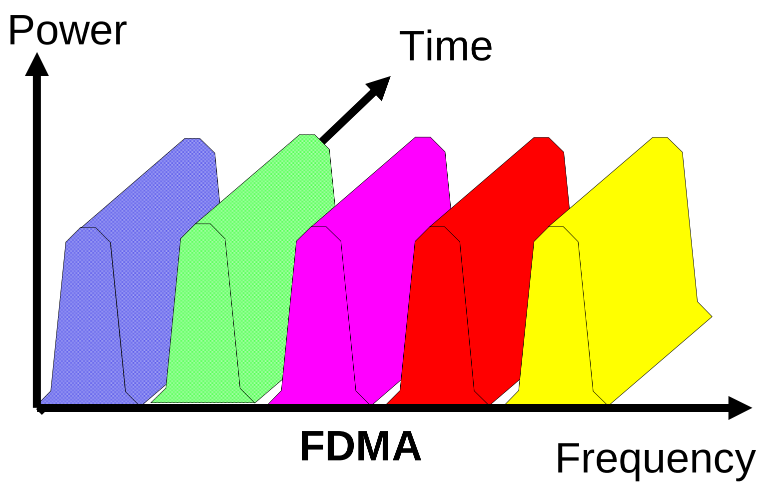
CDMA Fundamentals

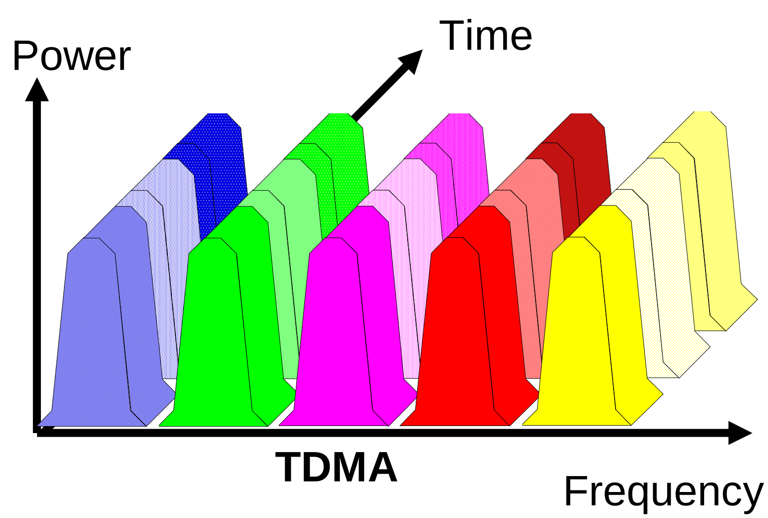
Agilent Technologies

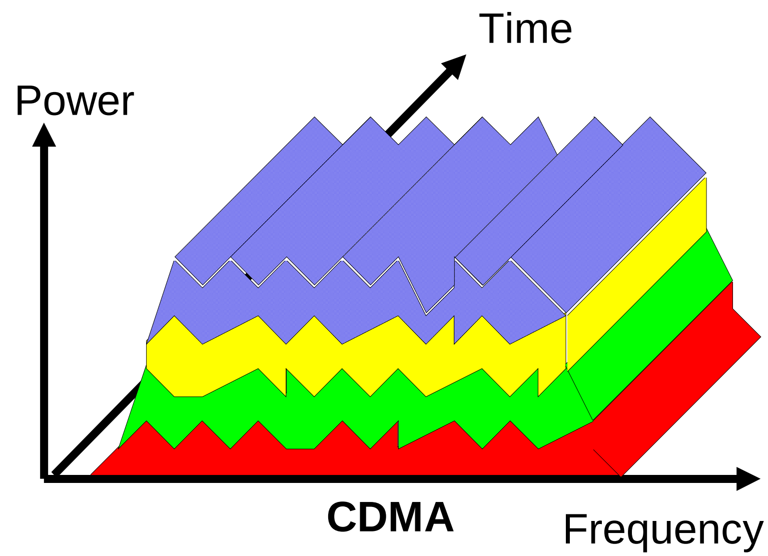
Agenda

- CDMA introduction
- CDMA makes use of Diversity
- Power control
- CDMA Forward Link
- CDMA Reverse Link
- CDMA call processing
- CDMA Measurement

Cellular Access Methods

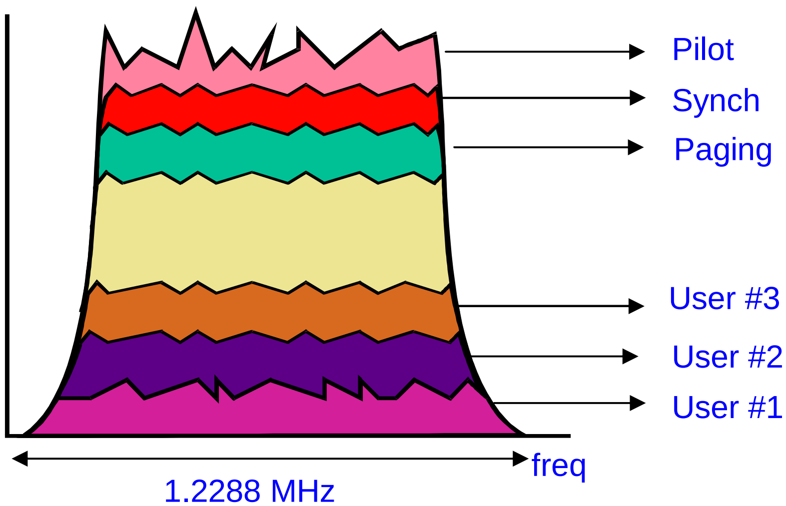




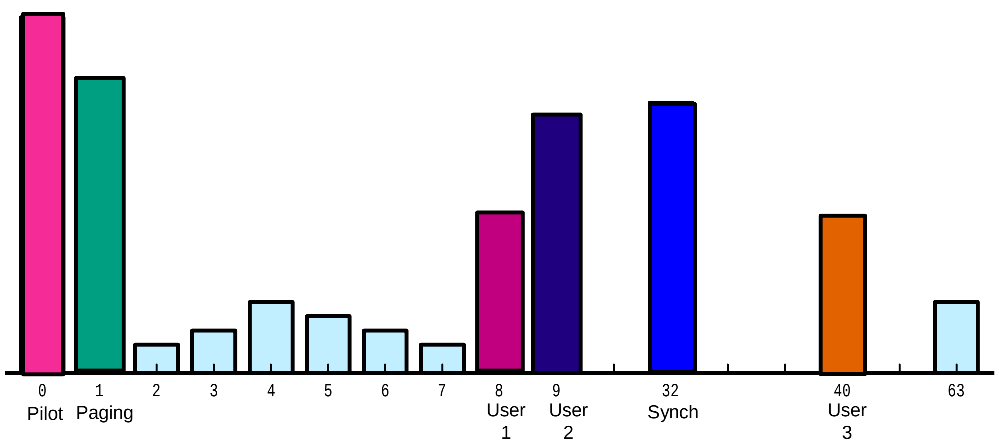


The CDMA Concept

Code Domain Power (cdma2000/IS-95)



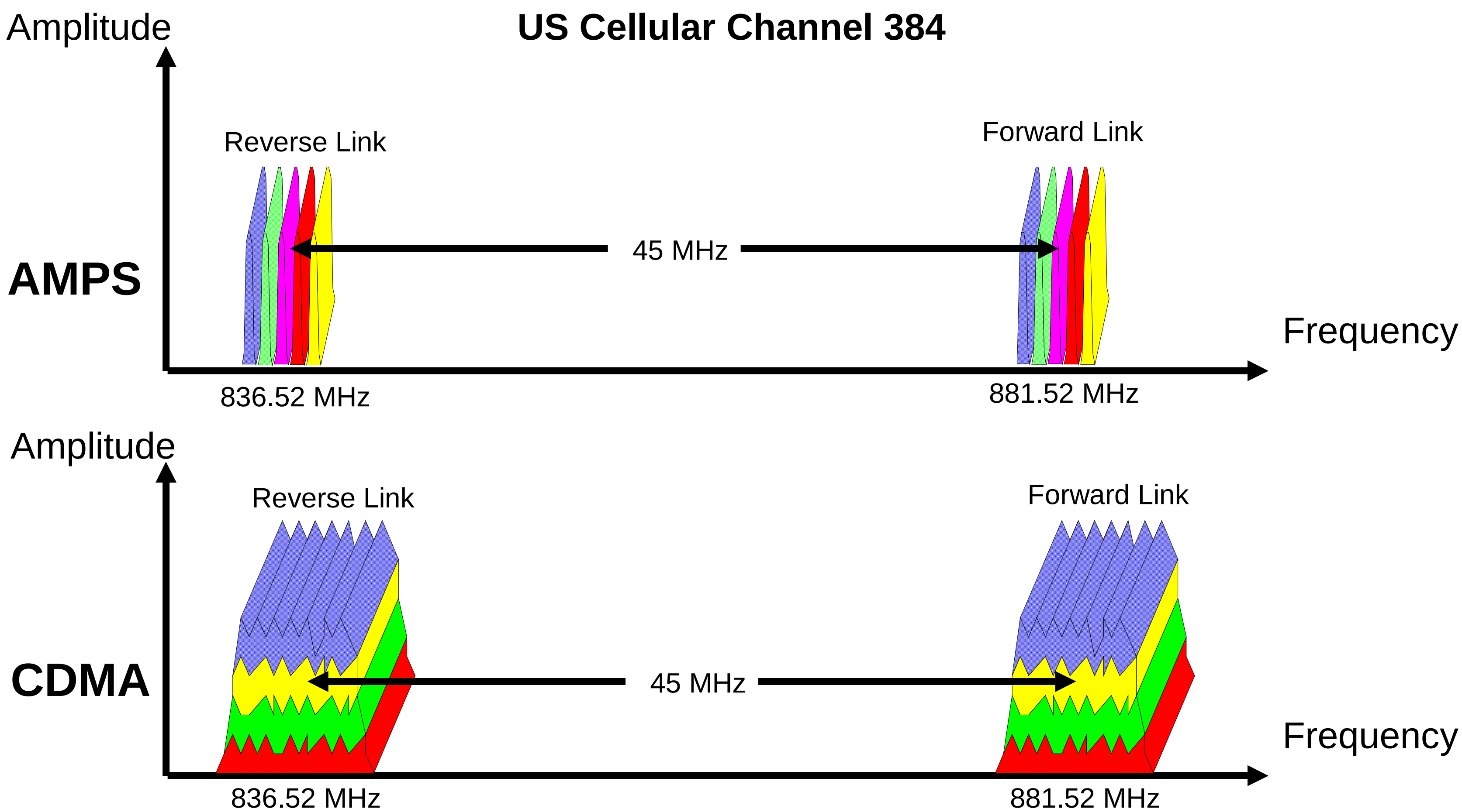
Frequency Domain



Code Domain

Walsh Code

CDMA is Also Full Duplex

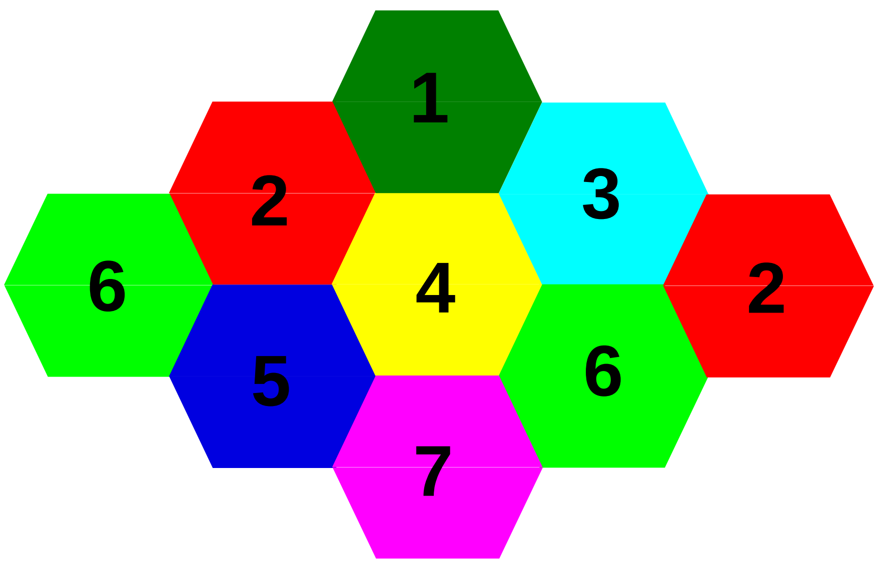


What is CDMA ?

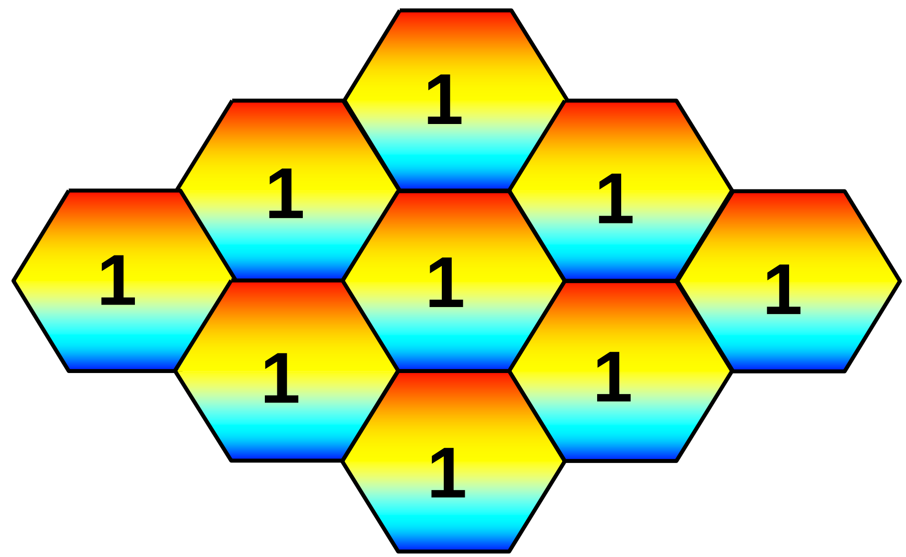
Code Division Multiple Access

- Spread spectrum technique
- Multiple users share the same frequency in one cell
- Same frequency in all the cells
- Operates under presence of interference
- Takes advantage of multipath
- Capacity is soft

Cellular Frequency Reuse Patterns

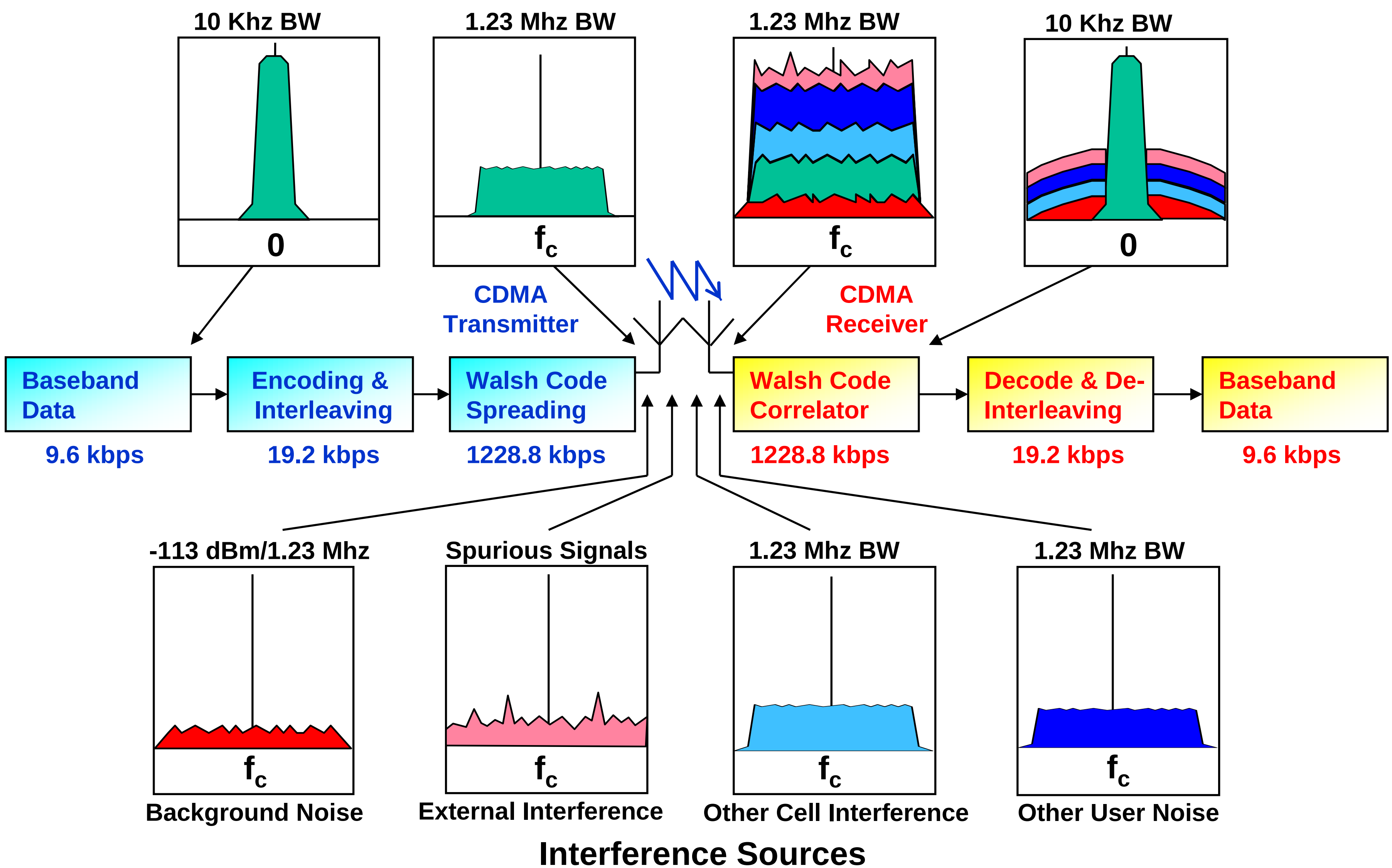


FDMA Reuse



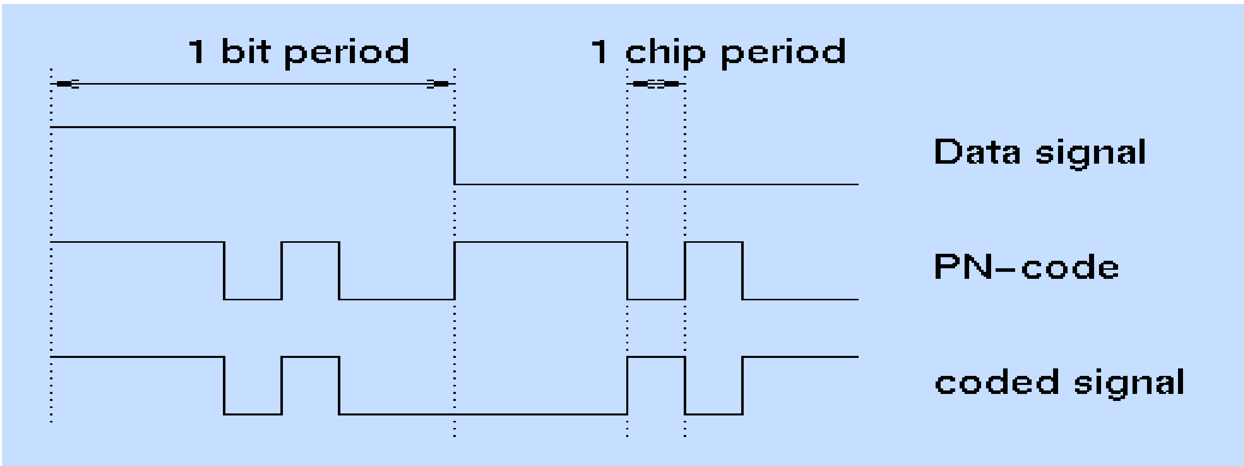
CDMA Reuse

The CDMA Concept



Direct Sequence Spread Spectrum

- Baseband data multiplied by a Pseudo Random Noise (PN) Code, which is a sequence of chips valued -1 & +1 or 0 & 1
- PN code is a noise-like code with certain properties (ex: orthogonal)



