compressed DL frames of both types.

2.4.7 Timeslot synchronization testing and searcher testing

In contrast with other CDMA systems, W-CDMA BTSs transmit asynchronously, as described in Chapter 1. The system relies on the UE's ability to recognize the appropriate BTS and synchronize to it. Each BS is assigned a unique code for identification purposes. It uses the P-SCH and S-SCH to tell the UE which of the 64 possible code patterns this unique code belongs to, as shown in Figure 38.

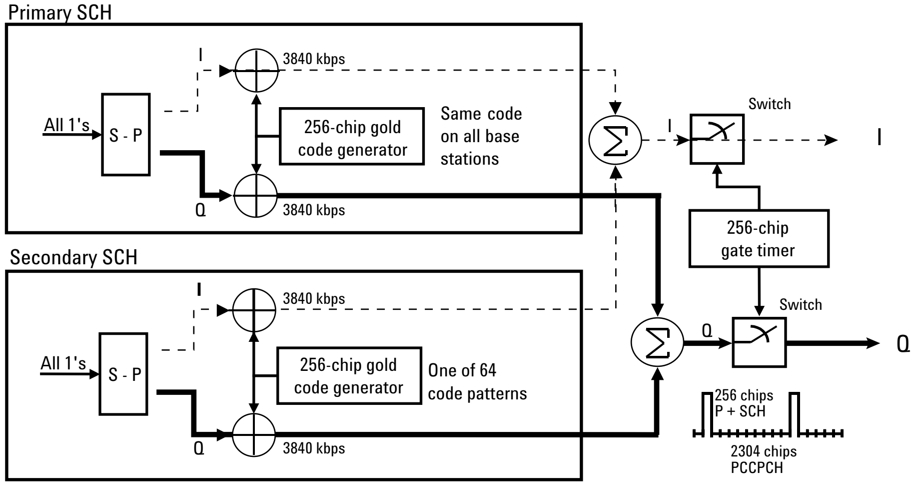


Figure 38. Physical structure for P-SCH and S-SCH

The UE must perform the following synchronization process:

1. Find and time synchronize to the P-SCH rate.

2. Find and decode the S-SCH. The BTS uses one of 512 unique scrambling codes. The UE must determine which of the 64 possible code groups is being indicated by the S-SCH. Each code group represents eight scramble codes (64 x 8 = 512).

3. Begin the search for which of the eight possible scrambling codes the BTS is using within the code group defined by the S-SCH. The UE searches for this scrambling code by determining which scramble code provides the best correlation to the CPICH. The CPICH is spread by $C_{ch,256,0} = \{1,1,1,1....\}$. Therefore, the scrambling code can be extracted from it. The BCH, which is carried on the P-CCPCH, contains additional timing information in the form of the system frame number (SFN). This number provides the UE with information about timing of transport block boundaries, which is critical to the decode processes.

The first step to verify the UE's synchronization functionality is to test the UE's timeslot synchronization. This test requires a stimulus signal comprising a P-SCH burst at timeslot intervals, as indicated in Figure 39.

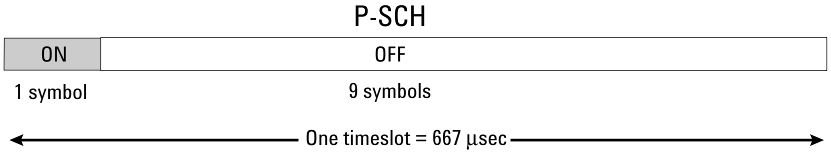


Figure 39. P-SCH timeslot structure

The second step is to verify the overall functionality of the mobile searcher, which includes synchronization, determining the scramble code group, and identifying the primary scramble code of the transmission. This test requires a stimulus signal comprising a P-SCH, a S-SCH, a P-CCPCH, and a CPICH, as shown in Figure 6. The S-SCH is configured to indicate one of the 64 scramble code groups. This test should be performed for each of the 64 scramble code groups.

After verifying the functionality of the searcher, you need to verify correct recovery of the SFN from the BCH. The SFN should be increasing every 20 ms.

