

INTRODUCTION TO CDMA

Code Division Multiple Access (CDMA) is a radically new concept in wireless communications. It has gained widespread international acceptance by cellular radio system operators as an upgrade that will dramatically increase both their system capacity and the service quality. It has likewise been chosen for deployment by the majority of the winners of the United States Personal Communications System spectrum auctions. It may seem, however, mysterious for those who aren't familiar with it. This site is provided in an effort to dispel some of the mystery and to disseminate at least a basic level of knowledge about the technology.

CDMA is a form of spread-spectrum, a family of digital communication techniques that have been used in military applications for many years. The core principle of spread spectrum is the use of noise-like carrier waves, and, as the name implies, bandwidths much wider than that required for simple point-to-point communication at the same data rate. Originally there were two motivations: either to resist enemy efforts to jam the communications (anti-jam, or AJ), or to hide the fact that communication was even taking place, sometimes called low probability of intercept (LPI). It has a history that goes back to the early days of World War II.

The use of CDMA for civilian mobile radio applications is novel. It was proposed theoretically in the late 1940's, but the practical application in the civilian marketplace did not take place until 40 years later. Commercial applications became possible because of two evolutionary developments. One was the availability of very low cost, high density digital integrated circuits, which reduce the size, weight, and cost of the subscriber stations to an acceptably low level. The other was the realization that optimal multiple access communication requires that all user stations regulate their transmitter powers to the lowest that will achieve adequate signal quality.

CDMA changes the nature of the subscriber station from a predominately analog device to a predominately digital device. Old-fashioned radio receivers separate stations or channels by filtering in the frequency domain. CDMA receivers do not eliminate analog processing entirely, but they separate communication channels by means of a pseudo-random modulation that is applied and removed in the digital domain, not on the basis of frequency. Multiple users occupy the same frequency band. This universal frequency reuse is not fortuitous. On the contrary, it is crucial to the very high spectral efficiency that is the hallmark of CDMA. Other discussions in these pages show why this is true.

CDMA is altering the face of cellular and PCS communication by:

- Dramatically improving the telephone traffic capacity
- Dramatically improving the voice quality and eliminating the audible effects of multipath fading

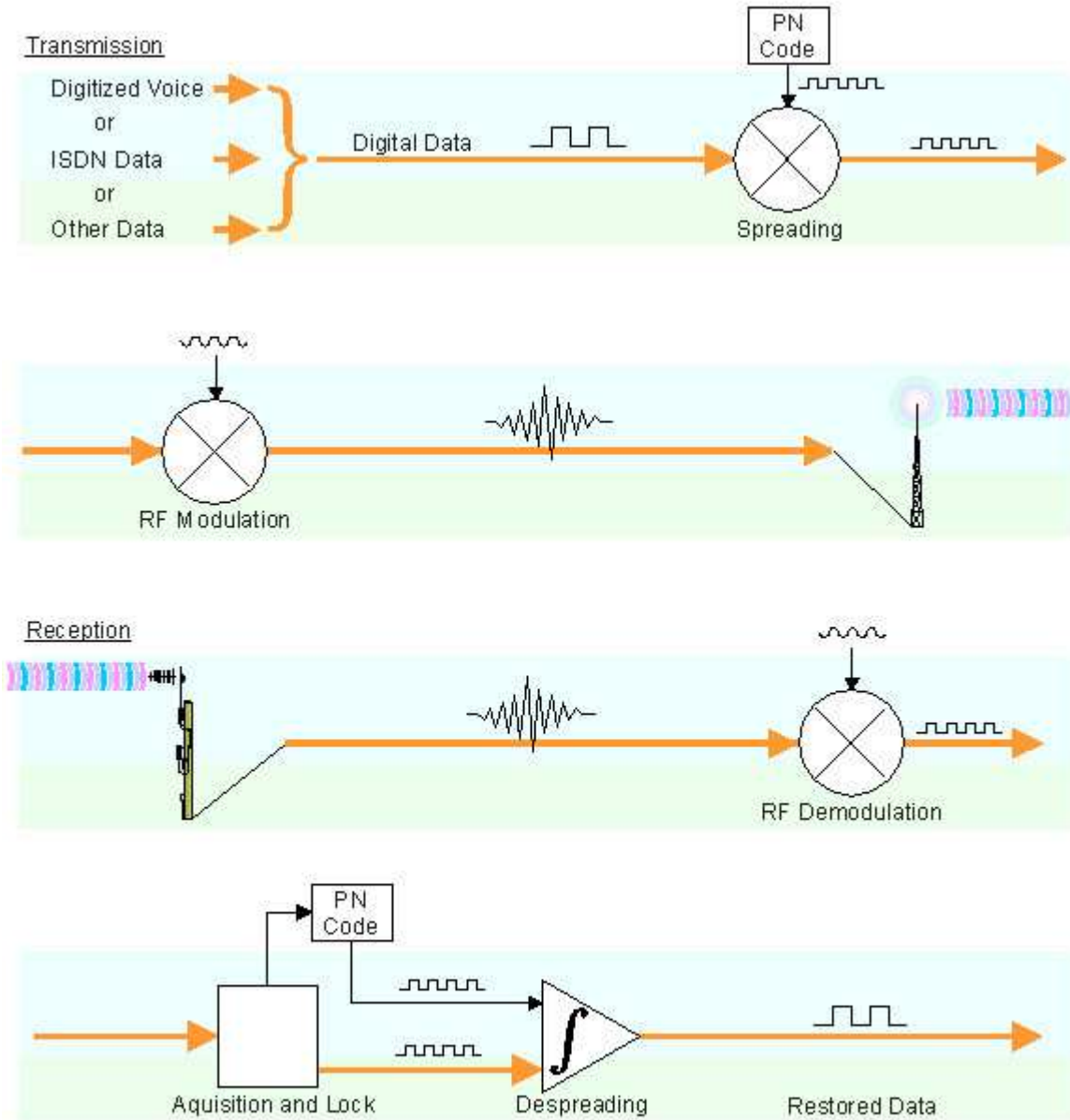
- Reducing the incidence of dropped calls due to handoff failures
- Providing reliable transport mechanism for data communications, such as facsimile and internet traffic
- Reducing the number of sites needed to support any given amount of traffic
- Simplifying site selection
- Reducing deployment and operating costs because fewer cell sites are needed
- Reducing average transmitted power
- Reducing interference to other electronic devices
- Reducing potential health risks

Commercially introduced in 1995, CDMA quickly became one of the world's fastest-growing wireless technologies. In 1999, the International Telecommunications Union selected CDMA as the industry standard for new "third-generation" (3G) wireless systems. Many leading wireless carriers are now building or upgrading to 3G CDMA networks in order to provide more capacity for voice traffic, along with high-speed data capabilities.

