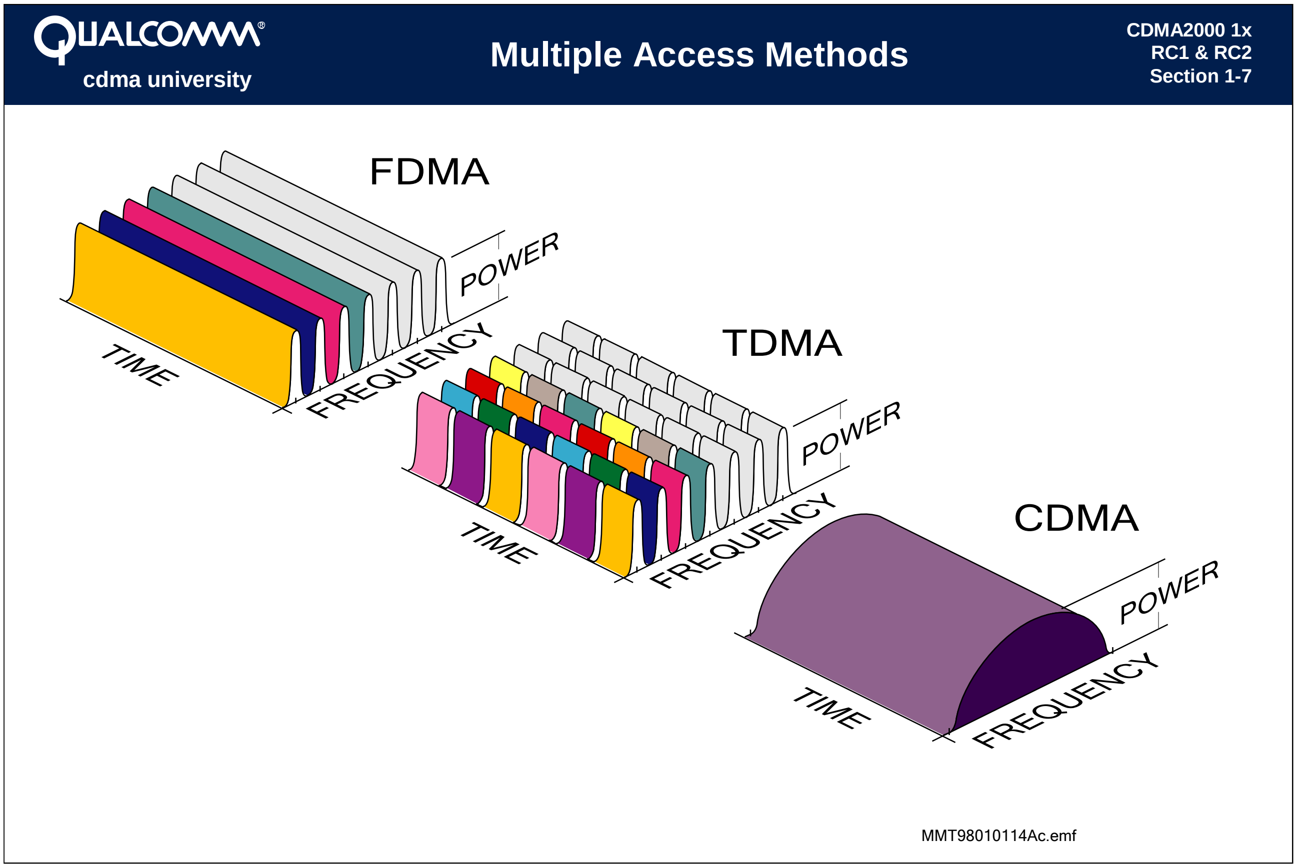

FDMA: Frequency Division Multiple Access

FDMA is a multiple access method in which users are assigned specific frequency bands. The user has sole right of using the frequency band for the entire call duration.

TDMA: Time Division Multiple Access

TDMA is an assigned frequency band shared among a few users. However, each user is allowed to transmit in predetermined time slots. Hence, channelization of users in the same band is achieved through separation in time.

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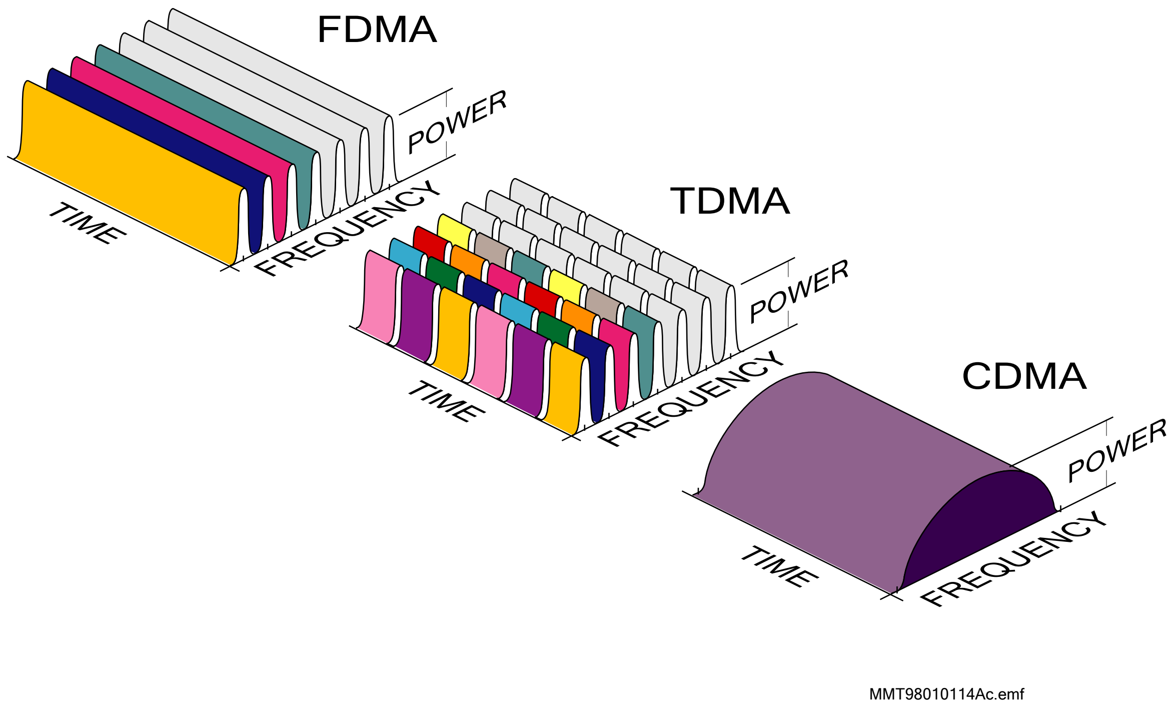
Multiple Access Methods (continued)

