



## PN Codes – Short and Long

CDMA2000 1x  
RC1 & RC2  
Section 3-27

- **Two Short Codes** ( $2^{15} = 32,768$ )
  - Termed “I” and “Q” codes (different taps)
  - Used for Quadrature Spreading
  - Unique offsets serve as identifiers for a Cell or a Sector
  - Repeat every 26.67 msec (at a clock rate of 1.2288 Mcps)
- **One Long Code** ( $2^{42} - 1 = 4400$  Billion)
  - Used for spreading and scrambling
  - Repeats every 41 days (at a clock rate of 1.2288 Mcps)

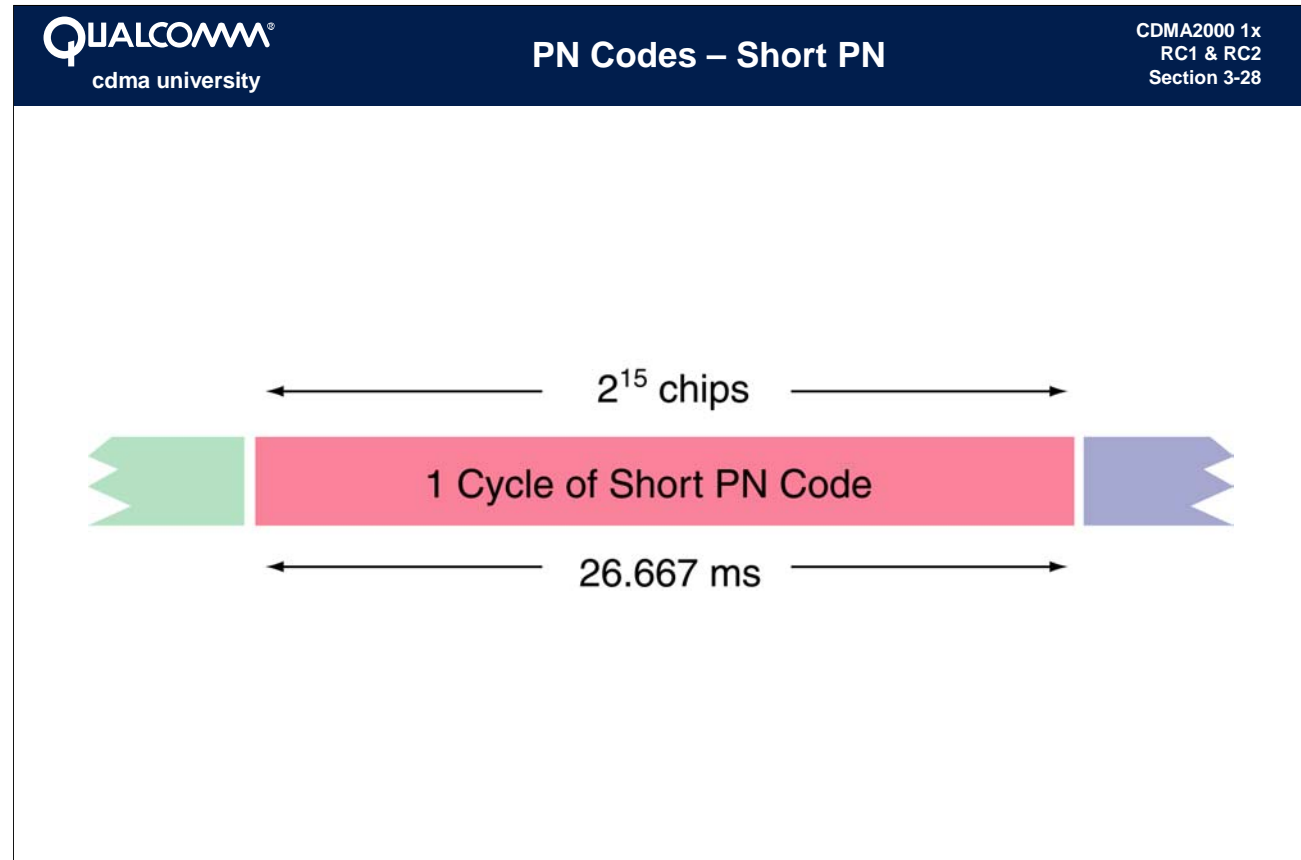
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### Short and Long PN Codes

The two short codes and one long code used in CDMA systems are time-synchronized to midnight, January 6, 1980 (GPS time). In CDMA2000 systems, all Base Stations and all mobiles use the same three PN sequences.

The two short codes are the same length, but are different codes. The codes are different patterns of ones and zeros because the feedback used to make the PN generator is tapped at different shift register outputs

A true Maximal Length PN code has a length of  $2^N - 1$  bits. The short codes used in CDMA2000 have been modified by adding an extra zero to increase the length to an even number of bits. This makes the system design and hardware design easier to implement.