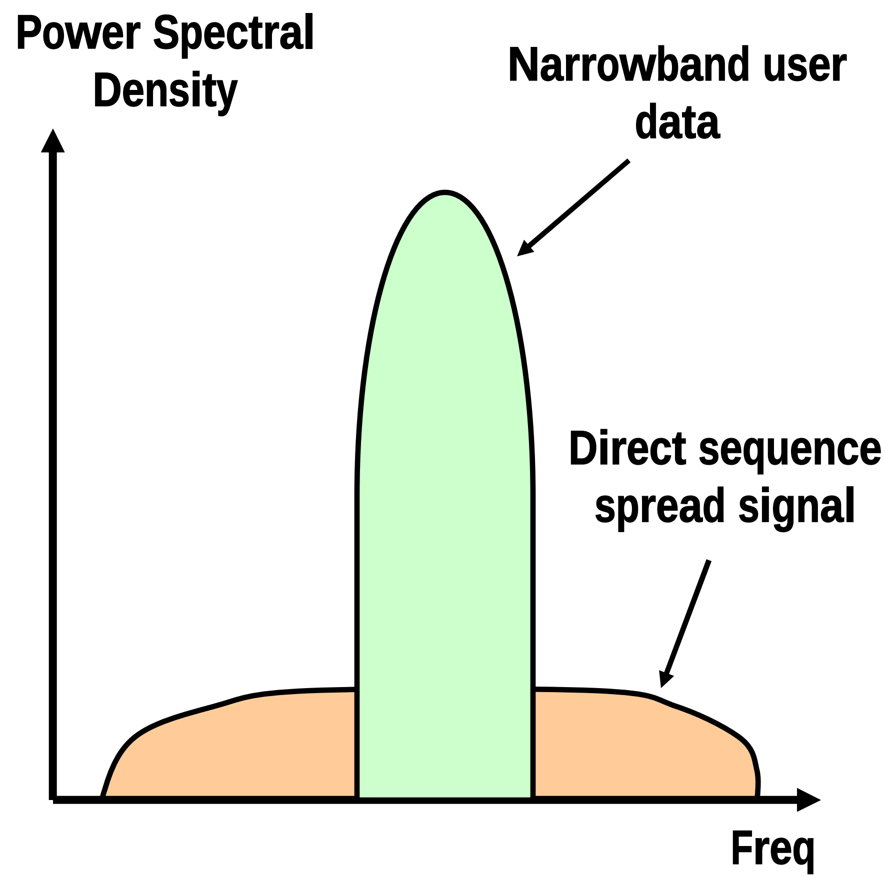
- **Multiple user data can be spread by using combinations of this PN code**

Agilent Technologies

3G

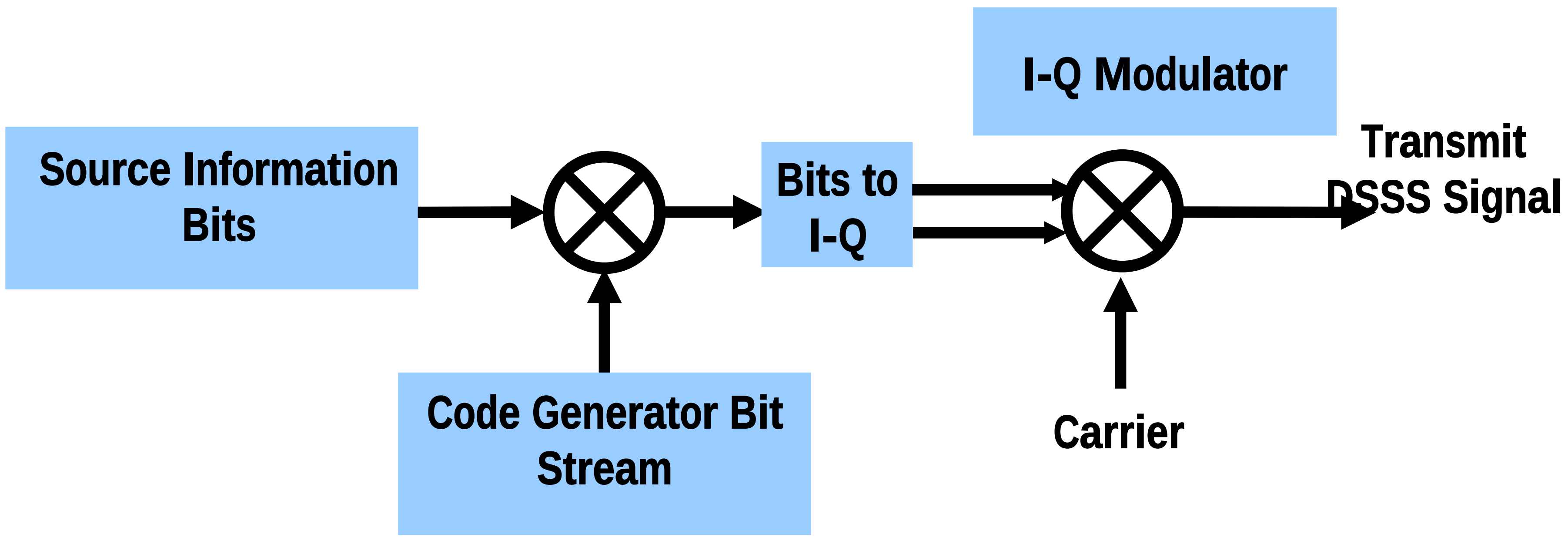
Direct Sequence Spread Spectrum

- Direct sequence spread spectrum signal is generated by multiplying narrowband user data with a well-defined wideband pseudo-random sequence.
- Recovering the narrowband user data is achieved by multiplying the received signal by an identical, accurately timed pseudo-random sequence.



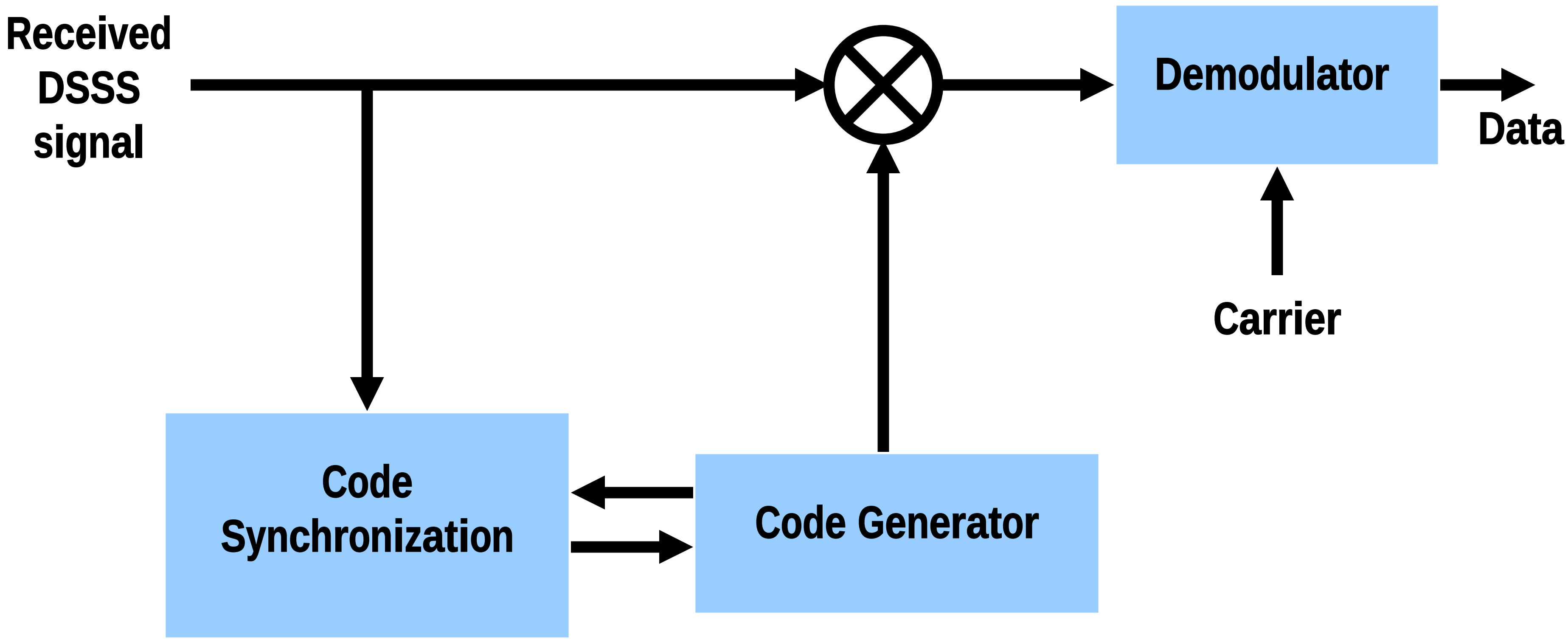
Direct Sequence Spread Spectrum

Direct Sequence Spread Spectrum



Block diagram of a Direct Sequence Spread Spectrum Transmitter

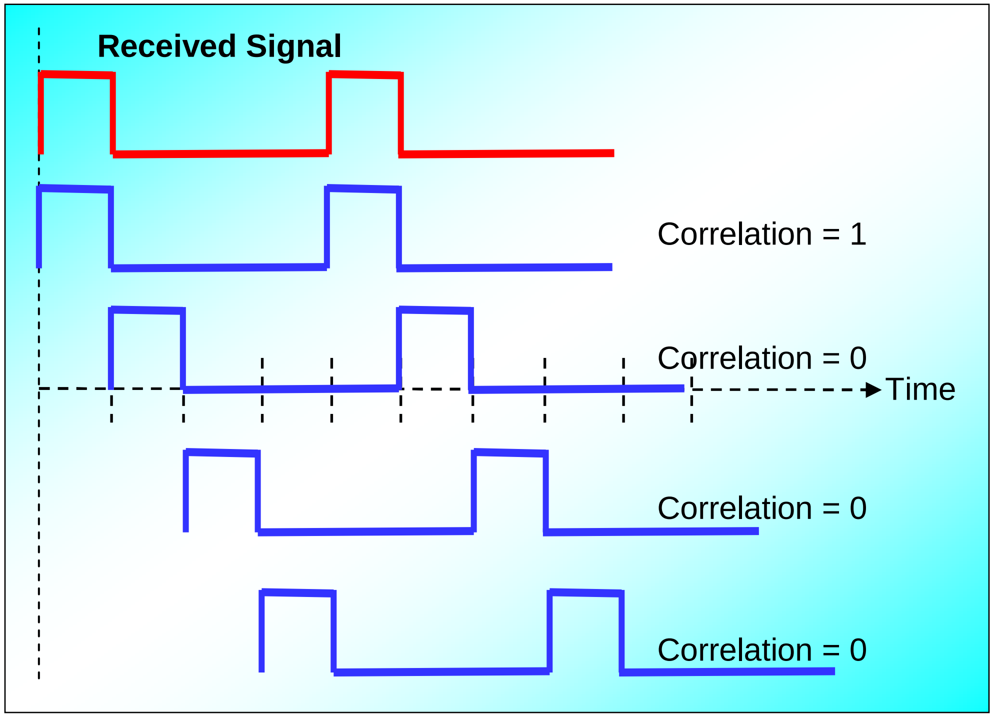
Direct Sequence Spread Spectrum



Block diagram of a Direct Sequence Spread Spectrum Receiver

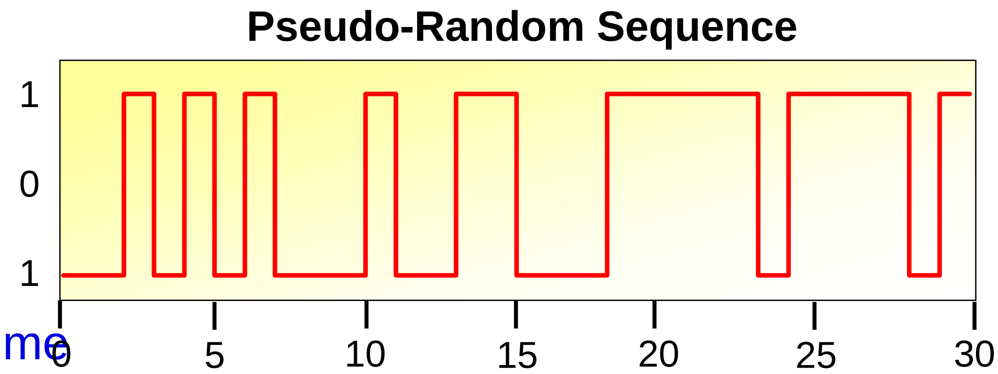
What is Correlation ?

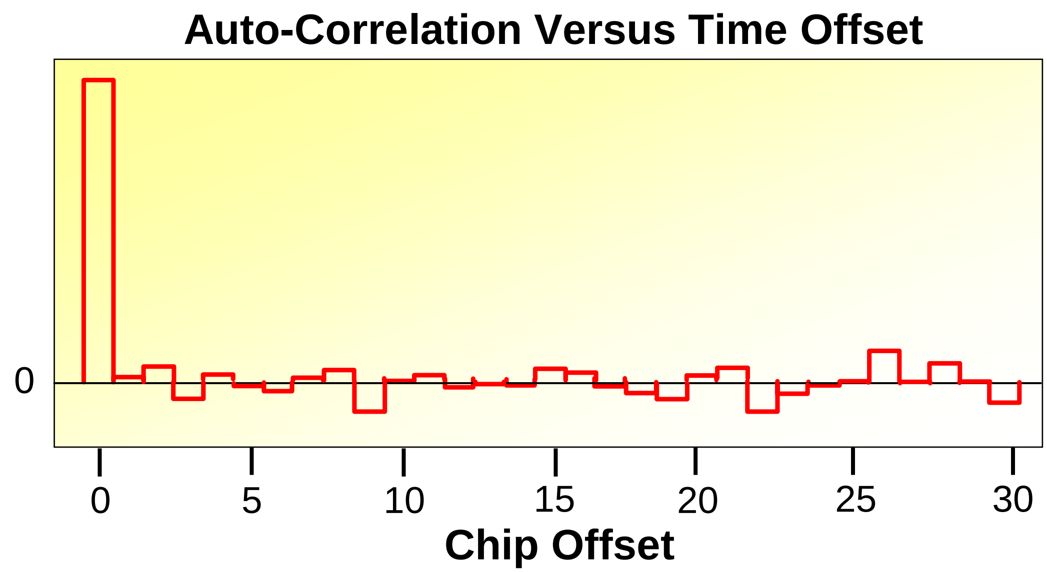
- Is a Measure of How Well a Given Signal Matches a Desired Code
- The Desired Code is Compared to the Given Signal at Various Test times



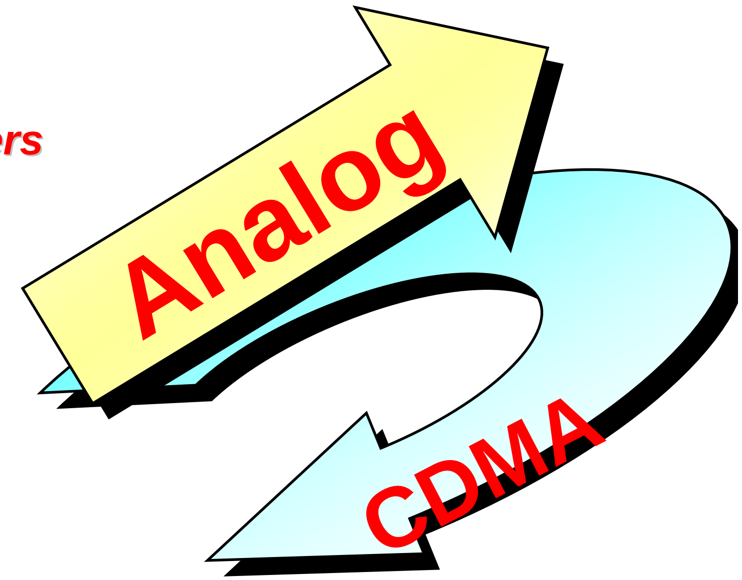
Auto-Correlation

- Is a Comparison of a Signal Against Itself
- Good Pseudo-Random Patterns Have:
  - Strong Correlation at Zero Time Offset
  - Weak Correlation at Other Time Offsets





CDMA Paradigm Shift



- Multiple Users on One Frequency
  - ***Analog/TDMA Try to Prevent Multiple Users Interface***
- Channel is Defined by Code
  - ***Analog Systems Defined Channels by Frequency***
- Traditional FDMA/TDMA are capacity-limited
  - ***Given N timeslots per frame and K frequency channels, maximum number of users is KN;***
  - ***To increase the number of users in the system, frequency reuse is used***
- Capacity Limit is Soft
  - ***Allows Degrading Voice Quality to Temporarily Increase Capacity***
  - ***Reduce Surrounding Cell Capacity to Increase a Cell's Capacity***

CDMA Capacity Gains

$$\text{Capacity} = \frac{(\text{Chan BW})}{(\text{Data Rate})} \times \frac{(1)}{(\text{S/N})} \times \frac{(1)}{(\text{Vaf})} \times (\text{Fr})$$

$$\text{CDMA} = \frac{(1{,}230{,}000)}{(9{,}600)} \times \frac{(1)}{(5.01)} \times \frac{(1)}{(.40)} \times (0.67)$$

CDMA = 42 Calls (Using 1.5 MHz BW)

Processing Gain

AMPS = 1.5 MHz / 30 kHz = 50 Channels

Capacity = 50 Channels / 7 (1/7 Frequency Reuse)

AMPS = 7 Calls (Using 1.5 MHz BW)

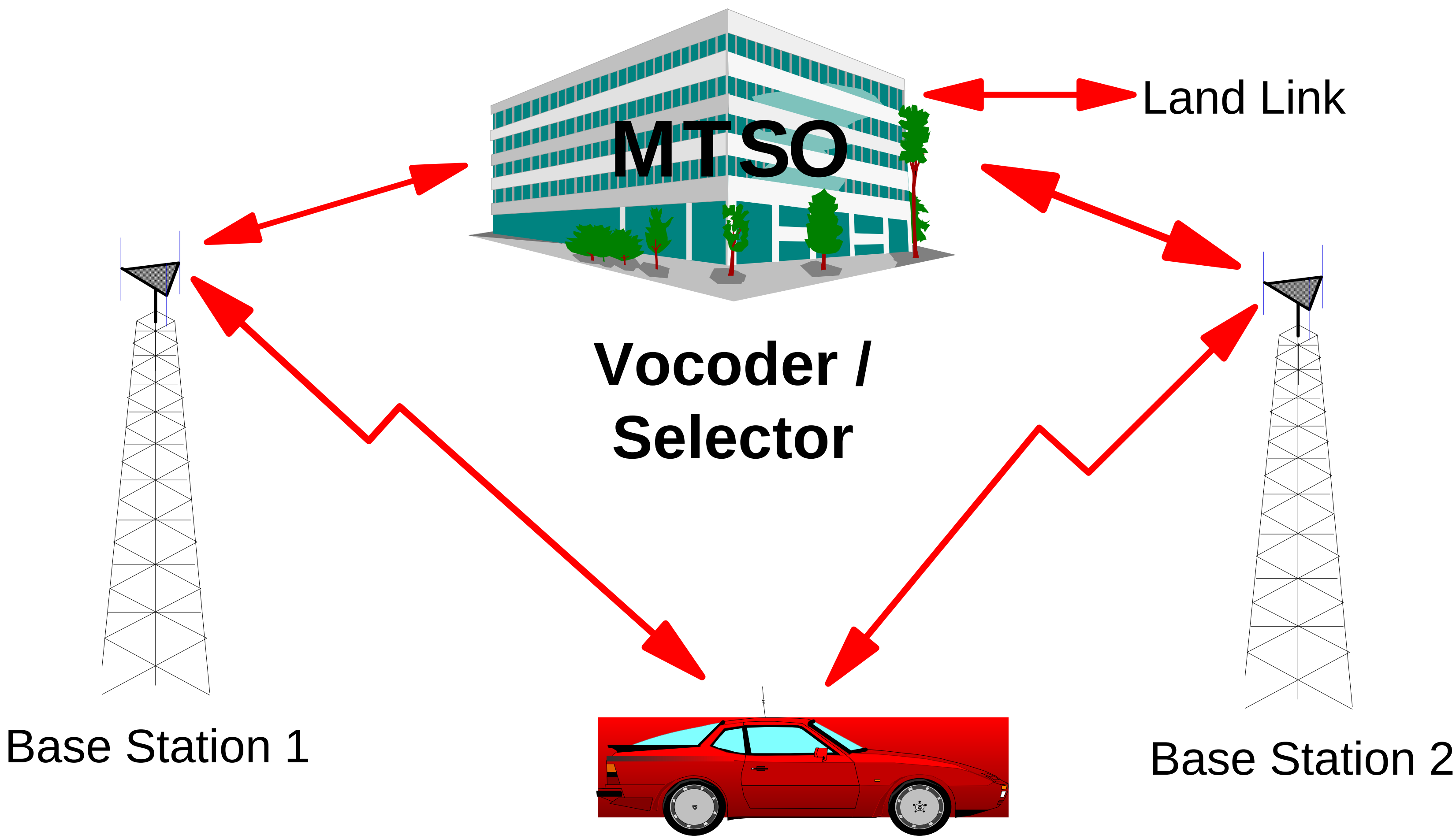
CDMA makes use of Diversity

- Spatial Diversity
  - Making Use of Differences in Position
- Frequency Diversity
  - Making Use of Differences in Frequency
- Time Diversity
  - Making Use of Differences in Time