CDMA2000 1x
RC1 & RC2
Section 1-8

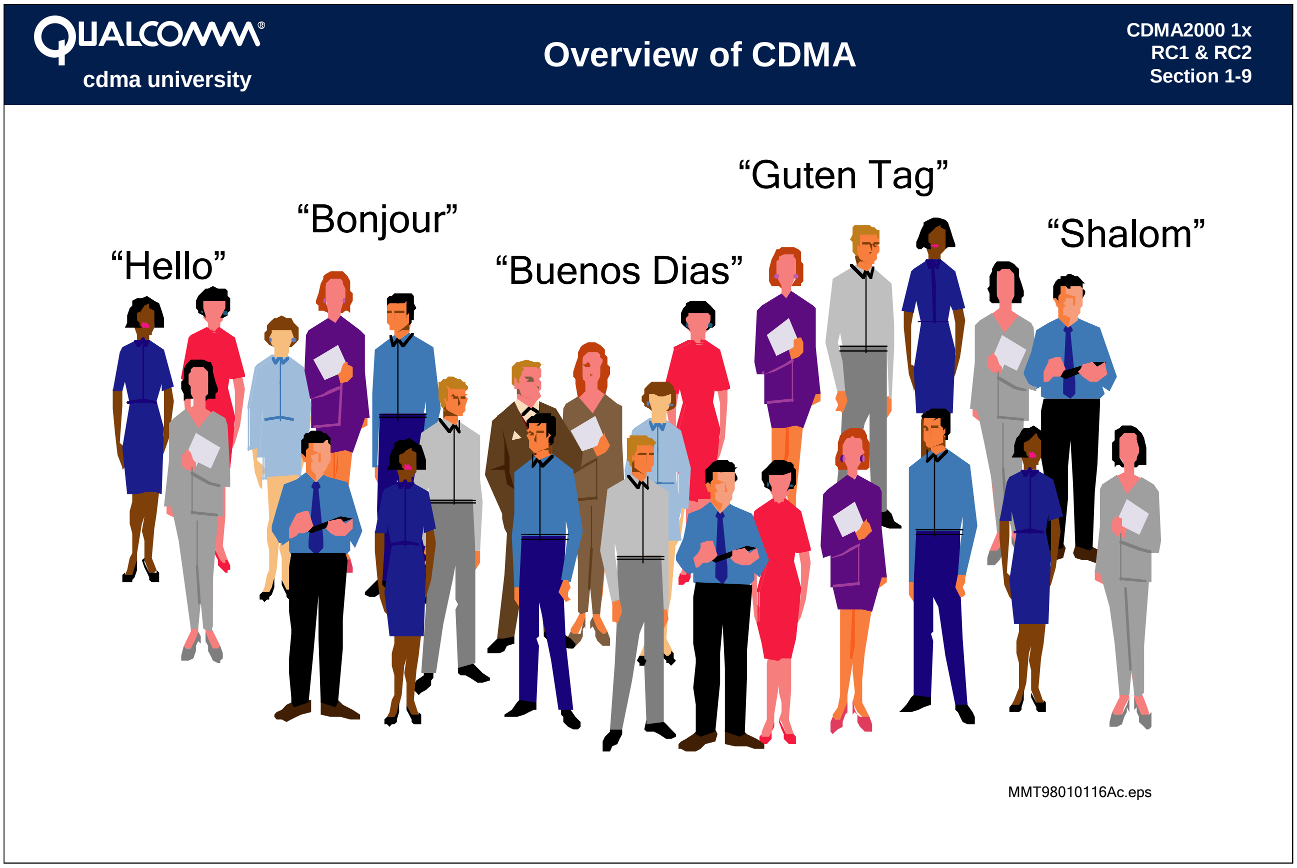


CDMA: Code Division Multiple Access

CDMA is a method in which users occupy the same time and frequency allocations, and are channelized by unique assigned codes. The signals are separated at the receiver by using a correlator that accepts only signal energy from the desired channel. Undesired signals contribute only to the noise.

In December of 1991, QUALCOMM presented to CTIA the results of some of the first CDMA field trials. Following these presentations, the CTIA Board of Directors unanimously adopted a resolution requesting that the Telecommunications Industry Association (TIA), prepare structurally to accept contributions regarding wideband cellular systems.

In March of 1992, a new subcommittee within the TR45 Committee was formed to develop spread spectrum cellular standards. That subcommittee published the first CDMA cellular standard, IS-95, in July 1993. CDMA systems based on the IS-95 standard and related specifications are referred to as *CDMAOne*™ systems. CDMAOne is a trademark of the CDMA Development Group (CDG).