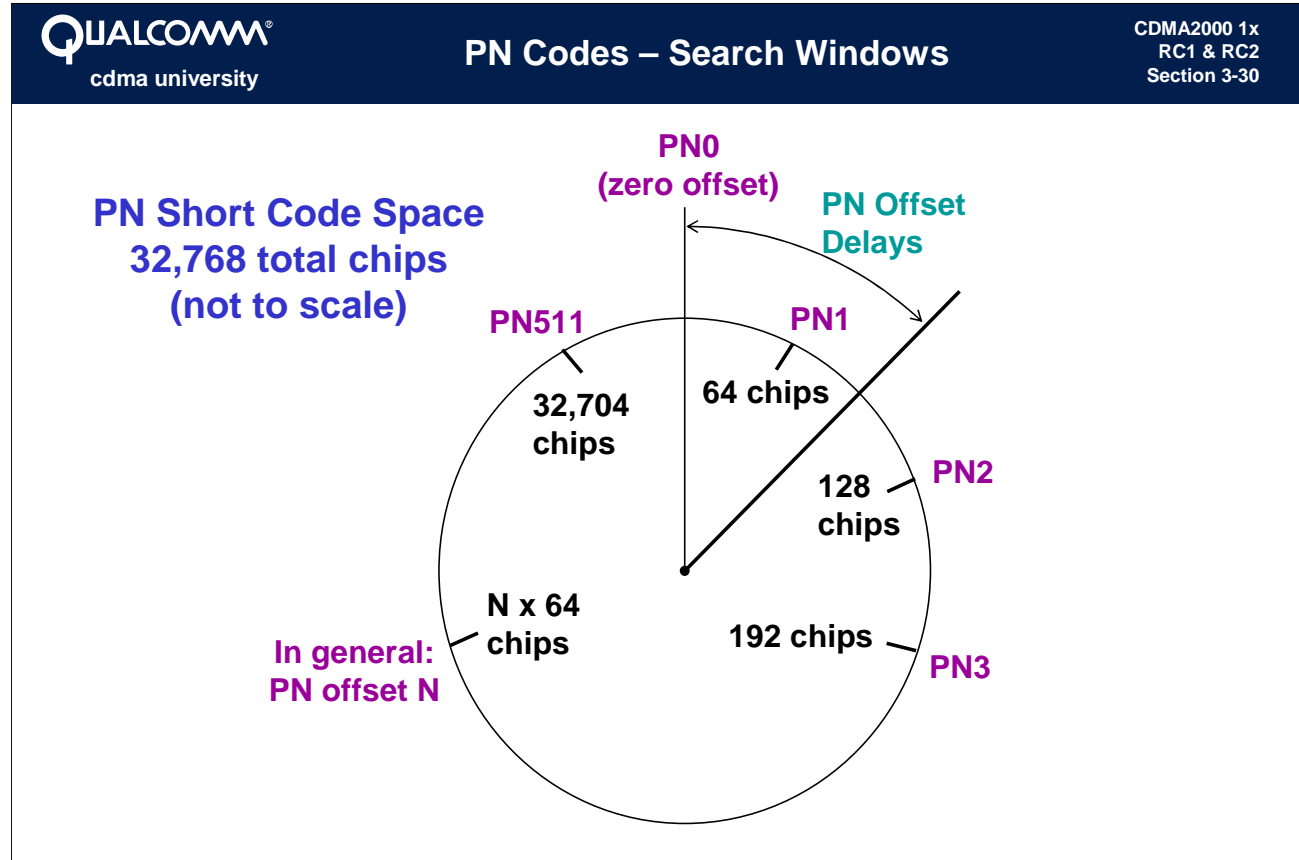


### Short PN Code

The short PN code repeats every 26.667 ms, with length  $2^{15}$  chips. Each sector of a Base Station uses the same short code phase to spread all the signals from that sector. Each sector uses a unique time offset.

The mobile can discern these unique offsets and thus identify the different sectors of the cellular system. It is desirable to have many unique offsets to make system planning easy.

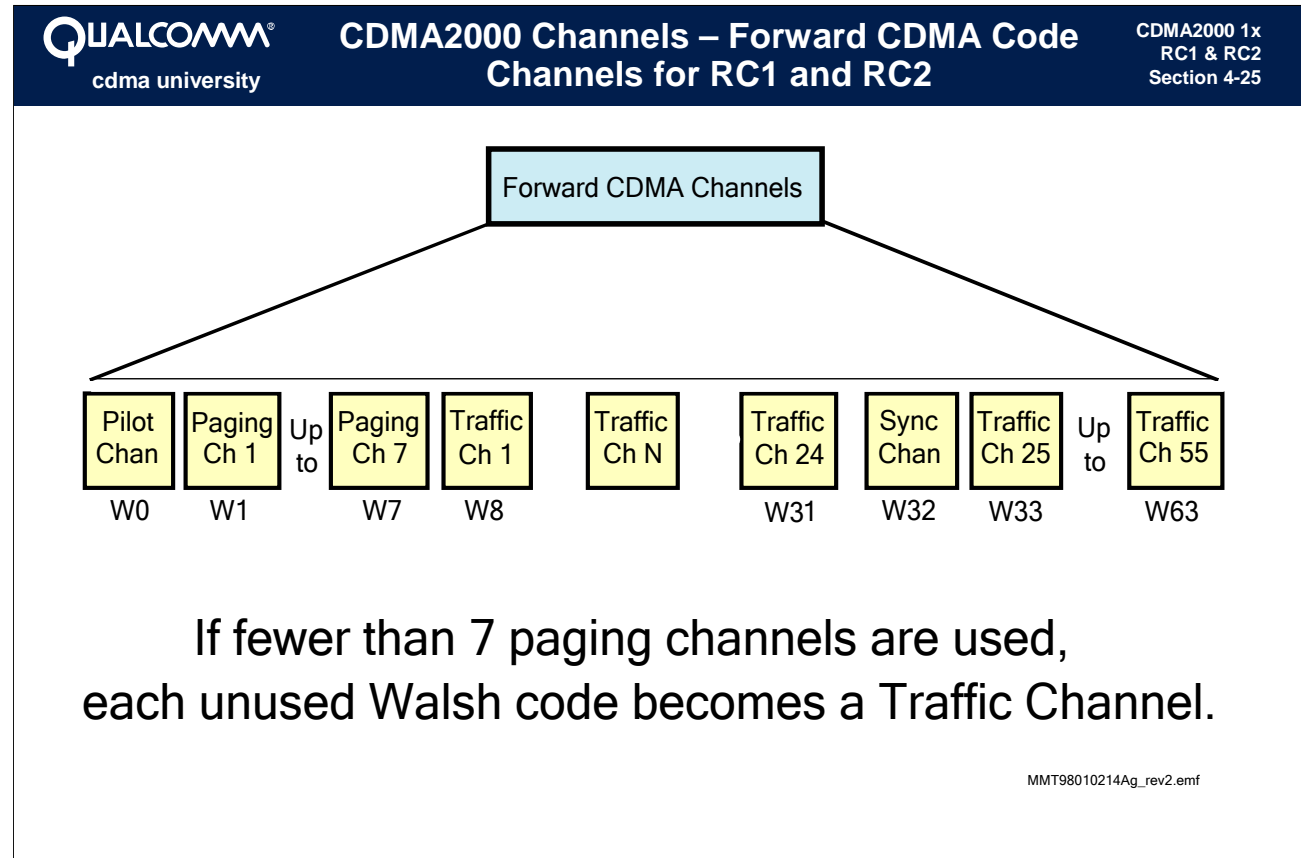
With 512, or  $2^9$ , unique offsets, then offsets occur every 64 chips, or  $2^6$ .



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The Short PN is offset in groups of 64 bits because the delay ambiguity of the mobile can be many chips in a real system due to the speed of light.

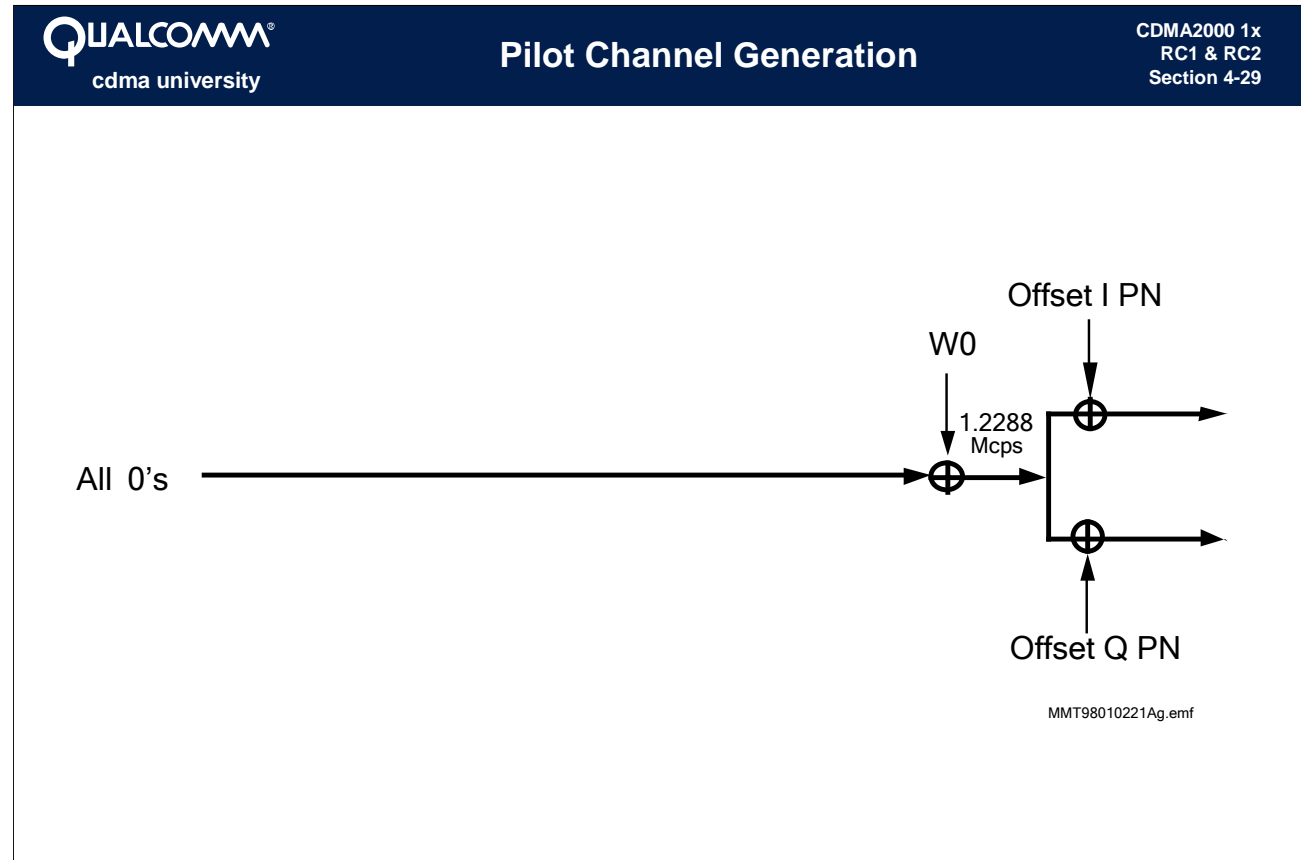
Most commercial networks use a PN increment of 4, resulting in an offset between sectors of 256 chips.