1. INTRODUCTION TO SPREAD SPECTRUM COMMUNICATIONS

CDMA is a form of Direct Sequence Spread Spectrum communications. In general, Spread Spectrum communications is distinguished by three key elements:

1. The signal occupies a bandwidth much greater than that which is necessary to send the information. This results in many benefits, such as immunity to interference and jamming and multi-user access, which we'll discuss later on.
2. The bandwidth is spread by means of a code which is independent of the data. The independence of the code distinguishes this from standard modulation schemes in which the data modulation will always spread the spectrum somewhat.
3. The receiver synchronizes to the code to recover the data. The use of an independent code and synchronous reception allows multiple users to access the same frequency band at the same time.



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Figure 1. Direct Sequence Spread Spectrum System

In order to protect the signal, the code used is pseudo-random. It appears random, but is actually deterministic, so that the receiver can reconstruct the code for synchronous detection. This pseudo-random code is also called pseudo-noise (PN).

Three Types of Spread Spectrum Communications

There are three ways to spread the bandwidth of the signal:

- Frequency hopping. The signal is rapidly switched between different frequencies within the hopping bandwidth pseudo-randomly, and the receiver knows beforehand where to find the signal at any given time.
- Time hopping. The signal is transmitted in short bursts pseudo-randomly, and the receiver knows beforehand when to expect the burst.
- Direct sequence. The digital data is directly coded at a much higher frequency. The code is generated pseudo-randomly, the receiver knows how to generate the same code, and correlates the received signal with that code to extract the data.

Direct Sequence Spread Spectrum

CDMA is a Direct Sequence Spread Spectrum system. The CDMA system works directly on 64 kbit/sec digital signals. These signals can be digitized voice, ISDN channels, modem data, etc.

Figure 1 shows a simplified Direct Sequence Spread Spectrum system. For clarity, the figure shows one channel operating in one direction only.

Signal transmission consists of the following steps:

1. A pseudo-random code is generated, different for each channel and each successive connection.
2. The Information data modulates the pseudo-random code (the Information data is "spread").
3. The resulting signal modulates a carrier.
4. The modulated carrier is amplified and broadcast.

Signal reception consists of the following steps:

1. The carrier is received and amplified.
2. The received signal is mixed with a local carrier to recover the spread digital signal.
3. A pseudo-random code is generated, matching the anticipated signal.
4. The receiver acquires the received code and phase locks its own code to it.
5. The received signal is correlated with the generated code, extracting the Information data.

The following sections describe how a system might implement the steps illustrated in Figure 1.

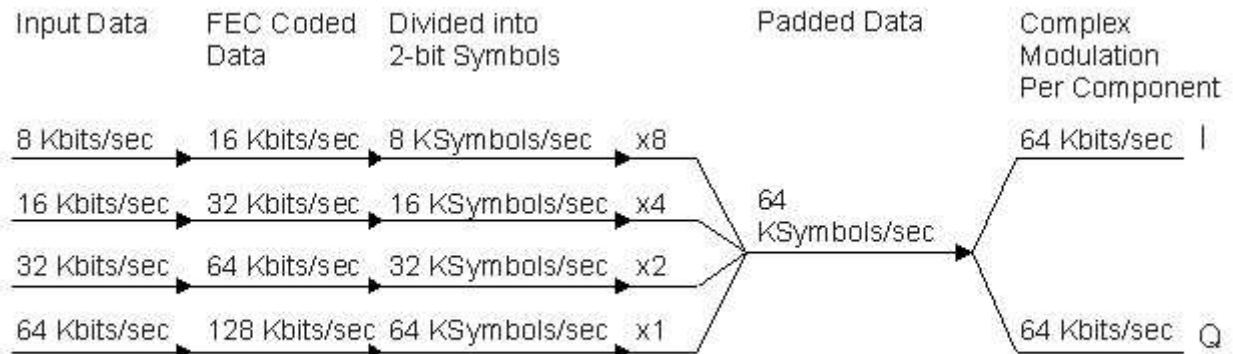
Input data

CDMA works on Information data from several possible sources, such as digitized voice or ISDN channels. Data rates can vary, here are some examples:

Data Source		Data Rate
Voice	Pulse Code Modulation (PCM)	64 kBits/sec
	Adaptive Differential Pulse Code Modulation (ADPCM)	32 kBits/sec
	Low Delay Code Excited Linear Prediction (LD-CELP)	16 kBits/sec
ISDN	Bearer Channel (B-Channel)	64 kBits/sec
	Data Channel (D-Channel)	16 kBits/sec

The system works with 64 kBits/sec data, but can accept input rates of 8, 16, 32, or 64 kBits/sec. Inputs of less than 64 kBits/sec are padded with extra bits to bring them up to 64 kBits/sec.

For inputs of 8, 16, 32, or 64 kBits/sec, the system applies Forward Error Correction (FEC) coding, which doubles the bit rate, up to 128 kbits/sec. The Complex Modulation scheme (which we'll discuss in more detail later), transmits two bits at a time, in two bit symbols. For inputs of less than 64 kbits/sec, each symbol is repeated to bring the transmission rate up to 64 kilosymbols/sec. Each component of the complex signal carries one bit of the two bit symbol, at 64 kBits/sec, as shown below.



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Generating Pseudo-Random Codes

For each channel the base station generates a unique code that changes for every connection. The base station adds together all the coded transmissions for every subscriber. The subscriber unit correctly generates its own matching code and uses it to extract the appropriate signals. Note that each subscriber uses several independent channels.

In order for all this to occur, the pseudo-random code must have the following properties:

1. It must be deterministic. The subscriber station must be able to independently generate the code that matches the base station code.
2. It must appear random to a listener without prior knowledge of the code (i.e. it has the statistical properties of sampled white noise).
3. The cross-correlation between any two codes must be small (see below for more information on code correlation).
4. The code must have a long period (i.e. a long time before the code repeats itself).

Code Correlation

In this context, correlation has a specific mathematical meaning. In general the correlation function has these properties:

- It equals 1 if the two codes are identical
- It equals 0 if the two codes have nothing in common

Intermediate values indicate how much the codes have in common. The more they have in common, the harder it is for the receiver to extract the appropriate signal.