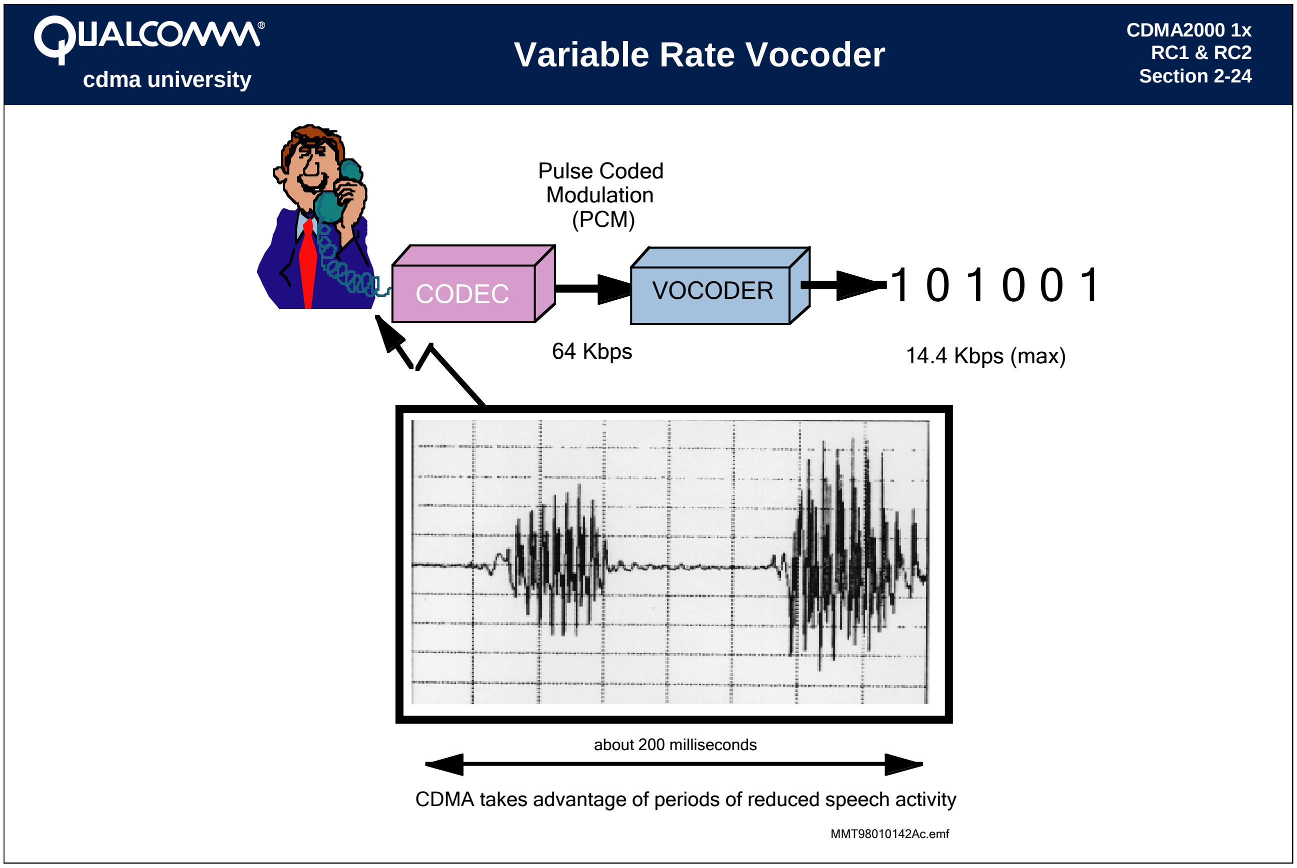


The CDMA “Cocktail Party”

The CDMA concept is analogous to the situation encountered at a party. At the “CDMA Cocktail Party,” all subscribers are talking in the same room together simultaneously. Imagine that every conversation in the room is being carried out in a different language that you do not understand. They would all sound like noise from your perspective.

If you “knew the code,” the appropriate language, you could imagine filtering out the unwanted conversations and listening only to the conversation of interest to you. A CDMA system must filter the traffic in a similar way.

Even with knowledge of the appropriate language, the conversation of interest may not be completely audible. The listener can signal the speaker to speak more loudly and can also signal other people to speak more softly. A CDMA system uses a similar power control process.



Codec

A *codec* is an analog-to-digital and digital-to-analog converter.

The figure depicts the codec as an analog-to-digital converter whose output is a wideband PCM signal (bit rate = 64 kbps).

Variable Rate Vocoder

The vocoder compresses the output of the codec to a lower bit rate to reduce bandwidth. The *variable rate vocoder* takes advantage of low speech activity and transmits at lower rates, thus reducing the average transmission to about 4 kbps. The vocoder outputs frames at full, half, quarter, and eighth rates.

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Orthogonal Sequences – Orthogonal Functions

CDMA2000 1x RC1 & RC2 Section 3-7

Orthogonal functions have ZERO CORRELATION. Two binary sequences are orthogonal if the process of "XORing" them results in an equal number of 1's and 0's:

EXAMPLE:

```
 0000
 0101
-----
 0101
```

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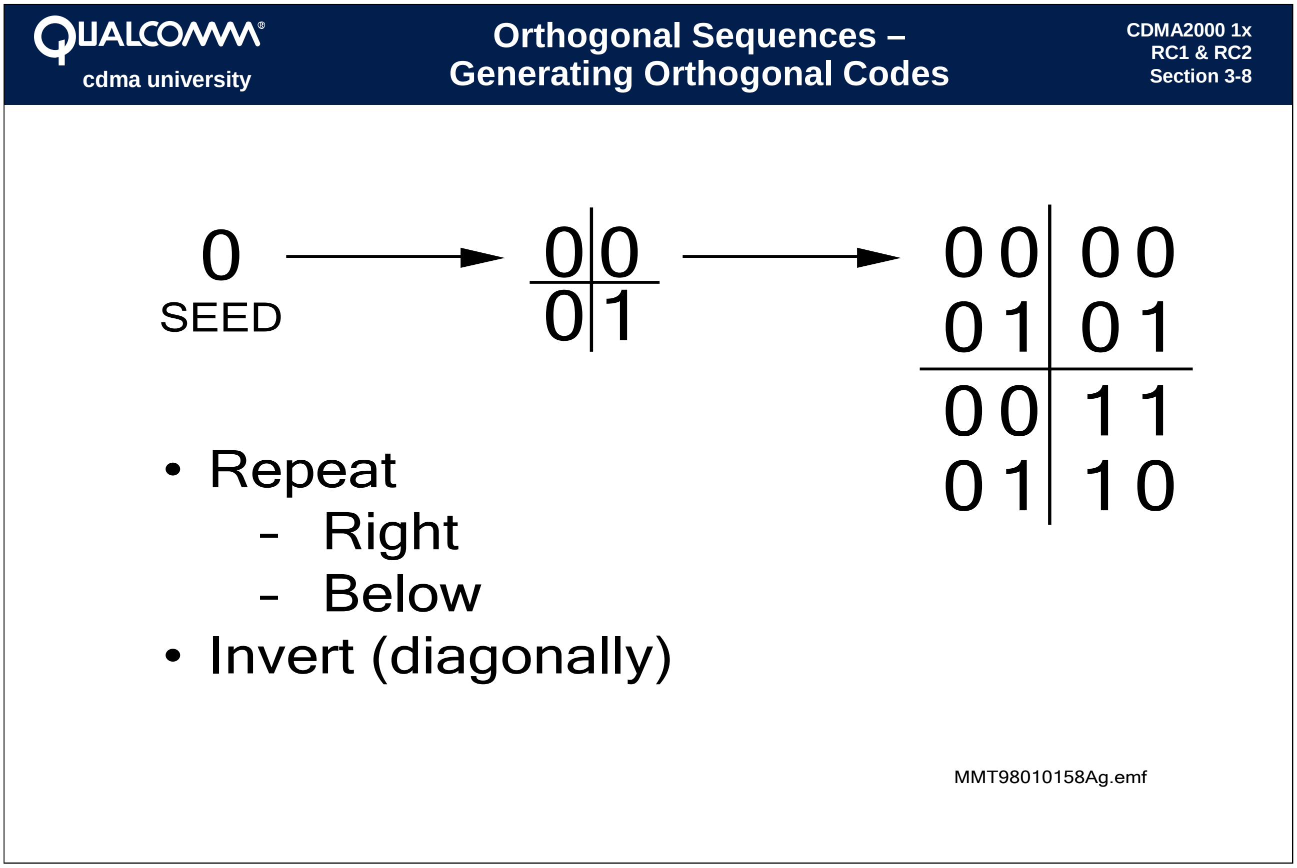
Orthogonal Functions

