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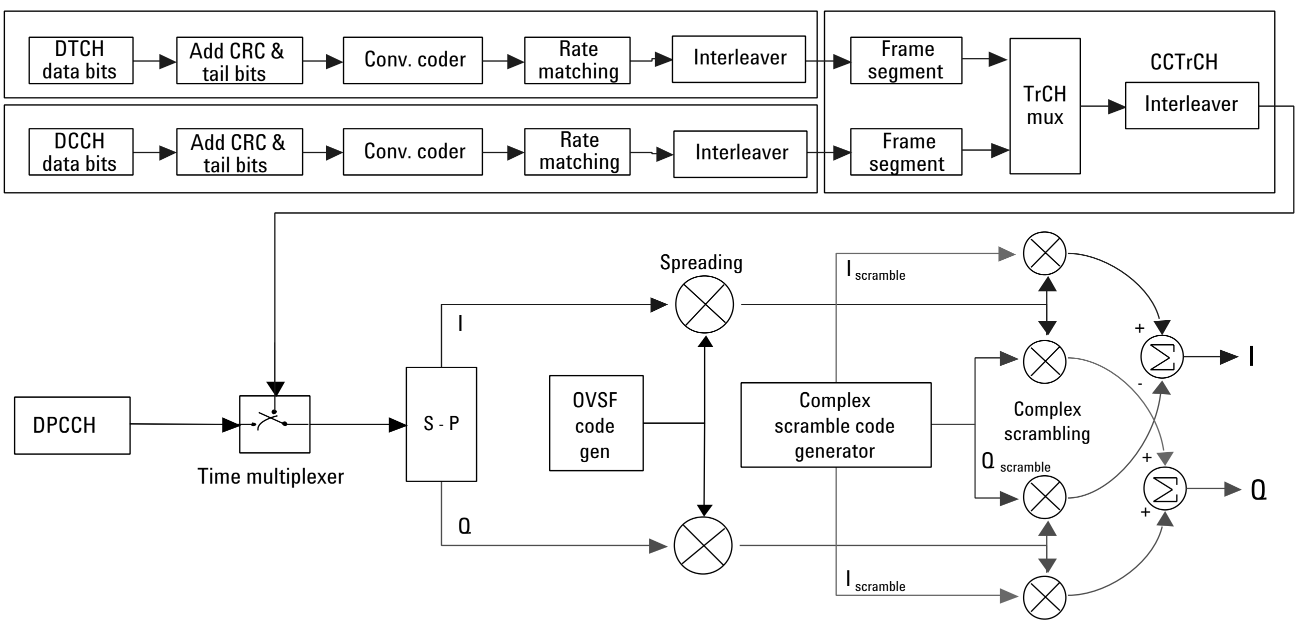
Designing and Testing 3GPP W-CDMA Base Stations

Application Note 1355



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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 base stations (BS). It consists of

- a brief overview of W-CDMA technology

- a discussion of design issues and measurement concepts related to the technol ogy that are important for the W-CDMA UE air interface because of the differ ences between W-CDMA and its second generation (2G) predecessors (specifically GSM and 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 BS. This section can also be used as background information for conformance tests.

- a table with an overview of the BTS transmitter, reciever, and performance conformance tests required by the standard **[1]**. In many cases, the tests are based on the more general measurements described previously. You can use this table as a quick guideline on what measurement and equipment to use for each test.

- a list of Agilent Technologies' solutions for the physical layer of W-CDMA base station design and test

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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) **[2]**.

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).

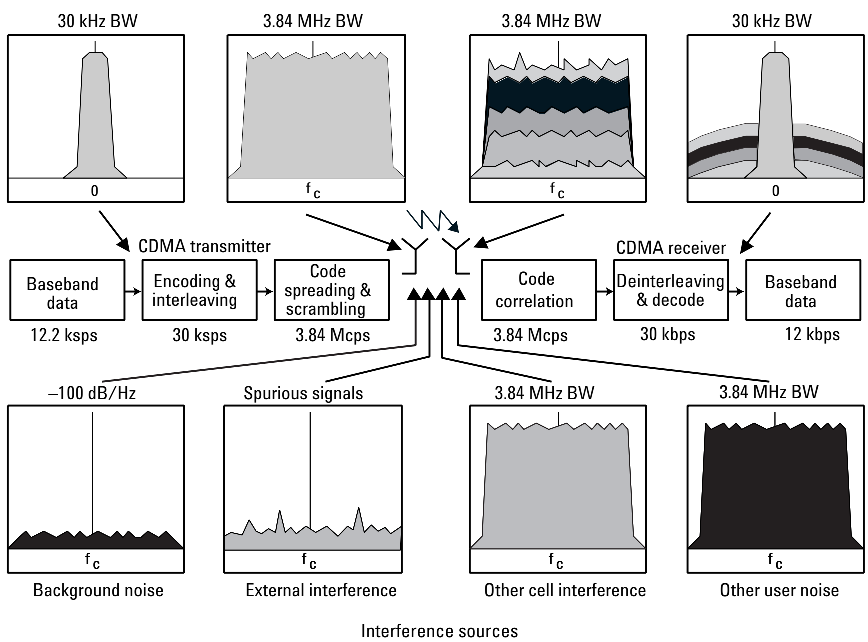


Figure 1. CDMA transmission and reception processes

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. 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 station and user equipment (UE)[1] identification

As in other CDMA systems, in W-CDMA each BS 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 (SC). A UE receiver can distinguish one base station from another by correlating the received signal spectrum with a scrambling code that is identical to that used in the desired BS. Similarly, each UE output signal is scrambled with a unique SC that allows the BS 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 BS 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 BS. In W-CDMA, this function is provided by using 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 BS or UE is multiplied by a different OVSF code[2]. In IS-95, CDMA Walsh codes were 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 BS. The scrambling code allows OVSF code reuse among UE and BS 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 BS.

The W-CDMA radio link between the BS 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.

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

Figure 2 illustrates a W-CDMA system with two BSs and four UEs. The SC provides a unique identity to each UE and each BS. The OVSF code allocations provide a unique identity to each channel conveyed by a UE or BS within one cell. For example, SC_2 identifies BS 2, and SC_6 identifies UE 4. BS 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 BS 2. Note that other BS and UE 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.

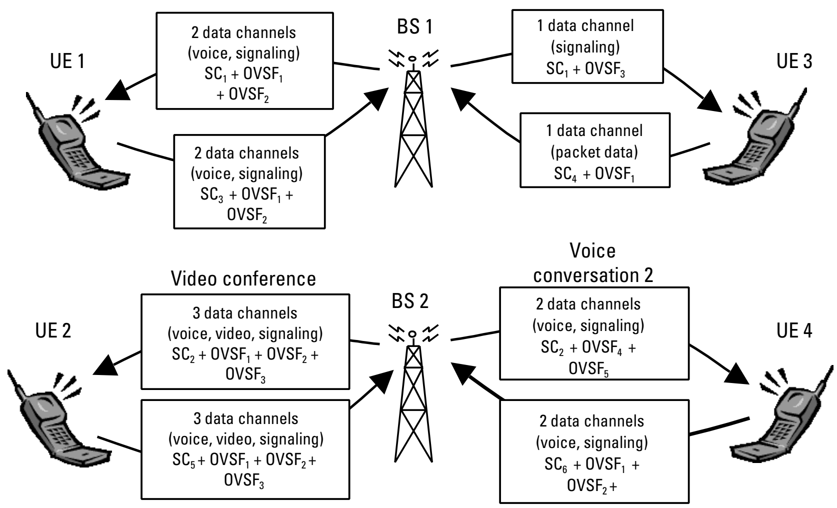


Figure 2. W-CDMA code allocations

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 msec. 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 controls

All W-CDMA uplink and downlink 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 msec 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.

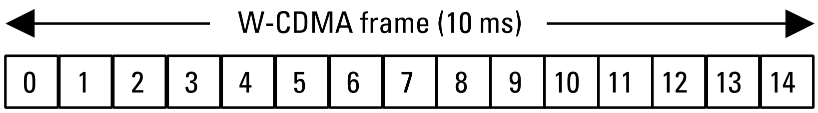


Figure 3. W-CDMA slot and frame structure

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

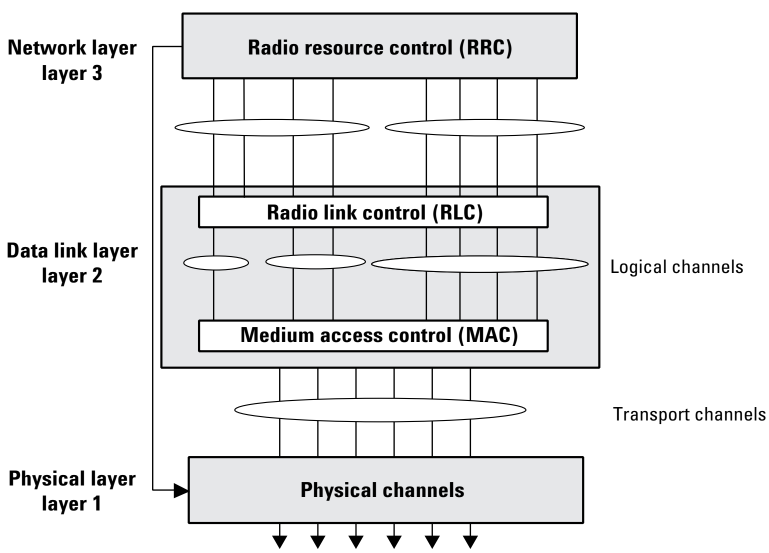


Figure 4. W-CDMA protocol structure

The network layer (layer 3) is based heavily on GSM standards. It is responsible for connecting services from the network to user equipment. 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) as well as providing the multiplexing/de-multiplexing function of various logical channels efficiently onto the same transport channel. The physical layer (layer 1) maps the transport channels on to 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 **[4]** and **[5]**. See **[6]** for information on layer 3. See **[7]** 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). **[8]**

The W-CDMA downlink 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 uplink 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 downlink. When a UE is in the idle mode, the BS 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 signalinginformation is routed through the DCH transport channel. This maps the information onto the DPCH (DPDCH/DPCCH) physical channel for transmission to the UE.

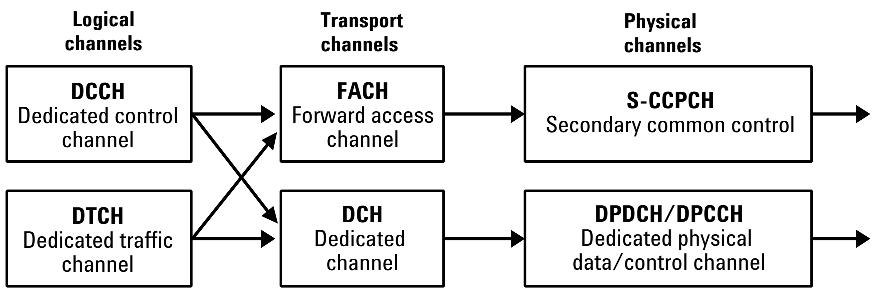


Figure 5. Example of logical, transport, and physical channel mapping (DL)

1.7 Downlink physical channels

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

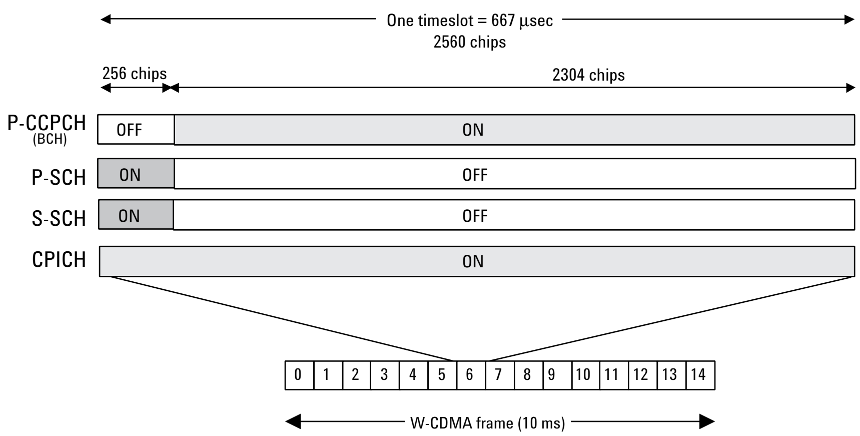


Figure 6. CPICH, P-CCPCH and SCH slot and frame structure

The CPICH is a continuous loop broadcast of the BS scrambling code. As described earlier, the scrambling code provides identification of the BS transmission. The UE uses the CPICH as a coherent reference for precise measurement of the BS time reference, as well as to determine the signal strength of surrounding BS 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 BS. During initial acquisition, the UE uses the PSC to determine if a W-CDMA BS is present and establish the slot boundary timing of the BS. The SSC represents a group, called a code group, of 16 subcodes, each with a length of 256 chips. The BS transmits these codes in an established order, one SSC subcode in each time slot of a frame. When a UE decodes 15 consecutive SSC transmissions, it can determine the BS frame boundary timing, as well as derive information that will aid in the identification of the BS 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. 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). Together, the multiplexed DPDCH/DPCCH form the DPCH, or the Dedicated Physical Channel (figure 7).

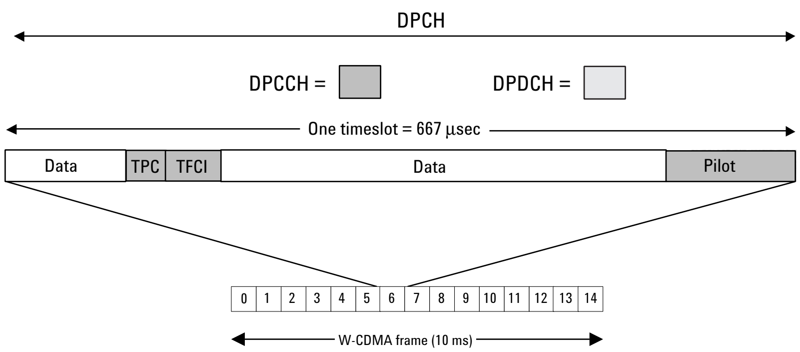


Figure 7. DPCH (DPDCH/DPCCH) slot and frame structure

Other downlink 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 downlink data throughput for a single UE.

1.8 Uplink physical channels

The PRACH carries the RACH transport channel used by the UE to request registration on the network. RACH transmissions begin with a short preamble pattern that alerts the BS of the forthcoming RACH access message. The RACH message, which includes the identification of the UE, is spread using a cell-specific scrambling code so that only the targeted BS will recognize the access attempt. In general, the RACH 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 message using different time slots until an acknowledgment is received.

The PCPCH carries the CPCH transport channel and it is used for uplink packet data transmission. The CPCH is an efficient way to send uplink 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 BS to control the PCPCH transmit power. After the CPCH access attempt is successfully acknowledged, the UE begins transmitting and the BS 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. 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 **[9]**.