Summary

W-CDMA provides a wideband, dynamically allocatable code space that can provide high data rate communication to many users in a cell. As with other cellular CDMA technologies, W-CDMA provides the simplicity of cell site code planning (instead of cell site frequency planning) and can achieve this benefit without requiring GPS time synchronization.

The advanced features of W-CDMA, including its unique acquisition and handover processes, present many challenges in the development, performance verification, and production test of W-CDMA systems. This application note provided an overview of some of the key design and test issues for W-CDMA UE. It also introduced measurements that can help you verify and troubleshoot your design.

Appendix A: Reference measurement channel examples

The following reference measurement channel examples have been extracted from the 3GPP specifications **[12]**.

UL reference measurement channel (12.2 kbps)

The parameters for the 12.2 kbps UL reference measurement channel are specified in Table 3 and Table 4. The channel coding is shown in Figure 40.

Parameter	Level	Unit
Information bit rate	12.2	kbps
DPDCH	60	kbps
DPCCH	15	kbps
DPCCH slot format #i	0	-
DPCCH/DPDCH power ratio	-5.46	dB
TFCI	On	-
Repetition	23	%

Table 3. UL reference measurement channel physical parameters (12.2 kbps)

Parameters	DCCH	DTCH
Transport channel number	1	2
Transport block size	244	100
Transport block set size	244	100
Transmission time interval	20 ms	40 ms
Type of error protection	Convolution coding	Convolution coding
Coding rate	1/3	1/3
Rate matching attribute	256	256
Size of CRC	16	12

Table 4. UL reference measurement channel, transport channel parameters (12.2 kbps)

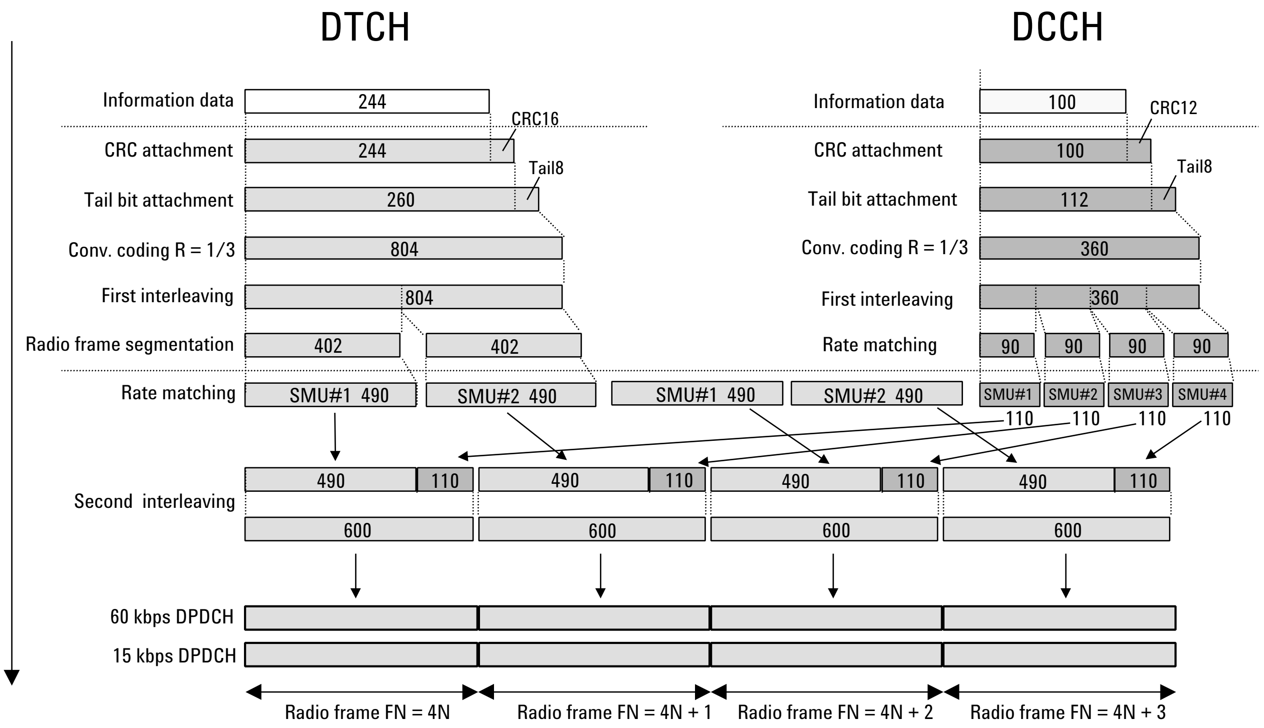


Figure 40. Channel coding of UL reference measurement channel (12.2 kbps)

DL reference measurement channel (12.2 kbps)

The parameters for the 12.2 kbps DL reference measurement channel are specified in Table 5 and Table 6. The channel coding is detailed in Figure 41.