Orthogonal functions (that is, signals or sequences) have zero cross-correlation. Zero correlation is obtained if the product of two signals, summed over a period of time, is zero.

For the special case of binary sequences, the values 0 and 1 may be viewed as having opposite polarity. Thus when the product (XORing in this case) of two binary sequences results in an equal number of 1’s and 0’s, the cross-correlation is zero.



Generating Orthogonal Codes

Orthogonal codes are easily generated by starting with a seed of 0, repeating the 0 horizontally and vertically, and then complementing the 0 diagonally. This process is continued with the newly-generated block until the desired codes with the proper length are generated.

Sequences created in this way are referred to as *Walsh codes*.

	0123	4567	1 8901	1111 2345	1111 6789	2222 0123	2222 4567	2233 8901	3333 2345	3333 6789	4444 0123	4444 4567	4455 8901	5555 2345	5555 6789	6666 0123
0	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000	0000
1	0101	0101	0101	0101	0101	0101	0101	0101	0101	0101	0101	0101	0101	0101	0101	0101
2	0011	0011	0011	0011	0011	0011	0011	0011	0011	0011	0011	0011	0011	0011	0011	0011
3	0110	0110	0110	0110	0110	0110	0110	0110	0110	0110	0110	0110	0110	0110	0110	0110
4	0000	1111	0000	1111	0000	1111	0000	1111	0000	1111	0000	1111	0000	1111	0000	1111
5	0101	1010	0101	1010	0101	1010	0101	1010	0101	1010	0101	1010	0101	1010	0101	1010
6	0011	1100	0011	1100	0011	1100	0011	1100	0011	1100	0011	1100	0011	1100	0011	1100
7	0110	1001	0110	1001	0110	1001	0110	1001	0110	1001	0110	1001	0110	1001	0110	1001
8	0000	0000	1111	1111	0000	0000	1111	1111	0000	0000	1111	1111	0000	0000	1111	1111
9	0101	0101	1010	1010	0101	0101	1010	1010	0101	0101	1010	1010	0101	0101	1010	1010
10	0011	0011	1100	1100	0011	0011	1100	1100	0011	0011	1100	1100	0011	0011	1100	1100
11	0110	0110	1001	1001	0110	0110	1001	1001	0110	0110	1001	1001	0110	0110	1001	1001
12	0000	1111	1111	0000	0000	1111	1111	0000	0000	1111	1111	0000	0000	1111	1111	0000
13	0101	1010	1010	0101	0101	1010	1010	0101	0101	1010	1010	0101	0101	1010	1010	0101
14	0011	1100	1100	0011	0011	1100	1100	0011	0011	1100	1100	0011	0011	1100	1100	0011
15	0110	1001	1001	0110	0110	1001	1001	0110	0110	1001	1001	0110	0110	1001	1001	0110
16	0000	0000	0000	0000	1111	1111	1111	1111	0000	0000	0000	0000	1111	1111	1111	1111
17	0101	0101	0101	0101	1010	1010	1010	1010	0101	0101	0101	0101	1010	1010	1010	1010
18	0011	0011	0011	0011	1100	1100	1100	1100	0011	0011	0011	0011	1100	1100	1100	1100
19	0110	0110	0110	0110	1001	1001	1001	1001	0110	0110	0110	0110	1001	1001	1001	1001
20	0000	1111	0000	1111	1111	0000	1111	0000	0000	1111	0000	1111	1111	0000	1111	0000
21	0101	1010	0101	1010	1010	0101	1010	0101	0101	1010	0101	1010	1010	0101	1010	0101
22	0011	1100	0011	1100	1100	0011	1100	0011	0011	1100	0011	1100	1100	0011	1100	0011
23	0110	1001	0110	1001	1001	0110	1001	0110	0110	1001	0110	1001	1001	0110	1001	0110
24	0000	0000	1111	1111	1111	1111	0000	0000	0000	0000	1111	1111	1111	1111	0000	0000
25	0101	0101	1010	1010	1010	1010	0101	0101	0101	0101	1010	1010	1010	1010	0101	0101
26	0011	0011	1100	1100	1100	1100	0011	0011	0011	0011	1100	1100	1100	1100	0011	0011
27	0110	0110	1001	1001	1001	1001	0110	0110	0110	0110	1001	1001	1001	1001	0110	0110
28	0000	1111	1111	0000	1111	0000	0000	1111	0000	1111	1111	0000	1111	0000	0000	1111
29	0101	1010	1010	0101	1010	0101	0101	1010	0101	1010	1010	0101	1010	0101	0101	1010
30	0011	1100	1100	0011	1100	0011	0011	1100	0011	1100	1100	0011	1100	0011	0011	1100
31	0110	1001	1001	0110	1001	0110	0110	1001	0110	1001	1001	0110	1001	0110	0110	1001