1.9 Downlink DPDCH/DPCCH coding and air interface

Figure 8 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 2.4 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 and used to modulate the RF carrier (not shown in the figure).

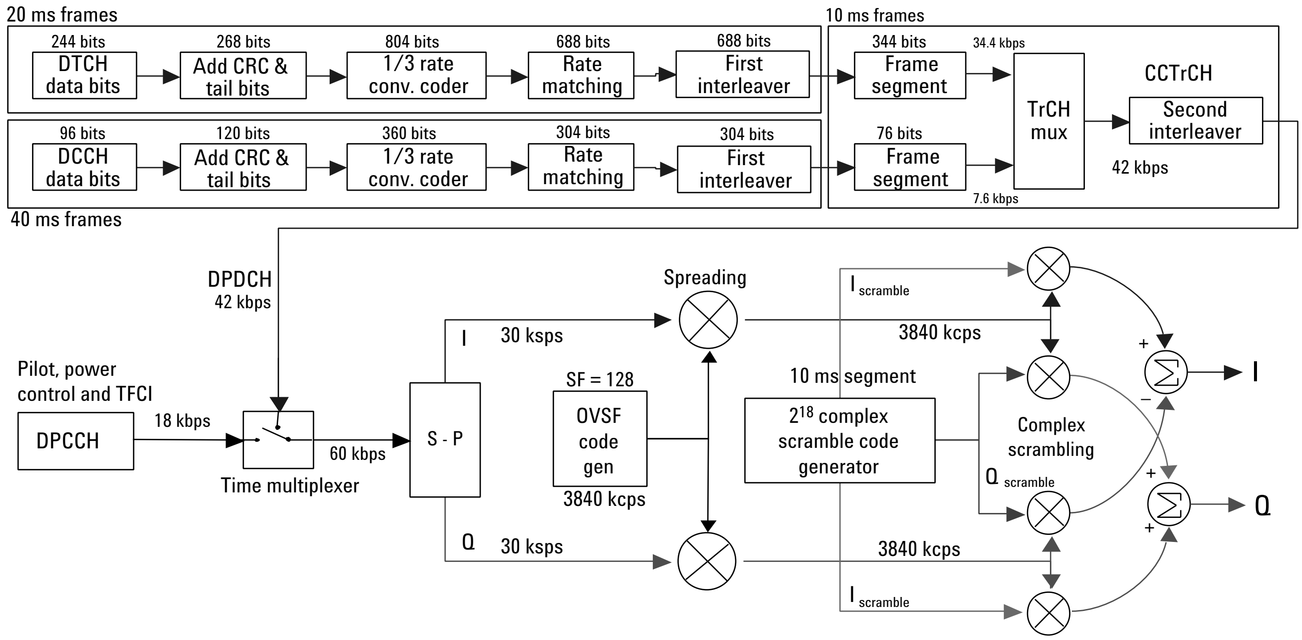


Figure 8. Downlink DPDCH/DPCCH coding, spreading, and scrambling. (Refer to [3], [10], and [11] for an alternative description.)

1.10 Uplink DPDCH/DPCCH coding and air interface

The spreading and scrambling used on the uplink DPDCH/DPCCH differs from the downlink in two key areas: I/Q multiplexing and hybrid phase shift keying (HPSK) scrambling (instead of complex scrambling). Figure 9 shows an example of the coding and air interface for an uplink DPDCH anDPCCH. In this an example, the logical DTCH carries a 12.2 kbps voice channel and the logical DCCH carries a 2.4 kbps signaling channel. Each of these logical channels is channel coded, convolutionally coded, and interleaved. The DTCH uses 20 msec 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 standard. The scrambling generator produces two random sequences (referenced in the standard as $C_{long,1}$ and $C_{long,2}$, if long scrambling sequences are used **[10]**).

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 **[12]**.

The resulting I and Q signals are then filtered and used to modulate the RF carrier (not shown in the figure).

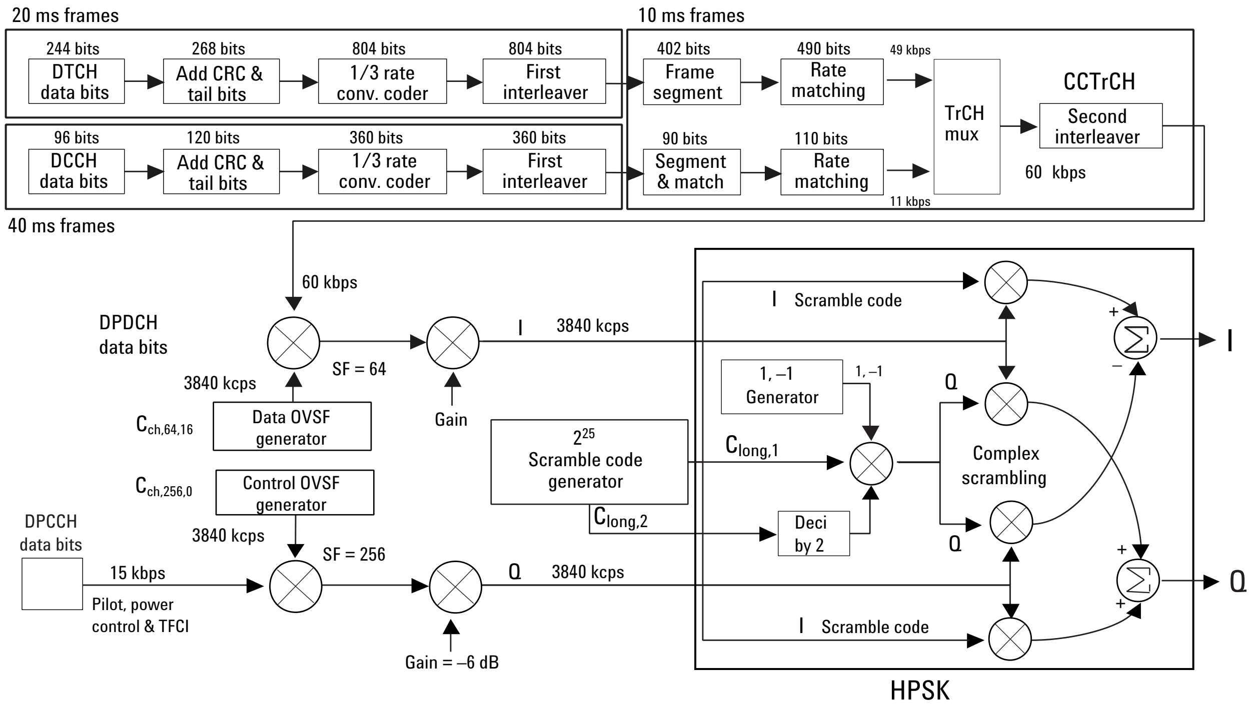


Figure 9. Uplink DPCH/DPCCH coding, spreading, and scrambling. (For an alternative description, refer to [3], [10], and [11].)

1.11 Test models and reference measurement channels

In order to avoid ambiguity and inconsistency across different equipment suppliers, the 3GPP standard defines the UL and DL channel configurations to use for BS transmitter and receiver conformance testing, respectively **[1]**.

The DL test configurations are called test models. There are four test models. Each transmitter conformance test requires the BS to transmit one of these models. For example, test model 2 is used for the output power dynamics tests. Appendix A provides all the test model configurations as specified in the standard **[1]**.

The UL test configurations are called reference measurement channels. There are five UL reference measurement channels. All of them consist of a DPDCH and a DPCCH. The main difference between the reference measurement channels is the information bit rate for the DTCH logical channel (12.2 kbps, 64 kbps, 144 kbps, 384 kbps, or 2048 kbps). As an example, appendix A provides the structure of the 12.2 kbps reference measurement channel, as specified in the standard **[1]**.

The data rates in the channel configuration example in figure 9 correspond to the 12.2 kbps UL reference measurement channel. This is the reference measurement channel specified by the standard for most receiver conformance tests. Appendix A provides the complete structure and parameter description for the 12.2 kbps UL reference measurement channel as it appears in the standard **[1]**.

1.12 Asynchronous cell site acquisition

Other CDMA systems use GPS to precisely synchronize the time reference of every BS. This provides the benefit of simplifying acquisition and inter-cell handover. In particular, the scrambling codes, short PN codes, used by IS-95 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 BS 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 BS 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.

1.13 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 BS are individually correlated and then combined. As such, communication is possible in situations where an individual signal from a single BS might otherwise be too weak to support the radio link.

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

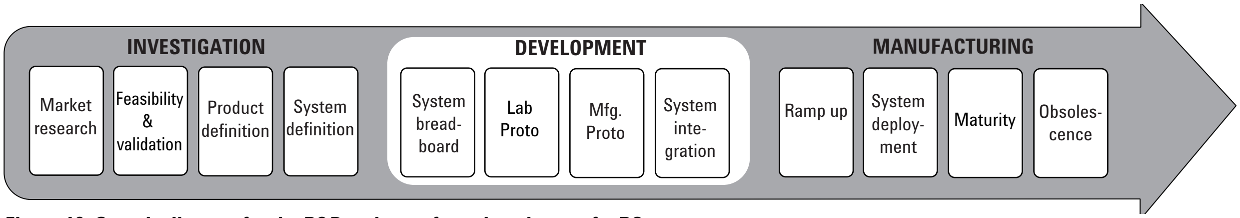


Figure 10. Generic diagram for the R&D and manufacturing phases of a BS

2. General design and measurement issues

Figure 10 shows a generic diagram for the R&D and manufacturing phases of a BS. This chapter focuses on the development phase of the BS (highlighted in white), however, it contains general information that may be useful to engineers involved in any area of the BS life cycle.

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 testing, 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 ratio, 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. There is no doubt this trend will continue but, with care, existing power meters can be used to perform these measurements.

To this end, 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 11).

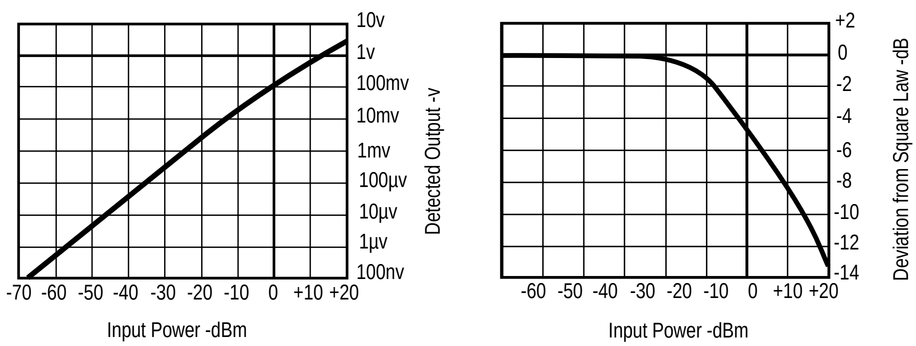


Figure 11. The diode detection characteristic ranges from square law through a transition region to linear detection

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 that care is taken. 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 power statistics and modulation quality analysis.

2.1.2 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 (BS 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:

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

The main source of adjacent channel leakage (ACL) is non-linear effects in the power amplifiers (PA). ACL 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 can cause the so called "near-far" problem, where a BS simply cannot communicate with a far away UE because of high ACL from a nearby adjacent channel BS. 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 standards committees. The current values in the 3GPP standard for the BS are 45 dB at 5 MHz offset and 50 dB at 10 MHz offset **[1]**.

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 root raised cosine (RRC) filter with a –3 dB bandwidth equal to the chip rate **[1]**. This provides a 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 particular W-CDMA ACLR capability, although in reality, the difference in the measurement result is very small (around 0.1 dB). Figure 12 shows an ACLR measurement for a W-CDMA DL signal configured as test model 1 with 16 DPCHs (see appendix B). The measurement was performed using a vector signal analyzer with the appropriate RRC filter, as specified in the standard **[1]**.

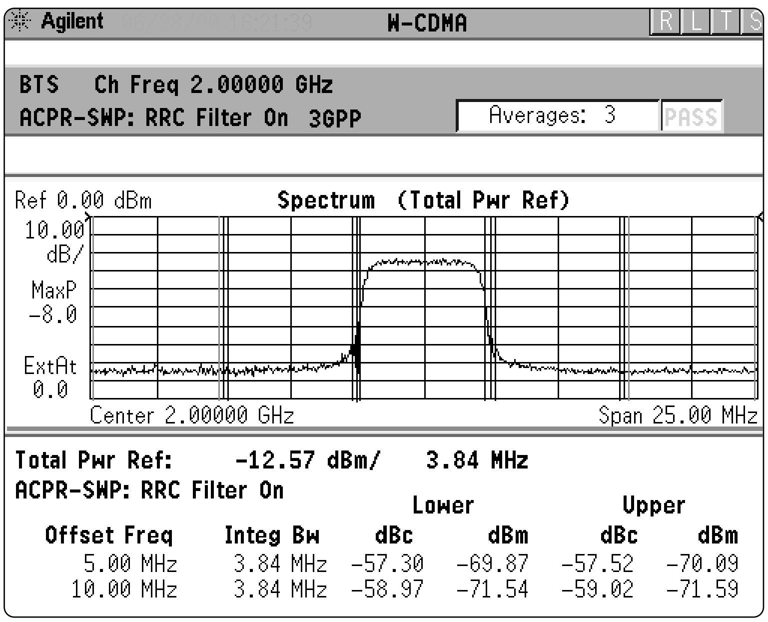


Figure 12. ACLR measurement for test model 1 with 16 DPCHs. Measurement uses RRC filter as specified in the standard [1].

2.2 Handling high peak-to-average power ratios (PAR)

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

Some of the 2G systems, such as GSM, use a constant modulation format (Gaussian minimum shift keying (GMSK)). GSM has the advantage of having a constant amplitude envelope, which allows the use of less expensive, non-linear, class B power amplifiers (PA).

By contrast, CDMA systems use non-constant modulation formats. 2G TDMA systems, such as PDC, that also use non-constant amplitude modulation formats, try to minimize the peak-to-average power ratio (PAR) by avoiding signal envelope transitions through zero. Peak-to-average power ratio is the ratio of the peak envelope power to the average envelope power of a signal. In general, low peak-to-average power ratios are desirable, which reduce the required PA linear dynamic range.

In CDMA systems, multiple channels are added to modulate a single carrier. The PAR increases as code channels are activated. A PAR of 8 dB is not uncommon for a W-CDMA DL multi-channel signal. Amplifier design for W-CDMA BS is particularly challenging because the amplifier must be capable of handling the high PAR the signal exhibits, while maintaining a good adjacent channel leakage performance. The use of multi-carrier power amplifiers pushes design complexity one step further.

Both the amplifier designer and the system integrator must make sure the amplifier (and other components) can handle the PAR for stressful channel configurations, while maintaining a good adjacent channel leakage performance. You can use the complementary cumulative distribution function to help you with this task.