Parameter	Level	Unit
Information bit rate	12.2	kbps
DPCH	30	ksps
Slot format #i	11	-
TFCI	On	
Power offsets PO1, PO2 and PO3	0	dB
Puncturing	14.7	%

Table 5. DL reference measurement channel (12.2 kbps)

Parameter	DCCH	DTCH
Transport channel number	1	2
Transport block size	244	100
Transport block set size	244	100
Transmission time interval	20 ms	40 ms
Type of error protection	Convolution coding	Convolution coding
Coding rate	1/3	1/3
Rate matching attribute	256	256
Size of CRC	16	12
Position of TrCH in radio frame	fixed	fixed

Table 6. DL reference measurement channel, transport channel parameters (12.2 kbps)

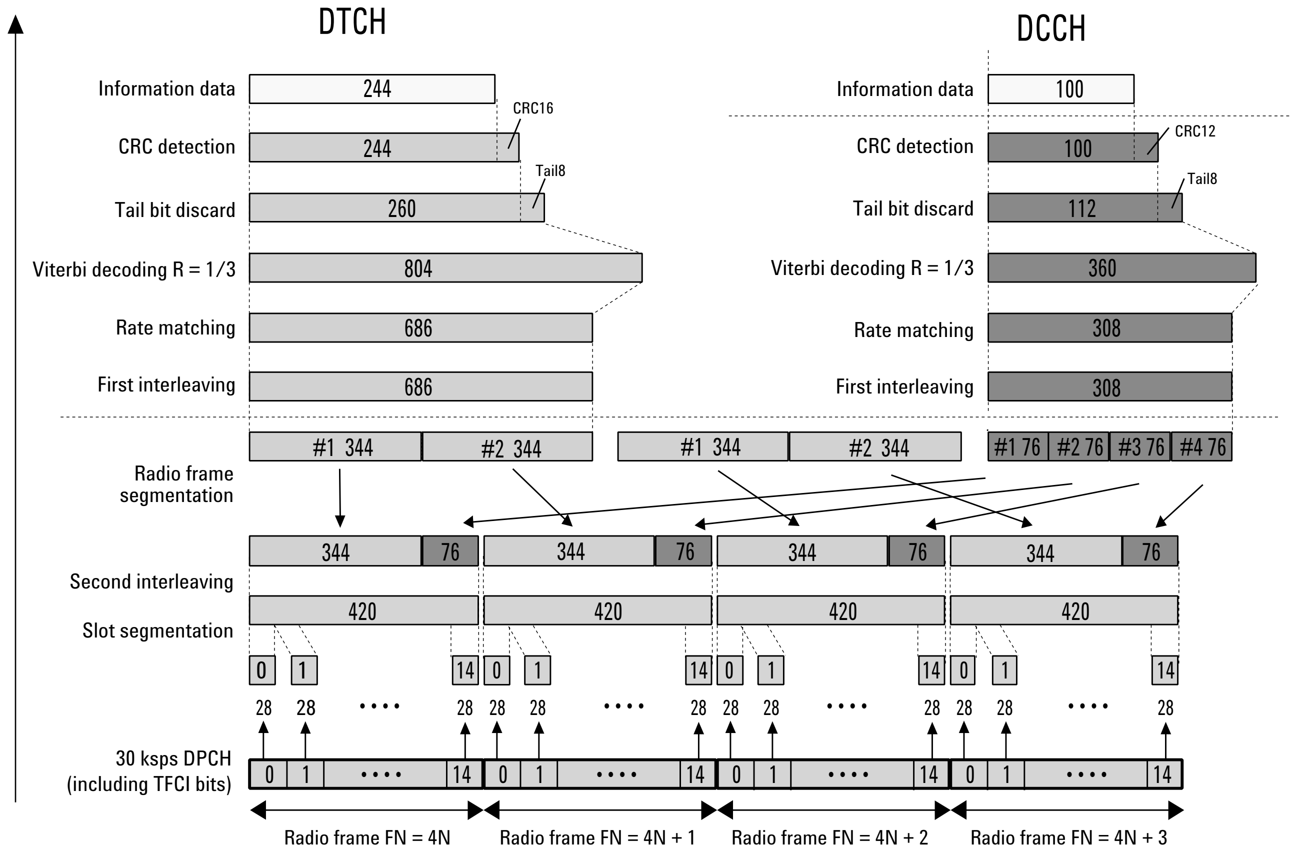


Figure 41. Channel coding of DL reference measurement channel (12.2 kbps)

Appendix B Agilent Solutions for W-CDMA UE Design and Test

This section provides a list of Agilent solutions that can you can use to design and test your UE subsystem and system.

Software design and simulation

You can use the Agilent Advanced Design System (ADS) to design and verify W-CDMA systems, circuits, and DSP designs. ADS is a versatile design tool that includes a wide array of RF, analog and DSP models and simulation capability.

The 3GPP W-CDMA design library (E8875 A/AN) models the physical layer, including the data and control logical channels, frame segmenting and multiplexing forming the coded composite transport channel, and the multiplexing for the dedicated physical data and control channels.

ADS with the E8875 A/AN design library option helps you to evaluate your designs against key W-CDMA performance parameters such as ACLR, EVM, BER, and BLER early in the design cycle. Many transmitter and receiver tests outlined in the specifications **[18]** can be simulated, as shown in Table 7.

UE transmitter tests		**ADS E8875 A/AN**
Peak-to-mean for selected channel configuration		X
CCDF for selected channel configuration		X
Transmitter tests [**18**]:	Transmit power	X
	Max output power	X
	Occupied bandwidth	X
	Out-of-band emission	X
	Spectrum emission mask (SEM)	X
	Adjacent channel leakage (ACL)	X
	Modulation accuracy	X
	Peak code domain error	X

UE receiver tests		**ADS E8875 A/AN**
Uncoded physical BER		X
Coded BER and receiver tests [**18**]:	Reference sensitivity level	X
	Receiver maximum level	X
	Adjacent channel selectivity	X