There are two correlation functions:

- **Cross-Correlation:** The correlation of two different codes. As we've said, this should be as small as possible.
- **Auto-Correlation:** The correlation of a code with a time-delayed version of itself. In order to reject multi-path interference, this function should equal 0 for any time delay other than zero.

The receiver uses cross-correlation to separate the appropriate signal from signals meant for other receivers, and auto-correlation to reject multi-path interference.

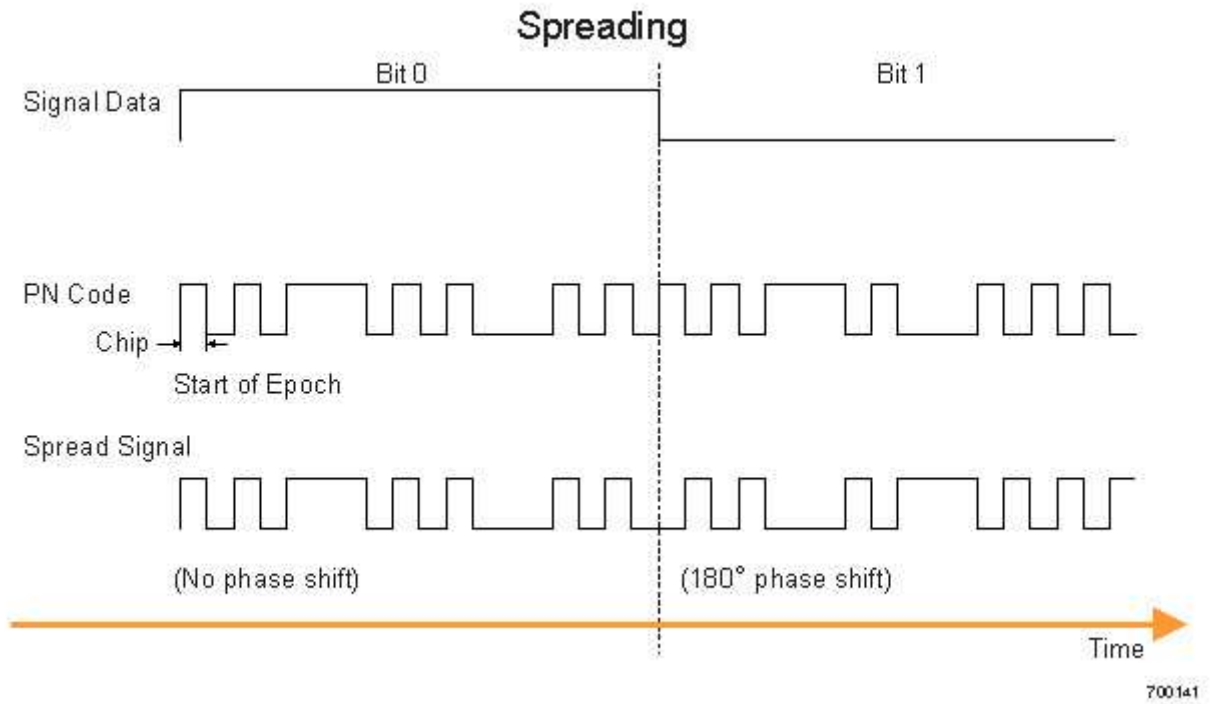


Figure 2a. Pseudo-Noise Spreading

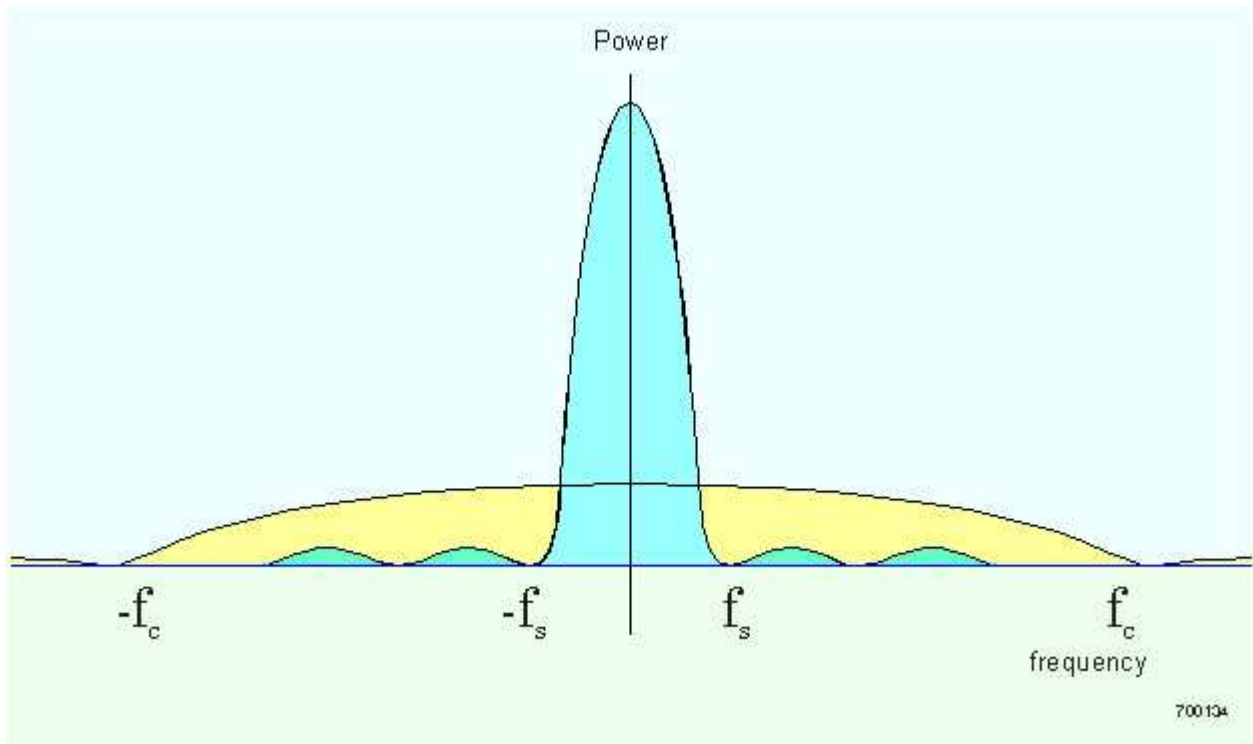


Figure 2b. Frequency Spreading

Pseudo-Noise Spreading

The FEC coded Information data modulates the pseudo-random code, as shown in Figure 2a. Some terminology related to the pseudo-random code:

- Chipping Frequency (f_c): the bit rate of the PN code.
- Information rate (f_i): the bit rate of the digital data.
- Chip: One bit of the PN code.
- Epoch: The length of time before the code starts repeating itself (the period of the code). The epoch must be longer than the round trip propagation delay (The epoch is on the order of several seconds).

