# Kyocera 200 Module Data Book

## 82-M8862-1, Rev. 003

## 1 February, 2005

## Kyocera Proprietary

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**KYOCERA WIRELESS CORP.**
10300 CAMPUS POINT DRIVE
SAN DIEGO, CA 92121

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*Caution*

The Kyocera 200 is an Electrostatic Discharge Sensitive (ESDS) product.

To protect the Kyocera 200 Module from electrostatic discharge, it must be completely enclosed with protective conductive packaging during storage and handling. Prior to opening the protective packaging, the part must be placed on a conductive workstation surface to dissipate any charge that has built up on the packaging.

Once the Kyocera 200 Module has been removed from its protective packaging, it must be handled by an operator grounded through a conductive wrist strap or foot strap to ensure the Module is not subjected to electrostatic discharge.

# 1

# Kyocera Wireless Corp.

## Introduction

Kyocera Wireless Corp. (KWC) is a wholly-owned subsidiary of Kyocera International, Inc. (KII), the North American headquarters and holding company of Kyocera Corporation. KII established Kyocera Wireless Corp. after acquiring QUALCOMM Incorporated's consumer wireless phone business in February 2000. KWC incorporates QUALCOMM's CDMA technology in developing, manufacturing, and marketing innovative wireless communications products for a wide range of markets and applications.

## Kyocera Corporation background

Kyocera Corporation, the parent and global headquarters of the Kyocera Group, was founded in 1959 as a producer of advanced ceramics. By combining these engineered materials with metals and plastics, and integrating them with other technologies, Kyocera has become a leading supplier of telecommunications equipment, semiconductor packages, electronic and automotive components, cameras, laser printers, copiers, solar energy systems, and industrial ceramics. Approximately 80 percent of Kyocera's revenue is currently derived from products that are telecommunications- or information-related. In the year ended March 31, 2002, Kyocera Corporation's consolidated net sales totaled 1035 billion yen (US$7.8 billion) with net income of 32 billion yen (US$240 million). Kyocera Corporation has been recognized by *Industry Week* magazine as one of "The World's 100 Best-Managed Companies."

## Kyocera Wireless Corp. CDMA consumer products

Kyocera Wireless Corp. is one of the world's largest manufacturers of CDMA digital subscriber equipment, and continues to set the industry standard for high-quality CDMA digital phones. KWC handsets feature a tremendous range of advanced communications capabilities beyond voice calling. All Kyocera handsets are fundamentally designed as data devices. Unlike handsets based on other technologies, Kyocera handsets are constructed to receive, process, and transmit data in its purest format, completely bypassing the use of the vocoder required for conversion of audio voice signals to binary codes, and maximizing the unit's data processing speed and efficiency. Voice calling, in fact, is more accurately seen as just one of many data services that the handsets are designed to support. Kyocera offers quick, cost-effective, and reliable wireless data solutions for mobile phones. Leading the way with new information services tailored to wireless users, the Kyocera brand is becoming synonymous with wireless data innovation. All KWC products are designed with the usage patterns and needs of the end user in mind.