	Blocking sensitivity	X
	Intermodulation sensitivity	X

Table 7. W-CDMA test simulation capabilities of ADS with the E8875 A/AN design library option for UE design

The E8875 A/AN design library also includes signal source configurations similar to those offered in the Agilent E4438C ESG signal generator.

Connected solutions

Connectivity between Agilent ADS and Agilent test equipment, such as signal sources and signal analyzers, helps minimize development risk and costs by identifying problems early in the design and fabrication cycle.
W-CDMA system designers can benefit from connected solutions because it can help:

- Evaluate system-level performance with partial RF hardware, using simulation to model missing hardware.
- Evaluate RF performance (such as BER), using simulation to model missing baseband functionality
- Evaluate system performance more continuously throughout the design/fabrication cycle to help reduce risk and costs.
- Evaluate system performance on the test bench with simulated impairments.

W-CDMA component designers benefit from connected solutions because they can use realistic signals for testing that reflect the environment in which the component will be used. Applications include:

- Testing/demonstrating a component DUT. Modeling a transmitter/receiver chain in simulation to show how it would perform in a system.
- Testing/demonstrating a component with various signal formats modeled in simulation
- Evaluating performance limits of a DUT – how impaired can the input signal be and still meet specifications?

For more information on connected solutions applications please see **[19]**.

Signal generation

Component testing

The Agilent E4438C ESG with Option 400 (E4438C-400) simulates the 3GPP W-CDMA physical layer. These statistically correct signals are designed to stress W-CDMA handset components and subsystems, just as a real-world signal would. An easy to use interface enables you to:

- select from several predefined W-CDMA channel configurations
- use the table editor to fully configure a W-CDMA multi-channel signal per your requirements

Additionally, Agilent offers the ESG-D/DP series RF signal generators with basic capability for component testing applications when the performance of the E4438C ESG is not required.