2.2.1 Complementary cumulative distribution function (CCDF)

The CCDF fully characterizes the power statistics of a signal **[15]**. It provides PAR versus probability. Figure 13 shows the CCDF curves for two W-CDMA DL signals with different channel configurations: a signal with one DPCH and a signal configured as test model 1 with 16 DPCHs (see appendix A.) For a probability of 0.1 percent, the signal with 16 code channels has a higher peak-to-average ratio (8.5 dB) than the signal with one code channel (4.5 dB).

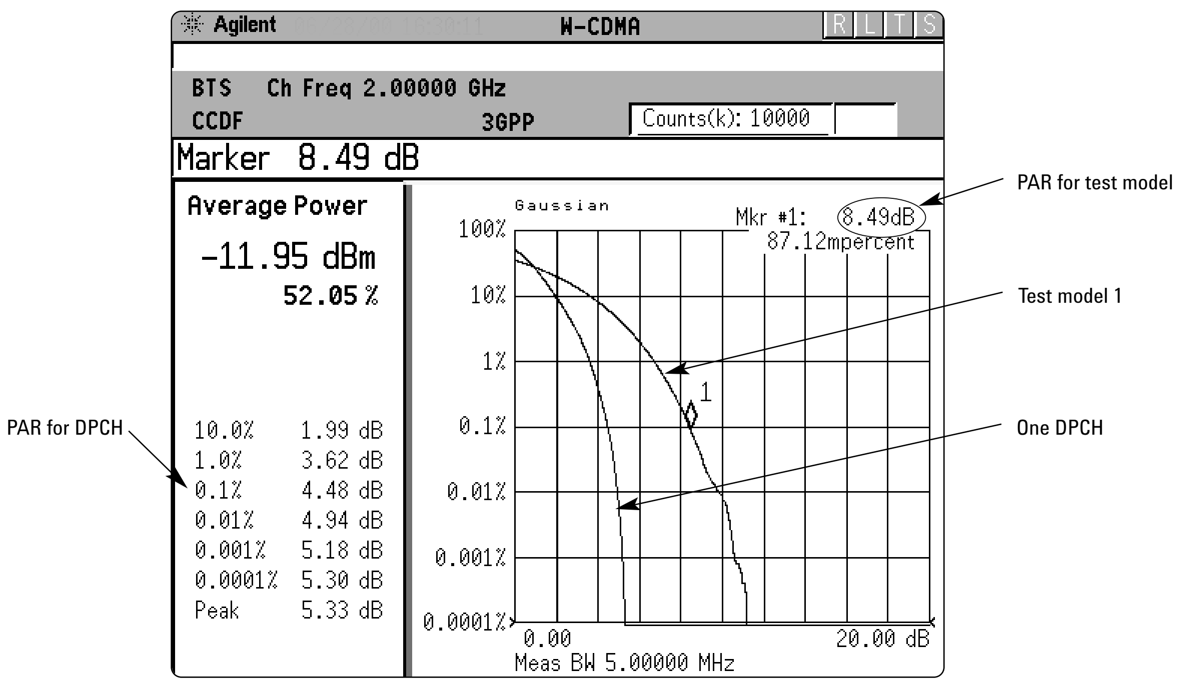


Figure 13. CCDF of a W-CDMA signal with one DPCH and a signal configured as test model one with 16 DPCHs

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 subsys tem 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 power amplifier. If the amplifier design is correct, the curves coincide. If the amplifier compresses the signal, the peak-to-average ratio of the signal is lower at the output of the amplifier (figure 14).

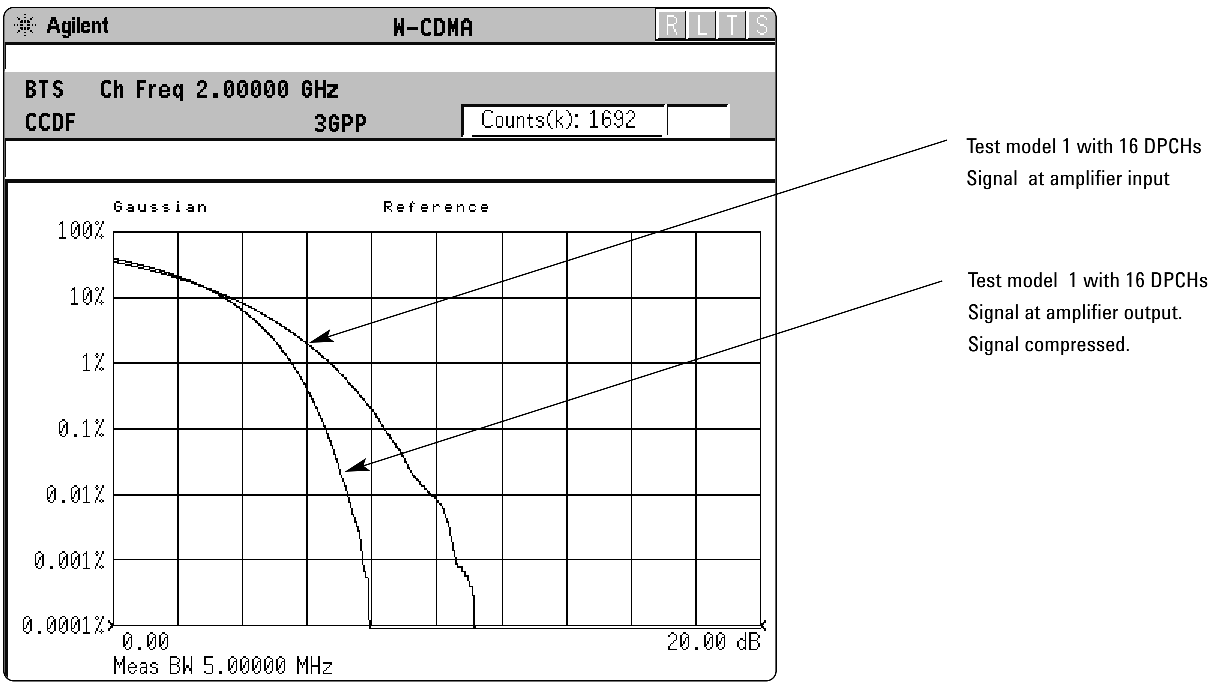


Figure 14. CCDFs for test model 1 with 16 code channels with and without compression

2.3 Measuring modulation accuracy

In constant amplitude modulation schemes, such as GMSK, the phase and the frequency error are the metrics for modulation quality. However, these metrics are not very effective for non-constant amplitude modulation formats, which 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 15.

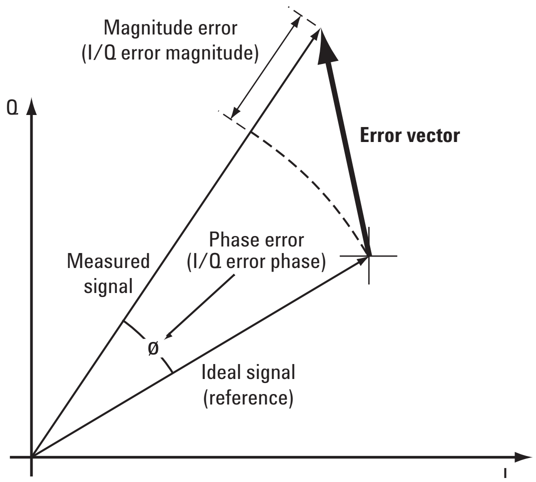


Figure 15. Error vector and related parameters

The reference position is determined from a reference signal that is synthesized by demodulating the data bits from the received signal and then re-modulating these bits "perfectly", for a generic QPSK signal, as shown in figure 16.

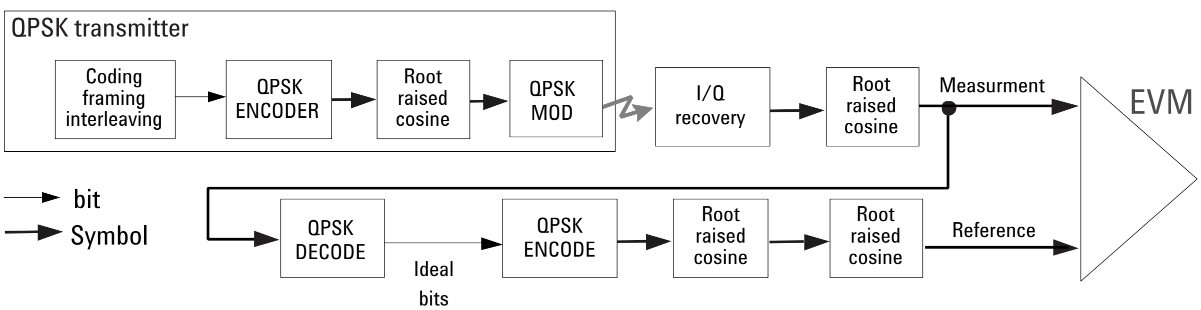


Figure 16. Process to calculate EVM for a generic QPSK signal

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. Shall we measure the EVM at the chip or at the symbol level? Shall we measure EVM for a signal with a single DPDCH channel or with another channel configuration? How do we calculate the reference?

The following sections explain the differences between the various EVM and other modulation quality measurements that you can perform on a W-CDMA DL signal and when they should be used.

1. The actual calculation methodd of the percentage depends on the specific standard. The EVM may be normal ized 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 standard requires normalization to the square root of the mean power of the ideal signal (see section on Composite EVM).

2.3.1 QPSK EVM

For a QAM or a PSK signal the ideal symbol points always map onto a few specific locations in the I/Q plane. W-CDMA uses a QPSK format to modulate the spread signal (chips). However, the signal consists of several code channels. Each channel is QPSK encoded1, and the I and Q are spread and complex scrambled (see figure 8). The code channels are typically added at this point, before the baseband filtering. The complex-valued chip sequence is then filtered with an RRC (a = 0.22) filter, and the result is applied to the QPSK modulator2. The final constellation at the RF does not typically look like QPSK, or any other known constellation, except for some very specific channel configurations. For example, a signal with a single code channel does map onto a 45°-rotated QPSK constellation, as shown in figure 18. The rotation is caused by the complex scrambling. Since the receiver does not care about the absolute phase rotation, it effectively sees a QPSK constellation.

Therefore, you can use a regular QPSK EVM measurement to get some indication of the modulation quality at the chip level for a single-channel signal. 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 17).

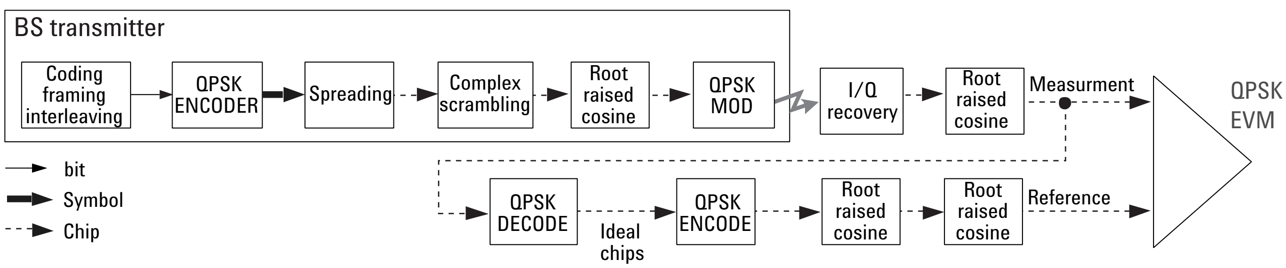


Figure 17. Process to calculate QPSK EVM for a W-CDMA DL signal

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 it does not detect OVSF spreading or complex scrambling errors.

If it is not possible to despread and descramble the signal, the QPSK EVM measurement may be the only choice. In that 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 18 shows the QPSK EVM measurement and vector diagram for a W-CDMA DL signal (one DPCH) with and without an I/Q gain error.

---

1. QPSK encoding, in this case, refers to the process of mapping the bits for a channel onto the I (or the Q) path in parallel.
2. QPSK modulation, in this case, refers to the upconversion process. The process of modulating the RF carrier with the I/Q baseband signal.

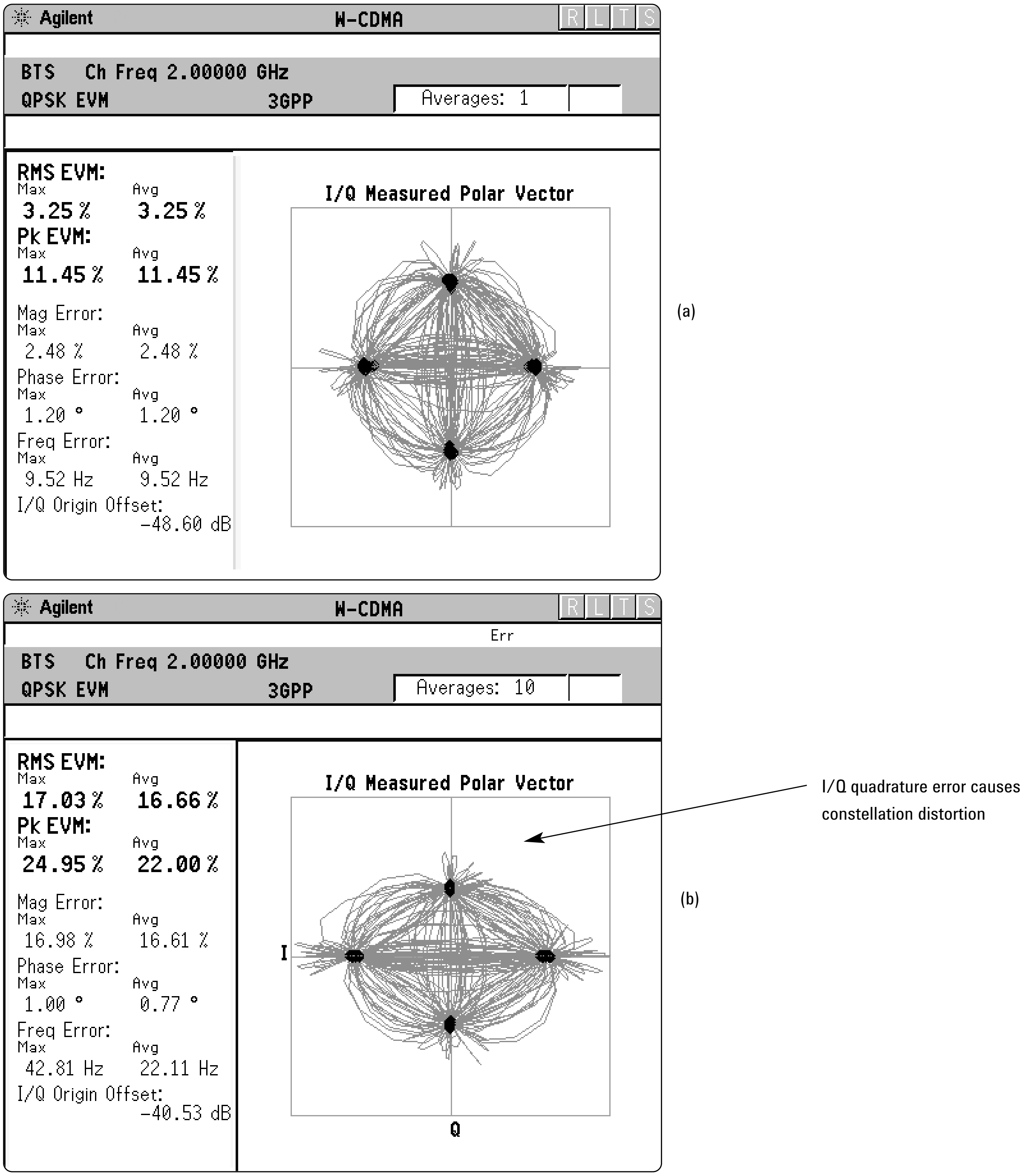


Figure 18. Vector diagram and QPSK EVM measurement for a W-CDMA DL signal with a single DPCH. (a) Transmitter without any impairment. (b) Transmitter with an I/Q gain error.