### Forward CDMA Code Channels

Overhead channels have fixed Walsh code assignments:

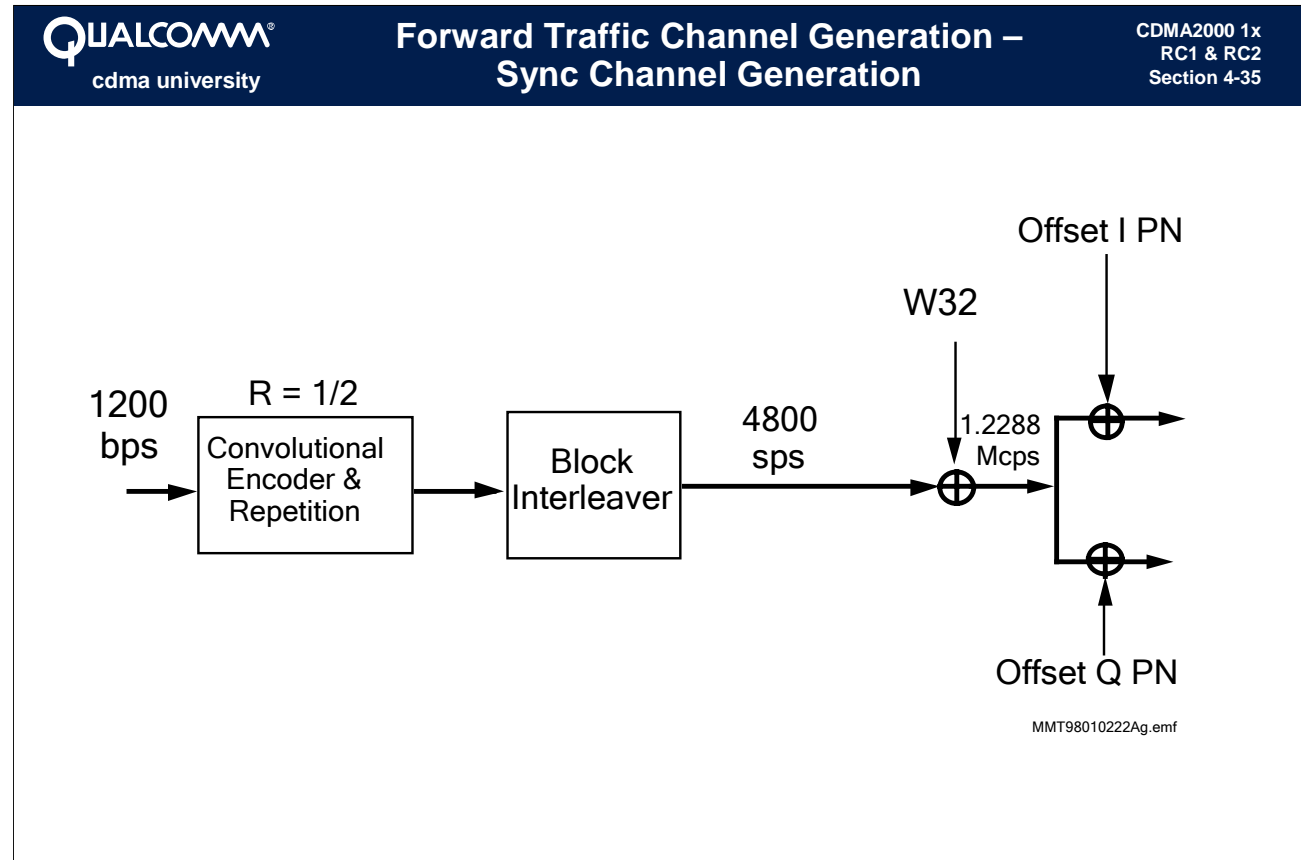
- The Pilot Channel is always Walsh code 0.
- The Sync Channel is always Walsh code 32.
- The Paging Channels use Walsh codes 1-7.



### Pilot Channel Generation

The Pilot Channel has no information on it; no message, no data.