# 2 CDMA and Cellular Fundamentals

## CDMA

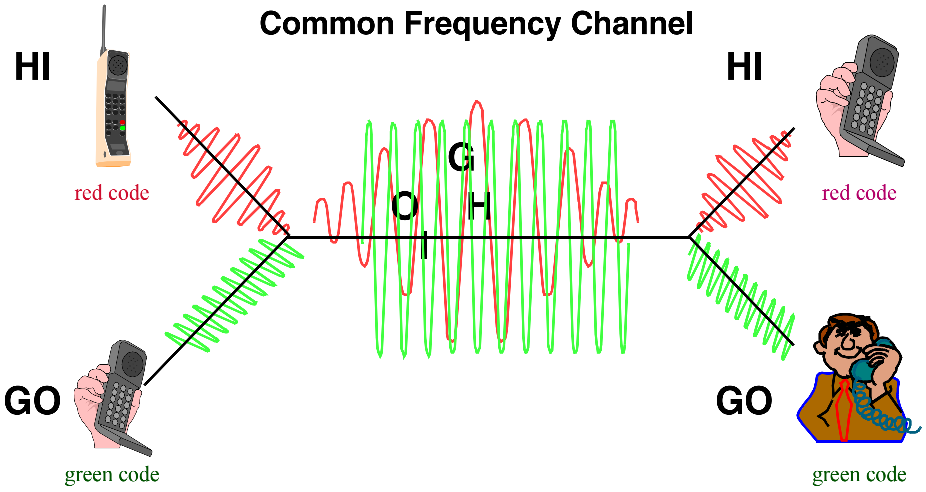
CDMA uses 1.23 MHz per channel. This means all users can transmit at the same time, relying on codes to differentiate the users. CDMA also uses sectored cells to increase capacity, like in the advanced mobile phone service (AMPS), but CDMA can use one frequency in all sectors of the cell instead of following a frequency reuse scheme.

CDMA uses correlative codes to let each user operate under substantial interference. For example, in a crowded cocktail party, people are talking at the same time but you are able to listen and understand only one person at a time. This is because your brain can sort out the voice characteristics of the one with whom you are speaking and differentiate that voice from the others. As the party grows larger, each person must talk louder and the size of the talk zone grows smaller. Thus the number of conversations is limited by the overall noise interference in the room.

CDMA is similar to this cocktail party analogy, but the recognition is based on digital codes. The interference is the sum of all other users on the same CDMA frequency, both from within and outside the home cell and from delayed versions of these signals. It also includes the usual thermal noise and atmospheric disturbances. Delayed signals caused by multipath are separately received and combined in CDMA.

**CDMA cocktail party example**

**How CDMA works**



## Cellular frequency reuse patterns

One of the major capacity gains with CDMA is from its frequency reuse efficiency. To eliminate interference from adjacent cells, narrowband FM systems must physically separate cells using the same frequency. Complex frequency reuse planning must be done in such a system to maximize capacity while eliminating interference. A reuse pattern for analog and time division multiple access (TDMA) systems employs only one-seventh of the available frequencies in any given cell. With CDMA, the same frequencies are used in *all* cells and can be used in all sectors of all cells.

This reuse is possible because CDMA is designed to decode the proper signal in the presence of high interference. Adjacent cells using the same frequency in CDMA simply cause an apparent increase in the channel background noise. By allowing the use of the same frequencies in every cell, CDMA has approximately six times the capacity of existing analog cellular systems.

## CDMA concept

CDMA starts with a narrowband signal. Through specialized codes this spreads to a bandwidth of 1.23 MHz. The ratio of the spread data rate to the initial data rate is called the processing gain. For IS-95 standard CDMA with an 8 kbps vocoder, the processing gain is 21 dB. When transmitted, a CDMA signal experiences high levels of interference dominated by the coded signals of other CDMA users. This takes two forms:

- Interference from other users in the same cell
- 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. The correlators use the processing gain to pull the desired signal out of the noise. Since a signal-to-noise ratio of 7 dB is required for acceptable voice quality, this leaves 14 dB of extra processing gain to extract the desired signal from the noise. This is possible because the interference sources are uncorrelated (orthogonal in the case of the forward link).

## CDMA versus analog FM

CDMA channels are defined by various digital codes as well as by frequency.

The capacity for CDMA is soft, not rigid. In analog systems, when all available channels are in use, no further calls can be added. Capacity in CDMA can be increased with some degradation of the error rate or voice quality, or can be increased in a given cell at the expense of reduced capacity in the surrounding cells.

Another advantage of CDMA is the use it makes of diversity. There are three types of diversity:

- Spatial diversity
- Frequency diversity
- Time diversity

### Spatial diversity

Spatial diversity takes two forms:

- Two antennas

  The base station uses two receive antennas for greater immunity to fading.