CDMA Spatial Diversity

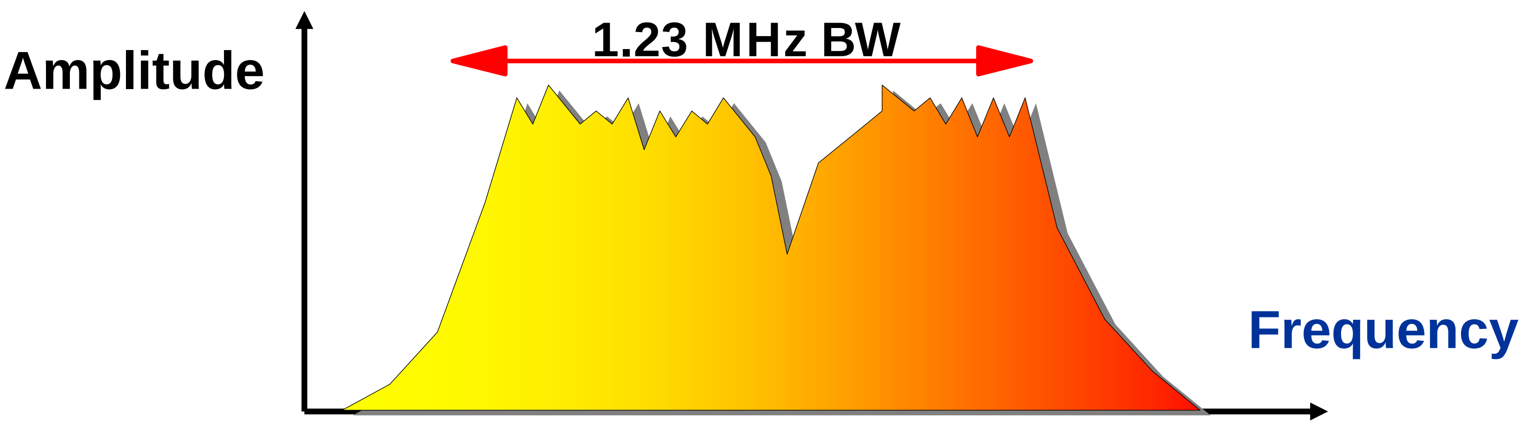
- Diversity Reception:
  - ➢ Multiple Antennas at Base Station
    - ✓ ***Each Antenna is Affected by Multipath Differently Due to Their Different Location***
    - ✓ ***Allows Selection of the Signal Least Affected by Multipath Fading***
- If Diversity Antennas are Good, Why Not Use Base Stations as a Diversity Network?
  - ➢ Soft Handoff

Spatial Diversity During Soft Handoff



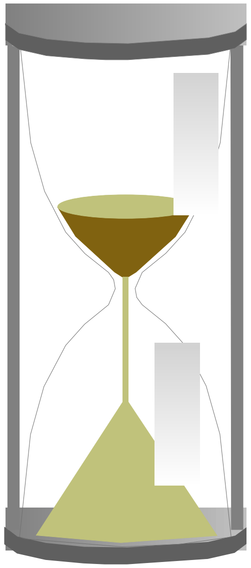
CDMA Frequency Diversity

- Combats Fading, Caused by Multipath
- Fading Acts like Notch Filter to a Wide Spectrum Signal
- May Notch only Part of Signal



CDMA Time Diversity

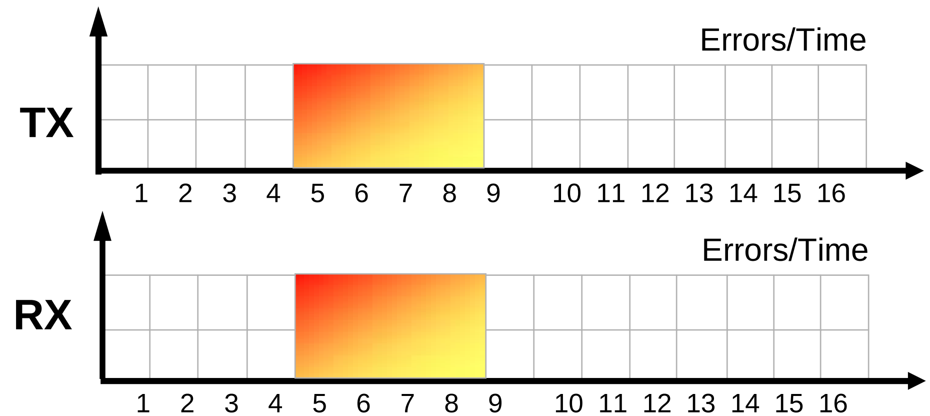
- Rake Receiver to Find and Demodulate Multipath Signals
- Data is Interleaved
  - Spreads Adjacent Data in time to Improve Error Correction Efficiency
- Convolutional Encoding
  - Adds Error Correction and Detection
- Viterbi Decoding
  - Most Likely Path Decoder for Convolutionaly Encoded Data



Why Interleaving Works

Original Data Frame

1	2	3	4
5	6	7	8
9	10	11	12
13	14	15	16

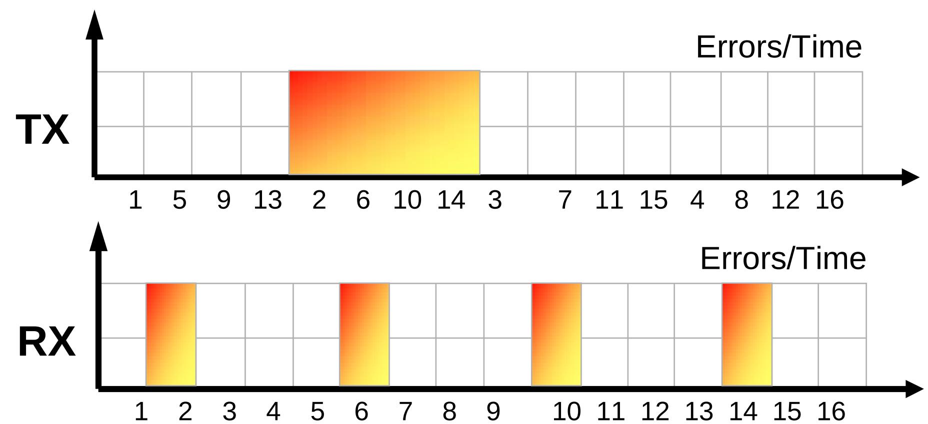


Interleaved Data Frame

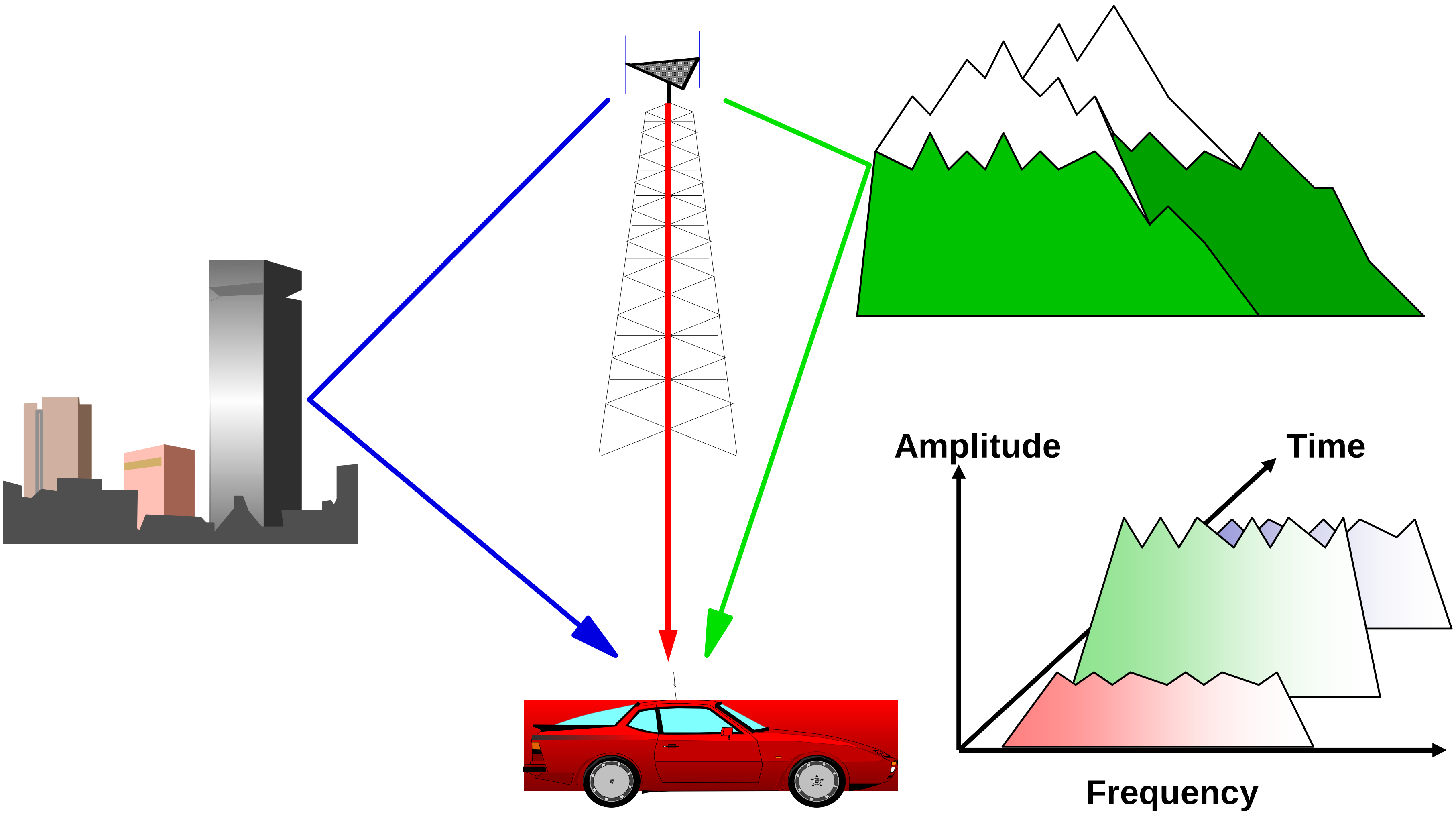
1	2	3	4
5	6	7	8
9	10	11	12
13	14	15	16

→

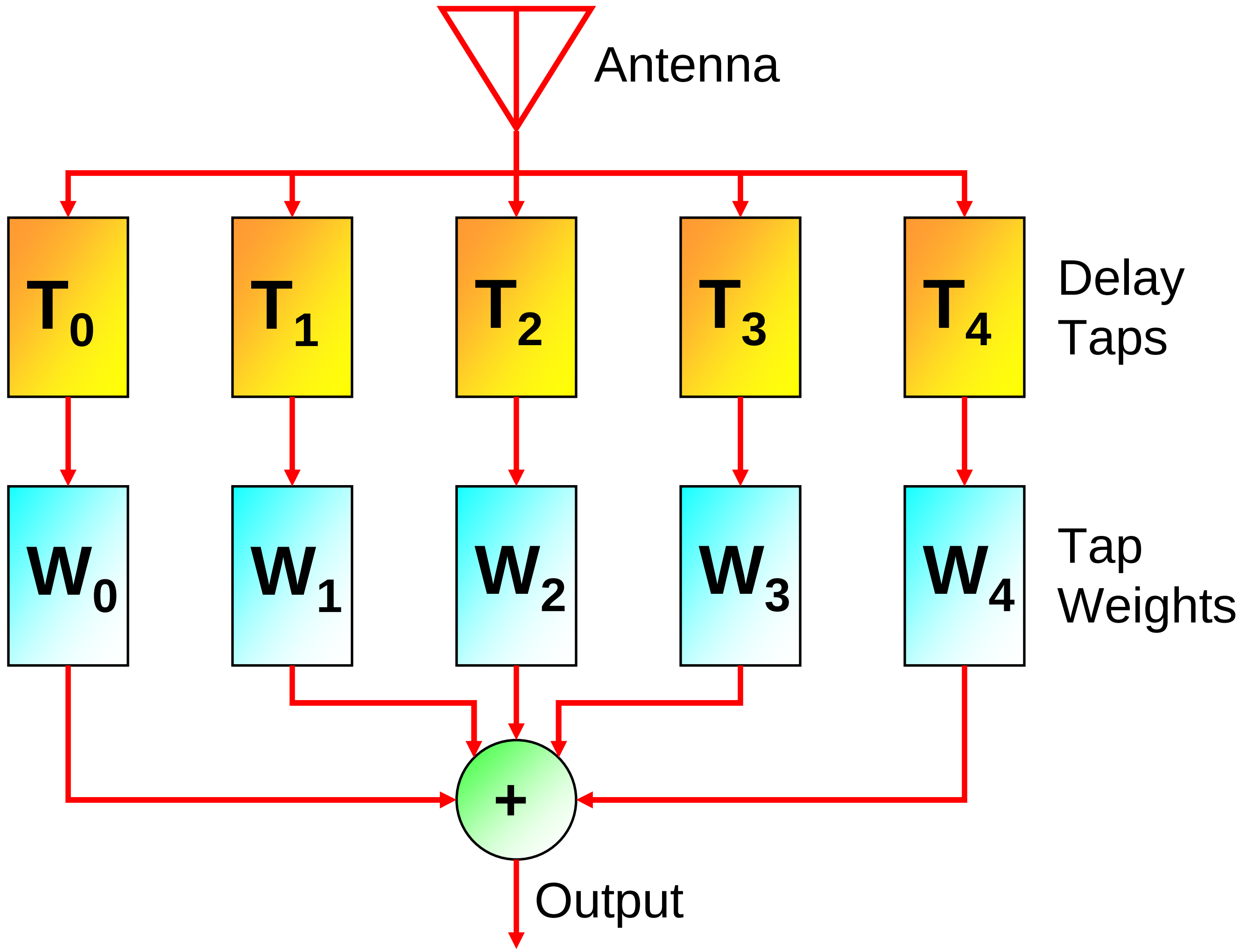
1	5	9	13
2	6	10	14
3	7	11	15
4	8	12	16



The Rake Receiver



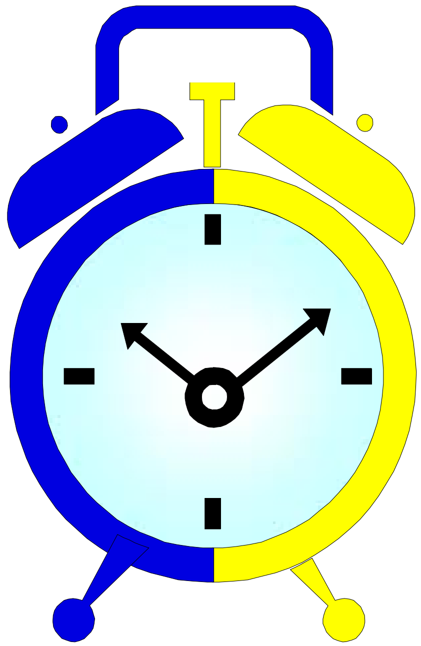
Rake Receiver Design



Synchronization

- All Direct Sequence, Spread Spectrum Systems Should be Accurately Synchronized for Efficient searching

- Finding the Desired Code Becomes Difficult without Synchronization

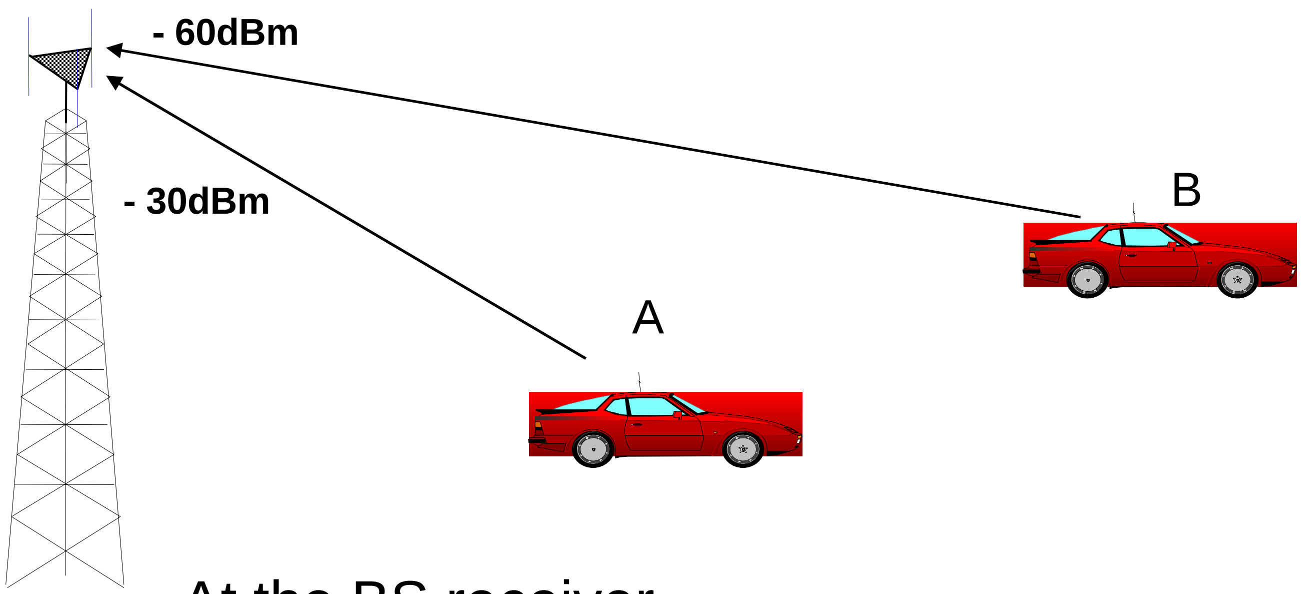


Agilent Technologies

3G

Power Control

Near-end Far-end Problem



At the BS receiver,
SNR for A reception = 30 dB, certified
SNR for B reception = -30 dB, not certified

Power Control

- Acceptable SNR is at least 7 dB
- For B, the signal needs 37 dB gain to meet the condition
- What if we increase the processing gain from 21 dB to 37 dB?

$$\mathbf{P_{gain} = 10 \log (W / R)}$$

R is fixed at 9600 bps, W can be increased

In this case, W = 48 MHz ➡ not practical

Is there another way to improve S/N?

Power Control

- In this case, B is the Signal and A is the Noise
- Both A and B are transmitting at constant power
- Since A is near, it can be asked to transmit at low power
- Since B is far, it can increase the power

This is Power Control !

- Base Station will change power levels based on the Path loss.
- Base Station will also command Mobile to increase or decrease power levels.