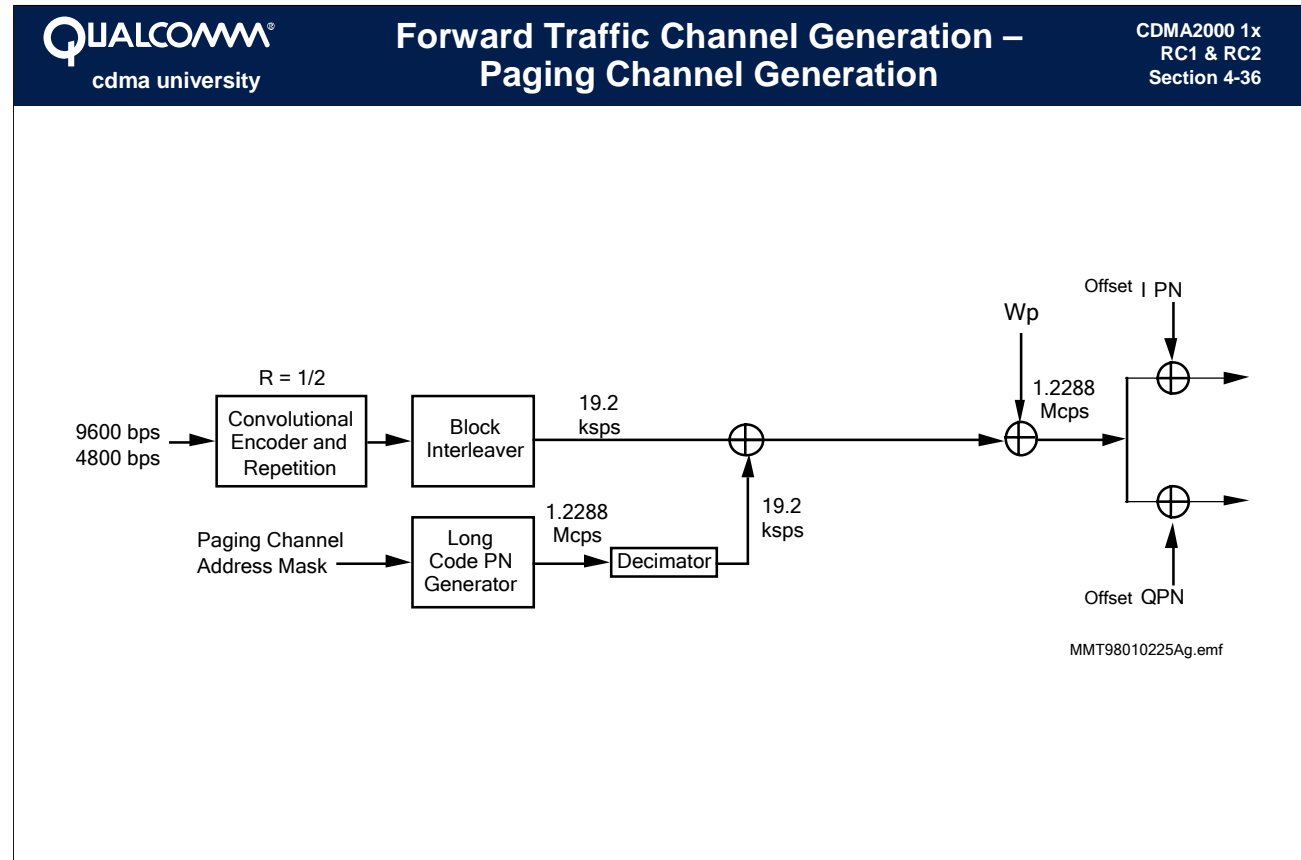
The Pilot Channel is simply all zeros spread by Walsh code zero and by the short PN codes.



### Sync Channel Block Diagram


Unlike the Pilot Channel, the Sync Channel transmits a message. Channel coding is used to protect the bits in this message. The same rate  $1/2$  coding is used followed by block interleaving. The Sync Channel is spread by Walsh code 32.

Section 4: CDMA Physical Layer



**Paging Channel Block Diagram**

Generation of the Paging Channel for RC1, RC2 and Release 0 is very similar to generation of the Forward Traffic Channel. A key difference is that the Paging Channel is not punctured with power control information.

 cdma university	<b>Forward Traffic Channel Generation – Paging Channel Long Code Mask</b>	CDMA2000 1x RC1 & RC2 Section 4-37
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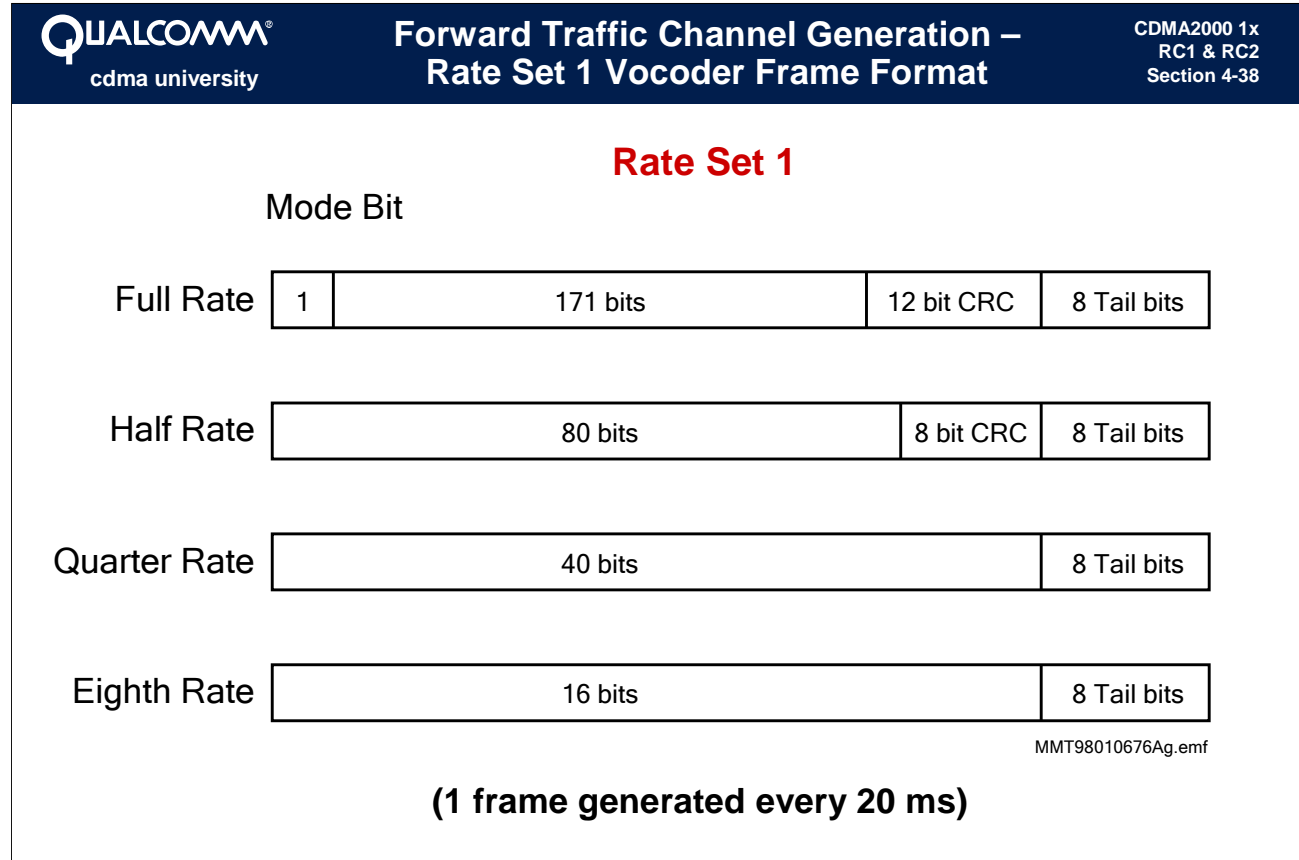
41		29 28	24 23	21 20		9 8	0
1100011001101		00000	PCN	000000000000		PILOT_PN	

PCN = Paging Channel Number  
 PILOT\_PN = PN offset for the Forward CDMA Channel

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### Paging Channel Long Code Mask

The Paging Channel is scrambled using the Long PN Code. The code generator is masked with a 42 bit mask as shown in the figure.