  This is the classical version of spatial diversity. AMPS analog cellular base stations use this type of diversity for improved fading resistance.

- Multiple base stations

  Multiple base stations simultaneously talk to the mobile phone during soft handoff.

### Frequency diversity

Frequency diversity is inherent in a spread-spectrum system. A fade of the entire signal is less likely than with narrowband systems. Fading is caused by reflected images of an RF signal arriving at the receiver such that the phase of the delayed (reflected) signal is 180° out of phase with the direct RF signal.

Since the direct signal and the delayed signals are out of phase, they cancel each other, causing the amplitude seen by the receiver to be greatly reduced. In the frequency domain, a fade appears as a notch and is on the order of one over the difference in the arrival time of two signals. For a 1 μsec delay, the notch is approximately 1 MHz wide.

The Telecommunications Industry Association (TIA) CDMA system prescribes a 1.23 MHz bandwidth, so only those multipaths of time less than 1 μsec actually cause the signal to experience a deep fade. In many environments, the multipath signals arrive at the receiver after a much longer delay, causing only a narrow portion of the signal to be lost. In a fade 20 to 200 kHz wide, this results in the complete loss of an analog or TDMA signal but only reduces the power in a portion of a CDMA signal. As the spreading width of a CDMA signal increases, so does its multipath fading resistance.

### Time diversity

Time diversity is a technique common to most digital transmission systems. Signals are spread in time through interleaving. Interleaving the data improves the performance of the error correction by spreading errors over time.

Errors in the real world during radio transmission usually occur in clumps, so when the data is de-interleaved, the errors are spread over a greater period of time. This allows the error correction to fix the resulting smaller, spread-out errors. Forward error correction is applied, along with maximal likelihood detection. The particular scheme used for CDMA is convolutional encoding in the transmitter with Viterbi decoding using soft decision points in the receiver.

Another form of time diversity occurs in the base station when transmitting at reduced data rates. When transmitting at a reduced data rate, the base station repeats the data resulting in full rate transmission. The base station also reduces the transmitted power when it operates at reduced data rates. This added redundancy in the transmitted signal results in less interference (power is lowered) and improves the CDMA mobile station receiver performance during high levels of interference.

## Synchronization

For any direct sequence spread spectrum radio system to operate, all mobiles and base stations must be precisely synchronized. If they are not synchronized, it becomes nearly impossible to recover the codes used to identify individual radio signals. Precise synchronization also leads to other benefits:

- It allows such services as precise location reporting for emergency or travel usage.
- It allows the use of rake receivers for improved reception in multipath fading conditions.

## Rake receiver

Instead of trying to overpower or correct multipath problems, CDMA takes advantage of the multipath to provide improved reception quality. CDMA does this by using multiple correlating receivers and assigning them to the strongest signals. This is possible because the CDMA mobile is synchronized to the serving base station. The mobile receiver can distinguish between direct and reflected (multipath) signals because of the time delay in receiving the reflected signals.

Special circuits called searchers are also used to look for alternate multipaths and for neighboring base station signals. The searchers slide around in time until they find a strong correlation with their assigned code. Once a strong signal is located at a particular time offset, the search assigns a receiver element to demodulate that signal. The mobile receiver uses three receiving elements, and the base station uses four. This multiple correlator system is called a rake receiver.

As conditions change, the searchers rapidly reassign the rake receivers to handle new reception conditions. While each signal being processed by an individual rake receiver experiences fading, the fades are independent because different path lengths are experienced by each signal. Thus the receiver can coherently recombine the outputs of the three rake receivers to reconstruct a much more robust version of the transmitted signal. In this way, CDMA uses multipath signals to create a more robust receiver. The rake receivers also allow soft handoff as one or more receivers can be assigned to another base station.