Reverse Link Power Control

- Maximum System Capacity is Achieved if:
  - ✓ All Mobiles are Power Controlled to the Minimum Power for Acceptable Signal Quality
  - ✓ As a Result, all Mobiles are Received at About Equal Power at the Base Station Independent of Their Location
- Two Types of Control
  - Open Loop Power Control
  - Closed Loop Power Control
- Open & Closed Loop Power Control are *Always Both Active*

Open Loop Power Control

- Assumes Loss is Similar on Forward and Reverse Paths
- Receive Power + Transmit Power = -73(-76dB for PCS Band
  - All Powers in dBm
- Example:
  - For a Received Power of -85 dBm

    Transmit Power = (-73) - (- 85)

    Transmit Power = +12 dBm
- Provides an Estimate of Reverse TX Power for Given Propagation Conditions

Closed Loop Power Control

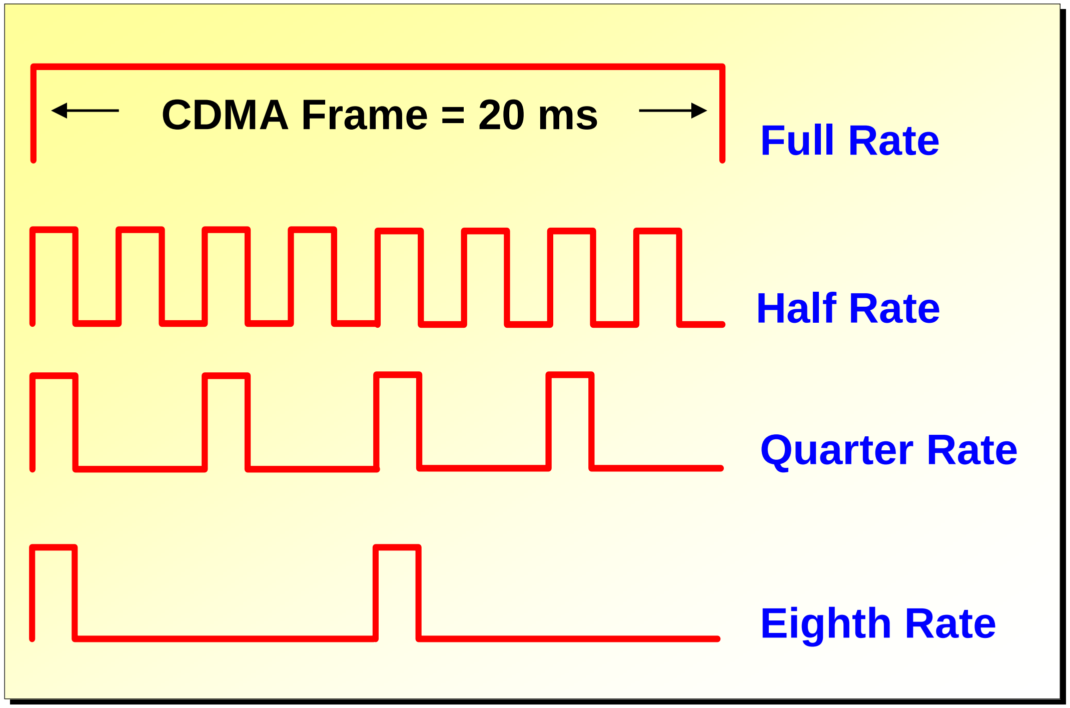
- Directed by Base Station
- Updated Every 1.25 msec
- Commands Mobile to Change TX Power in +/- 1 dB Step Size
- Fine Tunes Open Loop Power Estimate
- Power Control Bits are "Punctured" over the Encoded Voice Data
- Puncture Period is Two 19.2 kbps Symbol Periods = 104.2 usec

CDMA Variable Rate Speech Coder

- DSP Analyzes 20 Millisecond Blocks of Speech for Activity
- Selects Encoding Rate Based on Activity:
  - High Activity Full Data Rate Encoding (9600 bps)
  - Some Activity Half Data Rate Encoding (4800 bps)
  - Low Activity Quarter Data Rate Encoding (2400 bps)
  - No Activity 1/8 Data Rate Encoding (1200 bps)
- How Does This Improve Capacity?
  - Mobile Transmits in Bursts of 1.25 ms
- System Capacity Increases by 1/Voice Activity Factor

Mobile Power Bursting

- Each Frame is Divided into 16 Power Control Groups
- Each Power Control Group Contains 1536 Chips (represents 12 encoded voice bits)
- Average Power is Lowered 3 dB for Each Lower Data Rate



The CDMA2000 evolution path is flexible and future-proof

From CDG

- **Voice**
- **Data up to 14.4 kbps**

- **Voice**
- **Data up to 115 kbps**

- **2x increases in voice capacity**
- **Up to 307 kbps* packet data on a single (1.25 MHz) carrier**
- **First 3G system for any technology worldwide**

- **Optimized, very high-speed data (Phase 1)**
- **Up to 2.4 Mbps* packet data on a single (1.25 MHz) carrier**
- **Integrated voice and data (Phase 2); up to 4.8 Mbps**

***downlink**

CDMA Protocol Stacks

EIA/TIA/IS-856(1x EV-DO)
Optimized for packet data.

EIA/TIA/IS-2000 Rev C(1x EV-DV)
Segment channel between Voice and Data

EIA/TIA/IS-2000 Rev B
Add new functionality and support

EIA/TIA/IS-2000 Rev A
Add ***BCH,CCCH,CACH…new channel***

EIA/TIA/IS-2000 Rev 0
First release of IS-2000 standard(add QPCH)

EIA/TIA-95 Rev B
Combines TSB-74 & J-STD-008 for a Universal Protocol

J-STD-008
Not Backwards Compatible, PCS only Protocol

TBS- 74
Cellular Protocol that adds 14400 Channel Support

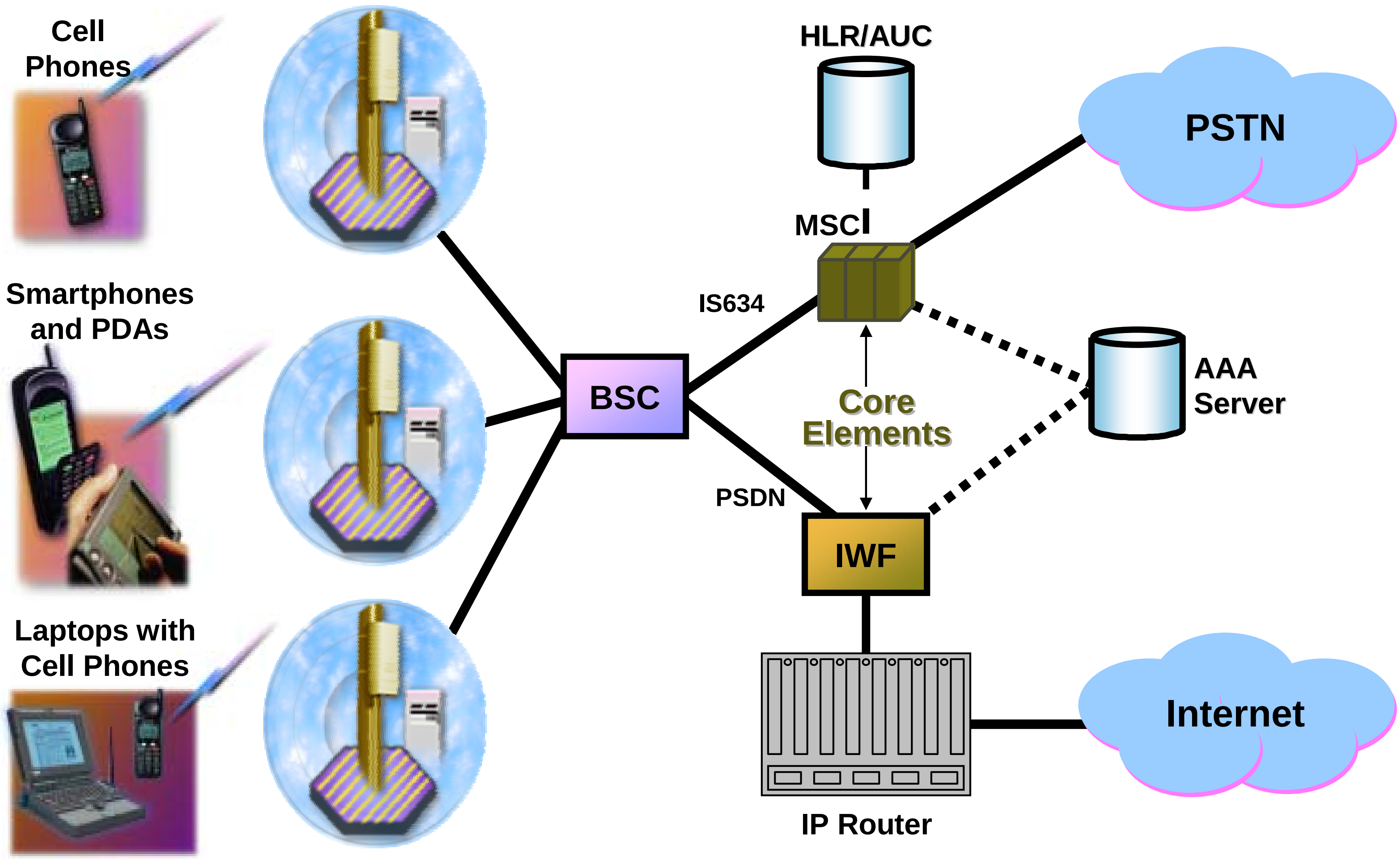
IS -95 Rev A
Backwards compatible with IS-95. First Deployed Protocol

IS -95 Rev 0
Original System-never actually deployed

ARIB T53
Japan CDMA System Cellular Protocol

The architecture for CDMA2000

From CDG



Agilent Technologies

3G

cdma2000 Key Standards

- EIA/TIA/IS-2000 rev. 0 Interoperability Standard for cdma2000 Spread Spectrum Systems
  - Defines channel coding, call processing procedures, protocol and other mobile / base procedures and RF requirements to ensure interoperability of equipment from multiple vendors
  - Defines how entire system works together in extreme detail
  - Revision 0 was first release of standard.
  - Revision A adds enhanced channels for paging, call set-up and call control.
  - Revision B enhanced from the cdma2000 Release A specifications

cdma2000 Standards Overview - IS-2000 Release 0 versus Revision A

Forward Channels

TIA/EIA-95-B	IS-2000	IS-2000-A
F-Pilot	F-Pilot	F-Pilot
F-Sync	F-Sync	F-Sync
F-PCH	**F-PCH** →	**F-BCCH** **F-CCCH**
	F-QPCH optional	F-QPCH optional
		F-CACH ★ **F-CPCCH**
F-Traffic	F-FCH F-SCH F-DCCH optional	F-FCH F-SCH F-DCCH optional

Reverse Channels

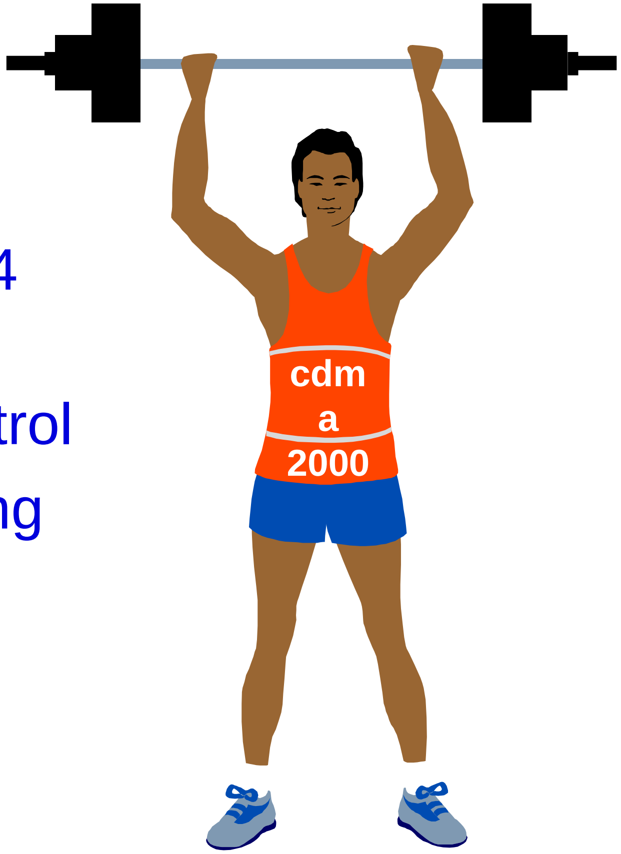
TIA/EIA-95-B	IS-2000	IS-2000-A
N/A	R-Pilot	R-Pilot
R-ACH	**R-ACH**	**R-EACH or R-CCCH** ★
R-Traffic	R-FCH R-SCH R-DCCH optional	R-FCH R-SCH R-DCCH optional

Benefits of cdma2000

- Improved Performance and Capacity:
  - ➢ About 2X Voice Capacity of TIA/EIA-95-B
  - ➢ Handles a Wide Range of Data Rates:
    - ✓ ***Voice and Low Speed Data while Driving***
    - ✓ ***Up to 384 kbps Packet or Circuit Data while Moving***
    - ✓ ***Up to 2 Mbps Data Rates for Fixed Installations***
- Meets All IMT-2000 Requirements
- Easy Upgrade for Service Providers Who Currently Operate TIA/EIA-95 Systems

Performance Enhancements

- Reverse Link Pilot for Each Mobile
- True QPSK Modulation
- Continuous Reverse Link Waveform
- Improved Convolutional Encoding for 14.4 kbps Voice Channels
- Fast Forward & Reverse Link Power Control
- Supports Auxiliary Pilots for Beam Forming
- Forward Link Transmit Diversity - OTD, STS, Multi-Antenna



Agilent Technologies

3G

Reuse of TIA/EIA-95-B

- cdma2000 is Fully Backwards Compatible with TIA/EIA-95-B
- Reused Aspects of TIA/EIA-95-B:
  - ✓ ***TIA/EIA-95-B Air Interface (RC1, RC2)***
  - ✓ ***IS-127 EVRC 8 kbps Vocoder and IS-733 13 kbps Vocoder***
  - ✓ ***All Existing Service Options***
  - ✓ ***IS-637 SMS & IS-683 Over the Air Activation***
  - ✓ ***IS-98 and IS-97 Minimum Performance Standards***
  - ✓ ***Common Broadcast Channels (Pilot, Sync ,Paging)***
- Allows cdma2000 to be Deployed Sooner

Terms and Definitions

- Chip
  - ✓ ***Is the period of a data bit at the final spreading rate***
- SR - Spreading Rate
  - ✓ ***Defines the final spreading rate in terms of 1.2288 Mcps(SR1). So a 3.6864 Mcps system is called a SR3 system.***
- RC - Radio Configuration
  - ✓ ***Defines the physical channel configuration based upon a base channel data rate.***
  - ✓ ***RCs contain rates derived from their base rate. For example, RC3 is based on 9.6 kbps and includes 1.5, 2.7, 4.8, 9.6, 19.2, 38.4, 76.8, 153.6, and 307.200 kbps.***
  - ✓ ***RCs are coupled to specific Spreading Rates***

IS-2000 SR1 (aka 1xRTT)

- Is an Improved TIA/EIA-95-B Narrowband System
- Occupies the Same 1.23 MHz Bandwidth as TIA/EIA-95-B
  - ➢ Forward Link:
    - ✓ ***Adds Fast Power Control***
    - ✓ ***Quick Paging Channel to Improve Standby Time***
    - ✓ ***Uses QPSK Modulation Rather than Dual BPSK to:***
      - – Use 3/8 Rate Convolutional Encoder instead of 3/4 for 14.4 Service (improves error correction)
      - – 128 Walsh Codes to Handle More Soft Handoffs for 9.6 service
  - ➢ Reverse Link:
    - ✓ ***Uses Pilot Aided BPSK to Allow Coherent Demodulation***
    - ✓ ***Uses 1/4 Rate Convolutional Encoder Instead of 1/2 or 1/3***
    - ✓ ***Uses HPSK Spreading***
- Doubles System Voice Capacity

SR1 Forward Radio Configurations

- Radio Configuration 1 - Required
  - ✓ ***Backwards compatible mode with TIA/EIA-95-B***
  - ✓ ***Based on 9,600 bps Traffic(RS1)***
- Radio Configuration 2
  - ✓ ***Backwards compatible mode with TIA/EIA-95-B***
  - ✓ ***Based on 14,400 bps Traffic(RS2)***
- Radio Configurations 3, 4, and 5
  - ✓ ***All use new cdma2000 coding for improved capacity***
  - ✓ ***RC3 is based on 9,600 bps and goes up to 153,600 bps***
  - ✓ ***RC4 is based on 9,600 bps and goes up to 307,200 bps***
  - ✓ ***RC5 is based on 14,400 bps and goes up to 230,400 bps***

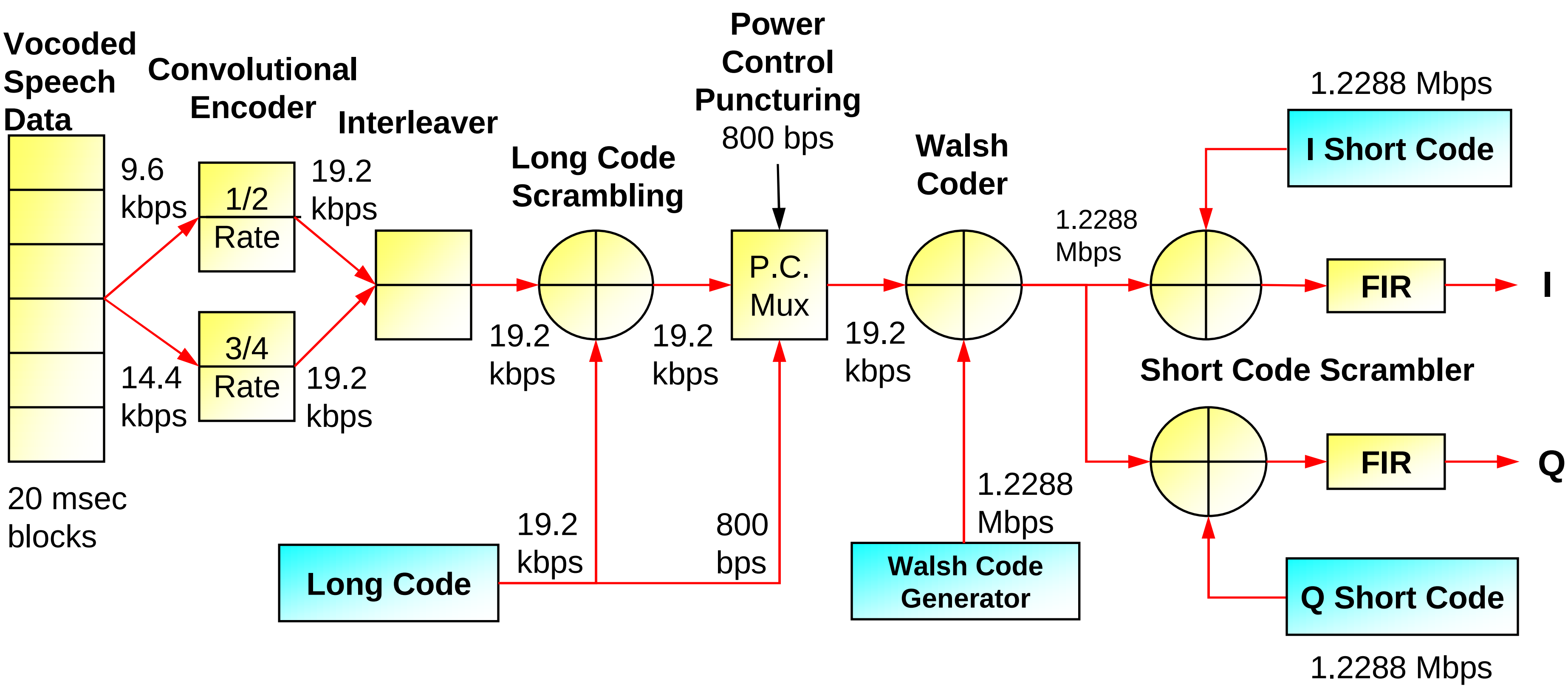
SR1 Forward Channels

- F-Pilot (Using TIA/EIA-95-B Coding)
- F-Sync (Using TIA/EIA-95-B Coding)
- Up to 7 F-Paging (Using TIA/EIA-95-B Coding)
- IS-2000 Rev.0
  - 0 to 3 F-QPCH (Quick Paging Channel)
- IS-2000 Rev.A/B
  - 0 or 8 F-BCH (Broadcast Channel)
  - 0 to 4 F-CPCCH (Common Power Control Channel)
  - 0 to 7 F-CACH (Common Assignment Channel)
  - 0 to 7 F-CCCH (Common Control Channels)
- Many F-Traffic Channels, Each Consisting of:
  - ✓ ***0 or 1 F-DCCH (Dedicated Control Channels)***
  - ✓ ***1 F-FCH (Fundamental Channel)***
  - ✓ ***0 to 7 F-SCCH (Supplemental Code Channels for RC1 & RC2)***
  - ✓ ***0 to 2 F-SCH (Supplemental Channel for RC3, 4, 5)***