Figure 2b shows the process of frequency spreading. In general, the bandwidth of a digital signal is twice its bit rate. The bandwidths of the information data (f_i) and the PN code are shown together. The bandwidth of the combination of the two, for $f_c > f_i$, can be approximated by the bandwidth of the PN code.

Processing Gain

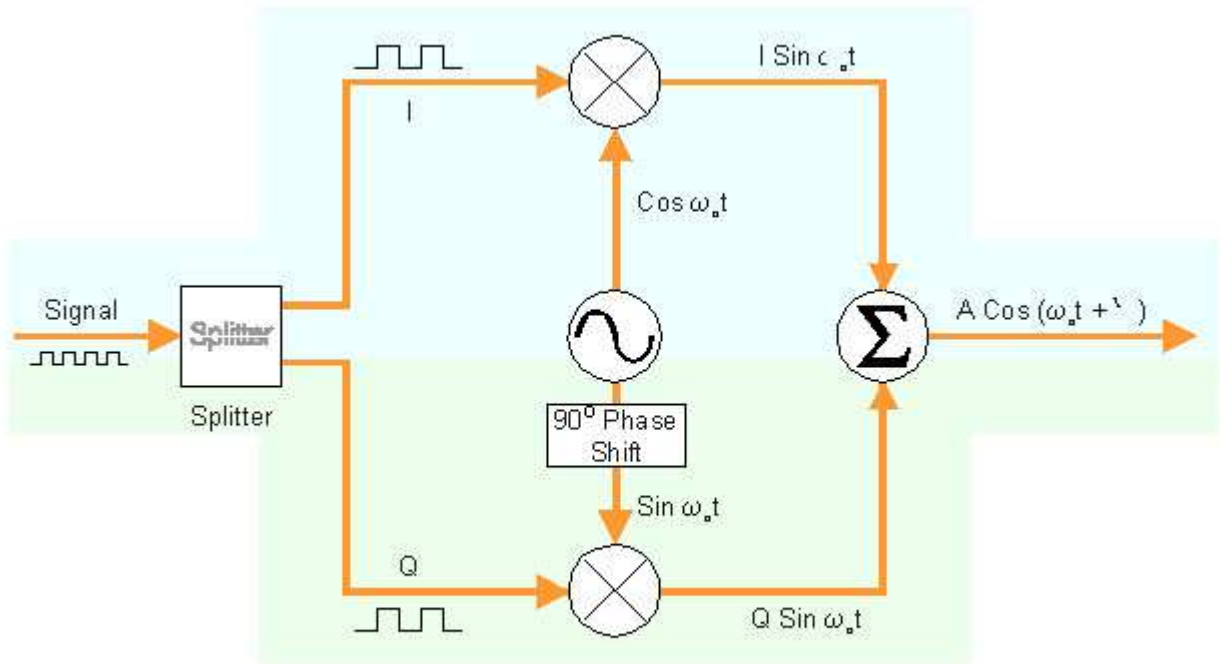
An important concept relating to the bandwidth is the processing gain (G_p). This is a theoretical system gain that reflects the relative advantage that frequency spreading provides. The processing gain is equal to the ratio of the chipping frequency to the data frequency:

$$G_p = \frac{f_c}{f_i}$$

There are two major benefits from high processing gain:

- Interference rejection: the ability of the system to reject interference is directly proportional to G_p .
- System capacity: the capacity of the system is directly proportional to G_p .

So the higher the PN code bit rate (the wider the CDMA bandwidth), the better the system performance.



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Figure 3a. Complex Modulator

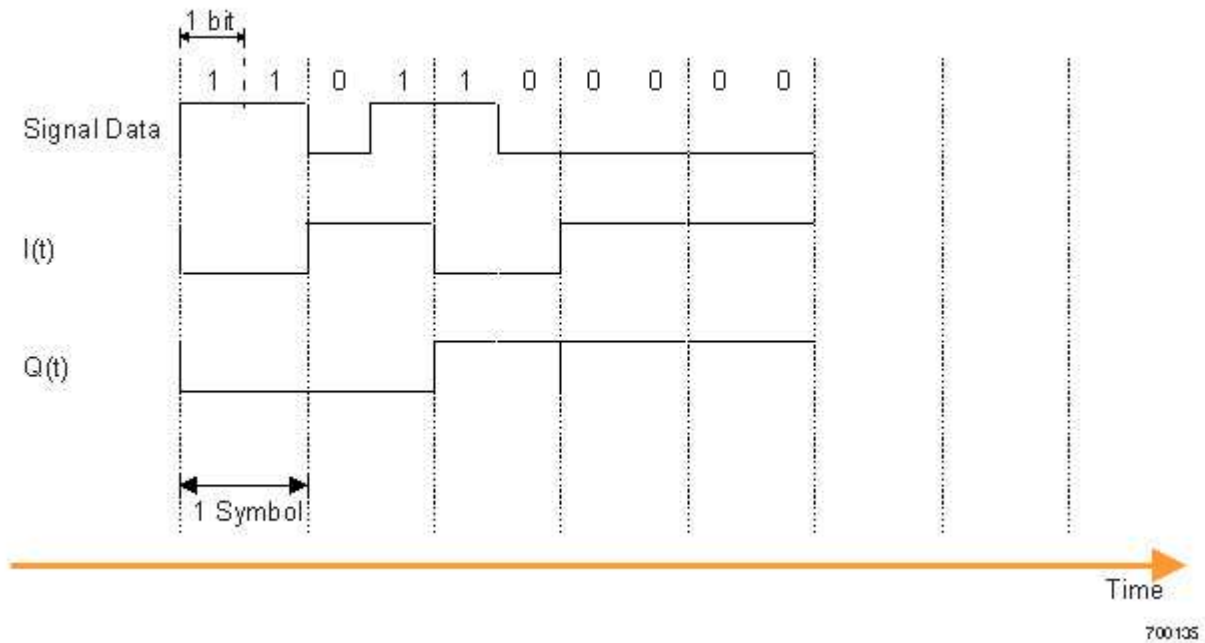


Figure 3b. Complex Modulation

Transmitting Data

The resultant coded signal next modulates an RF carrier for transmission using Quadrature Phase Shift Keying (QPSK). QPSK uses four different states to encode each symbol. The four states are phase shifts of the carrier spaced 90° apart. By convention, the phase shifts are 45, 135, 225, and 315 degrees. Since there are four possible states used to encode binary information, each state represents two bits. This two bit “word” is called a symbol. Figure 3 shows in general how QPSK works.