32	0000	0000	0000	0000	0000	0000	0000	0000	1111	1111	1111	1111	1111	1111	1111	1111
33	0101	0101	0101	0101	0101	0101	0101	0101	1010	1010	1010	1010	1010	1010	1010	1010
34	0011	0011	0011	0011	0011	0011	0011	0011	1100	1100	1100	1100	1100	1100	1100	1100
35	0110	0110	0110	0110	0110	0110	0110	0110	1001	1001	1001	1001	1001	1001	1001	1001
36	0000	1111	0000	1111	0000	1111	0000	1111	1111	0000	1111	0000	1111	0000	1111	0000
37	0101	1010	0101	1010	0101	1010	0101	1010	1010	0101	1010	0101	1010	0101	1010	0101
38	0011	1100	0011	1100	0011	1100	0011	1100	1100	0011	1100	0011	1100	0011	1100	0011
39	0110	1001	0110	1001	0110	1001	0110	1001	1001	0110	1001	0110	1001	0110	1001	0110
40	0000	0000	1111	1111	0000	0000	1111	1111	1111	1111	0000	0000	1111	1111	0000	0000
41	0101	0101	1010	1010	0101	0101	1010	1010	1010	1010	0101	0101	1010	1010	0101	0101
42	0011	0011	1100	1100	0011	0011	1100	1100	1100	1100	0011	0011	1100	1100	0011	0011
43	0110	0110	1001	1001	0110	0110	1001	1001	1001	1001	0110	0110	1001	1001	0110	0110
44	0000	1111	1111	0000	0000	1111	1111	0000	1111	0000	0000	1111	1111	0000	0000	1111
45	0101	1010	1010	0101	0101	1010	1010	0101	1010	0101	0101	1010	1010	0101	0101	1010
46	0011	1100	1100	0011	0011	1100	1100	0011	1100	0011	0011	1100	1100	0011	0011	1100
47	0110	1001	1001	0110	0110	1001	1001	0110	1001	0110	0110	1001	1001	0110	0110	1001
48	0000	0000	0000	0000	1111	1111	1111	1111	1111	1111	1111	1111	0000	0000	0000	0000
49	0101	0101	0101	0101	1010	1010	1010	1010	1010	1010	1010	1010	0101	0101	0101	0101
50	0011	0011	0011	0011	1100	1100	1100	1100	1100	1100	1100	1100	0011	0011	0011	0011
51	0110	0110	0110	0110	1001	1001	1001	1001	1001	1001	1001	1001	0110	0110	0110	0110
52	0000	1111	0000	1111	1111	0000	1111	0000	1111	0000	1111	0000	0000	1111	0000	1111
53	0101	1010	0101	1010	1010	0101	1010	0101	1010	0101	1010	0101	0101	1010	0101	1010
54	0011	1100	0011	1100	1100	0011	1100	0011	1100	0011	1100	0011	0011	1100	0011	1100
55	0110	1001	0110	1001	1001	0110	1001	0110	1001	0110	1001	0110	0110	1001	0110	1001
56	0000	0000	1111	1111	1111	1111	0000	0000	1111	1111	0000	0000	0000	0000	1111	1111
57	0101	0101	1010	1010	1010	1010	0101	0101	1010	1010	0101	0101	0101	0101	1010	1010
58	0011	0011	1100	1100	1100	1100	0011	0011	1100	1100	0011	0011	0011	0011	1100	1100
59	0110	0110	1001	1001	1001	1001	0110	0110	1001	1001	0110	0110	0110	0110	1001	1001
60	0000	1111	1111	0000	1111	0000	0000	1111	1111	0000	0000	1111	0000	1111	1111	0000
61	0101	1010	1010	0101	1010	0101	0101	1010	1010	0101	0101	1010	0101	1010	1010	0101
62	0011	1100	1100	0011	1100	0011	0011	1100	1100	0011	0011	1100	0011	1100	1100	0011
63	0110	1001	1001	0110	1001	0110	0110	1001	1001	0110	0110	1001	0110	1001	1001	0110

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Generating Orthogonal Codes (continued)

The orthogonal sequences currently used in terrestrial CDMA2000 systems are Walsh codes of length 64.

- In the Forward CDMA link, Walsh codes are used to separate users. In any given sector, each Forward Channel is assigned a distinct Walsh code.
- In the Reverse CDMA link, the 64 Walsh sequences are used as a signaling set by the Baseband Orthogonal Modulator.

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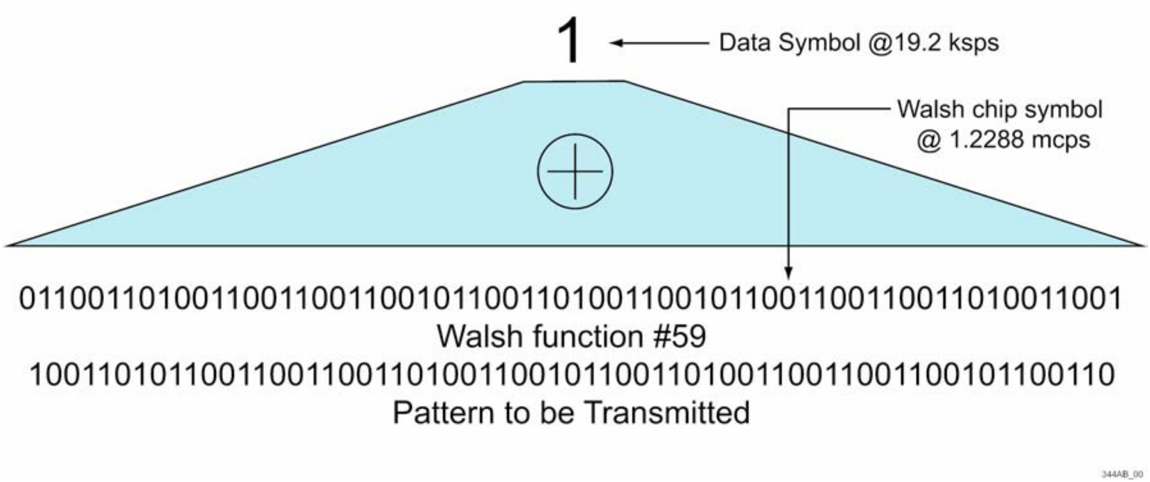
Orthogonal Sequences – Orthogonal Spreading

CDMA2000 1x
RC1 & RC2
Section 3-10



Orthogonal Spreading

The principle behind spreading and despreading is that when a symbol is XORed with a known pattern and the result is again XORed with the same pattern, the original symbol is recovered. In other words, the effect of an XOR operation if performed twice using the same code is null.