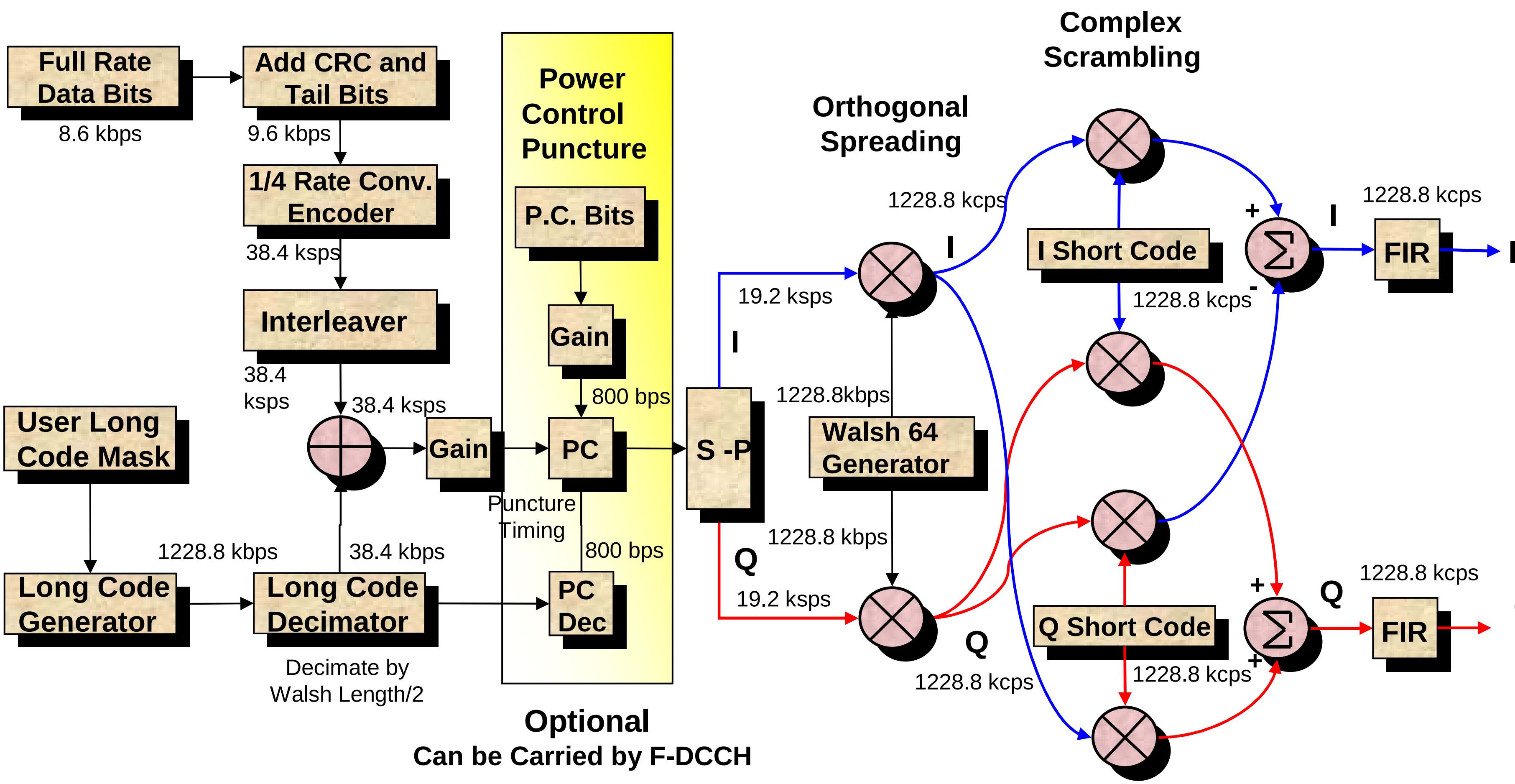
Base Station Variable Rate Vocoder

- Base Stations Do Not Pulse TX Channels
- How Does the Base Station Handle Variable Rate Vocoding?
  - Repeats Data Bits When Transmitting at Reduced Rates
  - Repeating Data Adds 3 dB Coding Gain
  - Lowers the TX Power 3dB for Each Lower Rate

Forward Link Traffic Channel Physical Layer (RC1,RC2)



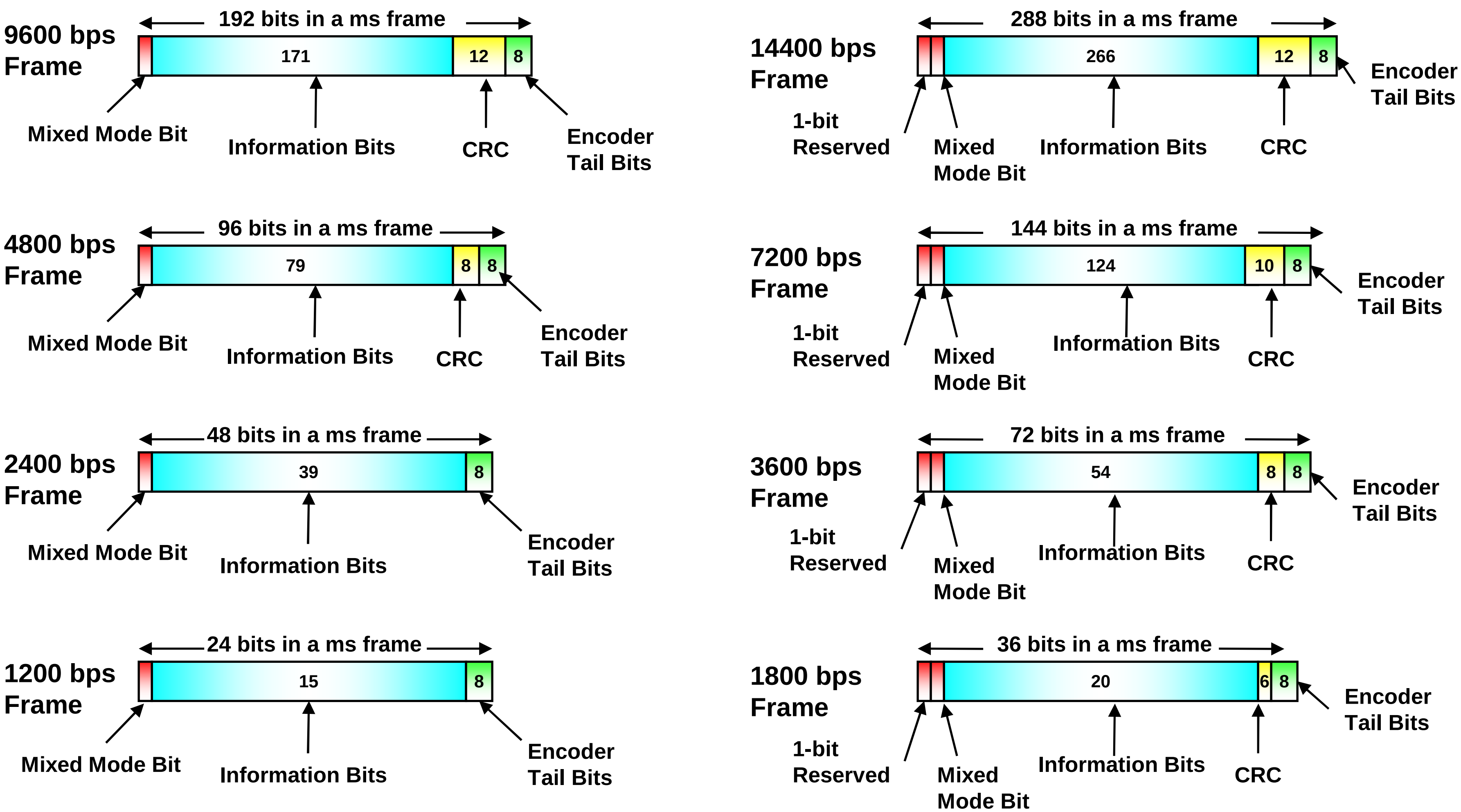
Forward FCH Physical Layer
RC3 (9.6 kbps)



CDMA Vocoders

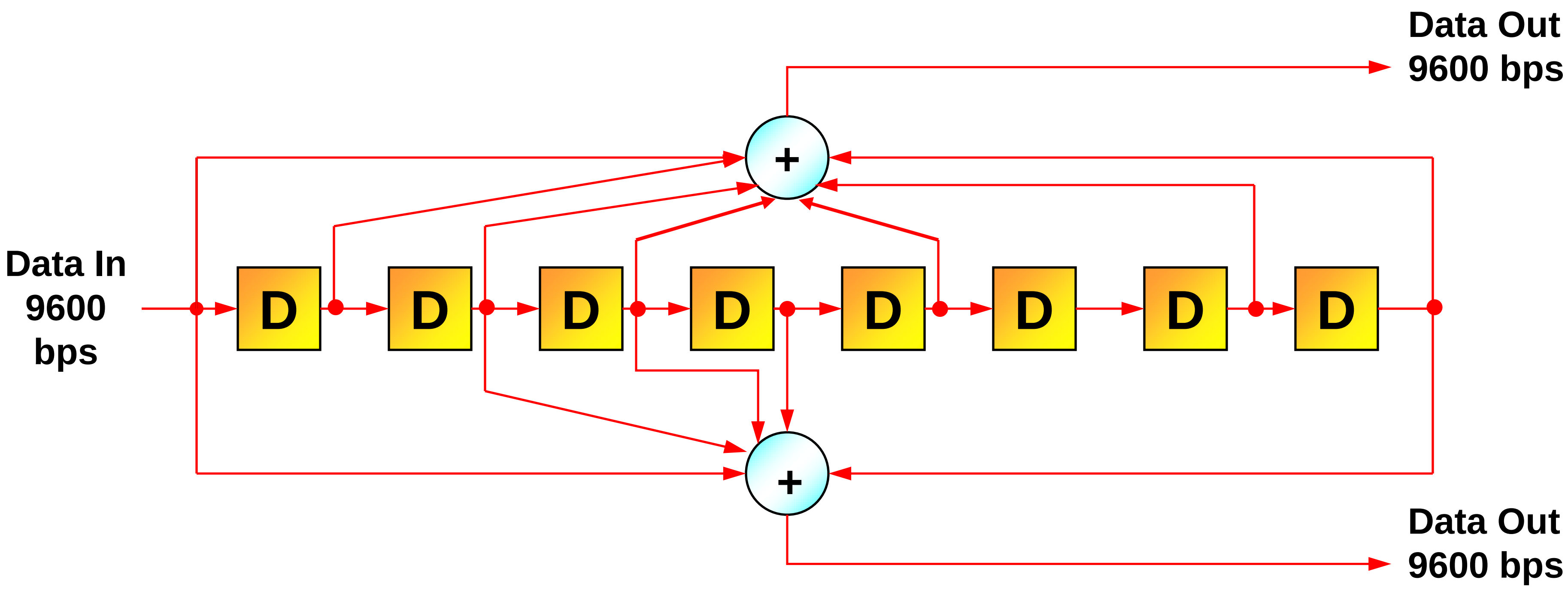
- Vocoders Convert Voice to/from Analog Using Data Compression
- There are Three CDMA Vocoders:
  - ➢ IS-96A Variable Rate (8 kbps maximum)
  - ➢ CDG Variable Rate (13 kbps maximum)
  - ➢ EVRC Variable Rate (improved 8 kbps)
- Each has Different Voice Quality:
  - IS-96A - moderate quality
  - EVRC - near toll quality
  - CDG - toll quality

CDMA Frame Formats



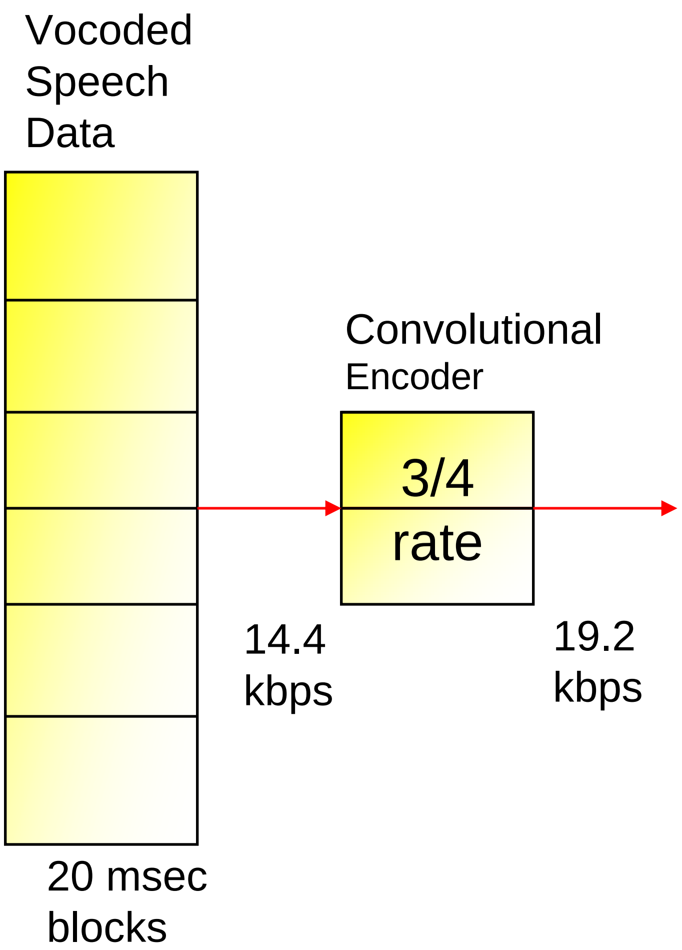
Forward Error Protection

- Uses Half-Rate Convolutional Encoder
- Outputs Two Bits of Encoded Data for Every Input Bit



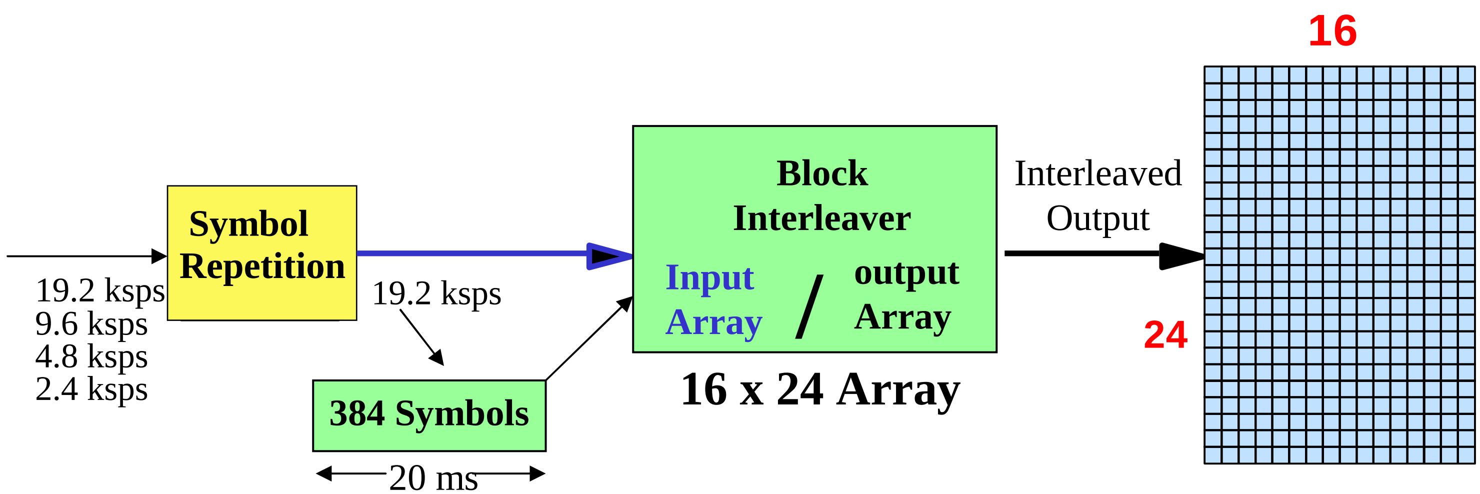
14.4 Traffic Channel Forward Link Modifications

- Replaces 8 kbps Vocoder with a 13 kbps Vocoder(both Variable Rate)
- Effects:
  - Provides Toll Quality Speech
  - Uses a 3/4 Rate Encoder
  - Reduces Processing Gain 1.76 dB
  - Results in Reduced Capacity or Smaller Cell Sizes



Interleaver

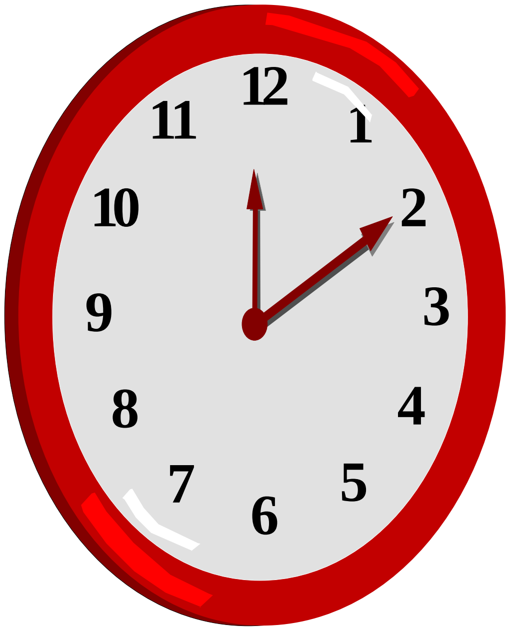
- Process of permuting a sequence of symbols to achieve time diversity
- CDMA uses block interleaving with 20 ms blocks



- 384 symbols are sequentially written in an input array
- Interleaved symbols are then read from the output array

CDMA System Time

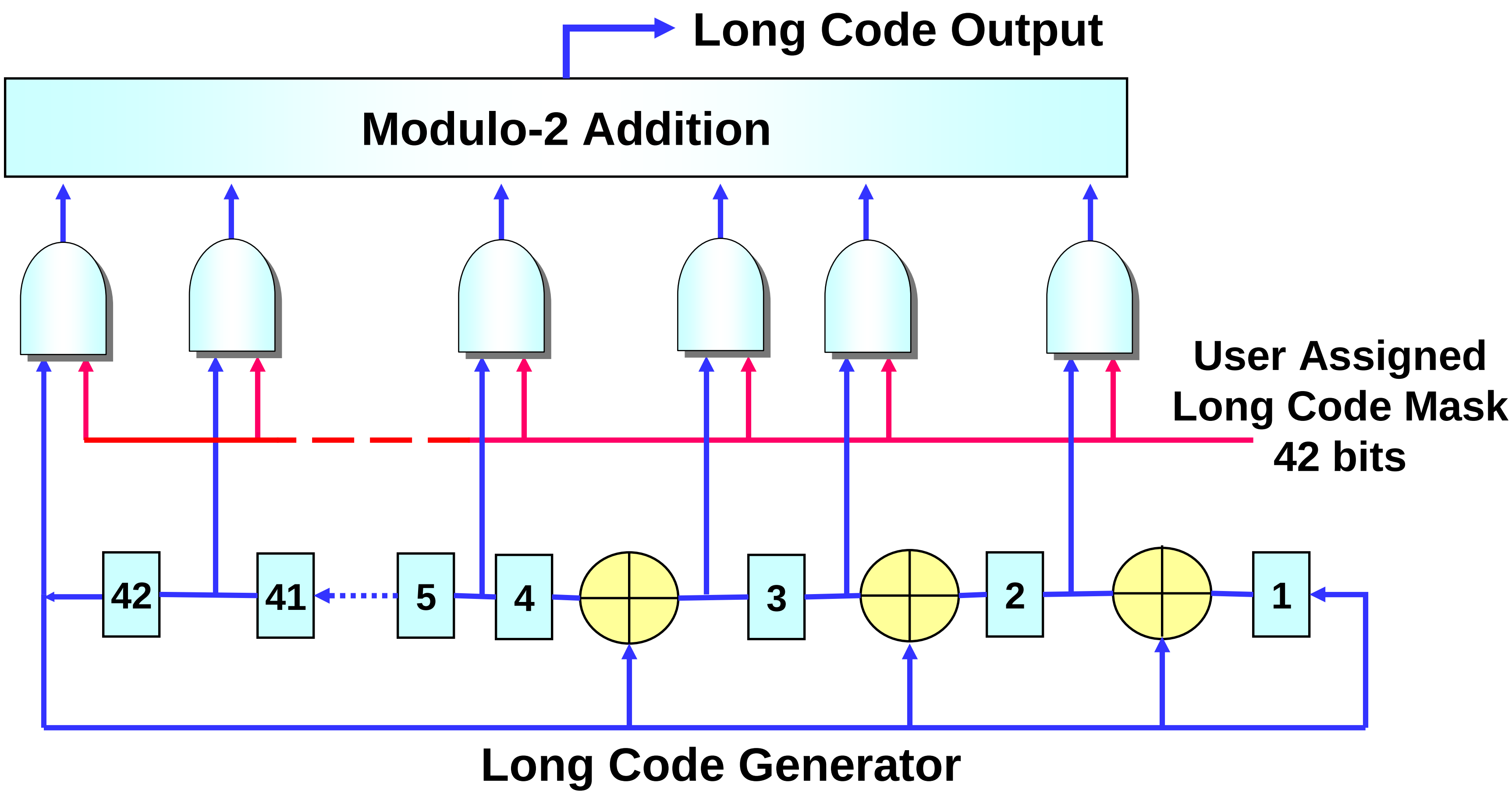
- How Does CDMA Achieve Synchronization for Efficient searching?
  - Use GPS Satellite System
- Base Stations Use GPS Time via Satellite Receivers as a Common Time Reference
- GPS Clock Drives the Long Code Generator