First, we’ll discuss Complex Modulation in general, applying it to a single channel with no PN-coding (that is, we’ll show how Complex Modulation would work directly on the symbols). Then we’ll discuss how we apply it to a multi-channel, PN-coded, system.

Complex Modulation

Algebraically, a carrier wave with an applied phase shift, $\phi(t)$, can be expressed as a sum of two components, a Cosine wave and a Sine wave, as:

$$A(t)\cos(\omega_c t + \phi(t)) = I(t)\cos(\omega_c t) + Q(t)\sin(\omega_c t)$$

I(t) is called the real, or In-phase, component of the data, and Q(t) is called the imaginary, or Quadrature-phase, component of the data. We end up with two Binary PSK waves superimposed. These are easier to modulate and later demodulate.

This is not only an algebraic identity, but also forms the basis for the actual modulation/demodulation scheme. The transmitter generates two carrier waves of the same frequency, a sine and cosine. I(t) and Q(t) are binary, modulating each component by phase shifting it either 0 or 180 degrees. Both components are then summed together. Since I(t) and Q(t) are binary, we'll refer to them as simply I and Q.

The receiver generates the two reference waves, and demodulates each component. It is easier to detect 180_ phase shifts than 90_ phase shifts. The following table summarizes this modulation scheme. Note that I and Q are normalized to 1.

Symbol	I	Q	Phase shift
00	+1	+1	45°
01	+1	-1	315°
10	-1	+1	135°
11	-1	-1	225°

For Digital Signal Processing, the two-bit symbols are considered to be complex numbers, $I + jQ$.

Working with Complex Data

In order to make full use of the efficiency of Digital Signal Processing, the conversion of the Information data into complex symbols occurs before the modulation. The system generates complex PN codes made up of 2 independent components, $PN_i + jPN_q$. To spread the Information data the system performs complex multiplication between the complex PN codes and the complex data.

Summing Many Channels Together

Many channels are added together and transmitted simultaneously. This addition happens digitally at the chip rate. Remember, there are millions of chips in each symbol. For clarity, let's say each chip is represented by an 8 bit word (it's slightly more complicated than that, but those details are beyond the scope of this discussion).

At the Chip Rate

- Information data is converted to two bit symbols.
- The first bit of the symbol is placed in the I data stream, the second bit is placed in the Q data stream.
- The complex PN code is generated. The complex PN code has two independently generated components, an I component and a Q component.
- The complex Information data and complex PN code are multiplied together.

For each component (I or Q):

- Each chip is represented by an 8 bit word. However, since one chip is either a one or a zero, the 8 bit word equals either 1 or -1.
- When many channels are added together, the 8-bit word, as the sum of all the chips, can take on values from between -128 to +128.
- The 8-bit word then goes through a Digital to Analog Converter, resulting in an analog level proportional to the value of the 8-bit word.
- This value then modulates the amplitude of the carrier (the I component modulates the Cosine, the Q component modulates the Sine)
- The modulated carriers are added together.

Since I and Q are no longer limited to 1 or -1, the phase shift of the composite carrier is not limited to the four states, the phase and amplitude vary as

$$A^2 = I^2 + Q^2$$

$$\text{Tan}(\theta) = Q/I$$

At the Symbol Rate

Since the PN-code has the statistical properties of random noise, it averages to zero over long periods of time (such as the symbol period). Therefore, fluctuations in I and Q, and hence the phase modulation of the carrier, that occur at the chip frequency, average to zero. Over the symbol period the modulation averages to one of the four states of QPSK, which determine what the symbol is.

The symbol only sees the QPSK, and obeys all the statistical properties of QPSK transmission, including Bit Error Rate.

Receiving Data

The receiver performs the following steps to extract the Information:

- Demodulation
- Code acquisition and lock
- Correlation of code with signal
- Decoding of Information data

Demodulation

The receiver generates two reference waves, a Cosine wave and a Sine wave. Separately mixing each with the received carrier, the receiver extracts I(t) and Q(t). Analog to Digital converters restore the 8-bit words representing the I and Q chips.

Code Acquisition and Lock

The receiver, as described earlier, generates its own complex PN code that matches the code generated by the transmitter. However, the local code must be phase-locked to the encoded data. The RCS and FSU each have different ways of acquiring and locking onto the other's transmitted code. Each method will be covered in more detail in later sections.

Correlation and Data Despreading

Once the PN code is phase-locked to the pilot, the received signal is sent to a correlator that multiplies it with the complex PN code, extracting the I and Q data meant for that receiver. The receiver reconstructs the Information data from the I and Q data.

Automatic Power Control

The RCS gets bombarded by signals from many FSUs. Some of these FSUs are close and their signals are much stronger than FSUs farther away. This results in the Near/Far problem inherent in CDMA communications. System Capacity is also dependant on signal power. For these reasons, both the RCS and FSU measure the received power and send signals to control the other's transmit power.

Near/Far Problem

Because the cross-correlation between two PN codes is not exactly equal to zero, the system must overcome what we call the Near/Far problem.

The output of the correlator consists of two components:

- The autocorrelation of the PN code with the desired coded signal
- The sum of the cross-correlation of the PN code with all the other coded signals.

Mathematically, if we are trying to decode the k^{th} signal, we have:

$$\text{output} = A_k + \sum_j A_j \rho_{jk}$$

Where:

- A_j is the amplitude of the j^{th} signal,
- ρ_{jk} is the cross-correlation between the k^{th} and j^{th} signal, and
- \sum_j is the sum over all the j signals (excluding k).

Since the cross-correlation is small (ideally, it is zero), the sum of cross-correlation terms should be much less than the amplitude of the desired signal. However, if the desired signal is broadcast from far away, and undesired signals are broadcast from much closer, the desired signal may be so small as to be drowned out by the cross-correlation terms.

Note that this problem only exists in the reverse direction. The RCS is receiving signals from many FSUs at different distances, but the FSU is receiving all signals from one

RCS. The RCS controls the power of each FSU so that the signals received from all FSUs are the same strength.