An easy-to-use interface link now enables you to easily download custom waveforms created with ADS into the ESG signal generators.

Receiver testing

The Agilent E4438C ESG with Option 400 (E4438C-400) simulates the transport and physical layers of a 3GPP W-CDMA signal. The transport layer coding enables thorough evaluation of receiver demodulation analysis capabilities at various design stages from components, such as ASICS, to completed receiver designs. The generated signal produces a stream of fully coded W-CDMA frames for performing BER and BLER measurements. An easy-to-use interface allows you to select from predefined channel configurations, including the reference measurement channels. Key features include:

- Compressed frames
- Add AWGN by setting Ec/No or C/N
- Closed loop power control capability
- 16 OCNS channels
- Flexible configuration of 6 transport layer channels
- Real-time power balancing between the DPCH and OCNS channels

		ESG E4438C-400[1]
Stimulus for component test		**X**
Stimulus for receiver tests:		
BER and receiver characteristics conformance tests [12]	6.2 Reference sensitivity level	X
	6.3 Maximum input level	X
	6.4 Adjacent channel selectivity (ACS)	X
	6.5 Blocking characteristics	X
	6.6 Spurious response	X
	6.7 Intermodulation characteristics	X
Variable coding parameters (e.g., rate matching)		X
Auto power balancing between DPCH and 16 OCNS		X
Compressed mode capability		X

Table 8. W-CDMA stimulus capabilities of ESG signal generators for UE testing

---

[1] Requires a baseband generator, Option 001 or 002. AWGN capability requires Option 403.

Power supplies and software for battery drain analysis

Agilent 66319B/D & 66321B/D single and dual dc output high performance power supplies provide very fast transient output response with a built-in advanced DSP-based digitizing measurement system. Combined with the 14565A Device Characterization Software battery drain current can be recorded, visualized, and analyzed from microseconds to weeks in duration. They provide the following functions for testing digital wireless devices:

- Replace the main battery (single or dual output) and power adapter (dual output)
- Emulate battery characteristics through fast output response and programmable output resistance
- Minimize transient voltage drop over long wiring resulting from the pulsed current drain
- Source/sink capability on main output for testing and calibrating battery charger circuitry
- Accurately measure battery current drains for all operating modes (off, sleep, standby, and active modes)
- With 14565A software, capture, visualize, and analyze current drain waveforms down to 15.6 microsecond resolution
- With 14565A software, record long-term battery drain up to 1,000 hours
- Visualize and analyze results by either data log or CCDF display

Power meter and sensor

The Agilent EPM-P series power meters and E9320 peak and average power sensors provide peak, average and peak-to-average ratio power measurements on W-CDMA signals. Extensive triggering features are available for making time-gated measurements. Fast test times, with a measurement speed of up to 1,000 corrected readings per second, over the GPIB, help increase throughput to meet time-to-market and time-to-volume goals. The E9320 peak and average power sensors have a maximum video bandwidth of 5 MHz, ideal for W-CDMA power measurements.

EPM-P analyzer software is provided with the EPM-P series power meters. This is a PC based tool for pulse and statistical analysis on TDMA and CDMA modulation formats. For statistical analysis of the power distribution, the EPM-P analyzer software provides the capability to determine the probability density function (PDF), cumulative distribution function (CDF), and CCDF on W-CDMA signals.

Recommended power meters and sensors for 3GPP W-CDMA users equipment peak, average and time-gated power measurements are:

- EPM-P series power meter E4416A, single channel
- EPM-P series power meter E4417A, dual channel
- E9323A peak and average power sensor, 50 MHz to 6 GHz, 5 MHz video bandwidth, -60 to +20 dBm

All 8480 and E-series power sensors are compatible with the EPM-P series power meters.

For average power measurements only, the lower cost EPM series power meters and other E-series power sensors recommended are:

- EPM series power meter E4418B, single channel
- EPM series power meter E4419B, dual channel
- E9301A power sensor, 10 MHz to 6 GHz, -60 to +20 dBm
- E9301H power sensor, 10 MHz to 6 GHz, -50 to +30 dBm

Other power sensors in the 8480 series are compatible with the EPM series power meters.