There are some limitations to this scheme. If strong, short transmission paths are present, such as in a very narrow canyon, the rake receiver system cannot function. If the arrival time of a multipath signal is less than one clock cycle of the CDMA system, the rake receiver cannot tell the difference between direct and reflected signals. It has been found, however, that in real world situations longer time-delayed signals coexist when very strong short multipath signals are present. This allows the searchers to find these other longer delayed signals under these difficult propagation conditions.

## CDMA reverse link power control

One of the fundamental enabling technologies of CDMA is power control. Since the limiting factor for CDMA system capacity is the total interference, controlling the power of each mobile is critical to achieve maximum capacity. CDMA mobiles are power controlled to the minimum power that provides acceptable quality for the given conditions. As a result, all mobile signals arrive at the base station at approximately equal levels. In this way, the interference from one unit to another is held to a minimum.

Two forms of power control are used for the reverse link:

- Open loop power control
- Closed loop power control

### Open loop power control

Open loop power control is based on the similarity of the loss in the forward path to the loss in the reversed path. (Forward refers to the base-to-mobile link, while reverse refers to the mobile-to-base link.)

Open loop power control sets the sum of transmit power and receive power to a constant, nominally -73 dBm (IS-98-A). A reduction in signal level at the receive antenna results in an increase in signal power from the transmitter. For example, when the received power from the base station is -85 dBm, this is the total energy received in the 1.23 MHz receiver bandwidth. It includes the composite signal from the serving base station as well as from other nearby base stations on the same frequency.

The open loop transmit power setting for a received power of -85 dBm would be +12 dBm. By the IS-98 specification, the open loop power control slew rate is limited to match the slew rate of closed loop power control directed by the base station. This eliminates the possibility of a sudden transmission of excessive power by the open loop power control in response to a receiver signal-level dropout.

### Closed loop power control

Closed loop power control is used to allow the power from the mobile unit to deviate from the nominal as set by open loop control. This is done with a form of delta modulation. The base station monitors the power received from each mobile station and commands the mobile to either raise power or lower power by a fixed step of 1 dB. This process is repeated 800 times per second, or every 1.25 msec.

The power control data sent to the mobile from the base station is added to the data stream by replacing the encoded voice data. This process is called "puncturing" because the power control data is written into the data stream by overwriting the encoded voice data. The power control data occupies 103.6 µsec of each 1.25 msec of data transmitted by the base station.

Because the mobile's power is controlled no more than is needed to maintain the link at the base station, a CDMA mobile typically transmits much less power than an analog phone. The base station monitors the received signal quality 800 times per second and directs the mobile to raise or lower its power until the received signal quality is adequate. This operating point varies with propagation conditions, the number of users, and the density and loading of the surrounding cells.

Analog cellular phones must transmit enough power to maintain a link even in the presence of a fade. Analog phones usually transmit excess power. CDMA radios are controlled in real time and kept at a power level that maintains a quality transmission based on the changing RF environment. The benefits include longer battery life and smaller, lower cost amplifier design.

## Mobile power bursting

Each 20 msec frame in IS-95 is divided into 16 power control groups. When the mobile transmits, each power control group contains 1536 data symbols (chips) at a rate of 1.2288 Mbps. When the vocoder moves to a lower data rate, the CDMA mobile bursts its output by sending only the appropriate number of power control groups. For example, transmitted groups are randomized to spread the transmitted power over time. For each lowering of the data rate, the transmitted power is reduced by 3 dB.

## CDMA system time

As mentioned earlier, both mobiles and base station in direct sequence CDMA must be synchronized. In the IS-95 system, synchronization is based on the Global Positioning System (GPS) time. Each CDMA base station incorporates a GPS receiver to provide exact system timing information for the cell. The base station then sends this information to each mobile via a special channel. In this manner, all radios in the system can maintain near-perfect synchronization.

Most designs also include atomic clocks to provide a backup timing reference. These are capable of maintaining synchronization for up to several hours. The GPS clock used for CDMA system time is then used to drive the long code pseudo-random sequence generator.