**Traffic Channel Frame**

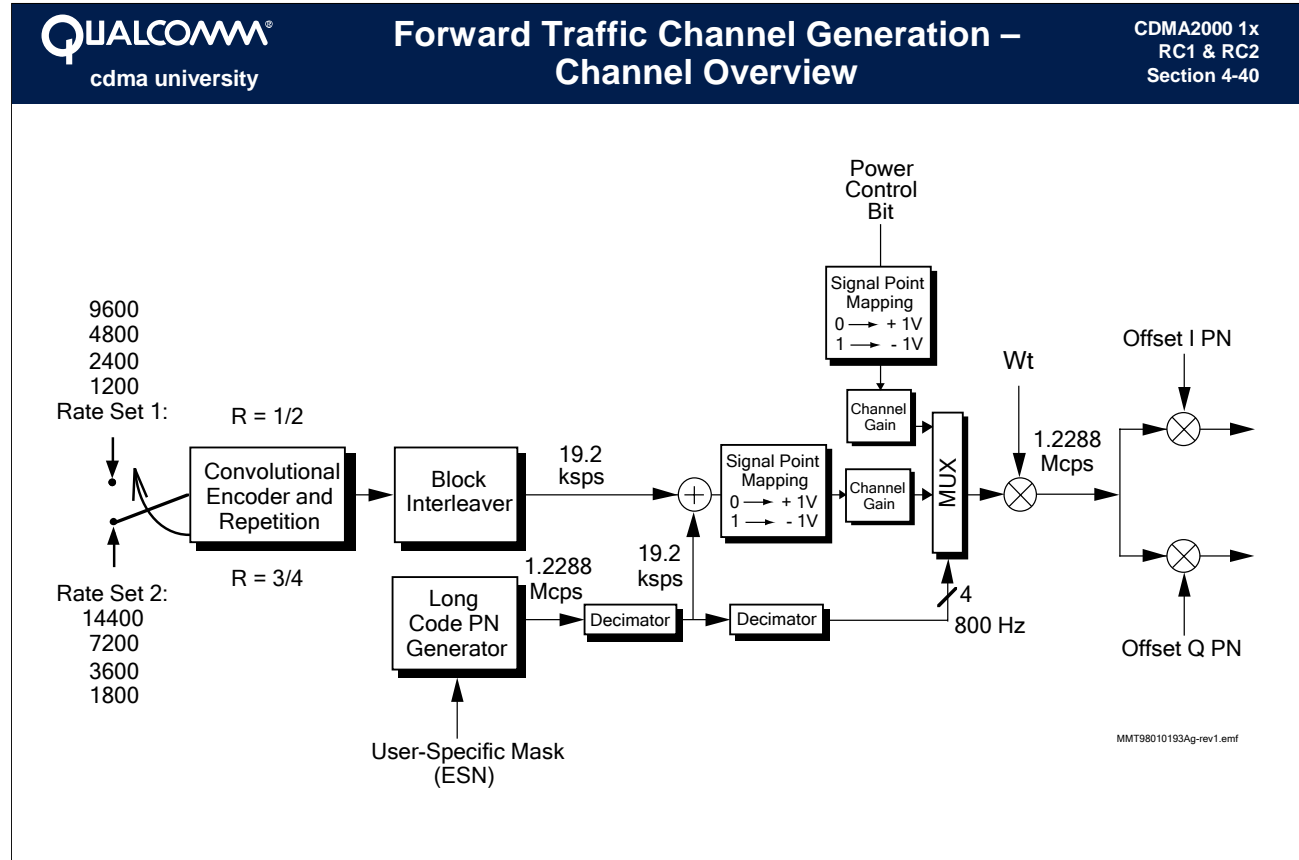
The variable rate vocoder produces a frame every 20 ms using Code Excited Linear Prediction (CELP) technique. These frames are either at full, half, quarter or eighth rate. The frame rate depends on the voice activity. Both cellular and PCS band can use either Rate Set 1 or Rate Set 2 vocoder. The quality of Rate Set 2 vocoder is superior to that of the Rate Set 1.

 cdma university	<h2 style="margin: 0;">Forward Traffic Channel Generation – Rate Set 2 Vocoder Frame Format</h2>	CDMA2000 1x RC1 & RC2 Section 4-39			
Rate Set 2					
Erasure Bit					
Full Rate	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 5%; text-align: center;">1</td> <td style="width: 60%; text-align: center;">267 bits</td> <td style="width: 20%; text-align: center;">12 bit CRC</td> <td style="width: 15%; text-align: center;">8 Tail bits</td> </tr> </table>	1	267 bits	12 bit CRC	8 Tail bits
1	267 bits	12 bit CRC	8 Tail bits		
Half Rate	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 5%; text-align: center;">1</td> <td style="width: 60%; text-align: center;">125 bits</td> <td style="width: 20%; text-align: center;">10 bit CRC</td> <td style="width: 15%; text-align: center;">8 Tail bits</td> </tr> </table>	1	125 bits	10 bit CRC	8 Tail bits
1	125 bits	10 bit CRC	8 Tail bits		
Quarter Rate	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 5%; text-align: center;">1</td> <td style="width: 60%; text-align: center;">55 bits</td> <td style="width: 20%; text-align: center;">8 bit CRC</td> <td style="width: 15%; text-align: center;">8 Tail bits</td> </tr> </table>	1	55 bits	8 bit CRC	8 Tail bits
1	55 bits	8 bit CRC	8 Tail bits		
Eighth Rate	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 5%; text-align: center;">1</td> <td style="width: 60%; text-align: center;">21 bits</td> <td style="width: 20%; text-align: center;">6 bit CRC</td> <td style="width: 15%; text-align: center;">8 Tail bits</td> </tr> </table>	1	21 bits	6 bit CRC	8 Tail bits
1	21 bits	6 bit CRC	8 Tail bits		
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(1 frame generated every 20 ms)					

### Rate Set 2 Vocoder Frames

Rate Set 2 frames contain the Erasure bit as the first bit of the frame. This allows the mobile to inform the Base Station of frame erasures on the Forward link using the Reverse link channel. This gives faster feedback (50 bps) to the Base Station about the quality of the Forward link than is available with Rate Set 1, which requires signaling messages.

Section 4: CDMA Physical Layer



**Overview of the Forward Traffic Channel**

- Both vocoder rates are supported.
- Convolutional coding is done differently for the two vocoders.
- The symbols are interleaved, then scrambled using the Long PN code.
- Power control information is “punctured” in and the signal is then orthogonally spread.
- The signal is next spread in quadrature using pseudorandom codes.



## Forward Traffic Channel Generation – Rate Set 1 Symbol Repetition

CDMA2000 1x  
RC1 & RC2  
Section 4-41

**Repetition Maintains Constant 19.2 ksps Output**

<u>Data Rate</u>	<u>Code Rate</u>	<u>Repetition Rate</u>	<u>Symbol Rate</u>
9600	19200	No repetition	19200
4800	9600	Repeat 1 time (2 symbols)	19200
2400	4800	Repeat 3 times (4 symbols)	19200
1200	2400	Repeat 7 times (8 symbols)	19200

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### Rate Set 1 Symbol Repetition

In addition to the convolutional coding, the symbols are repeated when lower rate frames are produced by the vocoder. The repetition maintains a constant symbol rate of 19,200 symbols per second regardless of the rate of the vocoder.