Signal analysis

Table 9 provides a list of Agilent signal analyzers and their W-CDMA UE transmitter measurement capabilities.

W-CDMA (3GPP)		**Agilent signal analyzers**				
Measurements		**E4406A** VSA series transmitter tester[1]	**89400A** series vector signal analyzers[3]	**89600** series vector signal analyzers[2]	**E4440A** PSA series spectrum analyzers[1]	**ESA-E** series spectrum analyzers[1]
General purpose measurements						
Channel power		X	X[4]	X[4]	X	X
CCDF		X	X	X	X	X
Modulation quality	QPSK EVM	X	X	X	X	X
	Composite EVM	X		X	X	X[6]
	Code-domain power	X		X	X	X[6]
	Peak code domain error	X		X	X	X[6]
	Symbol EVM	X		X	X	X[6]
	Symbol power versus time	X		X	X	X[6]
	Composite chip power versus time	X		X	X	X[6]
	Demodulated bits	X		X	X	X[6]
Transmitter conformance tests [12]						
5.2 Maximum output power		X	X[4]	X[4]	X	X
5.3 Frequency stability		X		X	X	X[6]
5.4.1 Open loop power control		X	X[4, 5]	X[4, 5]	X	X[4, 5]
5.4.2 Inner loop power control		X			X	X[4]
5.4.3 Minimum output power		X	X[4, 5]	X[4, 5]	X	X[4, 5]
5.5.1 Transmit OFF power		X	X[4, 5]	X[4, 5]	X	X[4]
5.5.2 Transmit on/off Time mask		X[7]			X[7]	
5.6 Change of TFC		X[4, 7]			X[4, 7]	
5.7 Power setting in UL compressed mode		X[7]			X[7]	
5.8 Occupied bandwidth		X	X[4]	X[4]	X	X
5.9 Spectrum emission mask (SEM)		X	X[4]	X[4]	X	X
5.10 Adjacent channel leakage ratio (ACLR)		X	X[4, 5]	X[4, 5]	X	X
5.11 Spurious emissions					X[4]	X[4]
5.12 Transmit Intermodulation					X[4]	X[4]
5.13.1 Modulation accuracy		X		X	X	X[6]
5.13.2 Peak code domain error		X		X	X	X[6]

Table 9. Agilent signal analysis tools for W-CDMA

---

1. Measurements pre-configured for W-CDMA.
2. Some measurements pre-configured for W-CDMA. Parameters for other measurements must be set up manually, as indicated (4).
3. Measurements are not pre-configured for W-CDMA. Measurement parameters must be set up manually, as indicated (4).
4. Measurement parameters must be set up manually
5. The measurement is performed using a rectangular filter, instead of the specified RRC filter.
6. Available with Option 231(link to 89600 software) and the 89600 software (89601A with #100, #AYA, and #B7N)
7. No PASS/FAIL mask settings are provided

Wireless communication test set

The Agilent E1963A W-CDMA mobile test application for the multi-format Agilent 8960 Series 10 (E5515C) wireless communications test set provides the following testing capabilities:

3GPP TS 34.121	Test description	Available
5.2	Maximum output power	Yes
5.3	Frequency error	Yes
5.4.1	Open loop power control	Yes
5.4.2	Inner loop power control	Yes
5.4.3	Minimum output power	Yes
5.4.4	Out-of-sync power control	
5.5.1	Transmit OFF power	Yes
5.5.2	Transmit ON/OFF time mask	Yes
5.6	Change of TFC	
5.7	Power setting in UL compressed mode	
5.8	Occupied bandwidth (OBW)	Yes
5.9	Spectrum emission mask (SEM)	Yes
5.10	Adjacent channel leakage ratio (ACLR)	Yes
5.11	Spurious emissions	Yes[1]
5.12	Transmit intermodulation	Yes[3]
5.13.1	Error Vector Magnitude (EVM)	Yes
5.13.2	Peak code domain error	Yes