## Closed loop power control puncturing

Once the data has been scrambled with the user-specific long code, the closed loop power control data is then punctured into the data stream. Power control bits are sent every 1.25 msec—once in every power control group (a CDMA frame is 20 msec, with each frame having 16 1.25 msec power control groups).

Since the power control bits replace the encoded voice data, holes (missing data) are introduced into the data stream from the receiver's point of view. These holes are accepted and the system uses the Viterbi decoder in the receiver to restore the data lost by puncturing. The recovery of the missing data uses some of the available processing gain in the system. The resulting loss of capacity has been accounted for in the system's design.

Another way to think of this is that slightly more power is required to maintain the link because of the missing data introduced by the power control puncturing. The power control data is sent only once in the 14.4 kbps case since the reduced processing gain results in higher power being transmitted from the base station to maintain an acceptable signal-to-noise ratio. The higher power results in a much lower symbol error rate and the need to send the power control data twice is eliminated.

## Walsh code spreading

In the forward channel (cell-site-to-mobile), the Walsh codes provide a means for uniquely identifying each user. A Walsh code generator provides 1 of the 64 codes to scramble the encoded voice data.

- Walsh code 0 = pilot channel
- Walsh code 32 = synchronous channel
- Walsh code 1 to 7 = paging channels
- Other Walsh codes = forward paging channel

## Respreading the short sequence

If all cells used the same 64 Walsh codes without another layer of scrambling, the resulting interference would severely limit the system capacity.

Since all cells can use the same frequency (frequency domain), and all cells use the same Walsh codes (code domain), the only other means to allow cells to reuse the same Walsh codes is by using time offset (time domain). This final layer of scrambling uses another code called the short code to allow reuse of the Walsh codes and to provide a unique identifier to each cell.

Because everything in CDMA is synchronized to system time, it is possible to have each cell site identified by using a time offset in the short sequence. These "PN offsets" are separated by multiples of 64 1.2288 Mbps clock chips. This allows for 512 unique time offsets for cell identification (32768 bits/64 bits = 512 offsets). By scrambling the Walsh encoded channels with the short code, each base station can reuse all 64 Walsh codes and be uniquely identified from other adjacent cells using the same frequency.

## Forward link channel format

The base station transmitter signal is the composite of many channels (with a minimum of four). The pilot channel is unmodulated (Walsh code 0); it consists of only the final spreading sequence (short sequences). The pilot channel is used by all mobiles linked to a cell as a coherent phase reference and also provides a means for mobiles to identify cells from each other. The other three channels are:

- Sync channel
- Paging channel
- Traffic channel

These channels use the same data flow, but different data are sent on each channel.

### Sync channel

The sync channel transmits time-of-day information. This allows the mobile and base to align clocks, which form the basis of the codes that are needed by both to make a link. Specifically, one message sent by the sync channel contains the state of the long code feedback shift registers 320 msec in the future. By reading this channel, the CDMA mobile can load the data into its long code generator, and then start the generator at the proper time. Once this has been accomplished, the CDMA mobile has achieved full synchronization. The sync channel always uses Walsh code channel 32.

### Paging channel

The paging channel is the digital control channel for the forward link. Its complement is the access channel, which is the reverse link control channel. One base station can have multiple paging channels and access channels if needed. Up to seven Walsh code channels can be allocated for use as paging channels. The first paging channel is always assigned to Walsh code 1. When more paging channels are required, Walsh codes 2 through 7 are used.

### Traffic channel

The traffic channel is equivalent to the analog voice channel. This is where actual conversation takes place. The remaining Walsh codes are assigned to traffic channels as required. At least 55 Walsh codes are available for use as traffic channels. The actual number that can be used is determined by the total interference levels experienced in any given cell. Nominal full loading would typically be around 30 traffic channels in use for equally loaded cells.