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 gain error in figure 18) can be easily recognized by looking at the vector diagram, while 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 code channel 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 that case is the composite EVM measurement. The EVM measurement corresponds to the modulation accuracy conformance test specified in the 3GPP standard **[1]**.

To evaluate the modulation accuracy of a W-CDMA multi-channel DL 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 receive filter. Active channels are descrambled, despread, and QPSK decoded to bits (see figure 19).

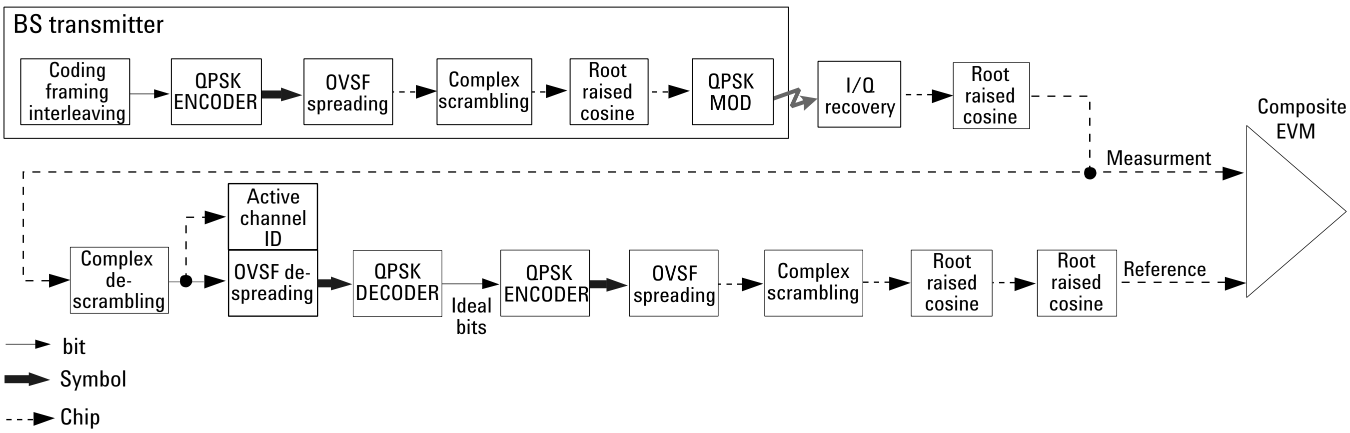


Figure 19. Process to calculate composite EVM for a W-CDMA DL signal

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.

To make a composite EVM measurement the W-CDMA DL signal must contain either the SCH or the CPICH. Otherwise, the analyzer cannot synchronize to the signal and calculate the appropriate reference. In that case, you can use QPSK EVM to measure the RF performance for a single channel (for example, the CPICH or a DPCH), 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. As mentioned earlier, the PAR 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 DL signals with differ ent 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 20a shows the vector diagram and composite EVM measurement for a W-CDMA signal with the P-CPCCH and SCH, which corresponds to test model 4, required by the modulation accuracy test in the standard **[1]**. Figure 20b shows the vector diagram and composite EVM measurement for a W-CDMA signal with the P-CCPCH/SCH, CPICH, and three DPCH.

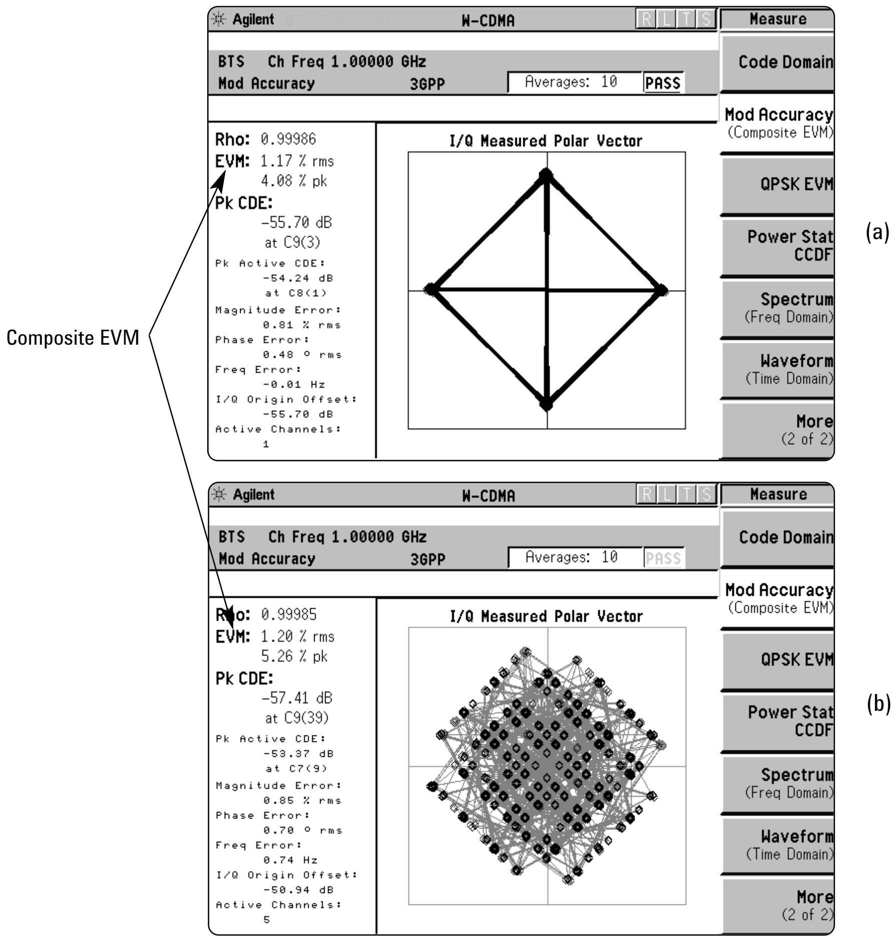


Figure 20. Vector diagram and composite EVM measurement for a W-CDMA DL signal with (a) the P-CPCCH/SCH, and (b) the P-CPCCH/SCH, CPICH, and three DPCHs.

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.

4. **To analyze errors that cause high interference in the signal.** If the interference is too high, the QPSK EVM measurement may not be able to recover the true ideal reference. In this case, the QPSK EVM and its related displays are not accurate. Since the composite EVM measurement descrambles and despreads the signal, it takes advantage of its spreading gain. This gain allows it to recover the true reference even when the signal is well beyond the interference level that will cause multiple chip errors. Therefore, composite EVM is a true indicator of modulation fidelity even when the signal under test is buried by interference. This measurement may be particularly useful in hostile field environments with high levels of interference. System integrators can use composite EVM to analyze how the interference will affect BS deployment, and to provide BS-to-UE sensitivity curves for the service providers (how bad EVM can get before the UE, or signal analyzer, cannot recover the signal). The spread ing gain benefits of composite EVM can also be useful to RF designers and system integrators for occasional bad cases of interference. For example,figure 21a shows the phase error versus time display for a QPSK EVM measurement for a signal with the a DPCH. The signal has a very high local oscillator (LO) instability and the analyzer is not able to recover the correct reference. Figure 21b shows the phase error versus time for a composite EVM measurement for a signal with a CPICH and a DPCH. In this case, the analyzer can demodulate the signal and calculate the reference accurately. The EVM metric given by the composite EVM measurement is correct and the phase error display in figure 21b will allow you to analyze the interference.

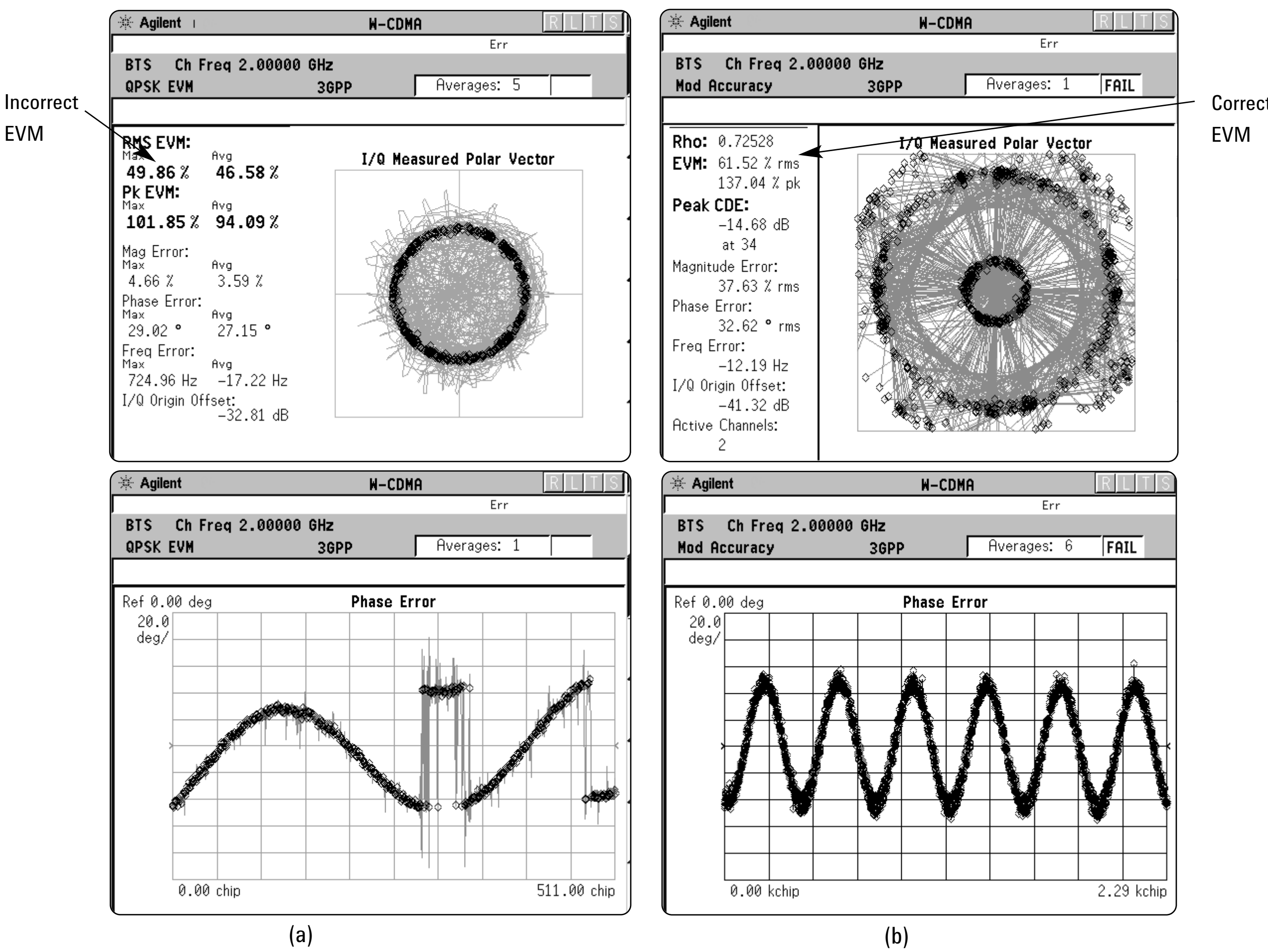


Figure 21. W-CDMA UL signal with the P-CCPCH/SCH. Signal with very high LO instability. (a) Vector diagram and phase error versus time for a QPSK EVM measurement. (b) Vector diagram and phase error versus time for a composite EVM measurement.

Composite EVM is useful throughout the development, performance verification, and manufacturing phases of the BS life cycle as a single figure of merit of the composite waveform as a whole. You will also be interested in the code-by-code composition of the mutiplex. 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, also known as the spreading factor (SF), varies to accommodate the different data rates. As the user rate increases the symbol period is shorter. Since the final chip rate is constant, fewer OVSF code chips are accommodated within the symbol period — the SF is smaller. The spreading factor can be 4, 8, 16, 32, 64, 128, 256, or 512 corresponding to DPCH symbol rates from 960 ksps down to 7.5 ksps.

Seven sets of spreading codes are specified, one set for each spreading factor. The OVSF codes can be allocated using the code tree of figure 22. Each code is denoted by $C_{ch,SF,n}$. For example, $C_{ch,4,2}$ means channelization code, SF = 4, code number two.

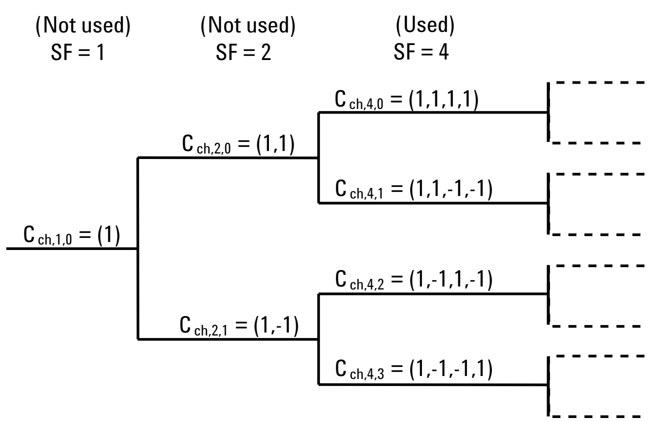


Figure 22. Code tree generation of OVSF codes [10]

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 Cch,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 23 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 codes that start with 1,1,-1,-1, have to be inactive because they are not orthogonal.