Agilent Technologies

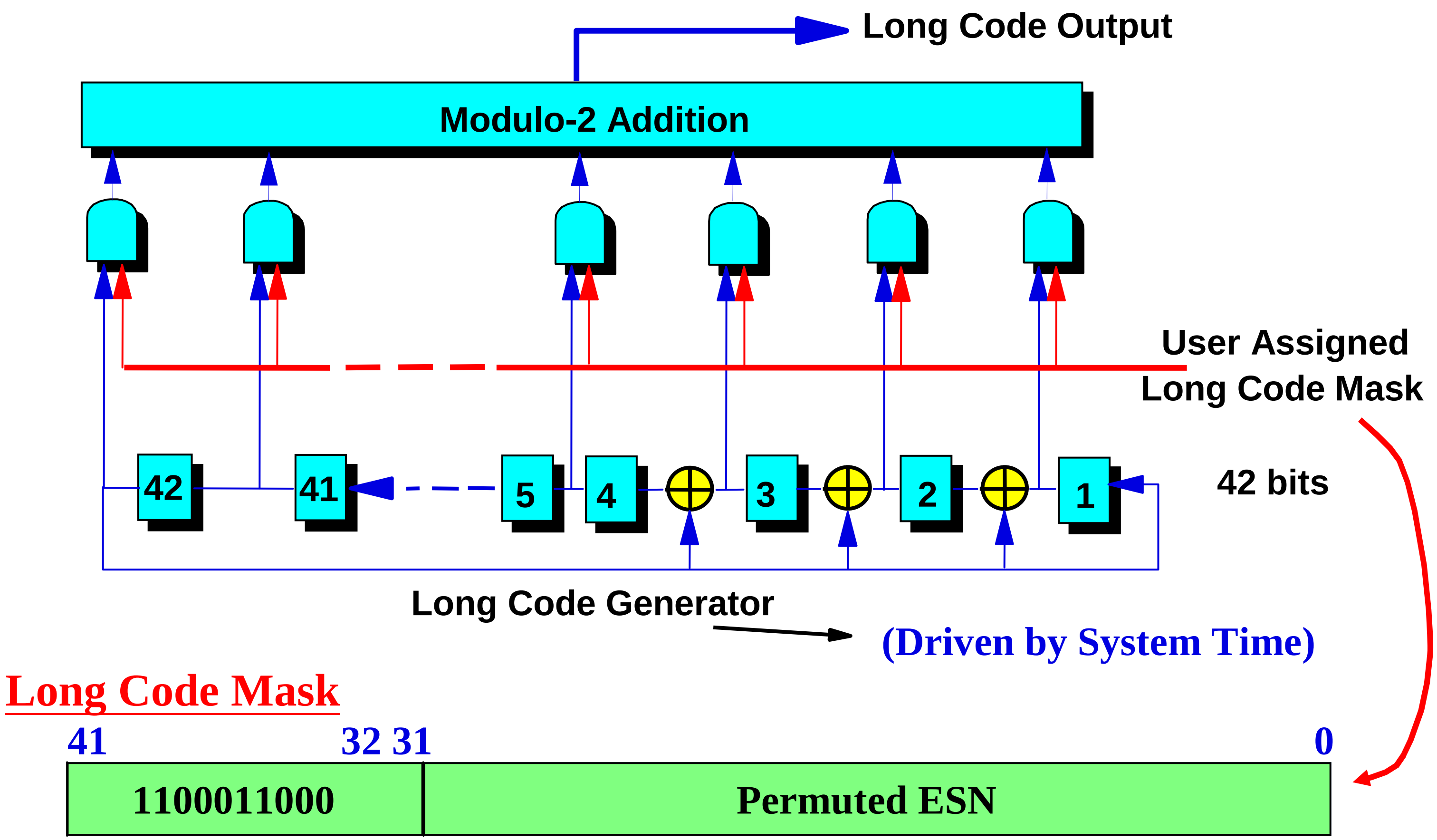
3G

Long Code Generation



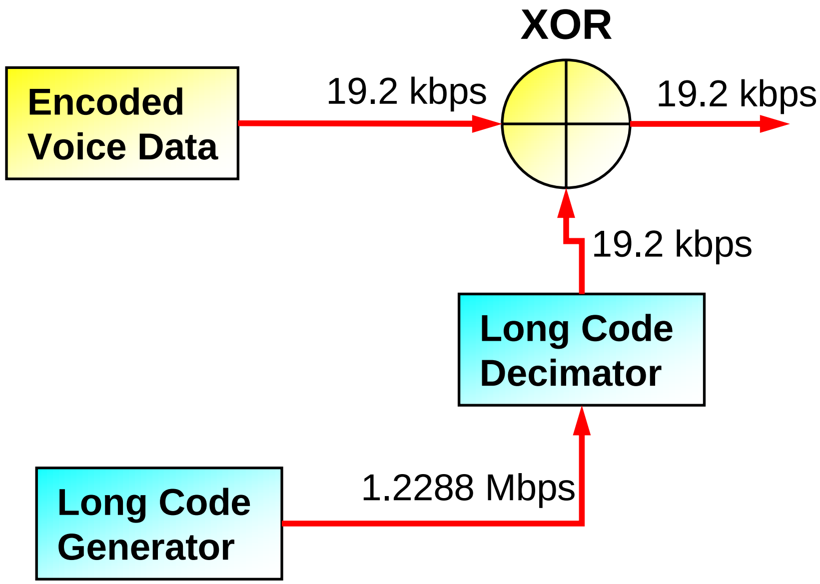
Agilent Technologies

Long Code Generation



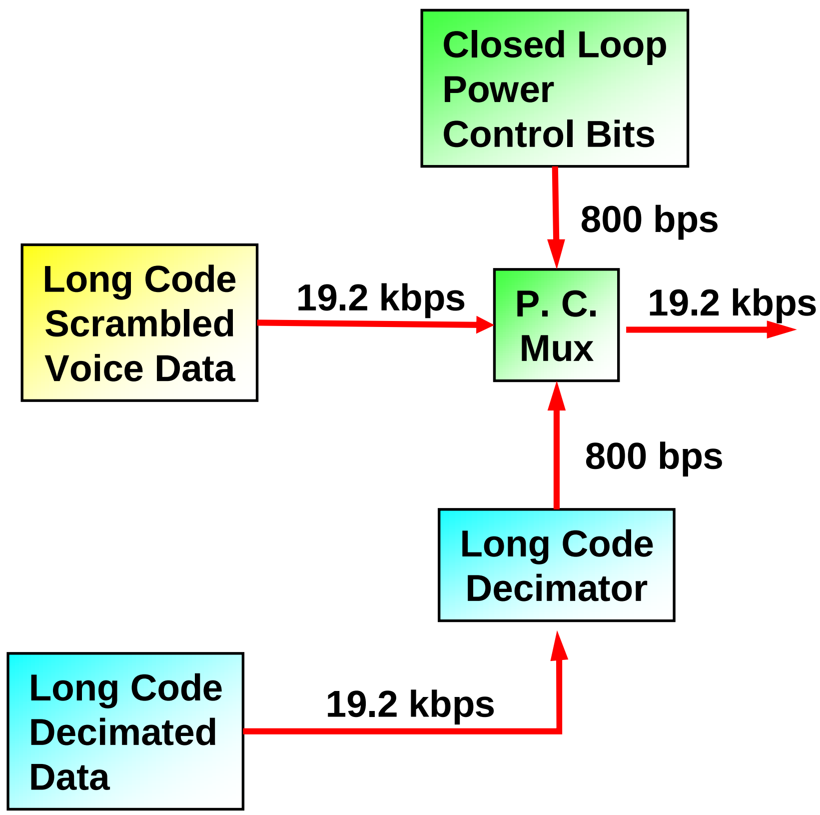
Long Code Scrambling

- User's Long Code Mask is Applied to the Long Code
- Masked Long Code is Decimated Down to 19.2 kbps
- Decimated Long Code is XOR'ed with Voice Data Bits
- Scrambles the Data to Provide Voice Security

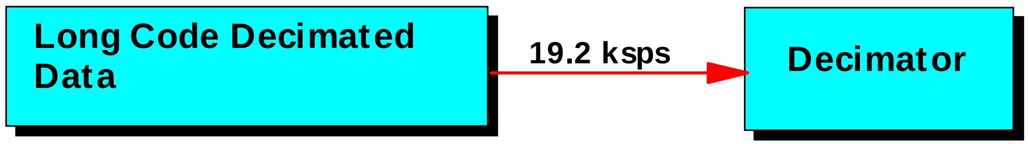


Closed Loop Power Control Puncturing

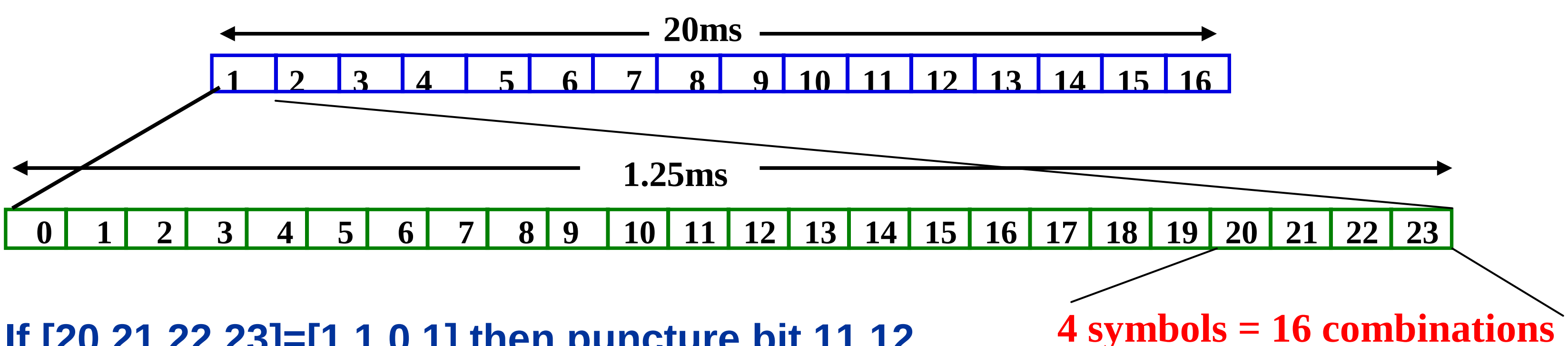
- Long Code is Decimated Down to 800 bps
- Decimated Long Code Controls the Puncture Location
- Power Control Bits Replace Voice Data
- Voice Data is Recovered by the Mobile's Viterbi Decoder



Power Control Bit Puncturing



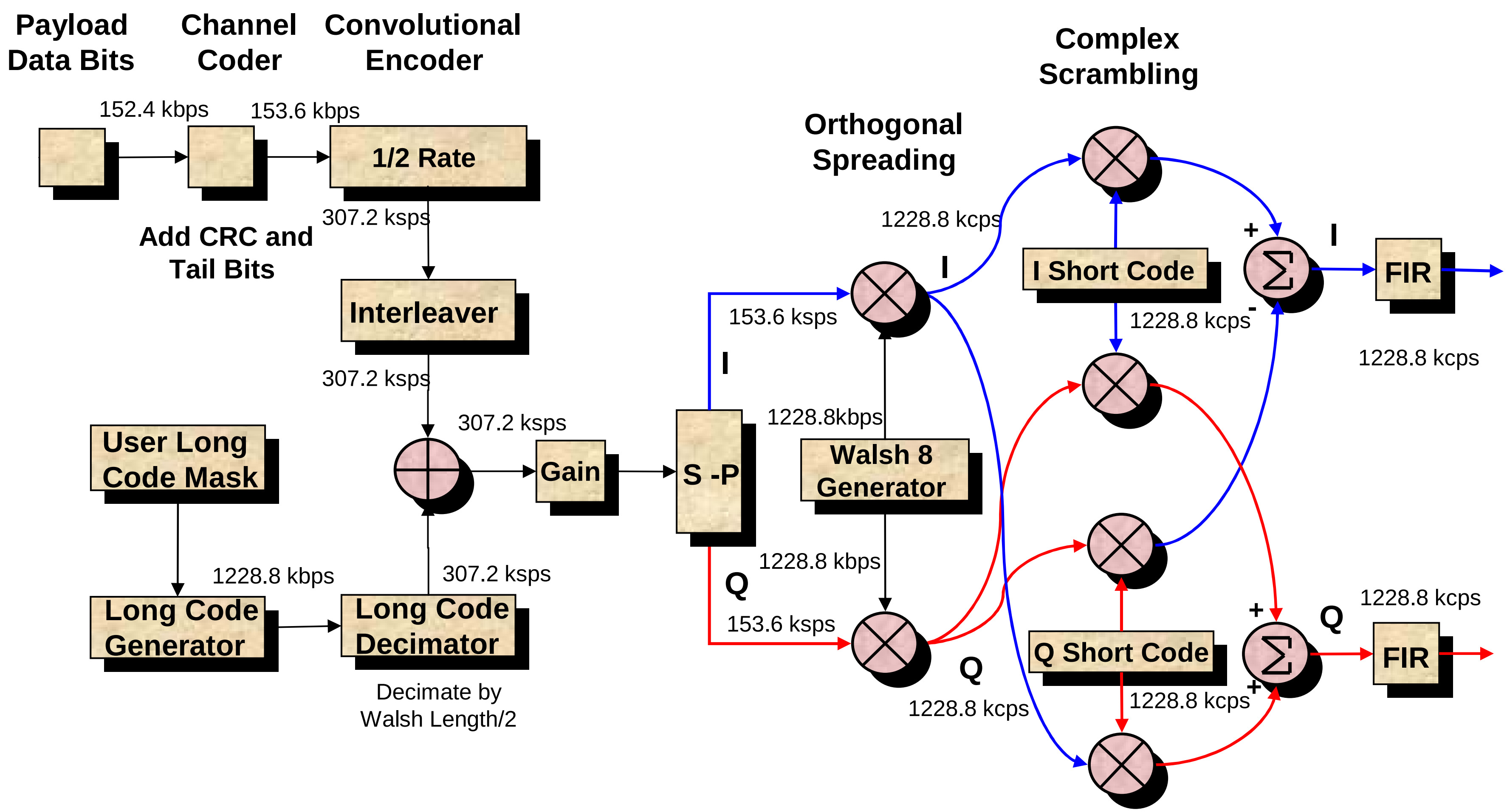
- 19.2 ksps: 384 symbols / 20ms frame
- Each 20ms frame is divided into 16 power control group (1.25 ms each)
- 24 modulation symbols in each power control group



If [20,21,22,23]=[1,1,0,1],then puncture bit 11,12

Agilent Technologies

SR1, RC4 (152.4 kbps) F-SCH



Walsh Codes

$$W_{2n} = \begin{bmatrix} W_n & W_n \\ W_n & \overline{W_n} \end{bmatrix}$$

$$W_1 = 0$$

$$W_2 = \begin{matrix} 0 & 0 \\ 0 & 1 \end{matrix}$$

$$W_4 = \begin{matrix} 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 1 \\ 0 & 1 & 1 & 0 \end{matrix}$$

Checking for Orthogonality

$$\text{Cross Correlation} = \frac{N_{agreements} - N_{disagreements}}{N_{total\_number\_of\_digits}}$$

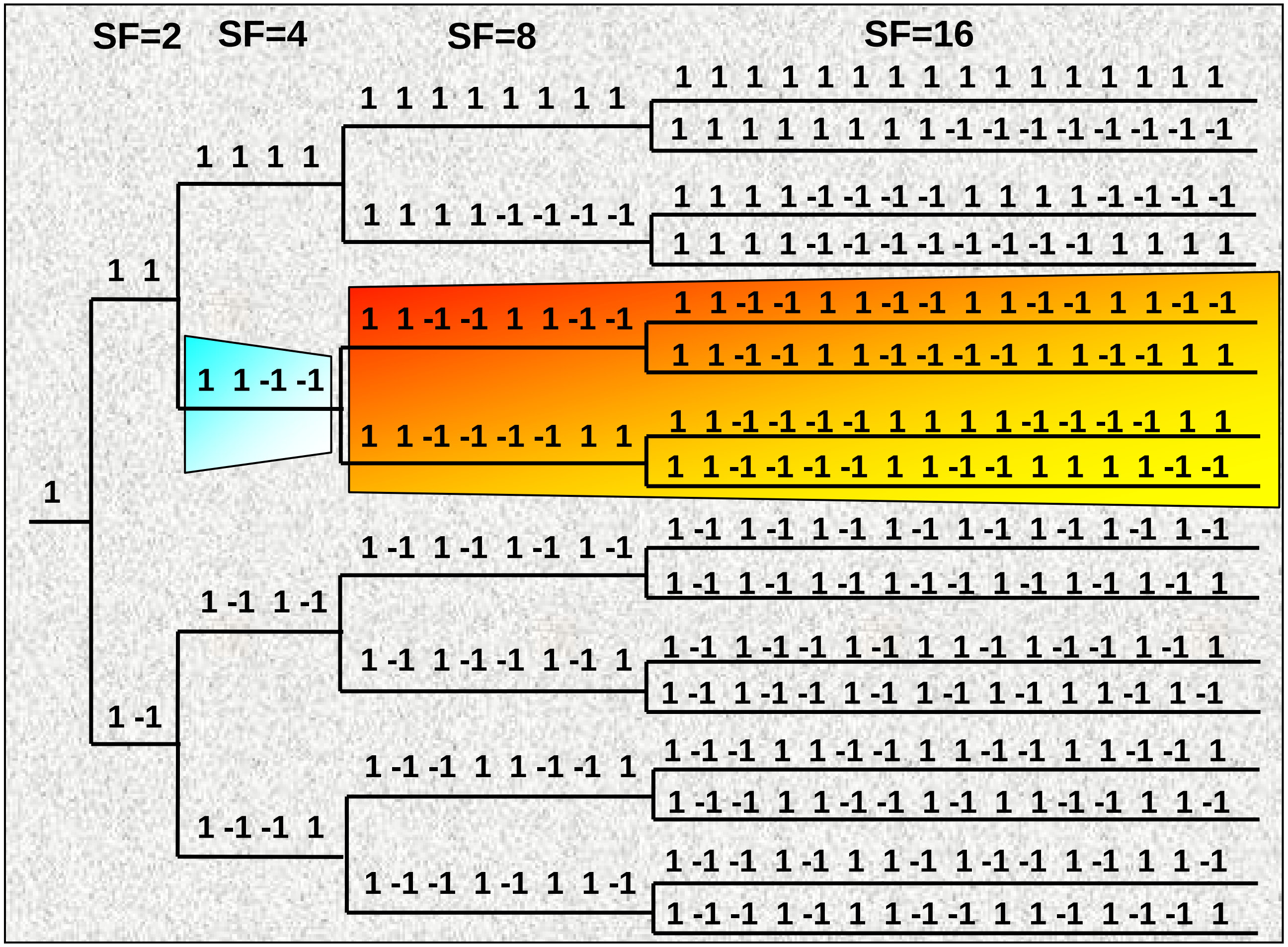
$$W_4 = \begin{matrix} 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 1 \\ 0 & 1 & 1 & 0 \end{matrix}$$

0	0	0	0
0	0	1	1
Y	Y	N	N

2 Match - 2 don't = 0

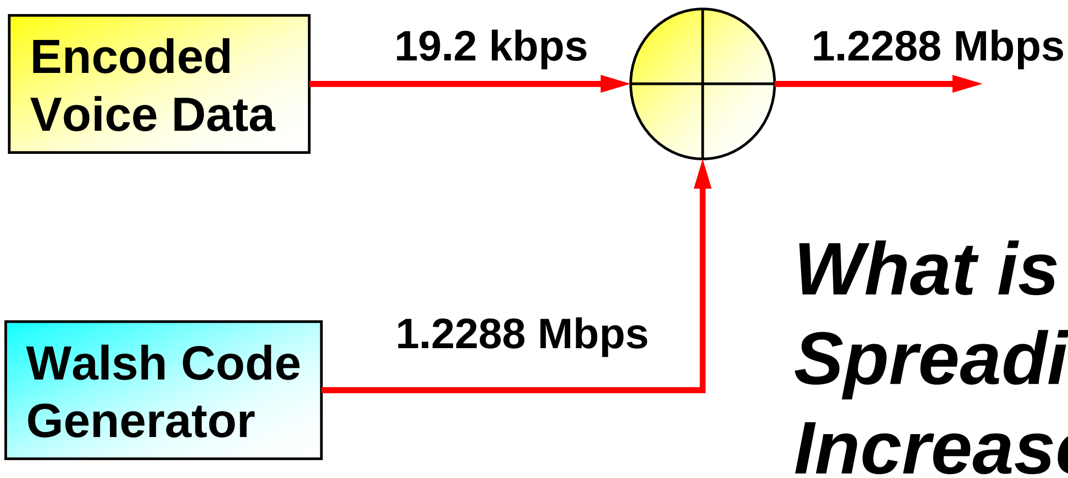
Effects of Using Variable Length Walsh Codes for Spreading

- Using Shorter Walsh Codes Precludes Using all Longer Codes Derived from the Original
- Shorter Codes on a Branch map into Longer Codes



Agilent Technologies

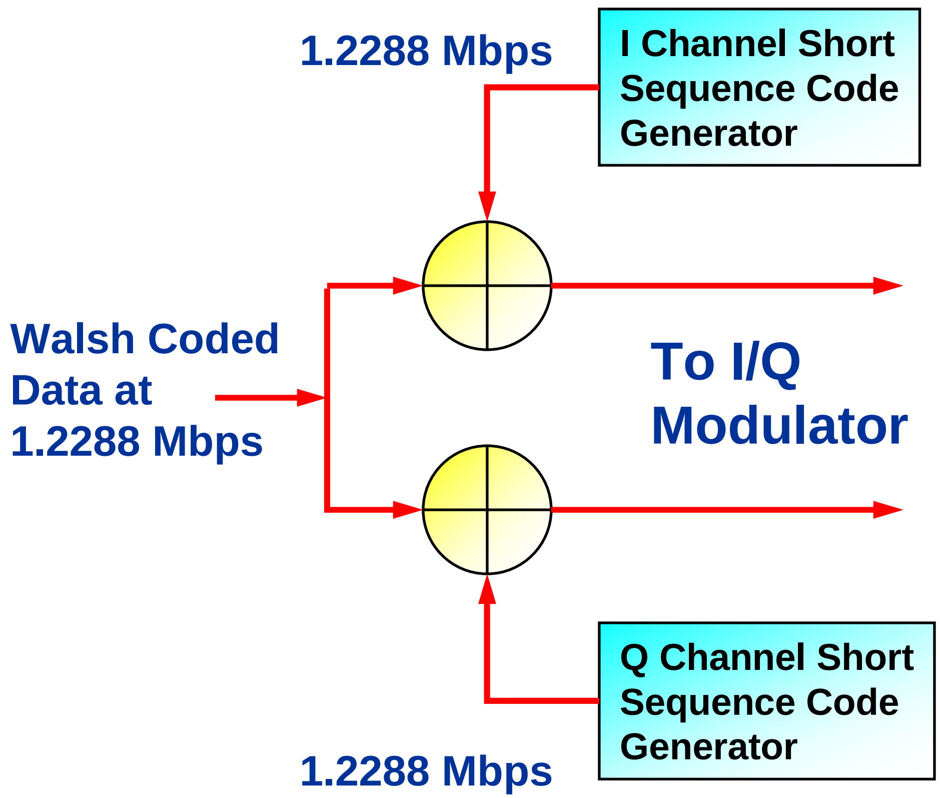
Walsh Code Spreading



What is the Spreading Rate Increase ?