In orthogonal spreading, each encoded symbol is XORed with all 64 chips of the Walsh code. For example, in the figure a symbol of value "1" is orthogonally spread with Walsh code 59, thus yielding a 64-chip representation of the symbol.

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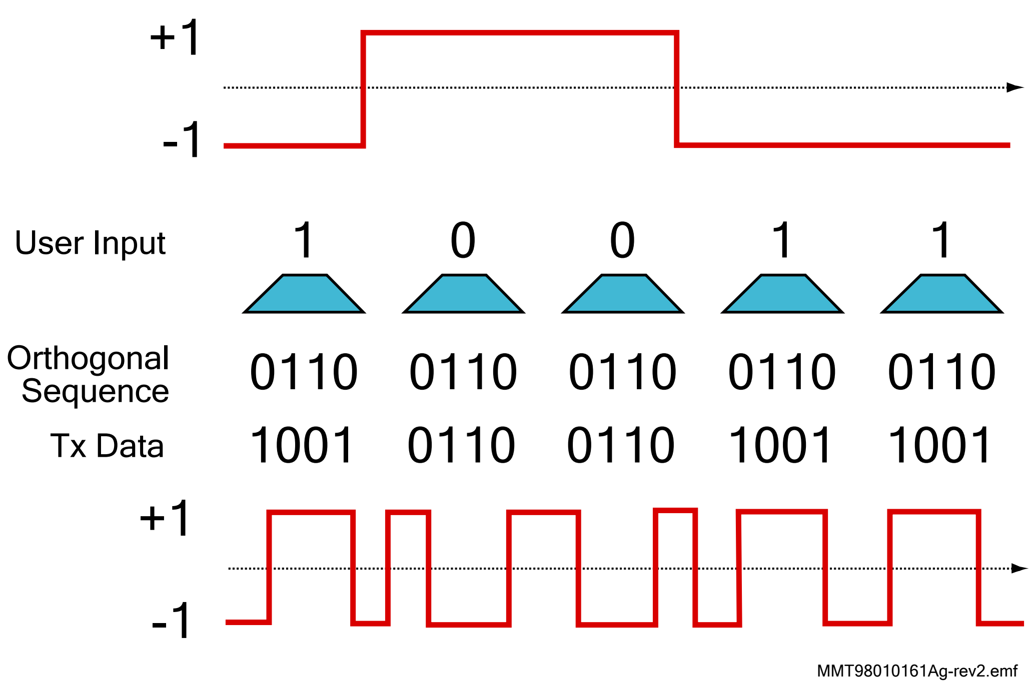
Orthogonal Sequences – Channelization Using Orthogonal Spreading