Table 10. Tx tests

3GPP TS 34.121	Test description	Available
6.2	Reference sensitivity	Yes
6.3	Maximum input level	Yes
6.4	Adjacent channel selectivity (ACS)	Yes[2]
6.5	Blocking characteristics	Yes[2]
6.6	Spurious response	Yes[2]
6.7	Intermodulation characteristics	Yes[2]
6.8	Spurious emissions	TBD

Table 11. Rx tests

---

[1] Requires external signal generator like the E4438C ESG vector signal generator

[2] Requires external spectrum analyzer like the E4445A PSA

[3] Requires external analyzer and signal generator

Additional functionality

Call processing

- Downlink channels CPICH, P-CCPCH/SCH, S-CCPCH, PICH, AICH, DPCH, AWGN, and OCNS
- Variable DL channelization and relative power levels per channel
- Test Control call processing for manufacturing
- Call Control processing for AMR Voice Echo
- W-CDMA to GSM handover
- Variable UL DPDCH and DPCCH relative power levels bd and bc
- Variable Open loop power control parameters
- Multiple UL power control schemes

Graphics

- Active cell spectrum analysis
- Measurement graphics for SEM, code domain power, adjacent channel leakage ratio, occupied bandwidth

The Agilent E6703A W-CDMA Lab Application includes all features and functionality of the E1963A, and adds:

Data channels

- UMTS/GPRS 64kbps packet switched
- 64kbps circuit switched
- Both channels can route data to IP over the instrument LAN
- Both channels can be brought up in test control for troubleshooting

Advanced protocol analysis

- Observation points:
  - Internet Protocol (IP)
  - Radio Resource (RR)
  - Call Control (CC)
  - Mobility Management (MM)
  - Test Control (TC)
  - GPRS Mobility Management (GMM)
  - Session Management (SM)
  - Radio Resource Control (RRC)
  - Radio Link Control (RLC)
  - Packet Data Convergence Protocol (PDCP)
  - Short Message Service (SMS)
  - Medium Access Control (MAC)
- PC-based Wireless Protocol Analyzer included

Soft/softer handover

W-CDMA adaptive multi rate (AMR) voice to GSM full rate (FR) voice handover

Instruments used for measurement examples

The measurement examples and screen images in this application note were obtained using the following instruments:

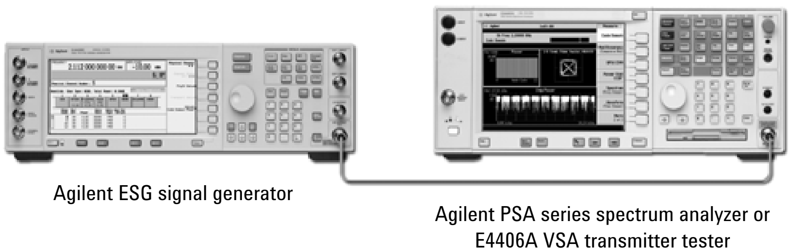


Figure 42. Agilent ESG signal generator with PSA series spectrum analyzer or E4406A VSA transmitter tester