## Forward Traffic Channel Generation – Rate Set 2 Symbol Repetition

CDMA2000 1x  
RC1 & RC2  
Section 4-42

### Repetition Maintains Constant 19.2 ksps Output

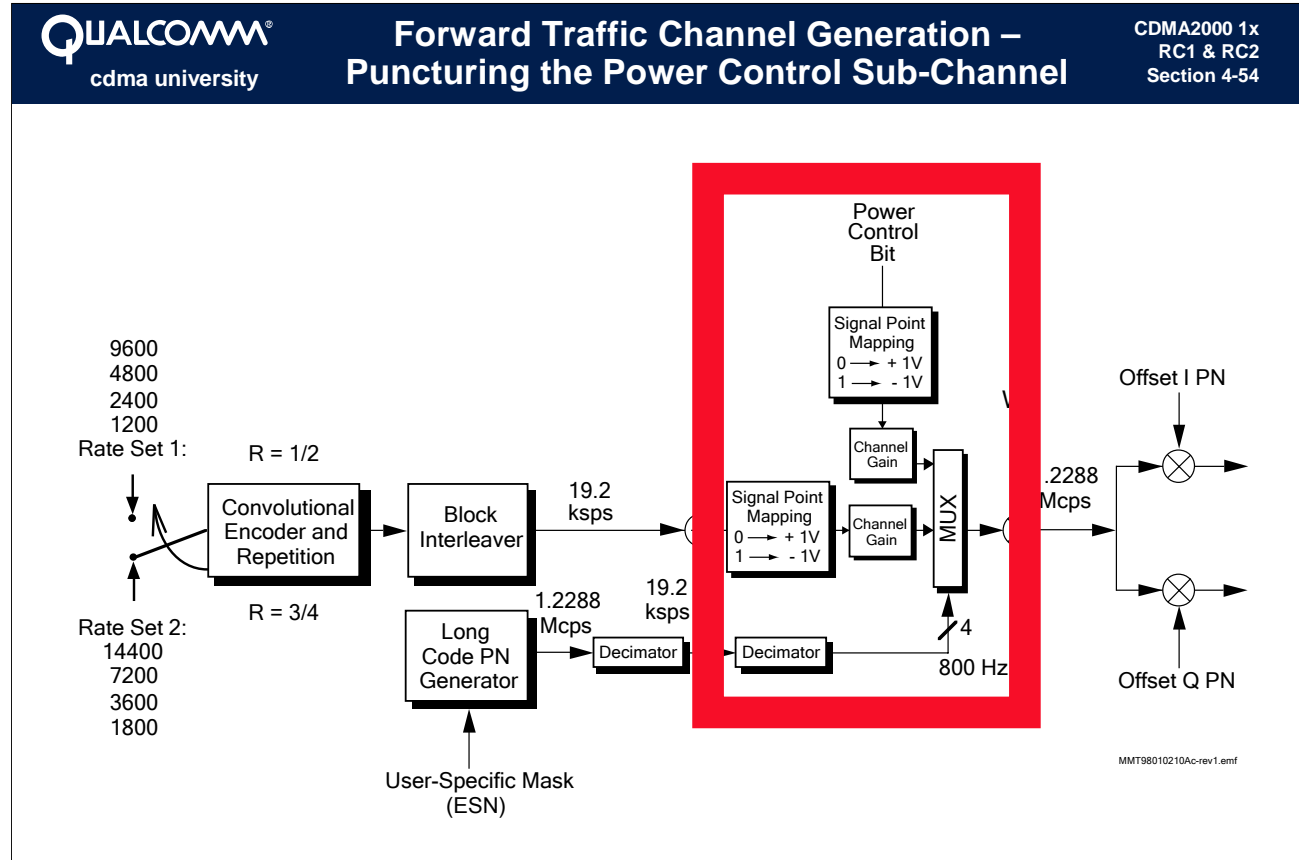
<u>Data Rate</u>	<u>Code Rate</u>	<u>Repetition Rate</u>	<u>Symbol Rate</u>
14400	19200	No repetition	19200
7200	9600	Repeat 1 time (2 symbols)	19200
3600	4800	Repeat 3 times (4 symbols)	19200
1800	2400	Repeat 7 times (8 symbols)	19200

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### Rate Set 2 Symbol Repetition

When the Rate Set 2 vocoder is used, the rate  $\frac{3}{4}$  convolutional coding results in the same number of symbols as the Rate Set 1 vocoder. Symbol repetition can then be done in the same way to maintain a constant symbol rate of 19,200 symbols per second.

Section 4: CDMA Physical Layer



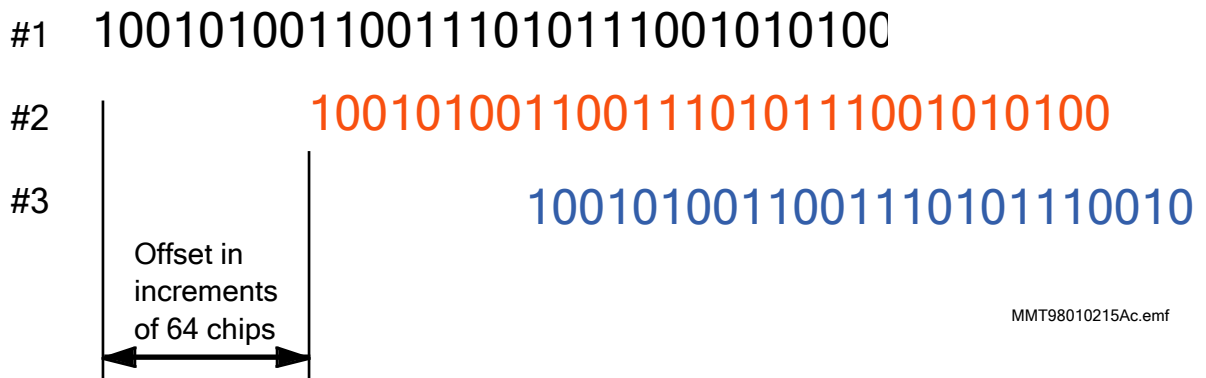
**The Power Control Sub-Channel**

The Reverse Closed Loop Power Control bits are punctured into the data at a rate of 800 Hz. The location of the puncture is pseudorandom and controlled by the Long Code PN stream.



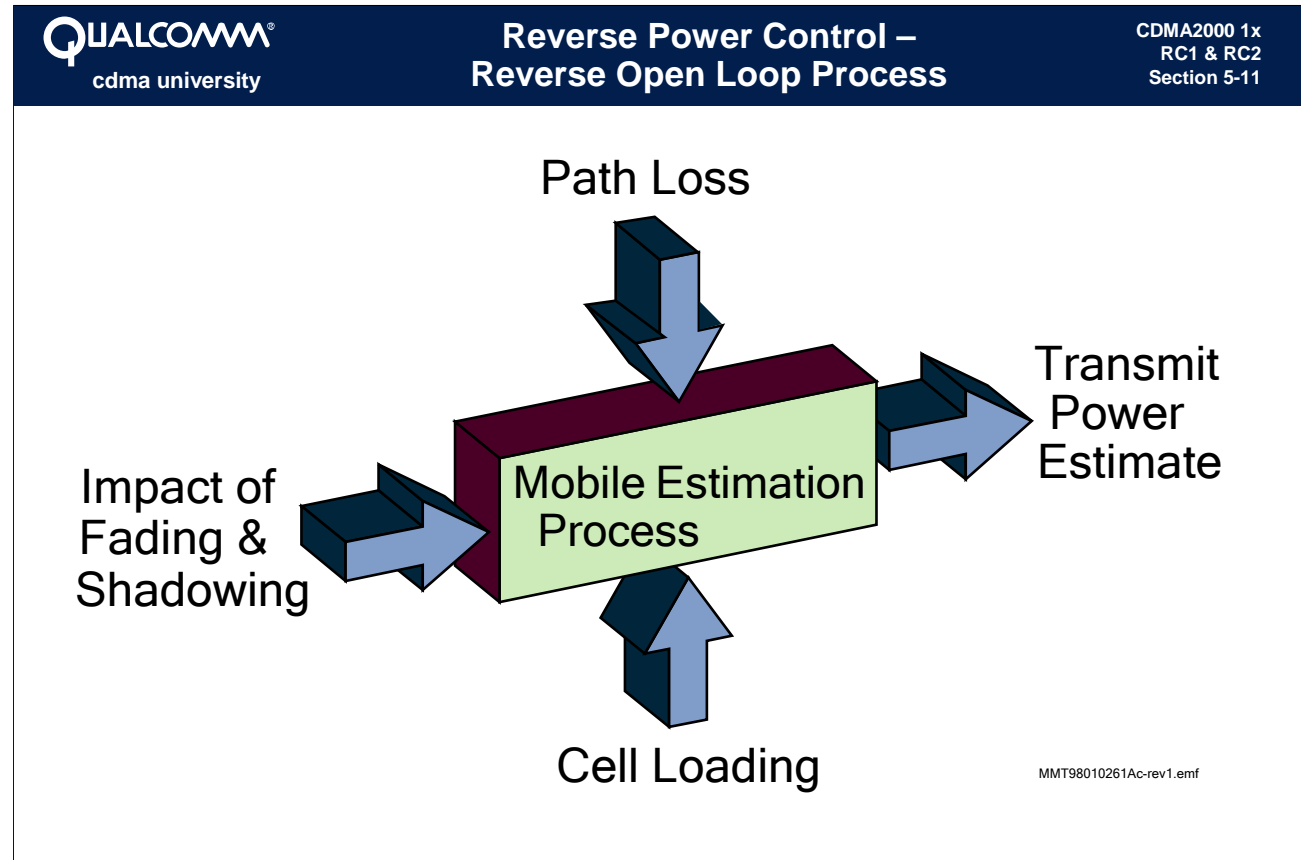
### Forward Traffic Channel Generation – PN Offset Cell Identification