System Capacity

The capacity of a system is approximated by:

$$C_{\max} = \frac{G_p}{\frac{E_b}{N_0}} \cdot \frac{1}{1 + \beta}$$

where:

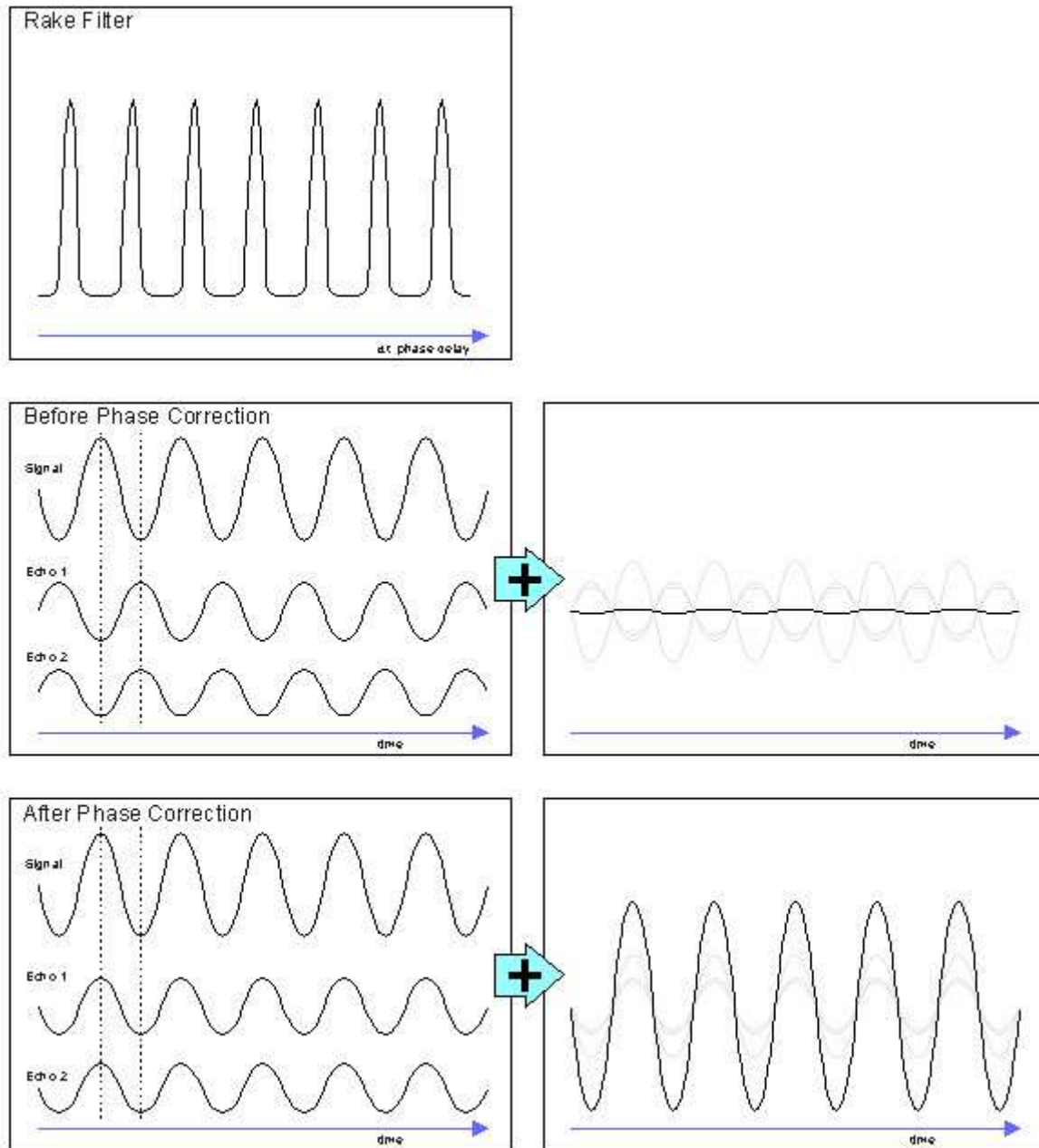
C_{\max} is the maximum number of simultaneous calls

G_p is the processing gain

$\frac{E_b}{N_0}$ is the total signal to noise ratio per bit, and

β is the inter-cell interference factor.

Notice, as we said earlier, the capacity is directly proportional to the processing gain. Capacity is also inversely proportional to the signal to noise ratio of the received signal. So, the smaller the transmitted signal, the larger the system capacity (as long as the receiver can detect the signal in the noise!). Both the RCS and FSU control the power transmitted by the other so that the received signal is as small as possible while maintaining a minimum signal to noise ratio. This maximizes system capacity.



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Figure 4. Multi-Path Interference Rejection

Interference Rejection

CDMA technology is inherently resistant to interference and jamming. A common problem with urban communications is multi-path interference.

Multi-path interference is caused by the broadcast signal traveling over different paths to reach the receiver. The receiver then has to recover the signal combined with echoes of varying amplitude and phase. This results in two types of interference:

- Inter-chip interference: The reflected signals are delayed long enough that successive bits (or chips, in this case) in the demodulated signals overlap, creating uncertainty in the data.
- Selective fading: The reflected signals are delayed long enough that they are randomly out of phase, and add destructively to the desired signal, causing it to fade.

Combating Interference

Two methods are commonly used to combat multi-path interference:

- Rake filter: Correlators are set up at appropriate time intervals to extract all the echoes. The relative amplitude and phase of each echo is measured, and each echo signal is phase corrected and added to the signal.
- Adaptive Matched Filter. This filter is “matched” to the transfer function (i.e. the propagation characteristics) of the signal path. It phase shifts the echo signals and adds them to maximize the received signal.

System Operation

The following sections describe a hypothetical implementation of CDMA technology. A connection can be one of many types of data, but for simplicity we will refer to any connection as a “call”.

These sections cover the following system states:

- System Idle: System operation when there is no call in progress.
- Call Setup: The steps to setup a connection.
- Call Processing: The processing and transmission of the digital data once a connection is established.
- Call Teardown: The steps taken once a call is finished to free system resources.

But first, in order to understand system operation, you must understand the Pilot codes and communication channels the system uses.

Pilot Codes

At each phase of operation, the system broadcasts pilot signals. These pilot signals are the unmodulated PN codes associated with each channel, used to synchronize and track

the locally generated PN codes for despreading. The system uses the following pilot signals.