Once all of the various channels are Walsh modulated, they are converted into I/Q format, re-spread with the I and Q short sequences, low pass filtered to reduced occupied bandwidth, and converted into analog signals. The resulting analog I and Q signals from all channels are summed together and then sent to the I/Q modulator for modulation into an RF carrier.

## CDMA reverse link physical layer

The CDMA reverse link uses a different coding scheme to transmit data. Unlike the forward link, the reverse link does not support a pilot channel for synchronous demodulation (since each mobile station would need its own pilot channel). The lack of a pilot channel is partially responsible for the reverse link's lower capacity than the forward link. In addition, Walsh codes cannot be used for channelization since the varying time delays from each mobile to the base station destroys the orthogonality of the Walsh codes. (Varying arrival time makes the Walsh codes non-orthogonal.)

Since the reverse link does not benefit from non-interfering channels, this reduces the capacity of the reverse link when compared to the forward link (all mobiles transmitting interfere with each other). To aid reverse link performance, the 9600 bps voice data uses a one-third (1/3) rate convolutional code for more powerful error correction. For the 14,400 bps vocoder, the convolutional encoder is only a half rate encoder that doubles the data rate. Thus the data rate coming out of the convolutional encoder is the same for either the 9.6 or 14.4 Kbps voice channels. Then, six data bits at a time are taken to point at one of the 64 available Walsh codes. The data, which is at 307.2 Kbps, is then XOR'ed with the long code to reach the full 1.2288 Mbps data rate. This unique long code is the channelization for the reverse link.

## Reverse error protection

To improve the performance of the reverse link, a more powerful convolution encoder is used. The third-rate encoder used in the reverse link outputs three 9600 bps data streams when driven with a single 9600 data stream. This provides increased error correction capability, but also increases the data rate to 28,800 bps.

## 64-ary modulation

Walsh codes are not used to provide the channelization in the reverse link. In the reverse link they are used to randomize the encoded voice data with a modulation format that is easy to recover. Each six serial data bits output from the convolutional encoder are used to point to one of the 64 available Walsh codes (26 = 64). This modulation has the effect of increasing the data rate 10.67 times to 307 Kbps. As the incoming voice data changes, a different Walsh code is selected. Since this type of modulation can output one of 64 possible codes, it is referred to as 64-ary modulation.

## Reverse channel long code spreading

The channelization in the reverse link must provide for unique code assignments for each operational phone. Walsh codes could not be used for the reverse channelization, since they would not provide enough unique channels. Since the long code is 42 bits in length, this allows 242 (4.3 billion) unique channel assignments. Thus the long code imprinted with your unique mask is used to provide the channelization in the reverse link. This allows all mobiles in even very large systems to have unique channel assignments. Since the long codes are simply uncorrelated and not orthogonal to each other, the recovery and demodulation process is more difficult for CDMA base stations. The high-speed searcher circuits in the base station let it quickly search over the wide range of long codes to lock on a particular user's signal. These modules represent a good design trade-off, since it is more feasible to design complex hardware/software into a base station than into a mobile phone.

### Reverse channel short sequence spreading

CDMA mobiles use the same pseudo-random number (PN) sequences as the base for final short sequence scrambling. An extra one half period clock delay in the mobile's Q channel produces offset quadrature phase shift keying (QPSK) modulation rather than straight QPSK modulation. Thus mobiles can use a simpler and more efficient power amplifier design. Offset QPSK modulation prevents the signal from going to zero magnitude and greatly reduces the dynamic range of the modulated signal. Less costly amplifiers can be used on CDMA mobiles because of the reduced linear dynamic range obtained with offset QPSK modulation.

## CDMA turn-on process

### System access

When the mobile is first powered on, it must find the best base station. This is similar to analog, where the phone scans all control channels and selects the best one. In CDMA, the mobile unit scans for available pilot signals, which are all on different time offsets. This process is made easier because of the fixed nature of these offsets.