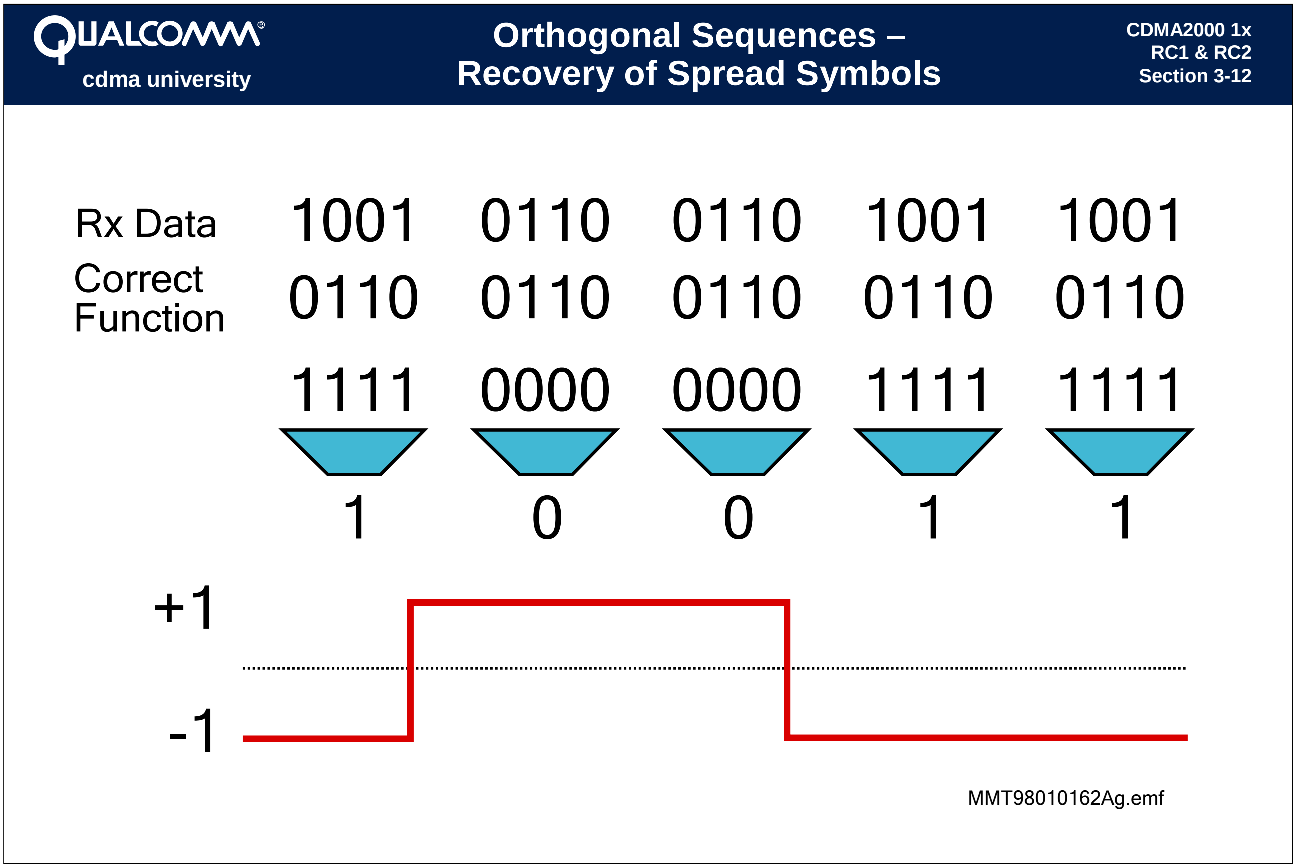
CDMA2000 1x RC1 & RC2 Section 3-11



Example of Channelization Using Orthogonal Spreading

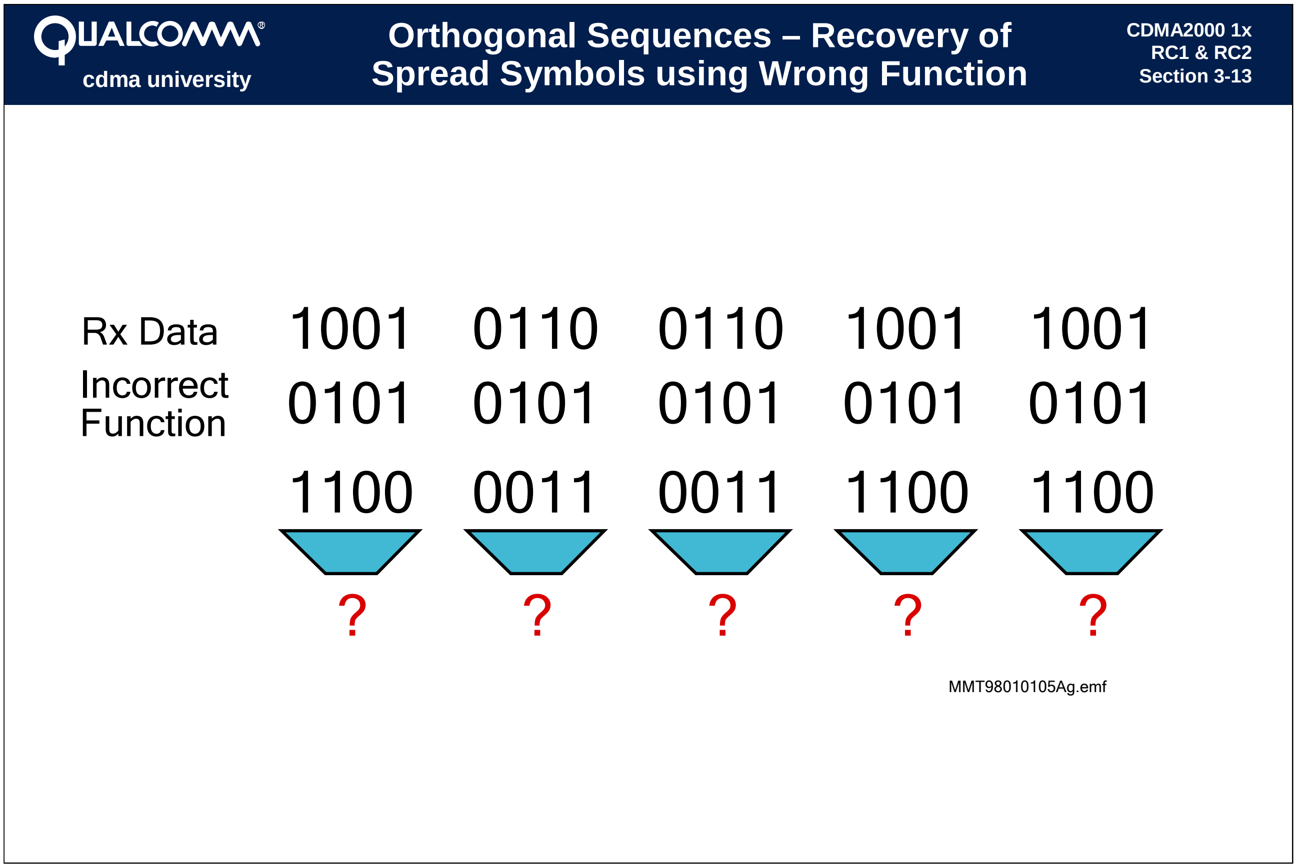
By spreading, each symbol is XORed with all the chips in the orthogonal sequence (Walsh sequence) assigned to the user. The resulting sequence is processed and is then transmitted over the Physical Channel along with other spread symbols.

In this figure, a 4-digit code is used. The product of the user symbols and the spreading code is a sequence of digits that must be transmitted at 4 times the rate of the original encoded binary signal.