- Global Pilot: Broadcast by the RCS. All FSUs use the Global Pilot for all received channels.
- Short Access Pilot: Broadcast by FSU. Monitored by the RCS for an incoming access attempt by an FSU. Alerts the RCS that an FSU is requesting access.
- Long Access Pilot: Broadcast by the FSU. Allows the RCS to synchronize to the FSU to setup a call.
- Assigned Pilot: Broadcast by FSU. Unmodulated PN code of the assigned channel. Allows RCS to synchronize to and track the PN codes of the FSU assigned channels for despreading.

Communication Channels

In order to understand system operation, we need to introduce the system communication channels. The system has the following channel groups:

- The Broadcast Channel group: Channels continuously broadcasted by the RCS.
- Call Setup Channel group: Channels used to setup a call. There are four sets of these channels; up to 4 FSUs can request access at one time.
- Assigned Channel group: Channels used for the call.

Each logical channel in each group is realized by assigning a unique PN code to it.

Channel Group	Channel Name	Direction	Number of Channels	Description
Broadcast	Global Pilot	F	One	An unmodulated PN code that the FSU can synchronize to.
	Fast Broadcast Channel	F	One	A single message indicating which services and access channels are available. This information may change rapidly.
	Slow Broadcast Channel	F	One	Paging messages and other system information that does not need to be updated rapidly.
Call Setup	Short Pilot	R	Four	Alerts the RCS that an FSU is requesting access.
	Long Pilot		Four	Allows the RCS to synchronize to the FSU to setup a call.
	Access Channel	R	Four	Used by the FSUs to access an RCS and get assigned channels.
	Control Channel	F	Four	Used by the RCS to reply to access attempts from FSUs.
	Control Channel APC	F	Four	Controls FSU power during initial access.
Assigned	Assigned Pilot	R	One per FSU	An unmodulated PN code that the RCS can synchronize to.
	APC Channel	F	One per FSU	Controls FSU power during call.
		R		Controls RCS power of assigned FSU channels.
	Traffic Channels	F	Up to 3 per FSU	Signal data from RCS to FSU.
		R		Signal data from FSU to RCS.
	Order wire	F	One per FSU	Control signals: CDMA and Telco messages.
		R		
Note on Direction: F - Forward - From RCS to FSU				
R - Reverse - From FSU to RCS				

Pilot Ramp Up

When the FSU transmits its Short and Long Access Pilots, it ramps the power up to determine what power level it should transmit. When the RCS detects the Short Access Pilot, it acknowledges over the Fast Broadcast Channel. The FSU then knows that it is being received, and switches to the Long Access Pilot code. The Long Access Pilot code

ramps up more slowly, until the RCS locks and starts transmitting Automatic Power Control signals.

System Idle

On startup, the RCS places one of its modems in broadcast mode, in which state it broadcasts the following Global Channels continuously:

- Global Pilot
- Slow Broadcast Channel
- Fast Broadcast Channel

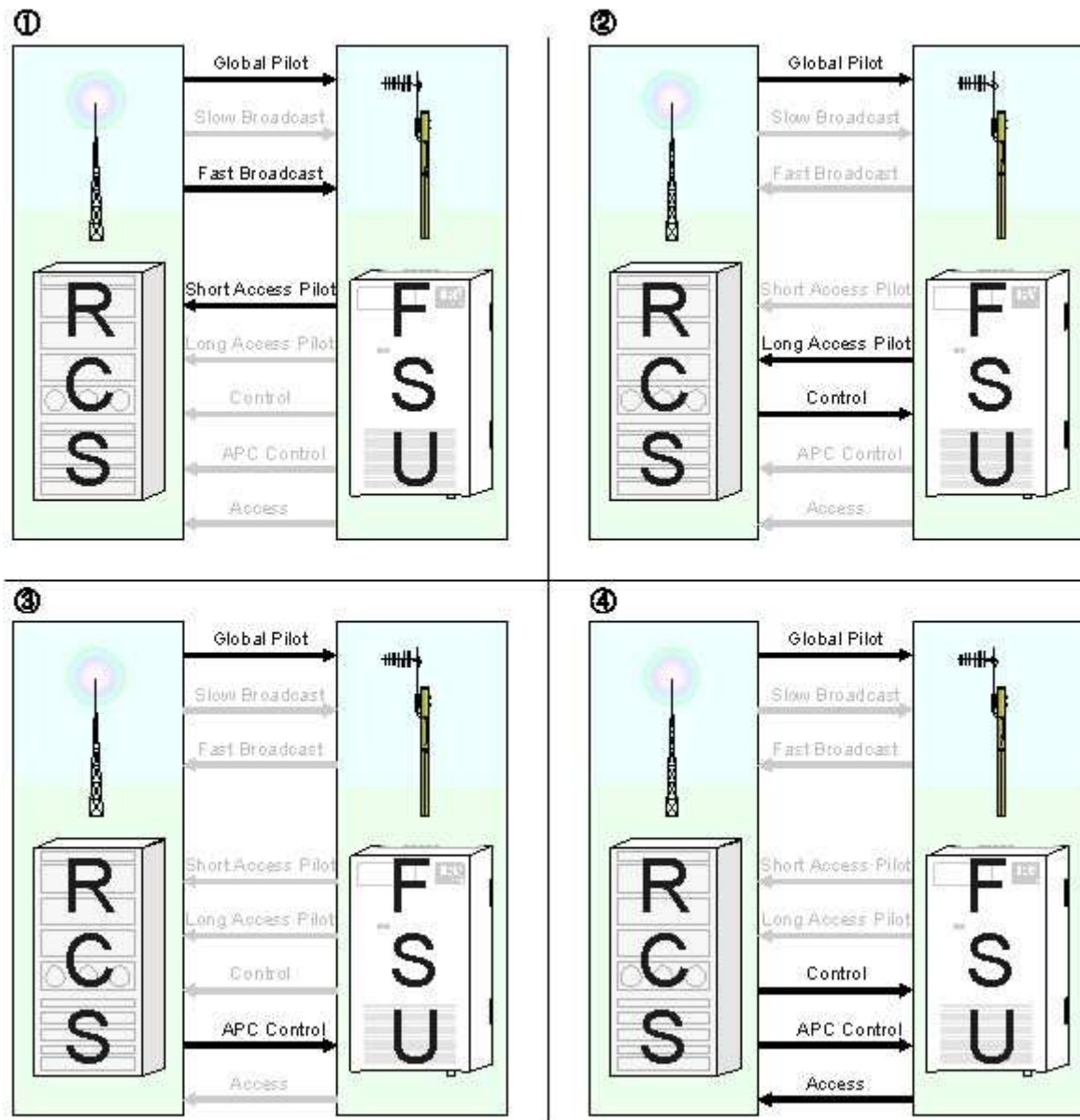
In addition, the RCS sets aside 4 modems for Call Setup channels. These modems continuously listen for access attempts by the FSUs. We'll discuss the operation of the modems in more detail later.