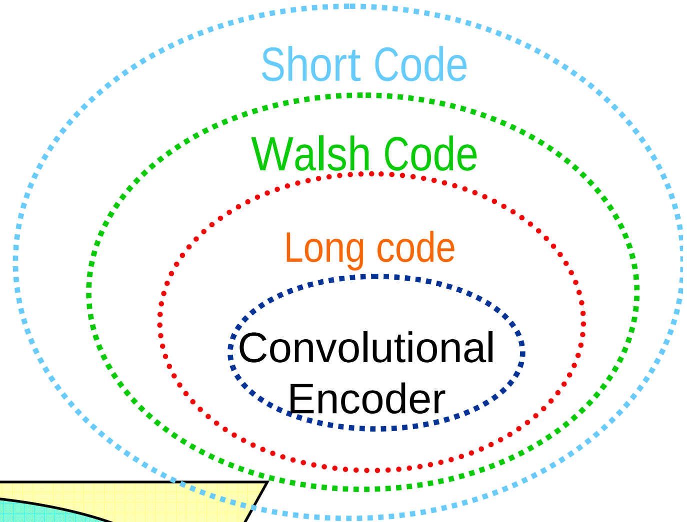
Why Spread Again with the Short Sequence

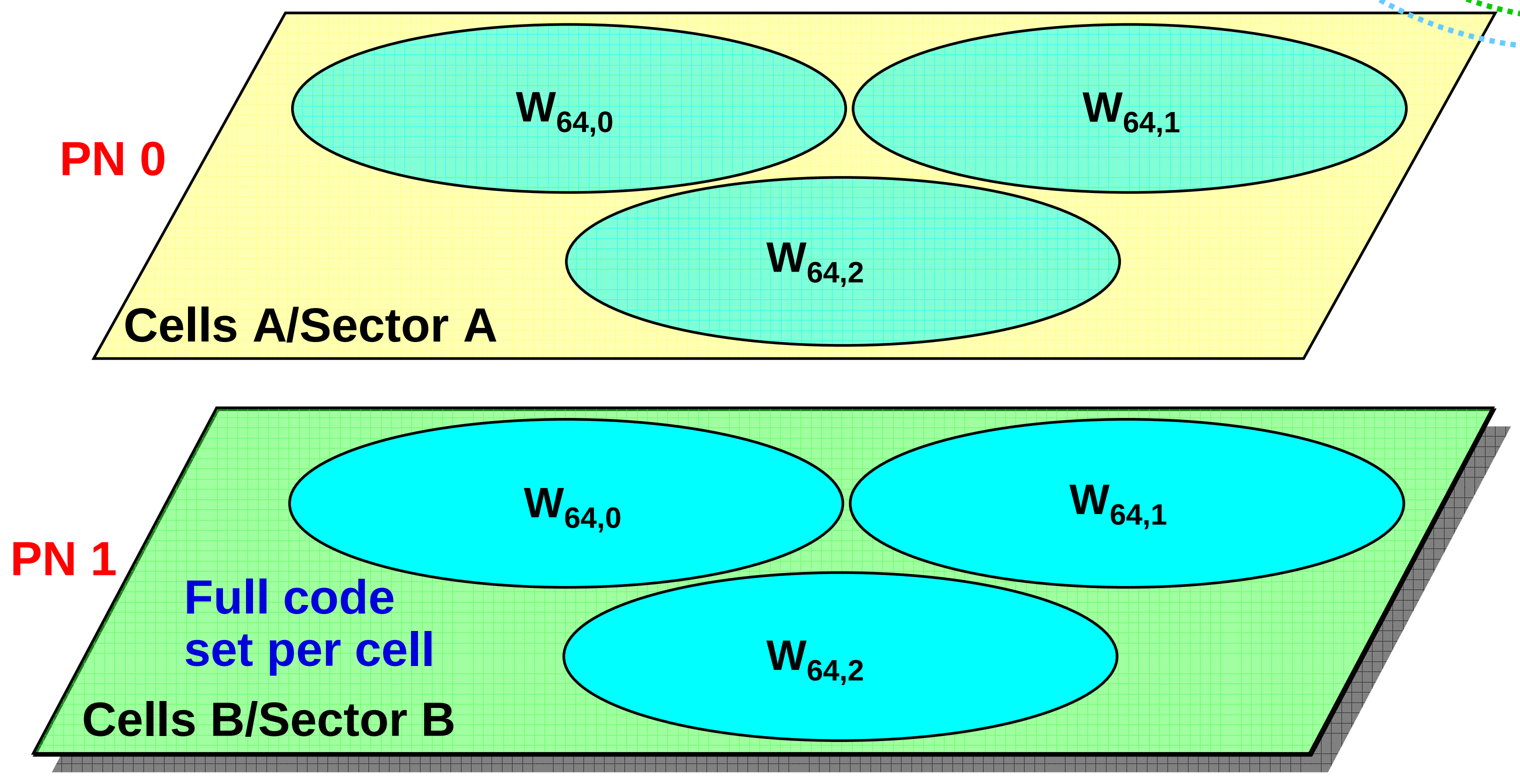
- Provides a Cover to Hide the 64 Walsh Codes
- Each Base Station is Assigned a Time Offset in its Short Sequences
- Time Offsets Allow Mobiles to Distinguish Between Adjacent Cells
- Also Allows Reuse of All Walsh Codes in Each Cell



Multi-Layer Code Assignment

CDMA as an Onion





Walsh Code layer (spreading code)

Short Code (PN) Generation

- PN sequence codes are generated using 15-bit shift registers
- PN sequence pattern repeats every 26.666 ms
- 75 PN sequences repetition occur every 2 seconds
- On every even second clock, MS will get PN sequence initial state

Jan 6, 1980 00:00:00

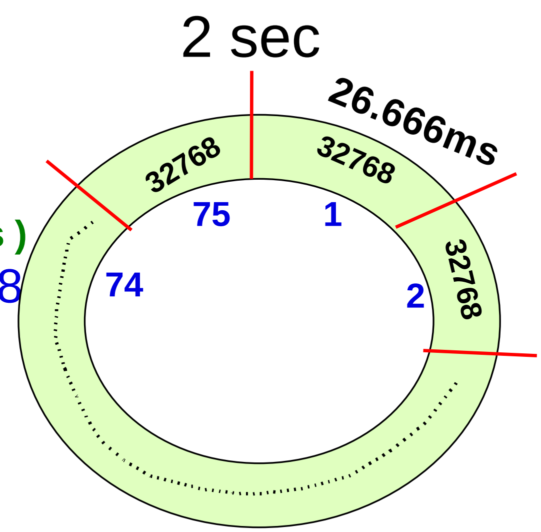
R1,R2,R3,R4.........R15

1, 0, 0, 0............. 0 (initial state of 15 registers)

PN Code Combinations: $2^{15} = 32768$

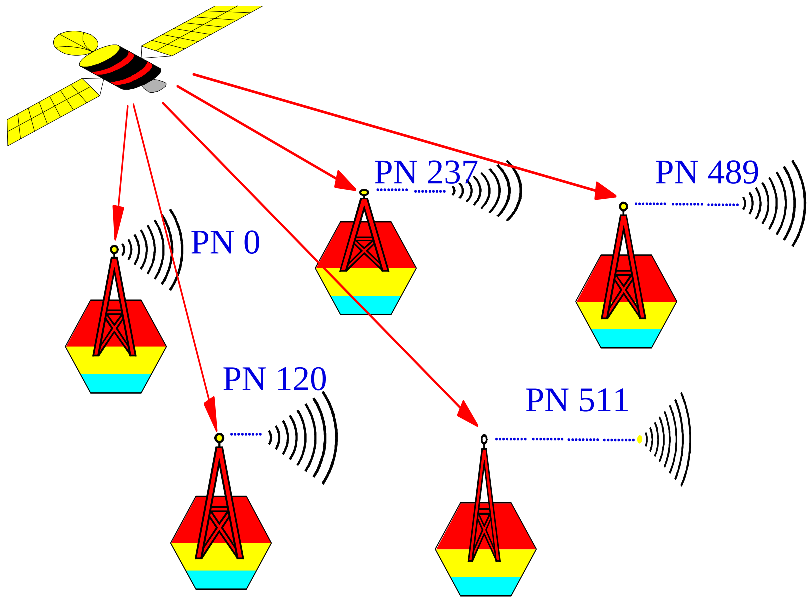
Clock Rate = 1.2288 Mcps

Return of Initial State = 26.666 ms



PN Offsets

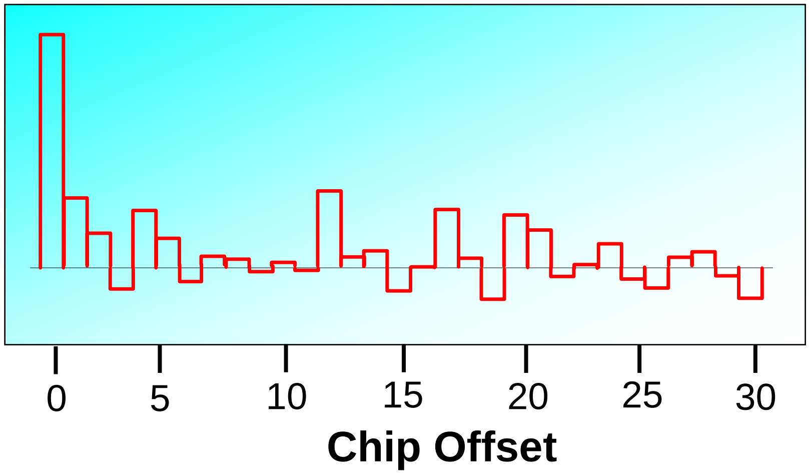
- Each BS scrambles PN sequence with data by some time offset
- Time offsets are in intervals of 64 clock chips (52.08 us) from even second clock
- 512 unique offsets are created (32768/64 = 512)
- Each BS is allotted an offset for PN sequence scrambling



Short Code Correlation

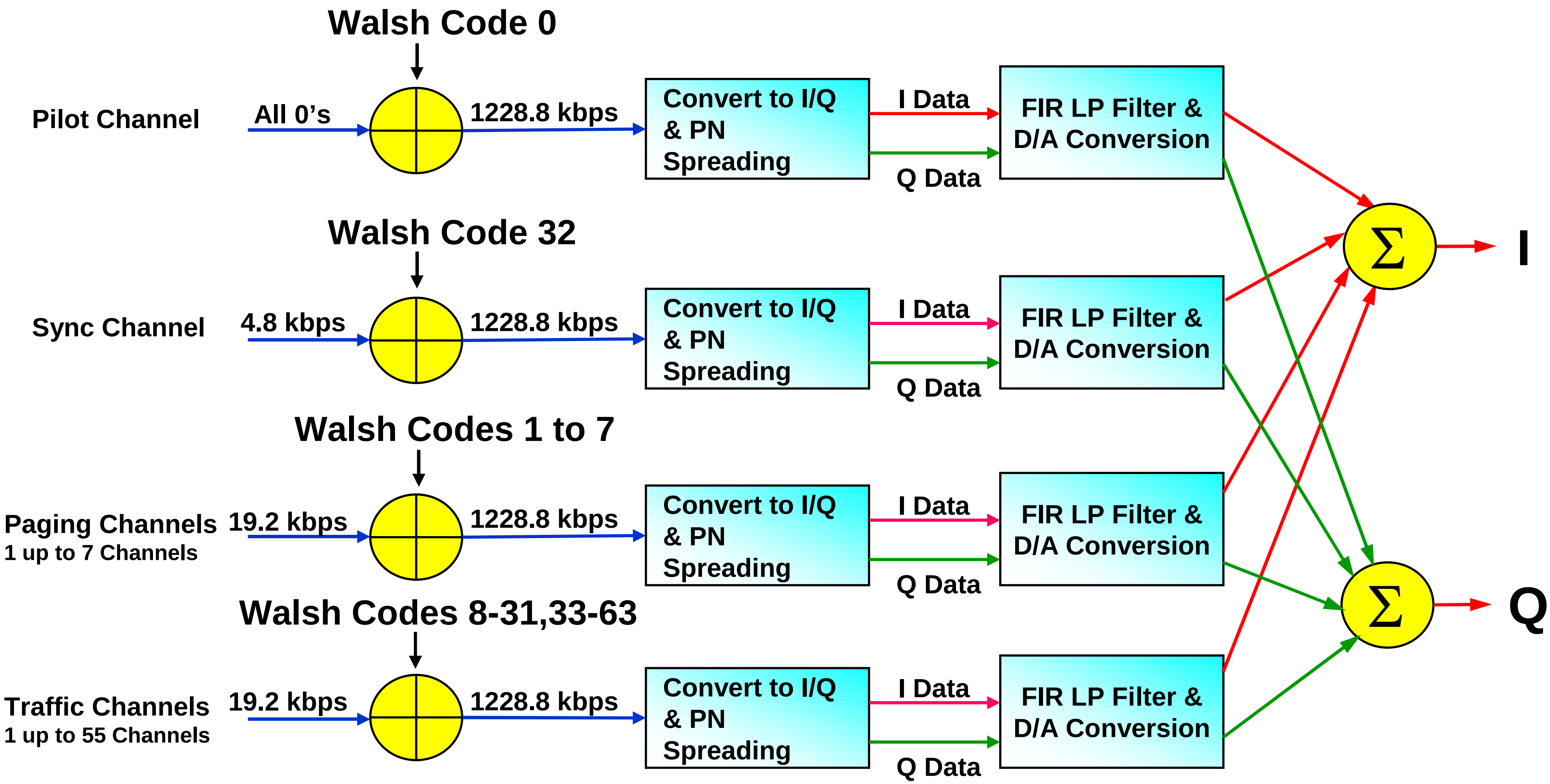
- Short Codes are Designed to Have:
  - Strong Auto-Correlation at Zero Time Offset
  - Weak Auto-Correlation at Other Offsets
  - Good Auto-Correlation in Very Poor Signal-to-Noise Ratio Environments
- Allows Fast Acquisition in Real World Environment