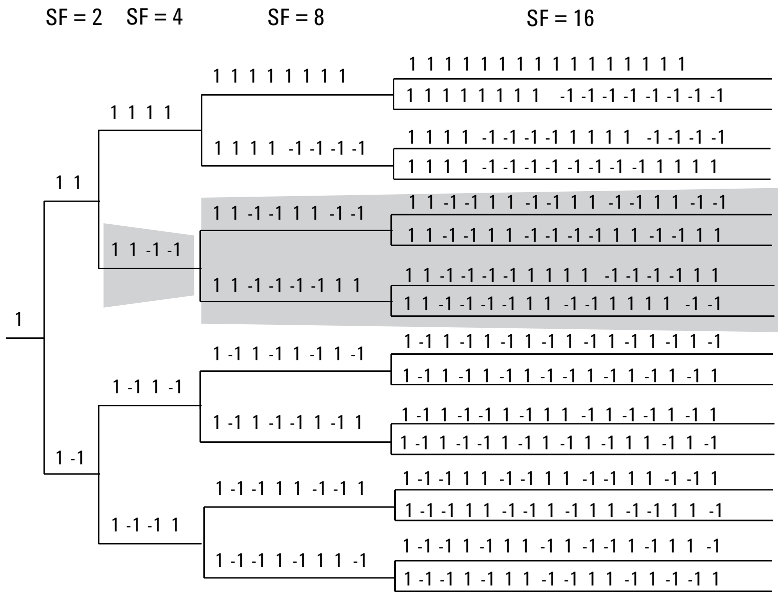


Figure 23. Effects of using variable SFs

In terms of code capacity, channels with higher data rates (lower SF) occupy more code space. For example, $C_{ch,4,1}$ occupies 4 times more code space than $C_{ch,8,2}$,and 16 times more code space than $C_{ch,16,4}$. In the code domain power display, the wider bars represent codes with low SF, which occupy more code space. Figure 24 shows the code domain power display for a signal with the P-CCPCH/SCH, CPICH, one DPCH at 30 ksps with SF = 128 ($C_{ch,128,8}$), and one DPCH at 120 ksps with SF = 32 ($C_{ch,32,15}$). The marker is positioned on the “wide” code channel ($C_{ch,32,15}$), which indicates a high data rate (120 ksps). In order to provide this display, the analyzer must be able to identify the SFs of the active code channels.

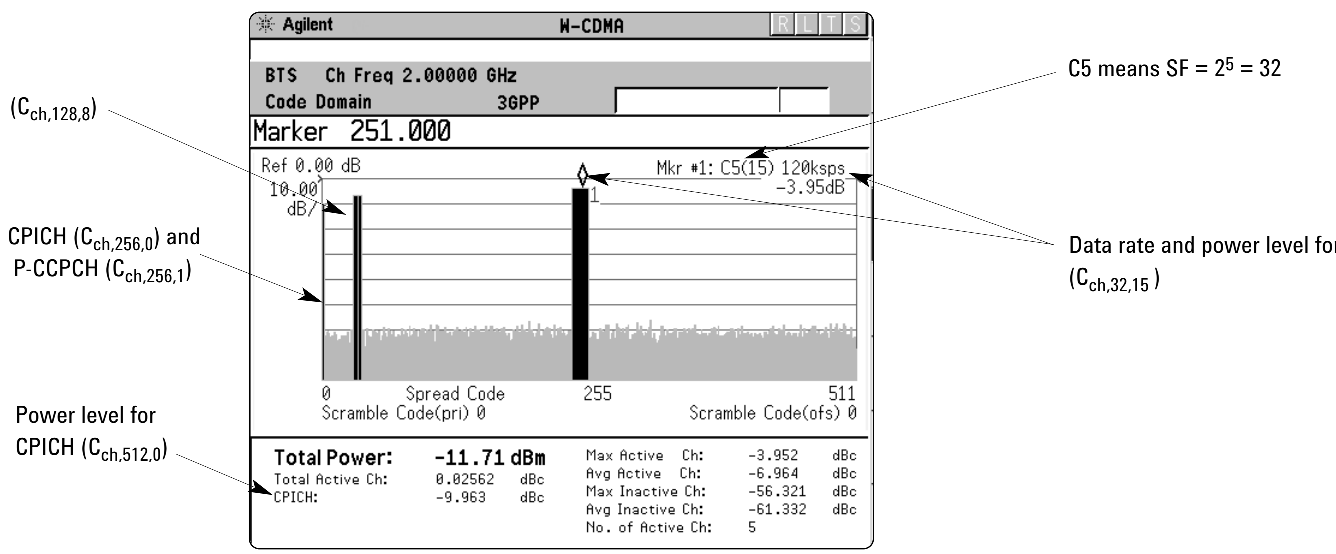


Figure 24. Code domain power display for a signal with the P-CCPCH/SCH, CPICH, and two DPCHs ($C_{ch,32,15}$ and $C_{ch,32,15}$).

The code domain power measurement helps you not only verify that each OVSF channel is operating at its proper level, 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 level for the inactive channels will be zero. In reality, signal and system imperfections compromise the code orthogonality and result in a certain amount of the signal power projecting onto inactive codes. A real signal will also have a certain noise level, which will project more or less evenly onto all codes randomly.

The projection of the error is interesting because it enables us 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 cause of uneven distribution of error power is power amplifier non-linearity. Signal compression causes what is known as code mixing. This effect can be predicted mathematically **[12]**. In essence, energy is lost from the active channels and appears in those channels with codes that are the exclusive OR (XOR) of the active channel codes. In figure 25, amplifier compression on a signal with channels $C_{ch,32,8}$ and $C_{ch,32,14}$ causes energy in the code space that would be occupied by $C_{ch,32,6}$.

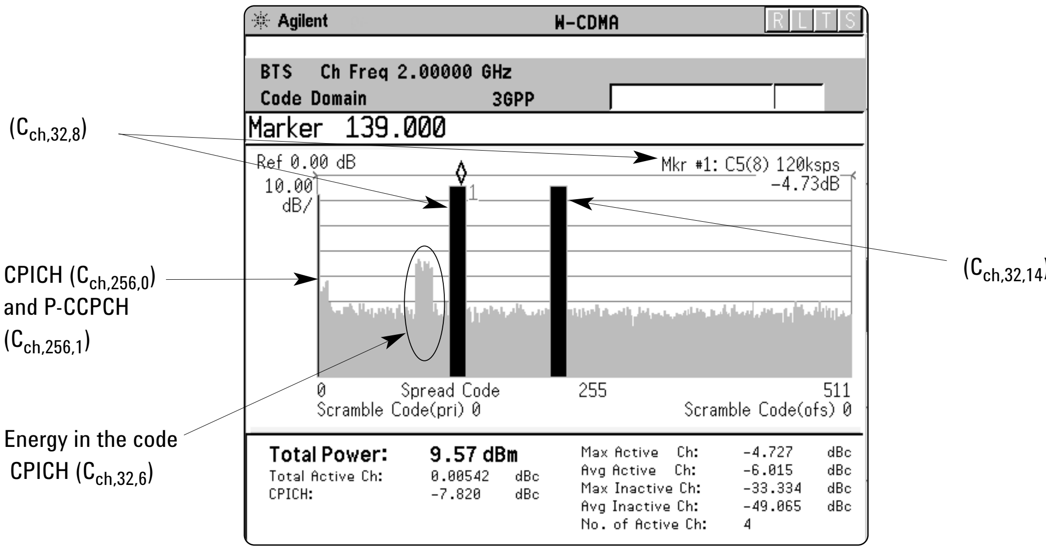


Figure 25. Code domain power display for a signal with the P-CCPCH/SCH, CPICH, and two DPCHs ($C_{ch,32,8}$ and $C_{ch,32,14}$). Amplifier compression causes code mixing.

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, which specifies a limit for the error power in any one code.

To provide this metric, the analyzer must project the error vector power on each code channel at a spreading factor of 256. The peak code domain power is then calculated from the code that returns the largest error power relative to the reference.

Gaussian noise distributes the power evenly through the code domain. By contrast, transmitter impairments typically cause the highest code domain errors in the active code channels, since the code domain energy lost from these channels (their code domain error) is spread in several code channels. Figure 26 shows the peak code domain error, in combination with the composite EVM for the same signal with the code-mixing problem above.

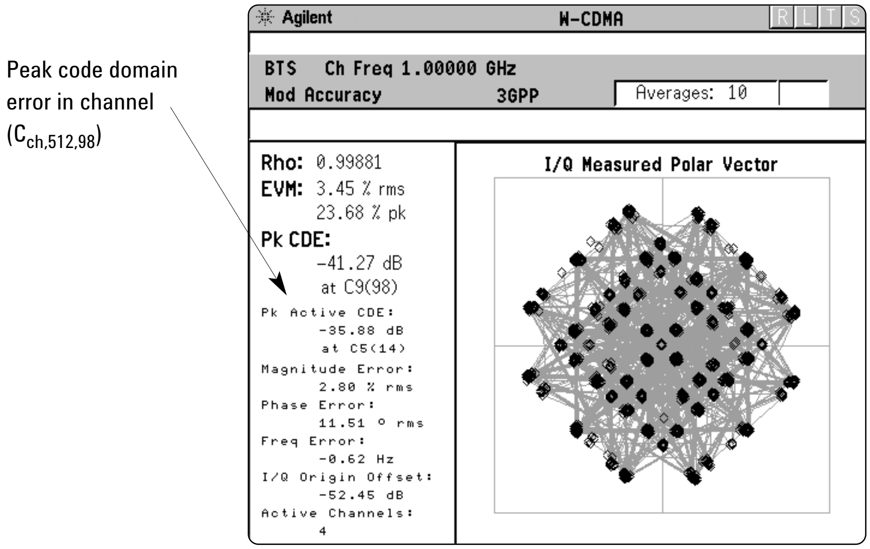


Figure 26. Peak code domain error and composite EVM for W-CDMA DL signal with the P-CCPCH/SCH, CPICH, and two DPCHs ($C_{ch,32,8}$ and $C_{ch,32,14}$). Signal with compression impairment.

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 27 shows how these measurements are calculated.

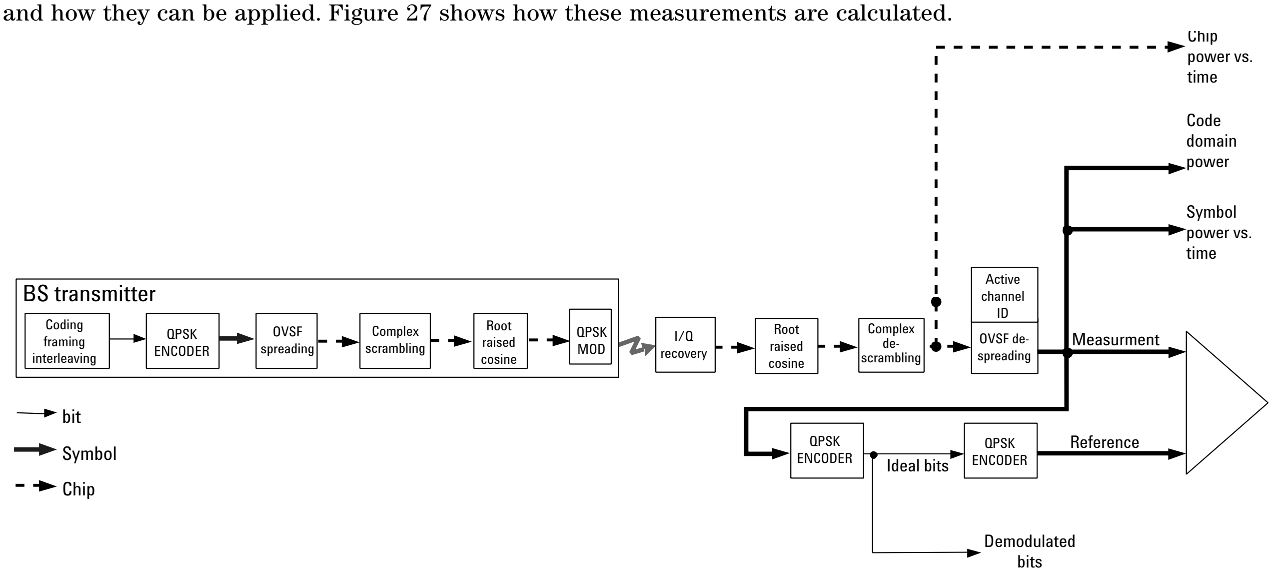


Figure 27. Process to calculate code domain power, symbol EVM, symbol power versus time, chip power versus time, and demodulated bits

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 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 27).

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 baseband engineers a measure of modulation quality closer to real-life performance. In this sense, you can think of it as the actual quality that the user in that channel will experience (similar to the reciprocal of bit error rate (BER)).

The relationship between symbol EVM and chip EVM depends on the spreading factor. At low spreading factors (high data rates) chip modulation errors have a significant effect on symbol EVM. At high spreading factors, chip modulation errors have little effect on symbol EVM. In this sense, it is particularly useful to baseband DSP engineers to evaluate symbol quality and analyze how specific impairments affect the quality of channels at different data rates. For example, figure 28 shows the symbol EVM for a signal with a phase error problem, for a channel at 15 kbps with SF = 256, and a channel at 480 kbps with SF = 8. The symbol EVM is higher for the higher data rate channel.