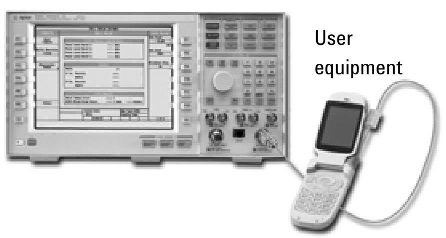


Figure 43. Agilent 8960 Series 10 with E1963A W-CDMA mobile test application lab

Acronym glossary

2G	Second Generation
3G	Third Generation
3GPP	Third-Generation Partnership Project
ACIR	Adjacent Channel Interference Ratio
ACL	Adjacent Channel Leakage
ACLR	Adjacent Channel Leakage Power Ratio
ACPR	Adjacent Channel Power Ratio
ACS	Adjacent Channel Selectivity
AICH	Acquisition Indication Channel
AMR	Adaptive Multi-Rate
ARIB	Association of Radio Industries and Businesses (Japan)
AWGN	Additive White Gaussian Noise
BCH	Broadcast Channel
BCCH	Broadcast Control Channel
BER	Bit Error Rate
BLER	Block Error Rate
BPSK	Binary Phase Shift Keying
BTFD	Blind Transport Format Detection
BTS	Base Transceiver Station
CC	Call Control
CCCH	Common Control Channel
CCDF	Complementary Cumulative Distribution Function
CCTrCH	Coded Composite Transport Channel
CDF	Cumulative Density Function
CDMA	Code Division Multiple Access
cdmaOne	Name identifying the EIA/TIA standard (commonly referred to as IS-95) for 2G
cdma2000	Name identifying the EIA/TIA standard (IS-2000) for 3G
C/N	Carrier-to-Noise Ratio
CPCH	Common Packet Channel
CPICH	Common Pilot Channel
CRC	Cyclic Redundancy Check
CW	Continuous Wave (unmodulated signal)
DCH	Dedicated Channel
DCCH	Dedicated Control Channel
DL	Downlink
DPCCH	Dedicated Physical Control Channel
DPDCH	Dedicated Physical Data Channel
DQPSK	Differential Quadrature Phase Shift Keying
DSP	Digital Signal Processing
DTCH	Dedicated Traffic Channel
DTX	Discontinuous Transmission
E_b/N_o	Energy-per-Bit-to-Noise Ratio
Ec/N_o	Energy-per-Chip-to-Noise Ratio
ETSI	European Telecommunications Standard Institute
EVM	Error Vector Magnitude
FACH	Forward Access Channel
FBI	Feedback Information
FDD	Frequency Division Duplex
FER	Frame Error Ratio
FR	Full Rate
GMM	GPRS Mobility Management
GMSK	Gaussian Minimum Shift Keying
GPS	Global Positioning System
GSM	Global System for Mobile Communications
HPSK	Hybrid Phase Shift Keying
IF	Intermediate Frequency
IMT-2000	International Mobile Telecommunications-2000 (Collective name for 3G technologies approved by the ITU)
IP	Internet Protocol
I/Q	In-phase/Quadrature
IS-2000	EIA/TIA interim standard 2000 (see cdma 2000)
IS-95	Interim standard for U.S. Code Division Multiple Access
LO	Local Oscillator
MAC	Medium Access Control
MM	Mobility Management
OCNS	Orthogonal Channel Noise Simulator
OCQPSK	Orthogonal Complex Quadrature Phase Shift Keying
OVSF	Orthogonal Variable Spreading Factor
PA	Power Amplifier
PAE	Power-Added Efficiency
PAR	Peak-to-Average Power Ratio
PCCH	Paging Control Channel
P-CCPCH	Primary Common Control Physical Channel
PCDP	Packet Data Convergence Protocol
PCPCH	Physical Common Packet Channel
PDC	Pacific Digital Cellular System
PDF	Probability Density Function
PDSCH	Physical Downlink Shared Channel
PICH	Paging Indication Channel
PN	Pseudo-Noise
PRACH	Physical Random Access Channel
PSC	Primary Synchronization Code
P-SCH	Primary Synchronization Channel
PSK	Phase Shift Keying
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
RACH	Random Access Channel
R&D	Research and Development
RF	Radio Frequency
RLC	Radio Link Control
RMS	Root Mean Square
RR	Radio Resource
RRC	Root Raised Cosine
RRC	Radio Resource Control
S-CCPCH	Secondary Common Control Physical Channel
SCH	Synchronization Channel
SEM	Spectrum Emissions Mark
SF	Spreading Factor
SFN	System Frame Number
SIR	Signal to Interference Ratio
SM	Session Management
SMS	Short Message Service
SSC	Secondary Synchronization Code
S-SCH	Secondary Synchronization Channel
TC	Test Control
TDD	Time Division Duplex
TDMA	Time Division Multiple Access
TF	Transport Format
TFC	Transport Format Combination
TFCI	Transport Format Control Indicator
TFCS	Transport Format Combination Set
TIA	Telecommunications Industries Association (U.S.)
TPC	Transmit Power Control
TTA	Telecommunications Technology Association (Korea)
TTC	Telecommunication Technology Committee (Japan)
TTI	Transmission Time Interval
UE	User Equipment
UL	Uplink
UMTS	Universal Mobile Telephone System (Europe)
W-CDMA	Wideband-Code Division Multiple Access (3G system)

For more information regarding these acronyms and other wireless industry terms, please consult our wireless dictionary at: www.agilent.com/find/wireless

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