Recovery of Spread Symbols

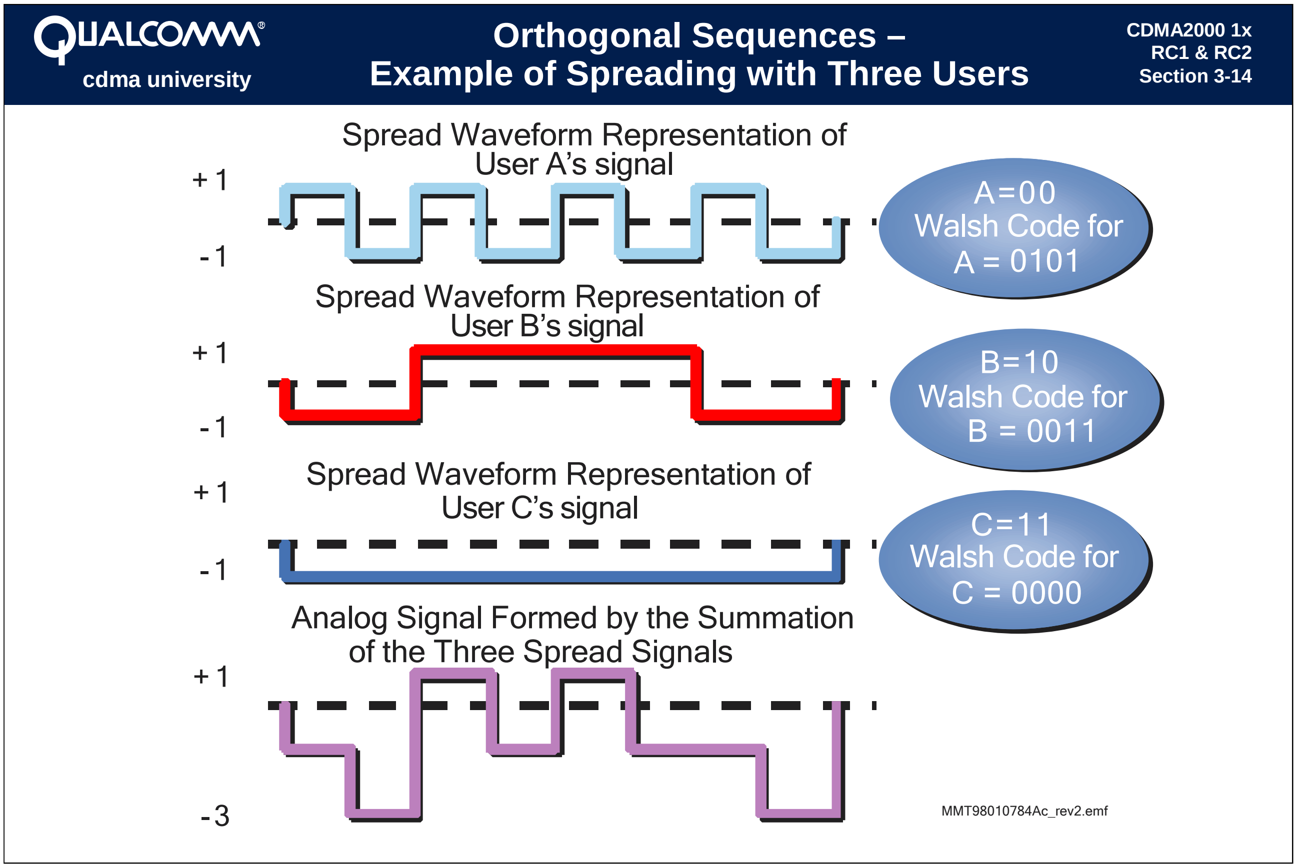
The receiver despreads the chips by using the same Walsh code used at the transmitter. Notice that under no-noise conditions, the symbols or digits are completely recovered without any error. In reality, the channel is not noise-free, but CDMA2000 systems employ Forward Error Correction (FEC) techniques to combat the effects of noise and enhance the performance of the system.



Recovery of Spread Symbols using Wrong Function

When the wrong Walsh sequence is used for despreading, the resulting correlation yields an average of zero. This clearly demonstrates the advantage of the orthogonality property of the Walsh codes.

Whether the wrong code is mistakenly used by the target user or by other users attempting to decode the received signal, the resulting correlation is always zero because of the orthogonality property of the Walsh sequences.



An Example of Spreading with Three Subscribers

In this example, three users, A, B, and C are assigned three orthogonal codes for spreading purposes:

- User A signal = 00, Spreading Code = 0101
- User B signal = 10, Spreading Code = 0011
- User C signal = 11, Spreading Code = 0000

The analog signal shown on the bottom of the figure is the composite signal when all of the spread symbols are summed together.

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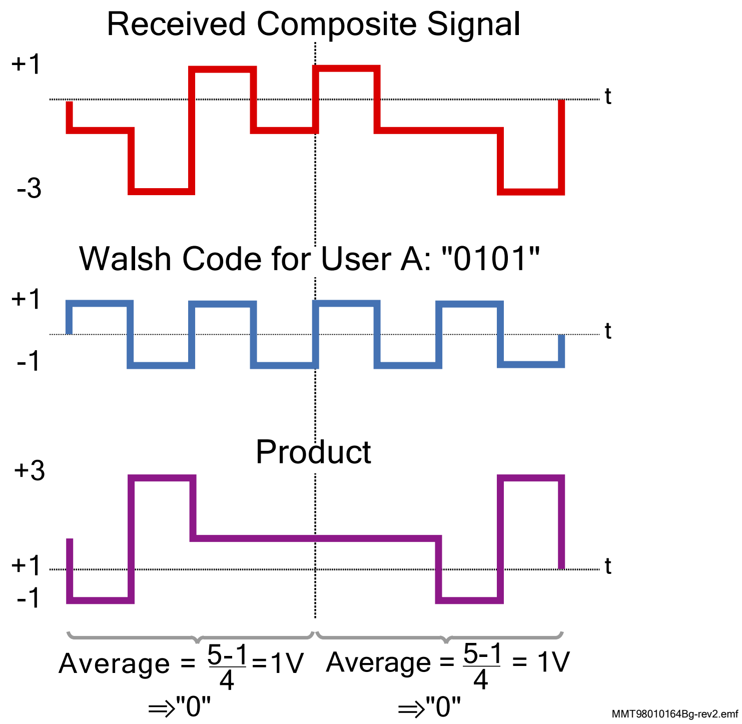
Orthogonal Sequences – Despreading Example

CDMA2000 1x RC1 & RC2 Section 3-15



Despreading Example

At the receiver of user A, the composite analog signal is multiplied by the Walsh code corresponding to user A and the result is then averaged over the symbol time. This process is called correlation. Note that the average voltage value over one symbol time is equal to 1. Therefore, the original bit transmitted by A was “0”.

You may try to decode the symbols for users B or C in the same manner. This process occurs in the CDMA mobile for recovering the signals.

Orthogonal Sequences – Walsh Usage

- RC1 and RC2 use Walsh 64.
- RC3 through RC9 use variable length Walsh functions.
  - 1x typically uses 64 and 128 length.
- Length is a function of data rate.
- For 1x the Walsh chip rate is always 1.2288 Mcps.

Walsh Usage

Since RC1 and RC2 are the TIA/EIA-95 mode, only Walsh 64 is used.

RC3 through RC9 use variable length Walsh functions to handle different data rates. For RC3, voice calls use Walsh 64, while for RC4 voice calls use Walsh 128.

The higher the data rate, the shorter the Walsh function used. This is because the chip rate for the Walsh function is constant (1.2288 Mcps for 1x), and the full length of the Walsh function must be employed for each data bit.