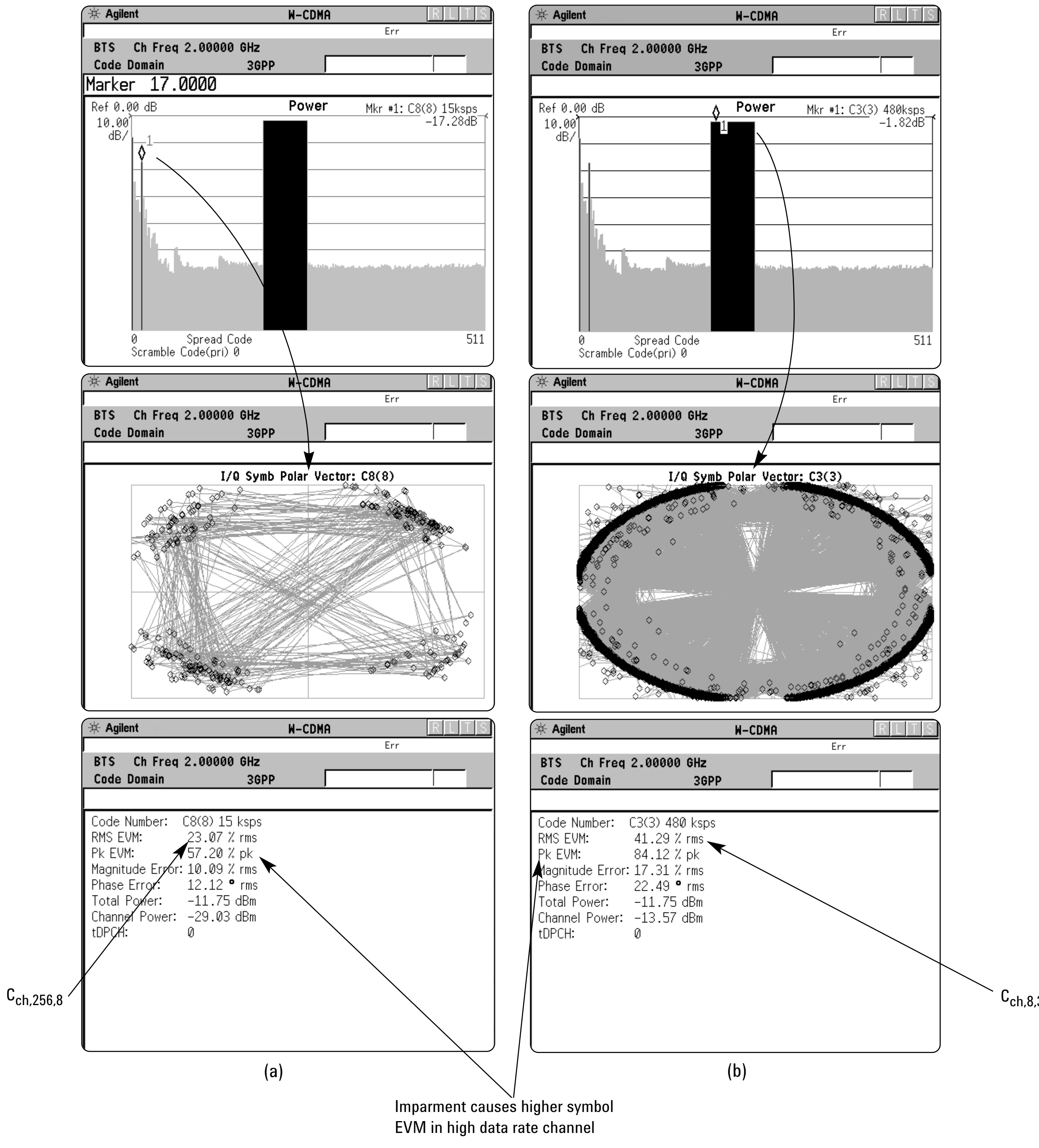


Figure 28. Code domain power measurement of a W-CDMA DL signal with the P-CCPCH/SCH, CPICH, and two DPCHs ($C_{ch,256,8}$ and $C_{ch,8,3}$). (a) Symbol EVM for the DPCH at 15 kbps ($C_{ch,256,8}$). (b) Symbol EVM for the DPCH at 480 kbps ($C_{ch,8,3}$).

2.3.6 Symbol power versus time

Each DL DPCH uses one of the slot structures shown in table 1. A DPCH slot consists of different fields. For example, the DPCCH may contain TFCI bits, TPC bits, and Pilot bits. These fields can have independent gain settings, as shown in the example in figure 29.

Slot format #i	Channel bit rate (kbps)	Channel symbol rate (kbps)	SF	Bits/frame			Bits/ slot	DPDCH bits/slot		DPCCH bits/slot		
				DPDCH	DPCCH	TOT		N_{data1}	N_{data2}	N_{TFCI}	N_{TPC}	N_{pilot}
0	15	7.5	512	60	90	150	10	2	2	0	2	4
1	15	7.5	512	30	120	150	10	0	2	2	2	4
2	30	15	256	240	60	300	20	2	14	0	2	2
3	30	15	256	210	90	300	20	0	14	2	2	2
4	30	15	256	210	90	300	20	2	12	0	2	4
5	30	15	256	180	120	300	20	0	12	2	2	4
6	30	15	256	150	150	300	20	2	8	0	2	8
7	30	15	256	120	180	300	20	0	8	2	2	8
8	60	30	128	510	90	600	40	6	28	0	2	4
9	60	30	128	480	120	600	40	4	28	2	2	4
10	60	30	128	450	150	600	40	6	24	0	2	8
11	60	30	128	420	180	600	40	4	24	2	2	8
12	120	60	64	900	300	1200	80	4	56	8*	4	8
13	240	120	32	2100	300	2400	160	20	120	8*	4	8
14	480	240	16	4320	480	4800	320	48	240	8*	8	16
15	960	480	8	9120	480	9600	640	112	496	8*	8	16
16	1920	960	4	18720	480	19200	1280	240	1008	8*	8	16

If TFCI bits are not used, then disontinous transmission (DTX) bits shall be used.

Table 1. DL slot structures for DPCH in normal mode

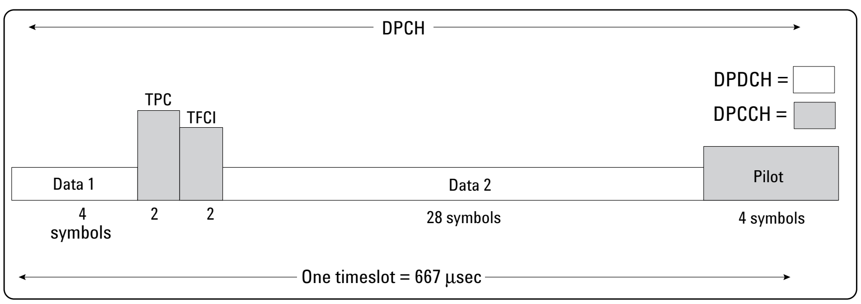
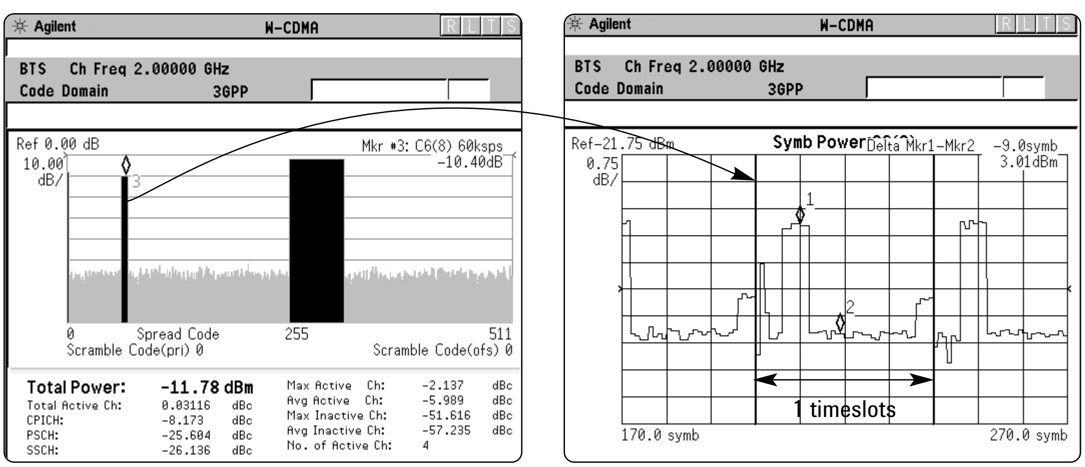


Figure 29. Example of variable power levels for DL DPCH fields

You can verify the accuracy of the power offsets for the different fields by looking at the symbol power versus time for a specific code channel (figure 30).



(a) (b)

Figure 30. (a) Code domain power measurement of a W-CDMA DL signal with the P-CCPCH/SCH, CPICH and two DPCHs ($C_{ch,64,8}$ and $C_{ch,8,4}$). (b) Symbol power versus time for the DPCH at 60 kbps ($C_{ch,64,8}$).

You can also use the symbol power versus time measurement to monitor the power and response of the BS power control system. This is the recommended method to perform the power control steps conformance test that requires measuring the accuracy of the power steps of a particular code channel as a response to a series of power control commands **[1]**.

Figure 31 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 power offsets or to a power control command.

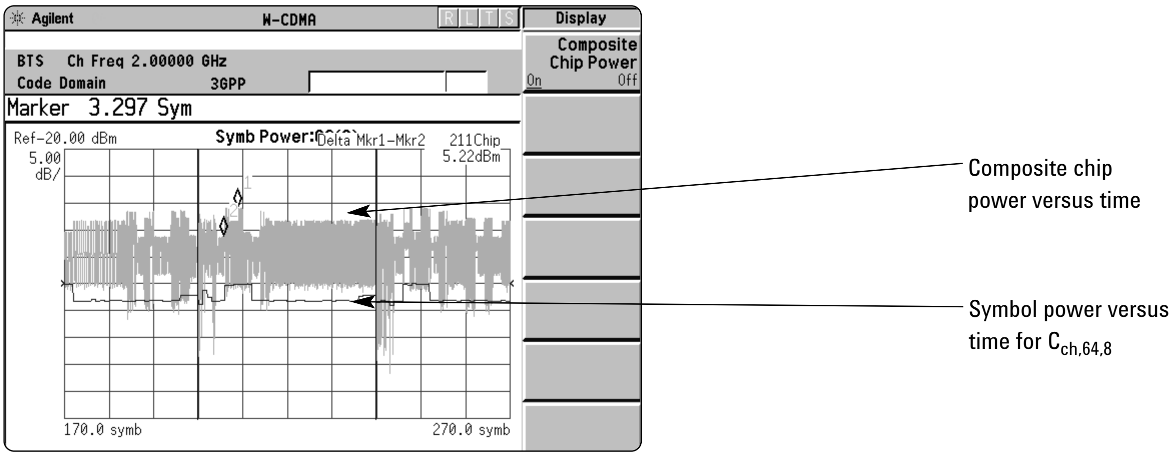


Figure 31. Chip power versus time for a signal with the P-CCPCH/SCH, CPICH, and two DPCHs ($C_{ch,64,8}$ and $C_{ch,8,4}$) and symbol power versus time for the channel at 60 kbps ($C_{ch,64,8}$)

2.3.7 Demodulated bits

By obtaining the demodulated symbols after descrambling and despreading for each code channel, the correct symbol 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, TFCI, TPC, etc.) are correct by using the demodulated bits measurement (figure 32).

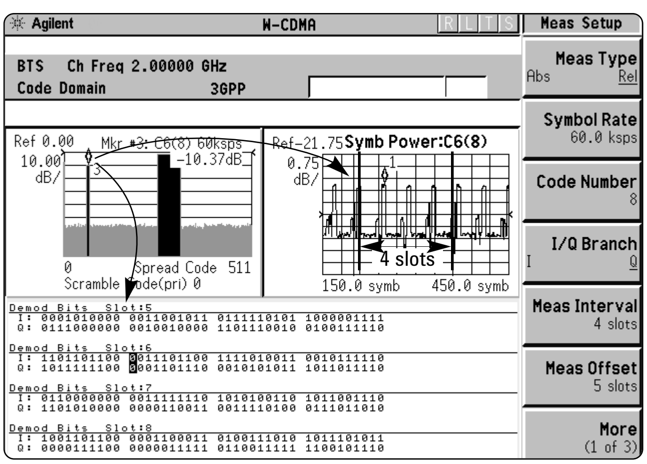


Figure 32. Code domain power measurement of a W-CDMA DL signal with the P-CCPCH/SCH, CPICH, and two DPCHs ($C_{ch,64,8}$ and $C_{ch,8,4}$) and symbol power versus time coupled with demodulated bits for the DPCH at 60 kbps ($C_{ch,64,8}$).

Demodulated bits is an important troubleshooting tool for baseband engineers to identify coding and interleaving errors. In many cases, it can help you clarify situations where the BS 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 BS de-interleaving and decoding process.

2.4 Measuring receiver performance

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

In the case of W-CDMA, the complexity greatly increases over IS-95. Unlike 2G systems, the UE can transmit more than one physical channel in order to account for the high data rates. The expectation is that most of the high data rate traffic will occur in the downlink, so the UE will probably not work at full capacity most of the time (it will not use all the available channels).

The minimum configuration for the UL consists of the DPCCH and one DPDCH. The DPDCH can use variable symbol rates (table 2). Figure 33 shows an example of the slot structure of a DPDCH and DPCCH. The DPCCH can use any of the slot formats shown in table 3.

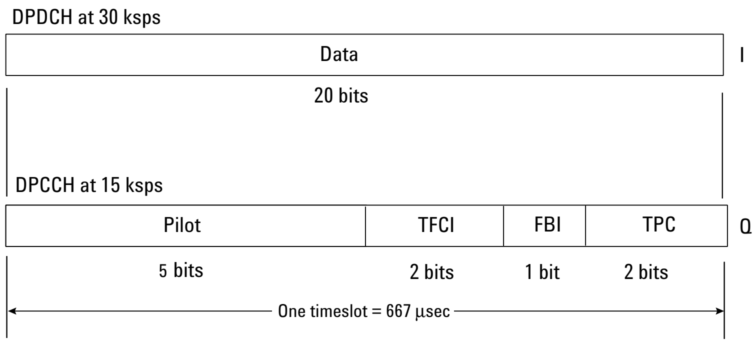


Figure 33. Example of DPDCH and DPCCH slot structure

Slot format #i	Channel bit rate (kbps)	Channel symbol rate (ksps)	SF	Bits/ frame	Bits/ slot	N_{data}
0	15	15	256	150	10	10
1	30	30	128	300	20	20
2	60	60	64	600	40	40
3	120	120	32	1200	80	80
4	240	240	16	2400	160	160
5	480	480	8	4800	320	320
6	960	960	4	9600	640	640

Table 2. DPDCH fields

Slot format #i	Channel bit rate (kbps)	Channel symbol rate (ksps)	SF	Bits/ frame	Bits/ slot	N_{pilot}	N_{TFCI}	N_{FBI}	N_{TPC}
0	15	15	256	150	10	6	2	0	2
1	15	15	256	150	10	8	0	0	2
2	15	15	256	150	10	5	2	1	2
3	15	15	256	150	10	7	0	1	2
4	15	15	256	150	10	6	0	2	2
5	15	15	256	150	10	5	2	2	1

Table 3. DPCCH fields

The receiver must descramble and despread the recovered baseband chips to obtain the symbols for each physical channel. Following this, the frames for the physical channels are combined and decoded. Figure 34 illustrates the receiver chain.

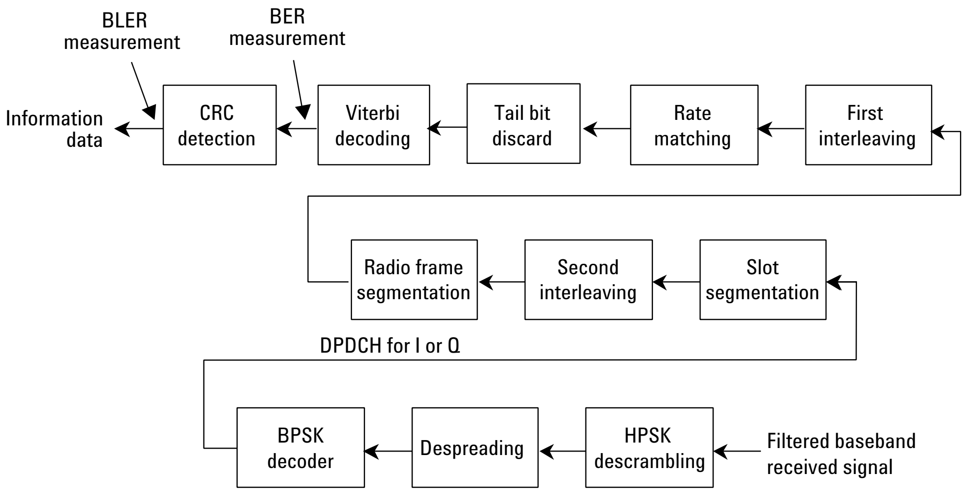


Figure 34. BER and BLER measurements in the W-CDMA BS receiver chain

The figure of merit in the 3GPP standard 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 (see appendix A or standard **[1]**). Performance 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 and demodulation of DCH in birth/death propagation conditions **[1]**.