Paging Groups and Sleep Cycles

The RCS divides all the FSUs associated with it into paging groups. The RCS assigns each paging group a particular time slot on its Slow Broadcast Channel (the first time slot is reserved for general Slow Broadcast information). When the RCS pages an FSU, the RCS will only page it during the time slot of that FSU's paging group.

The Slow Broadcast Channel cycles through all the paging groups. The cycle takes approximately one second to complete. Each FSU remains powered down for most of the cycle. When the Slow Broadcast Channel reaches the time slot of the FSU's paging group, the FSU powers up, synchronizes to the Global Pilot, and checks for its address in the paging group. If it recognizes its paging address, it requests access; if not, it powers down. This results in a duty cycle of less than 10%, and saves considerable power at the FSU.

Call Setup



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Figure 5. Call Setup

Call Setup

Two events can initiate a call:

- The FSU receives a page from the RCS, as explained above. This is called a terminating call.
- The FSU generates an off-hook signal in response to subscriber equipment. The FSU locks on to the Global Pilot. This is called an originating call.

Once either of these events occur, call setup proceeds as follows:

1. FSU requests access.

- FSU transmits Short Access Pilot Code.
- RCS detects transmission and acknowledges. Flags Call Setup Channel as busy.
- FSU transmits Long Access Pilot Code.
- RCS synchronizes to the FSU and confirms sync over Control Channel.
- RCS measures received power and starts transmitting APC signal on APC Control Channel.
- RCS and FSU exchange messages on Access and Control Channels. Type of service and types of traffic channels are specified.

2. RCS assigns channel group to FSU.

- RCS designates assigned code on Control Channel
- FSU generates complex PN codes for all channels in its assigned group.
- Both FSU and RCS synchronously switch to the assigned channel groups.
- The call is connected.
- The RCS flags the Call Setup Channel as available, and assigns it to the next available modem.

Note that the RCS now tracks the Assigned Pilot; the FSU continues to track the Global Pilot.

Call Processing

Call processing puts together everything we've covered so far. There are slight differences in the way the RCS and FSU process calls, so we will cover both the Forward link (RCS to FSU) and Reverse link (FSU to RCS). Note that the system uses Frequency Division Duplexing for the Forward and Reverse links: they transmit over different frequencies.

In the forward direction, the RCS:

1. Generates CDMA data signal for each traffic channel:

- FEC codes the Information data, and converts the data to two-bit symbols.
- Converts the symbols to I and Q data, and pads each data stream to 64 kbits/sec.
- Generates the Complex PN code for each channel.

- Multiplies the Complex Information data and the Complex PN code together.
 - Reads APC data from FSU, digitally scales channels accordingly.
2. Generates other signal channels:
 - Calculates APC signal
 - Converts it to I data only
 - Multiplies it with its own Complex PN code
 3. Adds all signals together:
 - Traffic channels
 - APC channel
 - Order Wire channel
 - Global Pilot
 4. Adds together the signals for all currently active FSUs.
 5. Modulates and transmits carriers
 - I and Q data modulate Cosine and Sine carriers.
 - Carriers are combined, amplified, and broadcast.

The FSU:

1. Extracts the I and Q data:
 - Receives and amplifies the modulated carriers.
 - Demodulates the signal and extracts the I and Q data.
2. Filters the I and Q data:
 - Extracts multi-path information from the Pilot Rake filter and supplies it to the Adaptive Matched Filter.
 - Removes multi-path interference from I and Q data using the Adaptive Matched Filter.
 - Performs Automatic Gain Control on received signal
3. Extracts the CDMA data signal for each traffic channel:
 - Generates the Complex PN code for each channel.
 - Multiplies the Complex signal and the Complex PN code together.
 - Converts the I and Q data to symbols.
 - Decodes the symbols for error correction.
 - Extracts the signal data.

In the reverse direction, the FSU:

1. Generates CDMA data signal for each traffic channel:
 - FEC codes the Information data, and converts the data to two-bit symbols.
 - Converts the symbols to I and Q data, and pads each data stream to 64 kbits/sec.
 - Generates the Complex PN code for each channel.
 - Multiplies the Complex signal and the Complex PN code together.
 - Reads APC data from FSU, digitally scales channels accordingly.
2. Generates other signal channels:
 - Calculates APC signal
 - Converts it to I data only
 - Multiplies it with its own Complex PN code
3. Adds all signals together:
 - Traffic channels
 - APC channel
 - Order Wire channel
 - Global Pilot
4. Passes the signal through a pulse shaping digital filter.
5. Modulates and transmits carriers
 - I and Q data modulate Cosine and Sine carriers.
 - Carriers are combined, amplified, and broadcast.

The RCS:

1. Extracts the I and Q data:
 - Receives and amplifies the modulated carriers.
 - Demodulates the signal and extracts the I and Q data.
2. Filters the I and Q data:
 - Extracts multi-path information from the Pilot Rake filter and supplies it to the Adaptive Matched Filter.
 - Removes multi-path interference from I and Q data using the Adaptive Matched Filter.
 - Performs Automatic Gain Control on the received signal
3. Extracts the CDMA data signal for each traffic channel, for each subscriber connection:
 - Generates the Complex PN code for each channel.
 - Multiplies the Complex signal and the Complex PN code together.
 - Converts the I and Q data to symbols.
 - Decodes the symbols for error correction.

- Extracts the Information data.

Call Teardown

An on-hook signal causes the RCS to release the resources, and the FSU returns to its idle state.

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References:

1. Viterbi, A. *CDMA: Principles of Spread Spectrum Communication* Addison-Wesley Wireless Communications Series, 1995
2. Pickholtz, R. L., Schilling, D. L., and Milstein, L. B. "Theory of Spread-Spectrum Communications—A Tutorial" IEEE Trans. Commun., vol. COM30, no. 5, May 1982, pp 855-884.
3. Pickholtz, R. L., Schilling, D. L., and Milstein, L. B. Revisions to "Theory of Spread-Spectrum Communications—A Tutorial" IEEE Trans. Commun., vol. COM32, no. 2, Feb 1984, pp 211-212.