The timing of any base station is always an exact multiple of 64 system clock cycles (called chips) offset from any other base station. The mobile selects the strongest pilot tone and establishes a frequency and time reference from this signal. The mobile then demodulates the sync channel, which is always on Walsh code 32. This channel provides master clock information by sending the state of the 42 bit long code shift register 320 ms in the future. Once the mobile has read the sync channel and established system time, the mobile uses the parameters from the sync channel to determine the long code mask being used by the cell site it is acquiring.

#### Sync channel message

The sync channel messages contains:

- CDMA protocol revision supported by the cell site
- Minimum protocol revision supported by a CDMA mobile to work with the cell site

- System and network identification numbers for the cell site
- PN offset of the cell site
- Paging channel data rate
- Timing parameters – including such items as local time offset from system time and a flag for indicating if daylight savings time is active in the area

## Read the paging channel

At this point the mobile demodulates the paging channel and decodes all of the data contained in the various messages supplied on the paging channel. If required by the parameters on the paging channel, the phone then registers with the base station. If the phone is a slotted mode phone, it must first register with the base station before it can be paged.

The slotted paging channel mode lets the phone save power by going to sleep and only awakening when it is time to check for a page from the base station. During registration, the time slot for the phone to wake up and listen is negotiated between the base and mobile. Once this is completed, the phone is ready to place or receive phone calls.

## Paging channel messages

The paging channel is the heart of a CDMA base station. All parameters and signaling necessary for the proper operation of a CDMA cell site are handled by the paging channel. The paging channel supports a number of distinct messages that provide information and send messages.

The system parameters message provides the mobile with system information such as the network, system and base station identification numbers, the number of paging channels supported, registration information, and the soft handoff thresholds.

The access parameters message provides information to the mobile that dictates the behavior of access probes when a CDMA mobile initiates a call.

The neighbor list message tells the mobile that the PN offsets of surrounding cell sites may become likely candidates for soft handoffs.

The CDMA channel list reports the number of CDMA frequencies supported by the cell site as well as the configuration of surrounding cell sites.

The slotted and non-slotted page messages lets the cell site page CDMA phones for incoming calls. CDMA mobiles operating in the slotted mode must first register with the cell site before they can be paged. This registration is required to establish which slot is used by the cell site to transmit the page to the mobile.

The channel assignment message is used to communicate the information needed to get the mobile onto a traffic channel.

Other supported messages on the paging channel include various types of signaling messages and authentication.

## CDMA idle state handoff

The mobile has searchers scanning for alternative pilot channels at all times. If a pilot channel is found from another base station that is strong enough for a link, the mobile requests a soft handoff if it crosses into a new zone. In this case, the CDMA cells must have commanded the CDMA mobile to perform zone-based registration to reregister the phone.

## CDMA call initiation

Keying in a phone number and pressing the Send key initiates an access probe. The mobile uses a special code channel called the access channel to make contact with the cell site. CDMA mobiles can transmit two types of channels on the single physical channel provided by the reverse link. These two channels are distinguished by the types of coding used.

The access channel is used by the mobile to initiate calls. The other possible channel is the traffic channel, which is used once a call is established. The long code mask used for access probes is determined from parameters obtained from the sync and paging channels. The parameters are the access channel number, the paging channel number, the base station ID, and the pilot PN offset used by the base station.

Before a link is established, closed-loop power control is not active. The mobile uses open-loop control to estimate an initial level. Multiple tries are allowed, with random times between the tries to avoid collisions that can occur on the access channel. For each cell site there is also a limited number of supported access channels, again to reduce the odds of collisions because of the limited number of access channel receivers in the base station.

## CDMA call completion

After each access attempt, the mobile listens to the paging channel for a response from the base station. If the base station detects the access probe from the mobile, it responds with a channel assignment message. This message contains all of the information required to get the mobile onto a traffic channel. This message includes such information as the Walsh code channel to be used for the forward traffic channel, the frequency being used, and the frame offset to indicate the delay between the forward and reverse links.