BER and BLER tests require full implementation of the BS receiver, which may not be available in the early stages of the receiver design. The following sections discuss the different tests you can perform to verify the functionality and performance of different aspects of your W-CDMA BS receiver subsystem and system design, and the stimulus signal requirements for these tests. For general information on troubleshooting digital communications receiver designs refer to **[17]**.

2.4.1 Verification of demodulation and despreading

In W-CDMA, it is important to verify the demodulation and despreading (processing from chips to symbols) functionality of the subsystem for various signals with different physical channel configurations and parameters: different bit rates for the DPDCH, scramble codes, for all slot structures for the DPCCH (e.g. with and without TFCI), different power ratios between the DPDCH and DPCCH, etc.

This test requires a stimulus signal comprising a single repeating frame of a DPCCH and a DPDCH. The stimulus generator must allow user control of the above mentioned variables. It must also allow user control of the bit pattern in the data field for verification of proper despreading.

2.4.2 Verification of control channel recovery and TFCI decoding

The objective for this test is to verify the ability of the BS subsystem to properly decode the TFCI field and to correctly recover TPC, FBI, and Pilot symbols.

This test requires a stimulus signal comprising a single repeating frame of a DPCCH with proper coding of the TFCI field based on a variable 10-bit input, as specified in the standard (figure 35) **[3]**. The stimulus generator must also allow user control of the TPC, FBI, and Pilot fields.

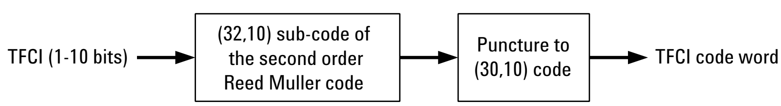


Figure 35. Channel coding of TFCI bits [2]

2.4.3 Verification of response to TPC commands

As mentioned earlier, fast and accurate power control is critical to ensure maximum system capacity. The UE uses the TPC bits in the DPCCH to tell the BS to increase or decrease the code channel power of that particular user.

Testing the accuracy of the step response of the BS code channel power is one of the conformance measurements for the transmitter **[1]**. Performing this test evaluates not only the accuracy of the transmitter's response but also verifies proper functionality for the receiver and the inner power control loop.

In order to determine the base station's response to TPC commands as specified by the standard **[1]**, the stimulus must contain a DPCCH and DPDCH configured as the UL 12.2 kbps reference measurement channel. The stimulus generator must allow user control of the TPC pattern. It is also desirable to support a ramp pattern of 10 steps up and 10 steps down, as requested in the standard. A possible solution is to generate multiple frames and sequence them, as shown in figure 36.

Frame 1	Frame 2	Frame 3	Frame 4
10 up, 5 down	5 down, 10 up	10 down, 5 up	5 up, 10 down

← Total: 30 up and 30 down commands →

Figure 36. Stimulus frame sequencing to support a series of 10 steps up and 10 down commands

2.4.4 Analysis of receiver's response to channel configuration changes

By demodulating dynamic channel configurations you can verify the receiver's response to changes in spreading factors, relative channel power, TFCI, etc. at frame boundaries.

This analysis requires a stimulus signal comprising a sequence of single frames, each of which consists of different channel configurations. Variability of all previously mentioned parameters on each frame is required.

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

BER is the figure of merit used in the standard for the receiver characteristics conformance tests (reference sensitivity level, ACS, etc.) **[1].**

BLER is used for the performance requirements tests (demodulation tests in multipath conditions, etc.) **[1]**.

BER counts the bit errors in the transport block after channel de-interleaving and decoding (see figure 34). BLER is also measured after channel de-interleaving and decoding by evaluating the cyclic redundancy check (CRC) on each transport block. Every rejected block counts as an error. Therefore, the main difference between BER and BLER is that BLER not only measures errors in the decoded block but also in the CRC. BLER is generally a more useful measure of CDMA system performance than BER. However, BER tests remain in the 3GPP standard due to this measure being used to evaluate receiver RF performance during radio development and having been extensively used in system simulations of the reference measurement channels. There is no direct relationship between BER and BLER. Bit errors tend to come in clumps which is how the system responds to single events happening at RF that would otherwise cause a block error.

Since W-CDMA employs robust coding algorithms, many errors can be corrected before bit errors are encountered. However, the "knee" of the BER curve is sharp; much sharper than the curves in systems that employ only moderate error correction. In W-CDMA, once the number of bit errors exceeds the capability of the error correction algorithms (e.g., convolutional encoding and interleaving), the BER climbs from a negligible value to one which is unrecoverable.

In order to make BER or BLER conformance tests, the standard requires a fully-coded signal as a stimulus, configured as one of the reference measurement channels. All the receiver characteristics tests require the 12.2 kbps reference measurement channel only. Each of the performance requirements tests, however, must be performed for several reference measurement channels **[1]**. Appendix B shows the coding structure and parameters for the UL 12.2 kbps reference measurement channel, as specified in the standard **[1]**.

Apart from the correct coding for the DPCH (as defined for the specific reference measurement channel), the stimulus must use a PN9 sequence as the information data for the DTCH (or the DCCH).

The BER and BLER calculations can be performed by the base station internally or by an external meter. If the BS calculates these metrics, the standard requires that it be calibrated using a stimulus signal with inserted errors as shown in figure 37.

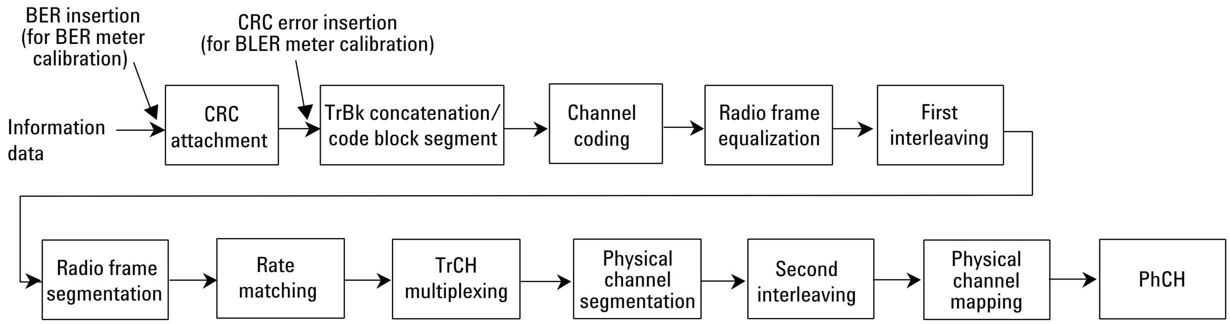


Figure 37. BER and BLER meter calibration

Appendix A provides a table with a list of the receiver and performance tests that require a BER or BLER measurement.

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 BS. It also introduced measurements that can help you verify and troubleshoot your design.

Appendix A: Conformance test setup tables

Table 4 shows a list of the BS conformance tests required by the standard **[1]**. You can use this table as a quick guideline on what measurements and equipment to use for each test.

Conformance test	3GPP		Measurment solution					
				Equipment required				
	Conf. test section [5]	Test model or reference measurment channel (RMC)	Measurement	Signal analyzer	Signal generator	Power meter	Additional parts	Additional comments
Transmitter tests								
Base station maximum output power	6.2.1	Test model 1	Channel power (or average power)	●		●	Attenuator (Att.)	Either a signal analyzer or a power meter can be used
CPICH power accuracy	6.2.2	Test model 2	Code domain power	●			Att.	
Frequency stability	6.3	Test model 4	Composite EVM or code domain power	●			External ref., att.	
Power control steps	6.4.2	Test model 2	Symbol power versus time	●	●		Att.	
Power control dynamic range	6.4.3	Test model 2	Symbol power versus time	●	●		Att.	
Total power dynamic range	6.4.4	Test model 2	Channel power	●		●	Att.	Either a signal analyzer or a power meter can be used
Occupied bandwidth	6.5.1	Test model 1	Occupied bandwidth	●			Att.	
Spectrum emission mask	6.5.2.1	Test model 1	Spectrum analysis	●			Att.	
Adjacent channel leakage power ratio (ACLR)	6.5.2.2	Test model 1	ACLR or ACPR	●			Att.	
Spurious emmision (Catagory A)	6.5.3.5	Test model 1	Spectrum analysis	●			Att.	
Spurious emmision (Catagory B)	6.5.3.6	Test model 1	Spectrum analysis	●			Att.	
Protective of BTS receiver	6.5.3.7	Test model 1	Spectrum analysis	●			Pre-amp filter	
Co-existence with GSM900	6.5.3.8	Test model 1	Spectrum analysis	●			Pre-amp filter	
Co-existence with DCS1800	6.6.3.9	Test model 1	Spectrum analysis	●			Pre-amp filter	
Co-existence with PHS	6.6.3.10	Test model 1	Spectrum analysis	●			Filter	
Co-existence with services in adjacent frequency bands	6.5.3.11	Test model 1	Spectrum analysis	●			Filter	
Co-existence with UTRA-TDD	6.5.3.12	Test model 1	Spectrum analysis	●			Filter	

Table 4 . Conformance test setup table

Conformance test	3GPP			Measurement solution				
				Equipment required				
	Conf. test section [5]	Test model or reference measurment channel (RMC)	Measurement	Signal analyzer	Signal generator	Power meter	Additional parts	Additional comments
Transmitter tests								
Transmit intermodulation	6.6	Test model 1	Spectrum analysis	●	●		Combiner, circulator, buffer and terminator	
Modulation accuracy	6.7.1	Test model 4	Composite EVM	●			Att.	
Peak code domain error	6.7.2	Test model 3	Peak code domain error				Att.	
Receiver tests								
Reference sensitivity level	7.2	RMC 12.2 kbps	BER		●			
Dynamic range	7.3	RMC 12.2 kbps	BER		●		AWGN generator & combiner	
Adjacent channel selectivity	7.4	RMC 12.2 kbps	BER		●		W-CDMA generator combiner and 2 att.	
Blocking characteristics	7.5	RMC 12.2 kbps	BER	●	●		W-CDMA generator or CW generator, combiner, circulator and 3 att.	Requires source with high spectral purity
Intermodulation characteristics	7.6	RMC 12.2 kbps	BER		●		W-CDMA generator, CW generator, 2 combiners and 3 att.	
Spurious emissions	7.7		Manual spectrum monitoring	●				
Verification of internal BER calculation	7.8	RMC 12.2 kbps	BER		●			Sig. gen. must be able to add specified BLER to RMC
Performance requirement tests								
Demodulation tests	8.1 to 8.5	RMC 12.2 kbps to 384 kbps	BLER		●		2 channel simulators, 2 AWGN generators, splitters and combiners	
Verification of internal BLER calculation	8.6	RMC 12.2 kbps to 2048 kbps	BLER		●		1 splitter	Sig. gen. must be able to add specified BER to RMC

Table 4 (continued). Conformance test setup table

Appendix B: Test models and reference measurement channels

Test models

The following information about Test Models has been extracted from the 3GPP standard **[1]**.

Test model 1

This model shall be used for tests on

- spectrum emission mask
- ACLR
- spurious emissions
- transmit intermodulation
- base station maximum output power

Type	Number of channels	Fraction of power (%)	Level setting (dB)	Channelization code	Timing offset ($x256T_{chip}$)
PCCPCH + SCH	1	10	–10	1	0
Primary CPICH	1	10	–10	0	0
PICH	1	3.2	–15	16	120
DPCH (SF = 128)	16/32/64	76.8 in total	See table 6	See table 6	See table

Table 5. Test model 1 active channels

Code	Timing offset ($x256T_{chip}$)	Level settings (dB) (16 codes)	Level settings (dB) (32 codes)	Level settings (dB) (64 codes)
2	86	–10	–13	–16
11	134	–12	–13	–16
17	52	–12	–14	–16
23	45	–14	–15	–17
31	143	–11	–17	–18
38	112	–13	–14	–20
47	59	–17	–16	–16
55	23	–16	–18	–17
62	1	–13	–16	–16
69	88	–15	–19	–19
78	30	–14	–17	–22
85	18	–18	–15	–20
94	30	–19	–17	–16
102	61	–17	–22	–17
113	128	–15	–20	–19
119	143	–9	–24	–21
7	83		–20	–19
13	25		–18	–21
20	103		–14	–18
27	97		–14	–20
35	56		–16	–24
41	104		–19	–24
51	51		–18	–22
58	26		–17	–21
64	137		–22	–18
74	65		–19	–20
82	37		–19	–17
88	125		–16	–18
97	149		–18	–19
108	123		–15	–23
117	83		–17	–22
125	5		–12	–21

Table 6 . DPCH spreading code, timing offsets, and level settings for test model 1

Code	Timing offset (x256T_{chip})	Level settings (dB) (16 codes)	Level settings (dB) (32 codes)	Level settings (dB) (64 codes)
4	91			–17
9	7			–18
12	32			–20
14	21			–17
19	29			–19
22	59			–21
26	22			–19
28	138			–23
34	31			–22
36	17			–19
40	9			–24
44	69			–23
49	49			–22
53	20			–19
56	57			–22
61	121			–21
63	127			–18
66	114			–19
71	100			–22
76	76			–21
80	141			–19
84	82			–21
87	64			–19
91	149			–21
95	87			–20
99	98			–25
105	46			–25
110	37			–25
116	87			–24
118	149			–22
122	85			–20
126	69			–15

Table 6 (continued). DPCH spreading code, timing offsets, and level settings for test model 1

Test model 2

This model shall be used for tests on

- output power dynamics

Type	Number of channels	Fraction of power (%)	Level setting (dB)	Channelization code	Timing offset (x256T_{chip})
PCCPCH + SCH	1	10	–10	1	0
Primary CPICH	1	10	–10	0	0
PICH	1	10	–10	16	120
DPCH (SF = 128)	3	2 x 10, 1 x 50	2 x –10, 1 x –3	24, 72,120	1, 7,2

Table 7. Test model 2 active channels

Test model 3

This model shall be used for tests on

- peak code domain error

Type	Number of channels	Fraction of power (%)	Level setting (dB)	Channelization code	Timing offset (x256T_{chip})
PCCPCH + SCH	1	12, 6/7, 9	–9 /–11	1	0
Primary CPICH	1	12, 6/7, 9	–9/–11	0	0
PICH	1	10/3, 2	–10/–15	16	120
DPCH (SF = 256)	16/32	63, 7/80, 4 in total	See table 9	See table 9	See table 9