CDMA2000 1x  
RC1 & RC2  
Section 4-57



#### PN Offset Cell Identification

The short PN codes are uniquely offset for each sector. The minimum offset permitted is 64 PN chips. This results in a maximum of 512 possible offsets. System operators can choose to further restrict the number of available offsets. Deployed systems typically use a minimum offset of 128 or 256 chips.




### The Reverse Open Loop Process

Required mobile transmit power is a function of distance from the cell, cell loading, and environmentally induced phenomena such as fast fading and shadowing. If the mobile can take all of these factors into account, it can arrive at a close approximation of the proper level of transmit power. Fast fading on the Forward link as measured by the mobile, however, is generally not the same as fast fading on the Reverse link measured by the cell. The mobile's approximation, therefore, shouldn't try to compensate for fast fading.

For the mobile to compensate for the other factors mentioned here, the Base Station must provide some information to the mobile regarding the cell's Effective Radiated Power (ERP) and the level of cell loading. Armed with this information the mobile could then measure received power and estimate Path Loss.

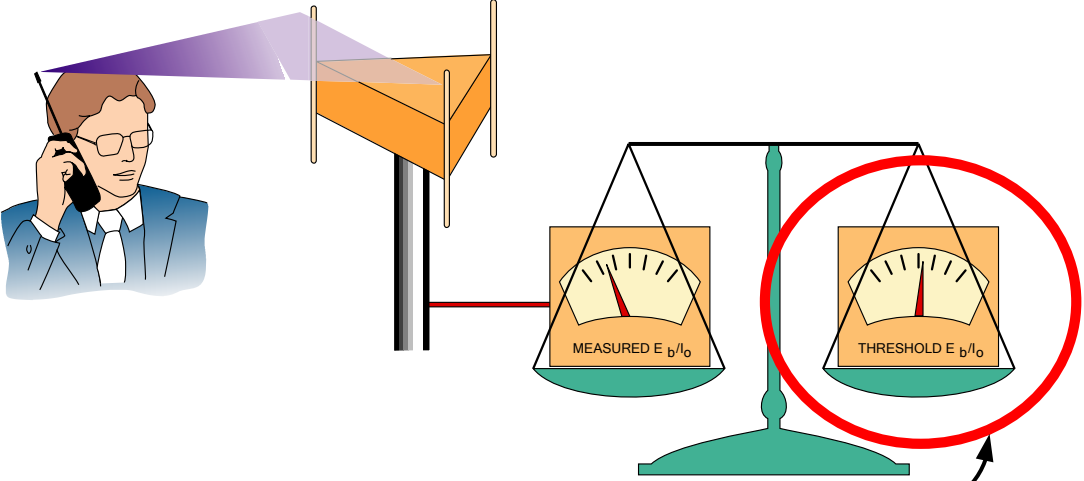
To simplify this process, the CDMA standards specify that the mobiles use a "hard-wired" constant to compensate for Path Loss and the effects of cell loading. The constant satisfies the nominal case. The Base Station then informs the mobile of any required deviation from the nominal EIRP, and the mobile estimates the cell loading by measuring interference.



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## Reverse Power Control – Reverse Outer Loop Power Control