Once the mobile has acknowledged the channel assignment message, the base station initiates the land link and the mobile moves from the access channel to the traffic channel. To accommodate signaling, IS-95 supports two methods for temporarily grabbing the traffic channel:

- Blank and burst signaling
- Dim and burst signaling

Both are similar except that the blank and burst steals a contiguous block of frames to transmit signaling messages, while dim and burst reduces the vocoder rate and then uses the remaining traffic channel time to more slowly send signaling messages.

# AMPS cellular overview

The cellular radio frequency spectrum has been divided by the Federal Communications Commission (FCC) into two equal segments or bands to allow two independent cellular carriers to coexist and compete in the same geographic coverage area. Each band occupies one half of the available channels in the cellular spectrum. Initially, there are 832 channels.

To guarantee nationwide compatibility, the signaling channel frequencies have been preassigned to each segment (band). The two bands and their assigned channels are defined as follows:

| **A Band** | **Channels** |
|---|---|
| Primary Control Channels (21): | 313 - 333 |
| Secondary Control Channels (21): | 688 - 708 |
| Voice Channels (395): | 001 - 312, 667 - 716, and 991 - 1023 |

| **B Band** | **Channels** |
|---|---|
| Primary Control Channels (21): | 334 - 354 |
| Secondary Control Channels (21): | 737 - 757 |
| Voice Channels (395): | 355 - 666 and 717 - 799 |

## Control (data) channels

A cellular telephone in the cellular system is under the indirect control of the switch, or central controller. The central controller uses dedicated control channels to provide the signaling required to establish a telephone call. Control channels are used to send and receive only digital data between the base station and the cellular telephone.

Voice channels are used for both audio and signaling once a call is established. The 21 control channels in each band may be dedicated according to access and paging channels. The data on the forward control channel generally provides some basic information about the particular cellular system, such as the system ID and the range of channels to scan to find the access and paging channels.

Access channels are used to respond to a page or originate a call. The system and the cellular telephone use access channels where two-way data transfer occurs to determine the initial voice channel.

Paging channels, if used, are the normal holding place for the idle cellular telephone. When a call is received at the central controller for a cellular telephone, the paging signaling occurs on a paging channel.

In many systems both control channel functions are served by the same control (access) channel for a particular cell. Only in very high density areas is multiple control (paging) channels required.

## Voice channels

Voice channels are primarily used for conversation, with signaling being employed as necessary to handle cell-to-cell handoffs, output power control of the cellular radio-telephone, and special local control features. Data from the cell site (known as FORWARD DATA) and data from the mobile or portable (known as REVERSE DATA) is sent using frequency shift keying. In AMPS signaling, various control and response tones are used for a variety of applications to be described later.

## Signaling protocol

In 1983, when the Federal Communications Commission (FCC) licensed cellular telephony, the signaling protocol used was AMPS. The AMPS signal protocol, an invention of Bell Labs, was ultimately adopted by all governments in the western hemisphere and eventually several other governments throughout the world.

Under the original AMPS protocol there were 21 control channels assigned to each of two possible carriers in any metropolitan area, with a total of 333 channels assigned to each carrier. Prior to 1987 the FCC had allocated 312 channels to voice (voice, DTMF, or data) applications for each carrier. In 1987 the FCC expanded the cellular spectrum (Expanded Spectrum) from a total of 666 channels to 832 channels, allowing for an increase of 83 voice channels for each carrier. But the number of control channels remained constant, with 21 control channels for each carrier. Each control channel had a bandwidth of 30 kHz and used the signaling protocol.

## Signaling tone (ST)

In AMPS, signaling tone is a 10 kHz signal used by the mobile or portable on the reverse voice channel (REVC) to signal certain activities or acknowledge various commands from the cell site, including handoffs, alert orders, and call terminations, and to indicate switch-hook operation.