Table 8. Test model 3 active channels

Code	T_{offset}	Level settings (dB) (16 codes)	Level settings (dB) (32 codes)
64	86	–14	–16
69	134	–14	–16
74	52	–14	–16
78	45	–14	–16
83	143	–14	–16
89	112	–14	–16
93	59	–14	–16
96	23	–14	–16
100	1	–14	–16
105	88	–14	–16
109	30	–14	–16
111	18	–14	–16
115	30	–14	–16
118	61	–14	–16
122	128	–14	–16
125	143	–14	–16
67	83		–16
71	25		–16
76	103		–16
81	97		–16
86	56		–16
90	104		–16
95	51		–16
98	26		–16
103	137		–16
108	65		–16
110	37		–16
112	125		–16
117	149		–16
119	123		–16
123	83		–16
126	5		–15

Table 9. DPCH spreading code, T_{offset}, and power for test model 3

Test model 4

This model shall be used for tests on

- EVM measurement

Type	Number of channels	Fraction of power (%)	Level setting (dB)	Channelization code	Timing offset
PCCPCH + SCH	1	50 to 1.6	–3 to –18	1	-

Table 10. Test model 4 active channels

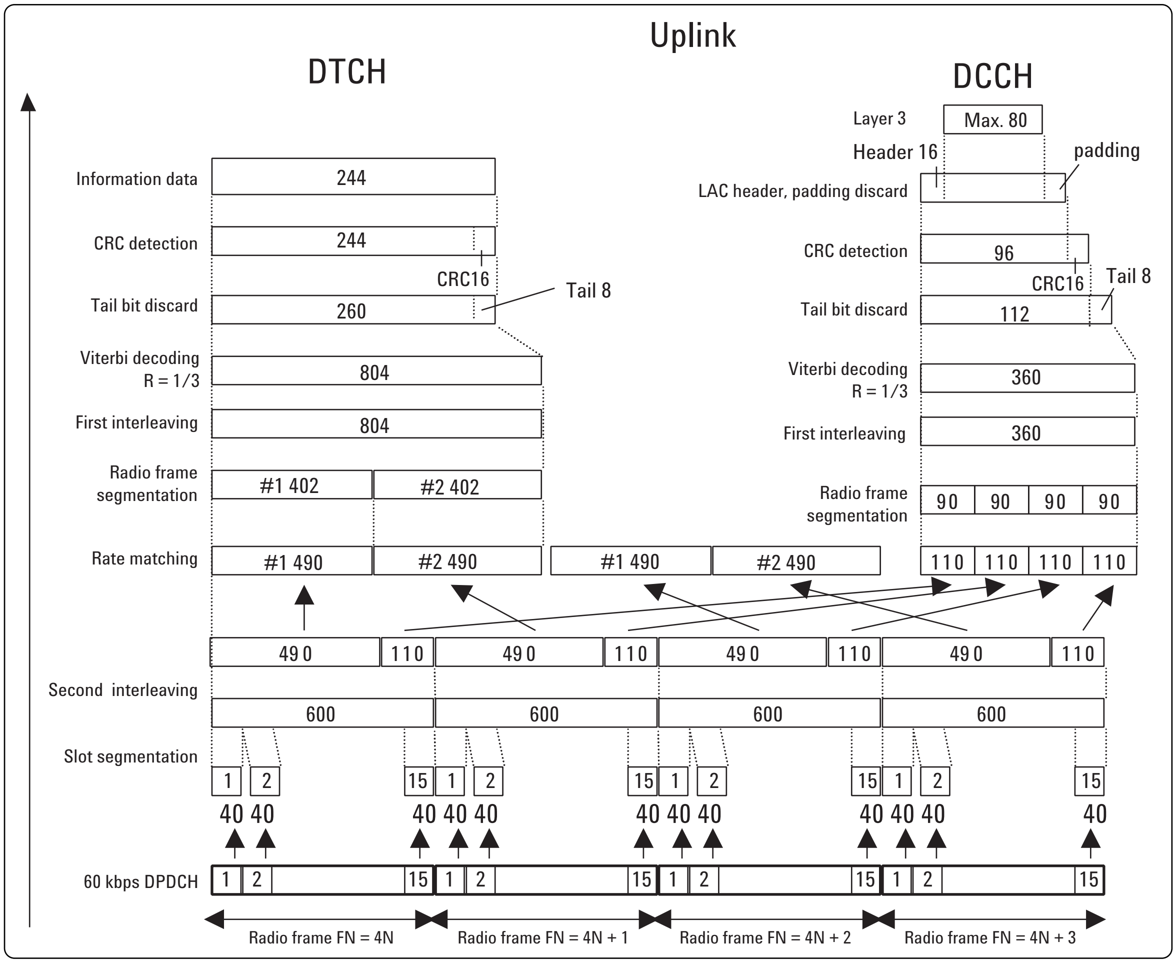


Figure 38. Channel coding for UL 12.2 kbps reference measurement channel

UL reference measurement channel example

The following UL reference measurement channel example has been extracted from the W–CDMA standard **[1]**.

Parameter	Level	Unit
Information bit rate	12, 2	kbps
DPCH	60	kbps
Power control	Off	–
TFCI	On	–
Repetition	22	%

Table 11. UL reference measurement channel (12.2 kbps)

Appendix C: Agilent solutions for W-CDMA BS design and test

This section provides a list of Agilent solutions you can use to design and test your BS subsystems and systems.

Software design and simulation

You can use the Agilent Advanced Design System (ADS) to design 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 allows you to evaluate your designs against the 3GPP specification or performance parameters such as ACLR, EVM, BER, and BLER early in the design cycle. Most of the transmitter and receiver tests outlined in version 3.1 of the TS 25.141 (BS) and TS 25.104 3GPP specifications can be simulated, as shown in the table below.

BS 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	X
	Adjacent channel leakage	X
	Spurious emissions	X
	Modulation accuracy	X
	Peak code domain error	X
BS receiver tests		**ADS E8875 A/AN**
Uncoded physical BER		X
BER and BLER with multiple OCNS interferers		X
BER & receiver tests [18]	Reference sensitivity level	X
	Receiver maximum level	X
	Adjacent channel selectivity	X
	Blocking sensitivity	X
	Intermodulation sensitivity	X

Table 12. Transmitter and receiver tests that can be simulated using the Agilent ADS E8875 A/AN

The E8875 A/AN signal source designs offer configurations consistent with some of the UL and DL configurations offered in the Agilent ESG–D/DP signal generator. Each of the design configurations includes a pre–configured link to the ESG signal generator so the signals can easily be recreated on the bench for prototype hardware verification.

Signal generation

The Agilent ESG-D and ESG-DP series RF signal generators with Option 100 have the capability of simulating statistically correct UL and DL signals for W-CDMA BS component and subsystem receiver testing. An easy-to-use interface allows you to

- select from several predefined W-CDMA channel configurations, including all the DL test models for transmitter conformance test
- generate multicarrier signals, for multicarrier component testing
- use the table editor to fully configure a W-CDMA multichannel signal per your requirements

In addition, Option H99 offers improved adjacent and alternate channel perfor-mance (ACLR). This is especially important to W-CDMA amplifier testing.

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

The Agilent ESG-D and ESG-DP series RF signal generators with Option 200 have the capability of simulating fully-coded signals for UE component, subsystem, and system receiver design. An easy-to-use interface allows you to select from predefined channel configurations, including all the reference measurement channels. They also offer flexibility for user data input and coding parameter modification.

		ESG Option 100	ESG Option 200
Module/receiver subsystem/component test (support of test models for stimulus/response)		X	X
Receiver test			
Verification of demodulation and despreading		X	X
Verification of control channel recovery and TFCI decoding		X	X
Verification of response to TPC commands		X	X
Analysis of receiver's response to dynamic changes		X	X
BER & receiver conformance tests **[5]**	Reference sensitivity level	-	X
	Dynamic range	-	X
	Adjacent channel selectivity	As a modulated interferer	X
	Blocking characteristics	-	X
	Intermodulation characteristics	As a modulated interferer	X
	Verification of the internal BER calculation	-	X
BLER & verification of the internal BLER calculation			X

Table 13. Component, receiver subsystem, and system tests that can be performed with the ESG-D and ESG-DP series RF signal generators

Power meter and sensors

The Agilent EPM series power meters and E9300 series power sensors provide average power measurements on W-CDMA signals over a wide 80–dB dynamic range. The E9300 power sensors employ a diode stack-attenuator-diode stack topology that ensures the accuracy and repeatability of measurements across the sensor's entire dynamic range **[13]**.

The E9300 power sensors are bandwidth independent, so you don't have to worry about matching sensor bandwidth to the modulation format of your signal under test. Fast measurement speeds are provided, up to 200 readings per second over the GPIB, with the E4418B power meter and E9300 sensors.Recommended power meters and sensors for 3GPP W-CDMA users equipment average power measurements are

- E4418B power meter, single channel
- E4419B power meter, 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
- E9300B power sensor, 10 MHz to 6 GHz, –30 to +44 dBm

Other power sensors in the 8480 series are compatible with the E4418B/9B power meters.

Signal analysis

This table provides a list of Agilent signal analyzers and their W-CDMA BS transmitter measurement capabilities (as of 8/2000).

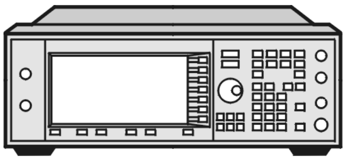
W-CDMA (3GPP)		Agilent signal analyzers				
		Vector signal analyzers			Spectrum analyzers	
Measurements		E4406A VSA transmitter tester[1]	89400A series vector signal analyzer[2]	89600 vector signal analyzer	8560-E series[3] spectrum analyzers	ESA-E series[3] spectrum analyzers
General purpose measurments						
Channel power		●	●[4]	●[4]	●[4]	●[4]
CCDF		●	●	●		
Modulation quality	QPSK EVM	●	●	●		
	Composite EVM	●				
	Code domain power	●	●			
	Peak code domain error	●				
	Symbol EVM	●	●			
	Symbol power versus time	●	●			
	Composite chip power versus time	●	●			
	Demodulated bits	●	●			
Transmitter conformance tests [5]						
BTS maximum output power		●	●[4]		●[4]	●[4]
CPICH power accuracy		●	●			
Frequency stability		●	●			
Inner loop power control and power control steps		●	●			
Power control dynamics range		●[4]	●[4]			
Total power dynamic range		●[4]	●[4]	●[4]	●[4]	●[4]
Occupied bandwicth		●				●
Out-of-band emission		●	●[4]		●[4]	●[4]
ACLR		●	●[4,5]	●[4,5]	●[4,5]	●[4,5]
Spurious emissions		From 330 MHz to 3.67 GHz	up to 4 GHz [4]		●[4]	●[4]
Transmit intermodulation		●	●[4]		●[4]	●[4]
Modulation accuracy		●				
Peak code domain error		●				

Table 14. Agilent signal analyzers and their W-CDMA BS transmitter measurement capabilities

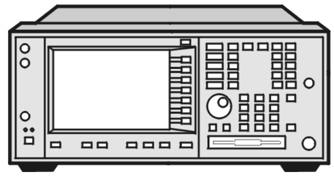
1. Measurements pre-configured for W-CDMA
2. Some measurements pre-configured for W-CDMA. Parameters for other measurements must be set up manually, as indicated.
3. Measurements are not pre-configured for W-CDMA. Measurement parameters must be set up manually, as indicated.
4. Measurement parameters must be set up manually.
5. Measurement can only be performed with a rectangular filter. The error is smaller than 0.1 dB.

Instruments used for measurement examples

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



Agilent ESG-D series RF digital signal generator Option 100



Agilent E4406A VSA transmitter tester

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
ARIB . . . . Association of Radio Industries an Businesses (Japan)
BCH . . . . Broadcast Channel
BCCH . . . . Broadcast Control Channel
BER . . . . Bit Error Rate
BLER . . . . Block Error Rate
BPSK . . . . Binary Phase Shift Keying
BTS . . . . Base Transceiver Station
CCCH . . . . Common Control Channel
CCDF . . . . Complementary Cumulative Distribution Function
CCTrCH . . . . Coded Composite Transport Channel
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
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
E_b/N_o . . . . Energy-per-Bit-to-Noise Ratio
ETSI . . . . European Telecommunications Standard Institute
EVM . . . . Error Vector Magnitude
FACH . . . . Forward Access Channel
FBI . . . . Feedback Information
FDD . . . . Frequency Division Duplex
GMSK . . . . Gaussian Minimum Shift Keying
GPS . . . . Global Positioning System
GS . . . . MGlobal 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)
I/Q . . . . In-phase/Quadrature
IS-2000 . . . . EIA/TIA interim standard 2000 (see cdma2000)
IS-95 . . . . Interim standard for U.S. CodeDivision Multiple Access
LO . . . . Local Oscillator
MAC . . . . Medium Access Control
OCNS . . . . Orthogonal Channel Noise Simulator
OCQPSK . . . . . . Orthogonal Complex Quadrature Phase Shift Keying
OVSF . . . . Orthogonal Variable Spreading Factor
PA . . . . Power Amplifier
PAR . . . . Peak-to-Average Power Ratio
PCCH . . . . Paging Control Channel
P-CCPCH . . . . . . Primary Common Control Physical Channel
PCPCH . . . . Physical Common Packet Channel
PDC . . . . Pacific Digital Cellular System
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
RRC . . . . Root Raised Cosine
RRS . . . . Radio Resource Control
S-CCPCH . . . . . . Secondary Common Control Physical Channel
SCH . . . . Synchronization Channel
SF . . . . Spreading Factor
SFN . . . . System Frame Number
SIR . . . . Signal to Interference Ratio
SSC . . . . Secondary Synchronization Code
S-SCH . . . . Secondary Synchronization Channel
TDD . . . . Time Division Duplex
TFCI . . . . Transport Format Control Indicator
TIA . . . . Telecommunications Industries Association (U.S.)
TPC . . . . Transmit Power Control
TTA . . . . Telecommunications Technology Association (Korea)
TTC . . . . Telecommunication Technology Committee (Japan)
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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[17] *Testing and Troubleshooting Digital RF Communications Receiver Designs*, Application Note 1314, literature number 5968-3579E.

[18] 3rd Generation Partnership Project. Technical Specification Group Radio Access Network. BS Radio Transmission and Reception (FDD). Release 99. 3G TS 25.104 (v3.1.0).

Related literature

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Agilent 8560 E-Series Spectrum Analyzers, literature number 5968-9571E

Agilent 89400 Series Vector Signal Analyzers, literature number 5965-8554E

Agilent E4406A Vector Signal Analyzer Brochure, literature number 5968-7618E

Agilent EPM Series Power Meters, literature number 5965-6380E.

Agilent ESA-E Series Spectrum Analyzers, literature number 5968-3278E

Agilent ESG Series RF Digital and Analog Signal Generators, literature number 5968-4313E.

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