CDMA2000 1x  
RC1 & RC2  
Section 5-28



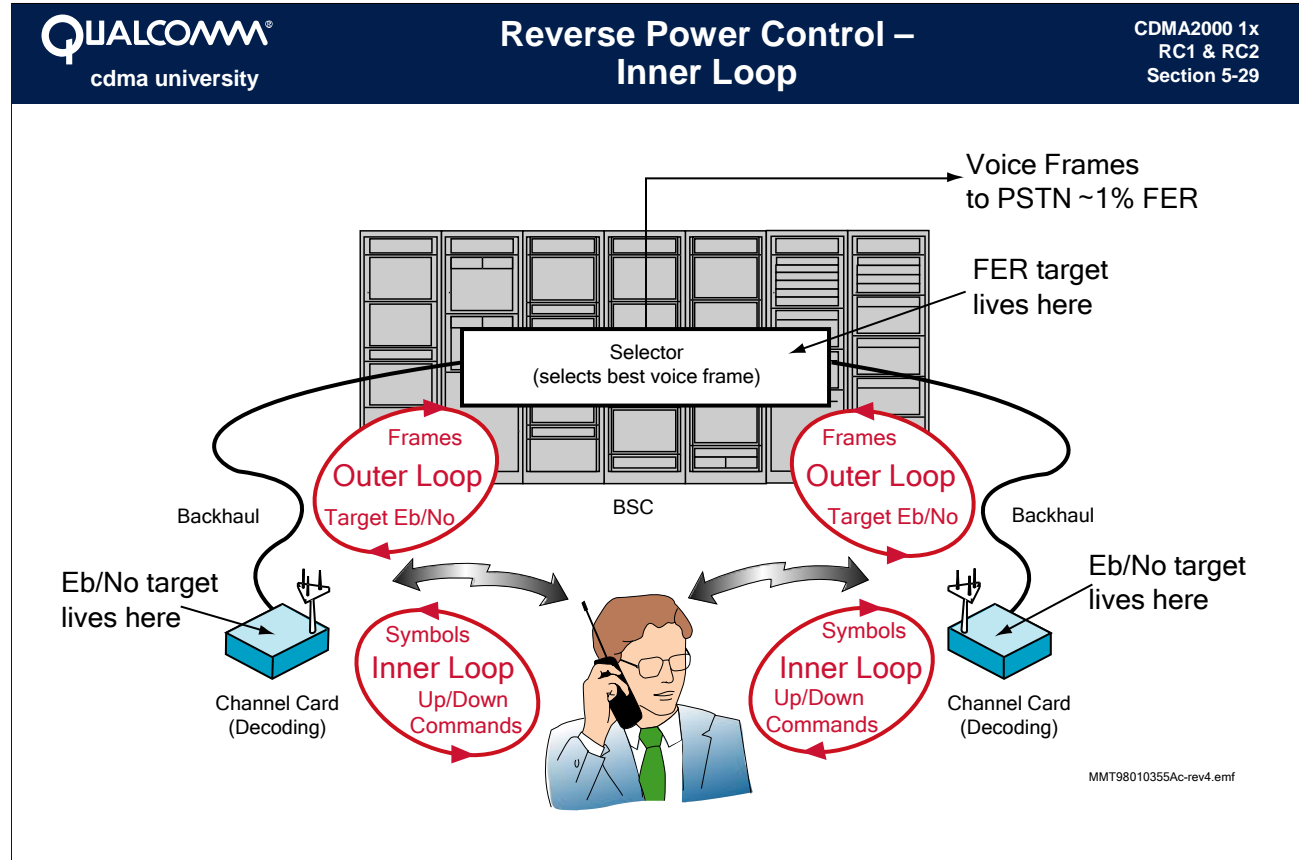
Adjusts the Threshold in the Cell

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### The Reverse Outer Loop Process

In the Closed Loop Power Control process, the  $E_b/I_0$  measured at the cell is compared to an adjustable threshold. The threshold determines the *Frame Error Rate* (FER). Increasing the threshold reduces the FER, thereby improving the quality of the speech. Reducing the threshold tends to increase the FER. Typically, a system would attempt to maintain a FER of 1%. Adjusting this threshold is referred to as *Outer Loop Power Control*. There is no standardized process for Outer Loop Power Control. Infrastructure manufacturers are free to implement their own proprietary algorithms.

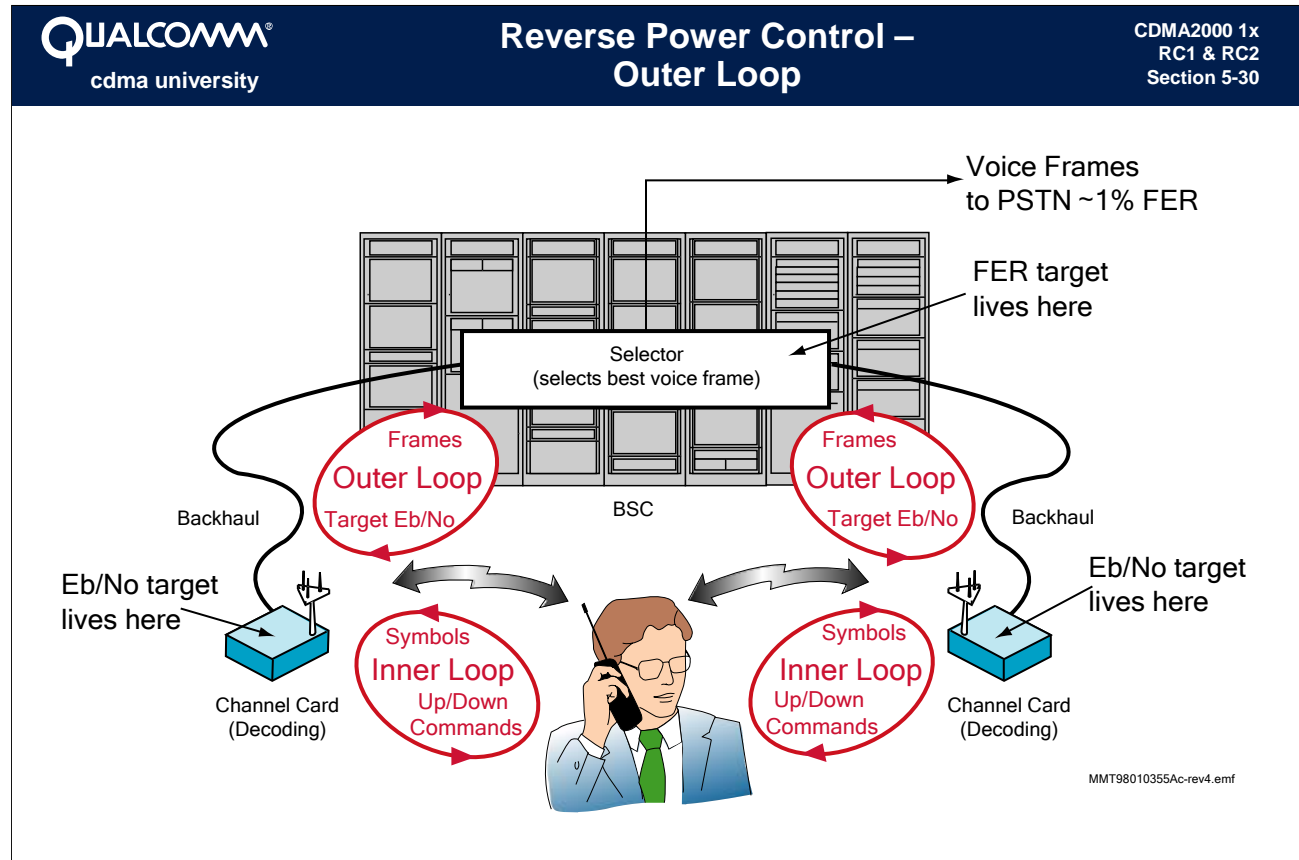
A single threshold can be used for every mobile in the cell or each mobile can have its own threshold. Individual thresholds are not expected to vary over a range of more than a few dB. Individual thresholds will be beneficial since this allows mobiles in extremely advantageous circumstances to have a lower threshold, while providing a higher threshold to disadvantaged users. The use of individual thresholds significantly increases capacity. Typically, the sectors involved in a call (there may be several due to soft handoff) all deliver frames to the selector (at the MSC). The selector selects the frames that are not in error and delivers these to the PSTN. The output of the selector is used to determine the FER.



### Inner Loop

The Inner Loop is the power control loop between the Base Station and the mobile.

The Base Station compares the local Base Station target to the signal received from the mobile, and makes the 1 bit up/down command to send to the mobile 800 times each second.



## Outer Loop

The Selector (usually located in the MSC) is the entity that receives frames from all Base Stations that are involved with this user's call. Soft handoff involves multiple Base Stations, with each Base Station sending frames over the backhaul to the Selector. The Mobile transmits the frames over-the-air to the Base Stations involved in soft handoff for this user; the Base Station time-tags each frame and sends it to the Selector. The Selector has the job of selecting the frames that are correct, based upon the CRC bits in the frame.

The frames being sent to the PSTN are used to calculate the FER. The FER for each Base Station will be different, because the channel between the mobile and each Base Station is unique. The FER between each Base Station and mobile changes with time, because the channel changes due to mobile movement or other changes in the local fading environment. Thus the Selector is the only network element that knows the FER going to the PSTN, making the Selector the correct network element to determine the required user Eb/No target.

This target changes slowly with time (slower than the 800 bit per second of the inner loop) and is broadcast over the backhaul to the Base Stations involved in the user's call. Each user can have a separate target Eb/No, because the FER target typically requires a different Eb/No for each user due to the different user environments. A static (non-moving) user typically requires a smaller Eb/No target than a moving user. A user in a difficult fading/multipath environment requires a higher Eb/No target than a user that has line-of-sight to the Base Station.