Auto-Correlation Versus Time Offset With 17 dB Noise Added

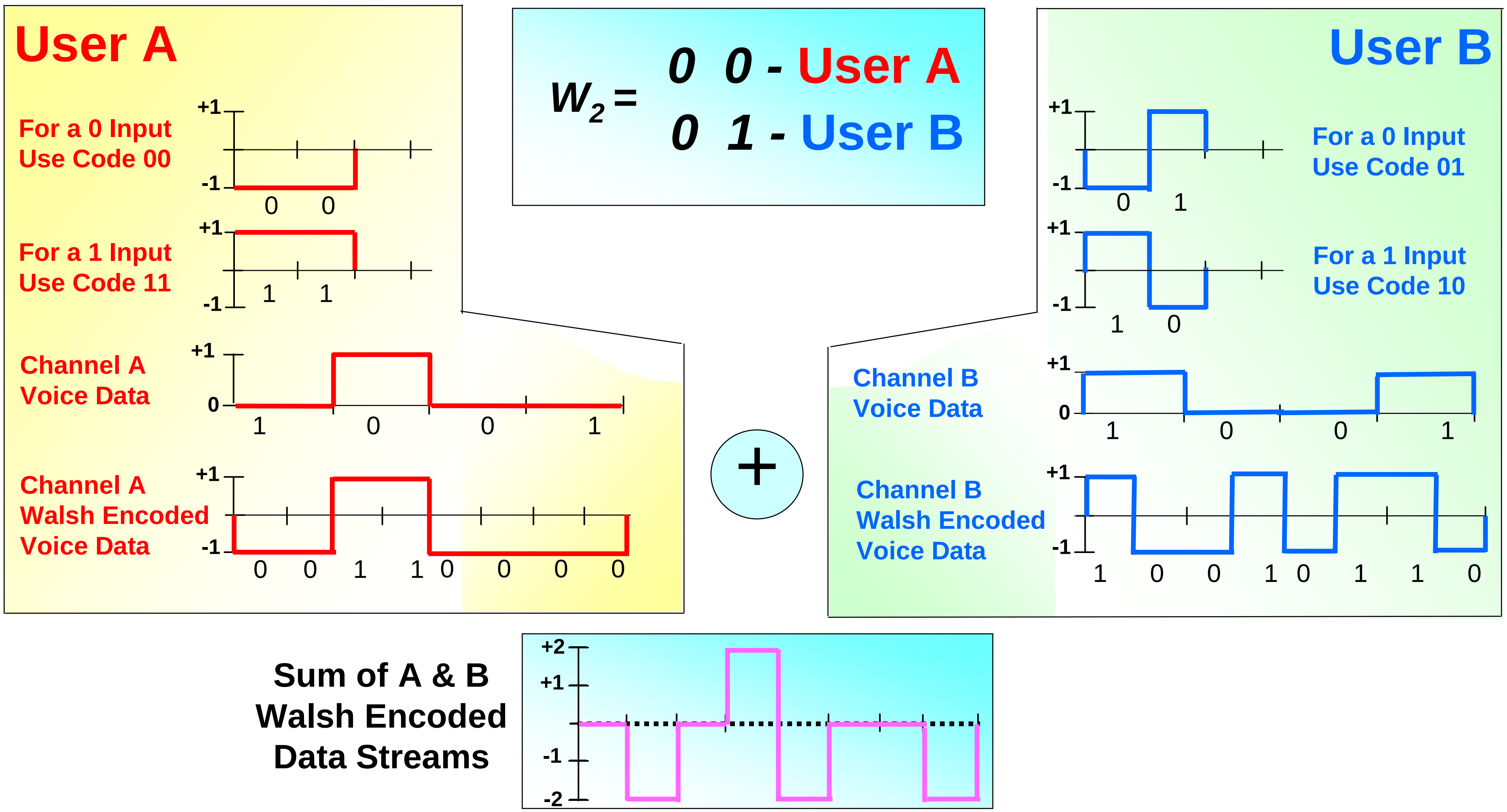


Agilent Technologies

Forward Link Channel Format



Walsh Coding Example

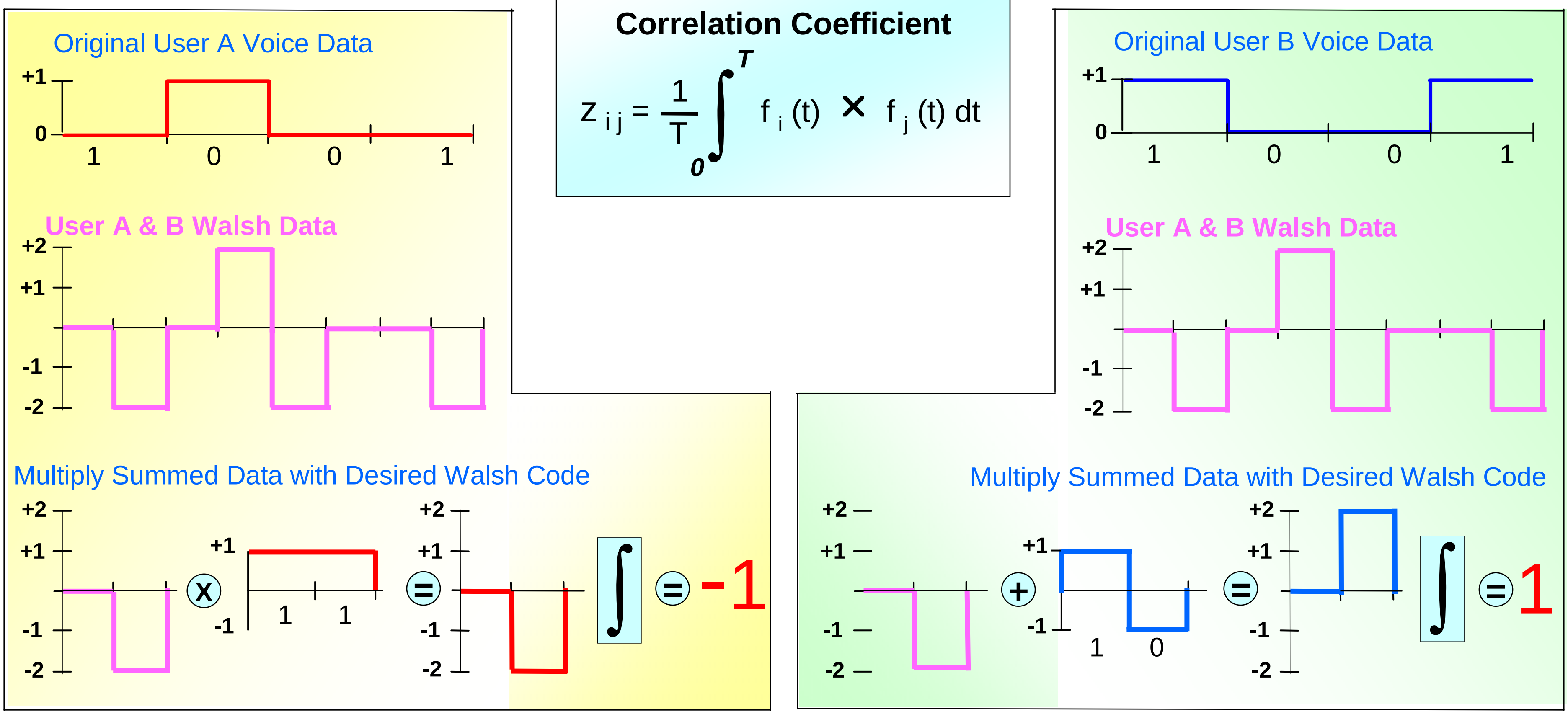


Agilent Technologies

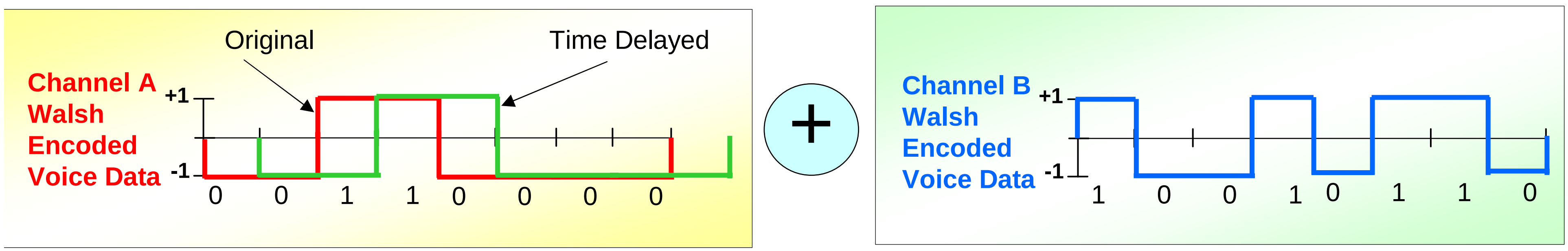
Walsh Decoding Example

Correlation Coefficient

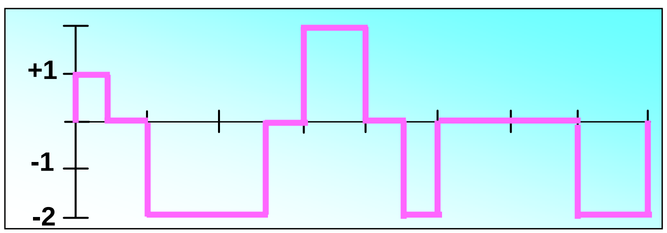
$$Z_{ij} = \frac{1}{T}\int_{0}^{T} f_i(t) \times f_j(t)\,dt$$

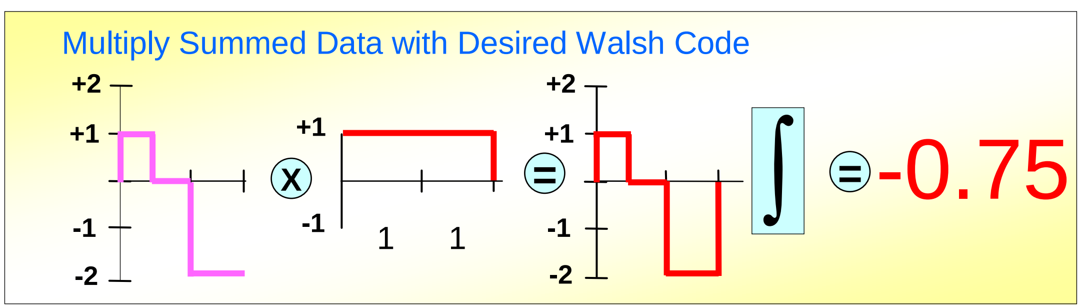


What if Walsh Codes are Not Time Aligned ?



Sum of A & B Walsh Encoded Data Streams

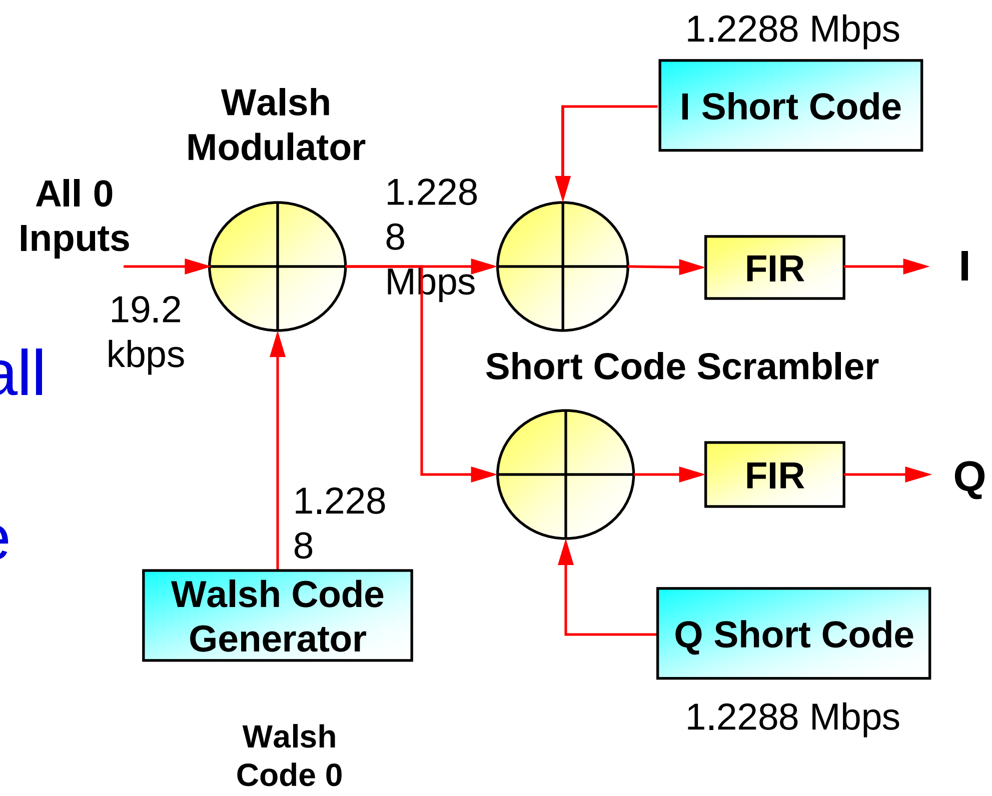




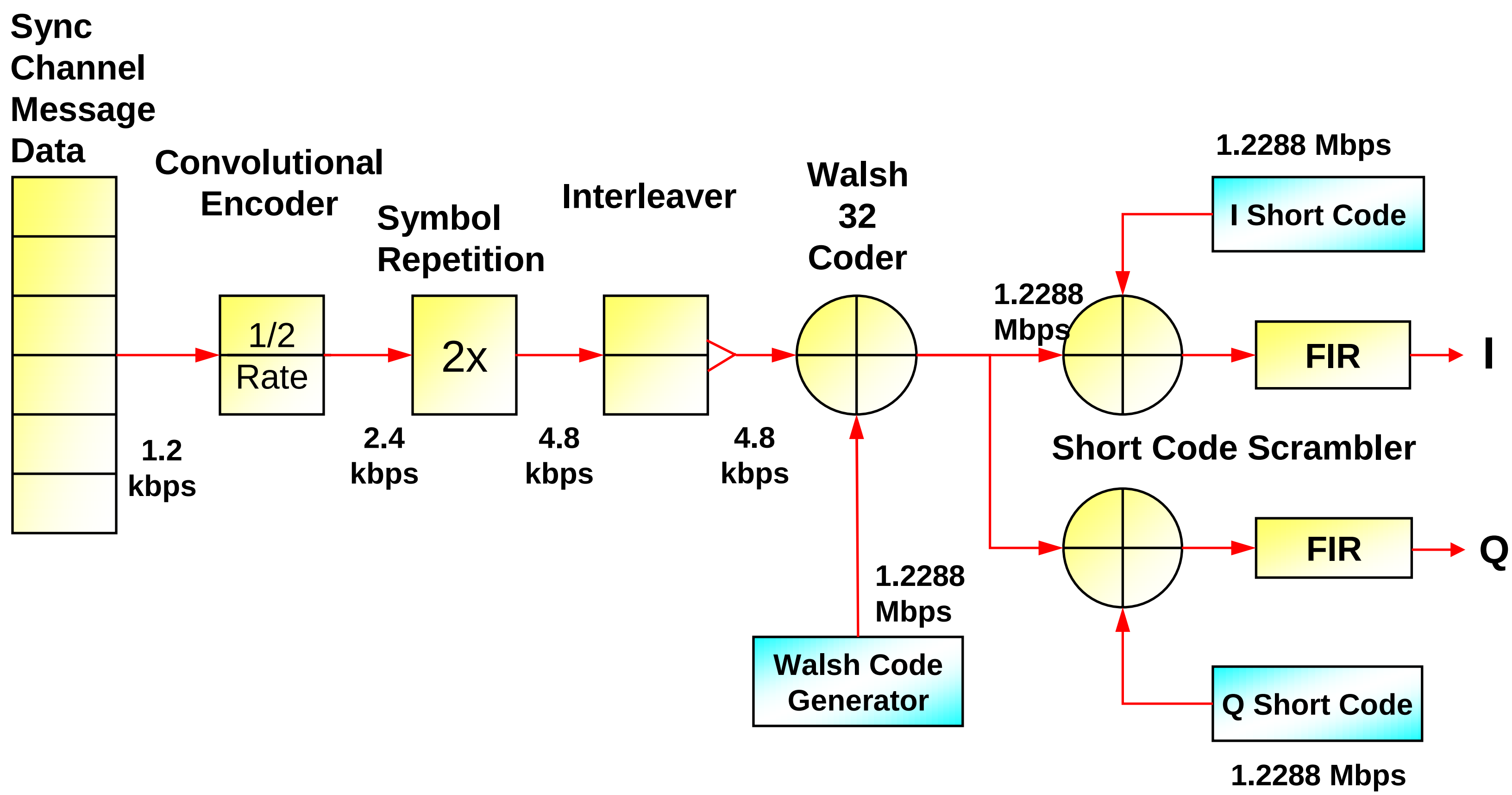
Original Data Was 0 (-1), We Have Interference Now!

Pilot Channel Physical Layer

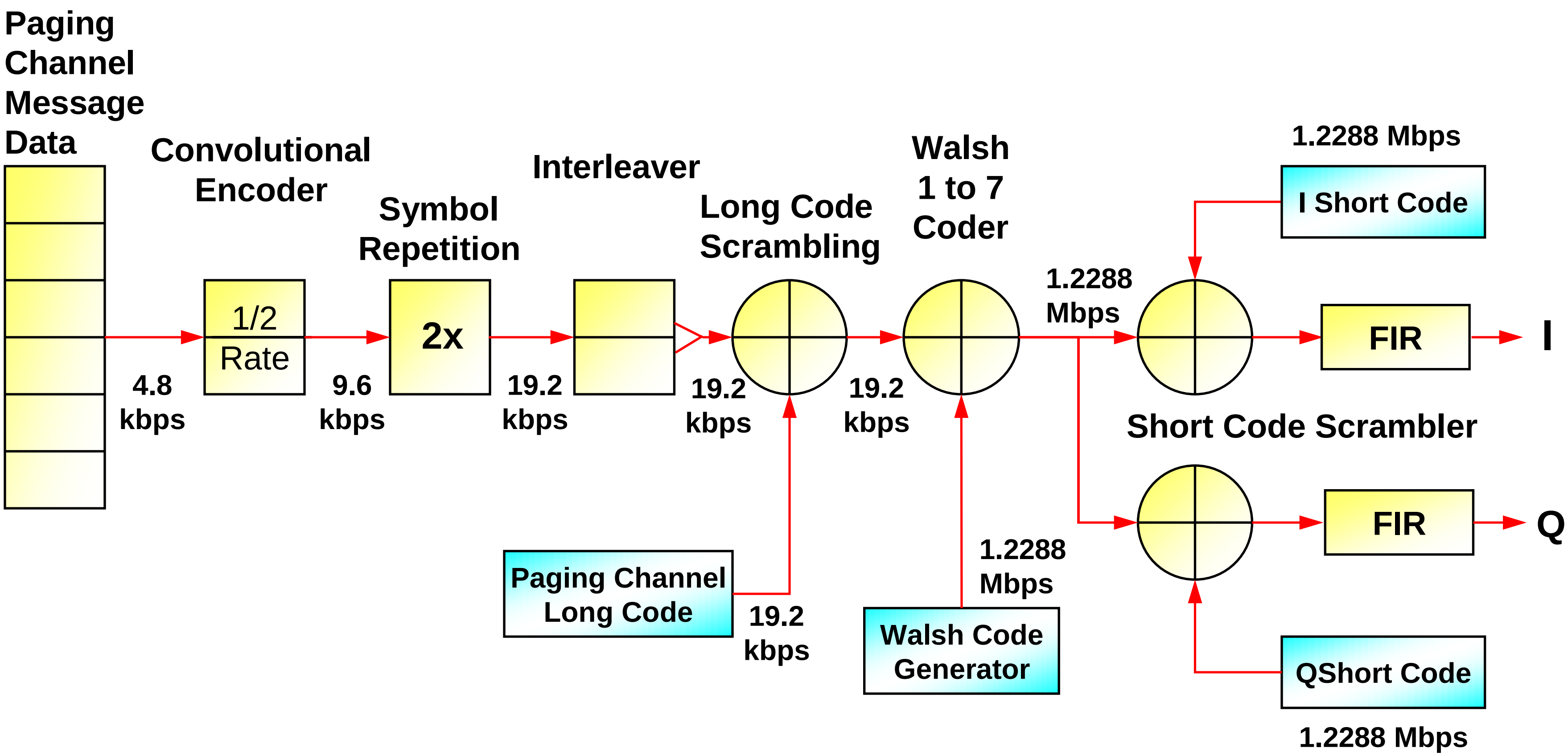
- Uses Walsh Code 0:
  - All 64 bits are 0
- All Data into Walsh Modulator is 0
- Output of Walsh Modulator is therefore all 0's
- Pilot Channel is just the Short Codes



Sync Channel Physical Layer



Paging Channel Physical Layer



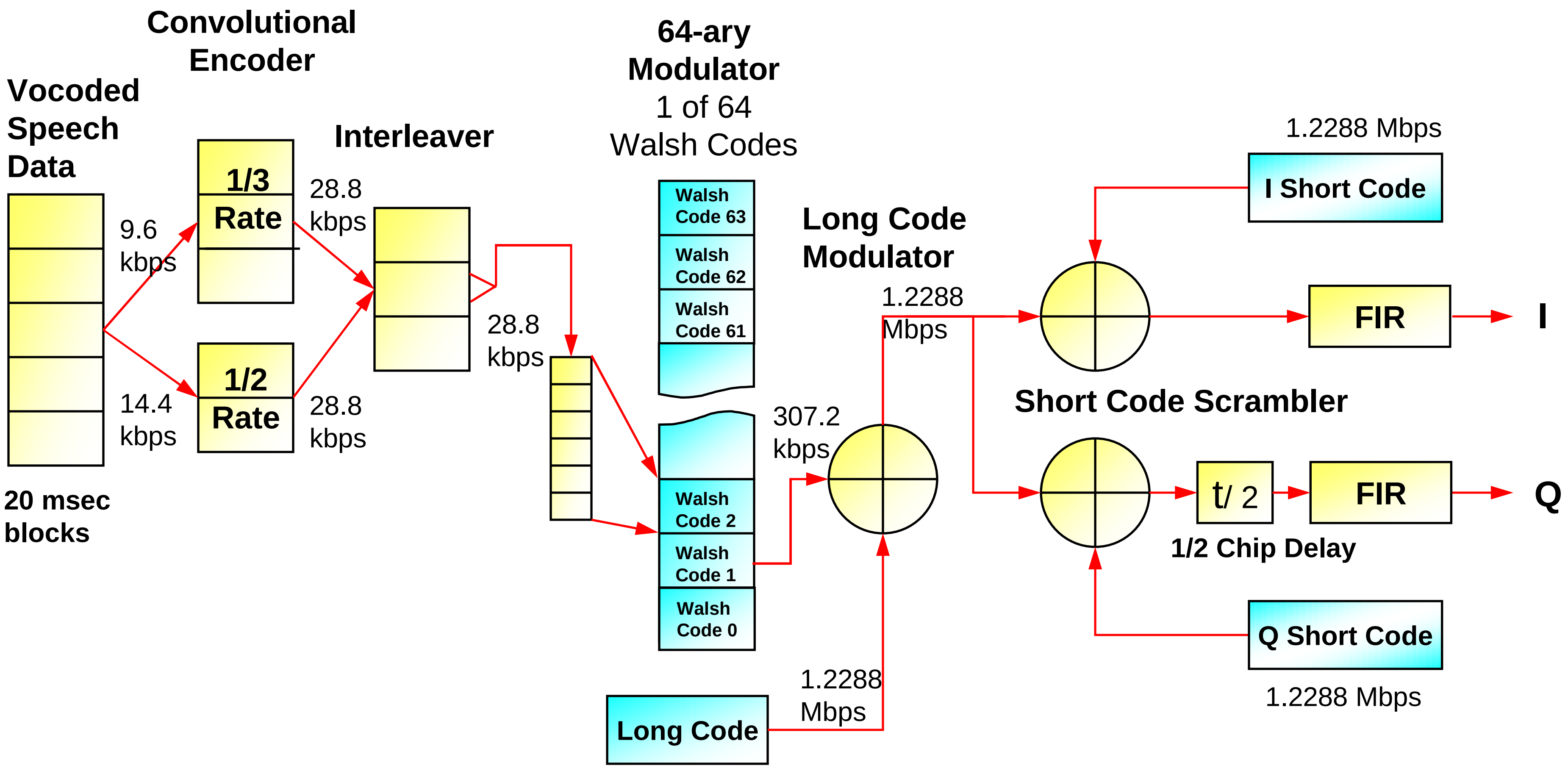
SR1 Reverse Radio Configurations

- Radio Configuration 1 - Required
  - ✓ ***Backwards compatible mode with TIA/EIA-95-B***
  - ✓ ***Based on 9,600 bps Traffic***
- Radio Configuration 2
  - ✓ ***Backwards compatible mode with TIA/EIA-95-B***
  - ✓ ***Based on 14,400 bps Traffic***
- Radio Configurations 3 and 4
  - ✓ ***All use new IS-2000 coding for improved capacity***
  - ✓ ***RC3 is based on 9,600 bps and goes up to 307,200 bps***
  - ✓ ***RC4 is based on 14,400 bps and goes up to 230,400 bps***

SR1 Reverse Channels

- Each Mobile Transmits Several Channels:
  - ***1 R-Pilot*** (Reverse Pilot)
    - ***Includes Power Control Sub-Channel***
  - ***1 R-ACH or R-EACH*** (Access or Enhanced Access Channel)
    - ***Used to Initiate Calls***
  - ***0 or 1 R-CCCH*** (Common Control Channel)
    - ***Used to Initiate Calls in the Reservation Access Mode***
  - ***0 or 1 R-DCCH*** (Dedicated Control Channel)
    - ***Provides Signaling while a Traffic Channel is Active***
  - ***0 or 1 R-FCH*** (Reverse Fundamental Channel)
    - ***Primary Channel, usually Voice***
  - ***0 to 2 R-SCHs*** (Reverse Supplemental Channels)
    - ***Carries High Speed Data***

R-FCH Coding for SR1(RC1,RC2)

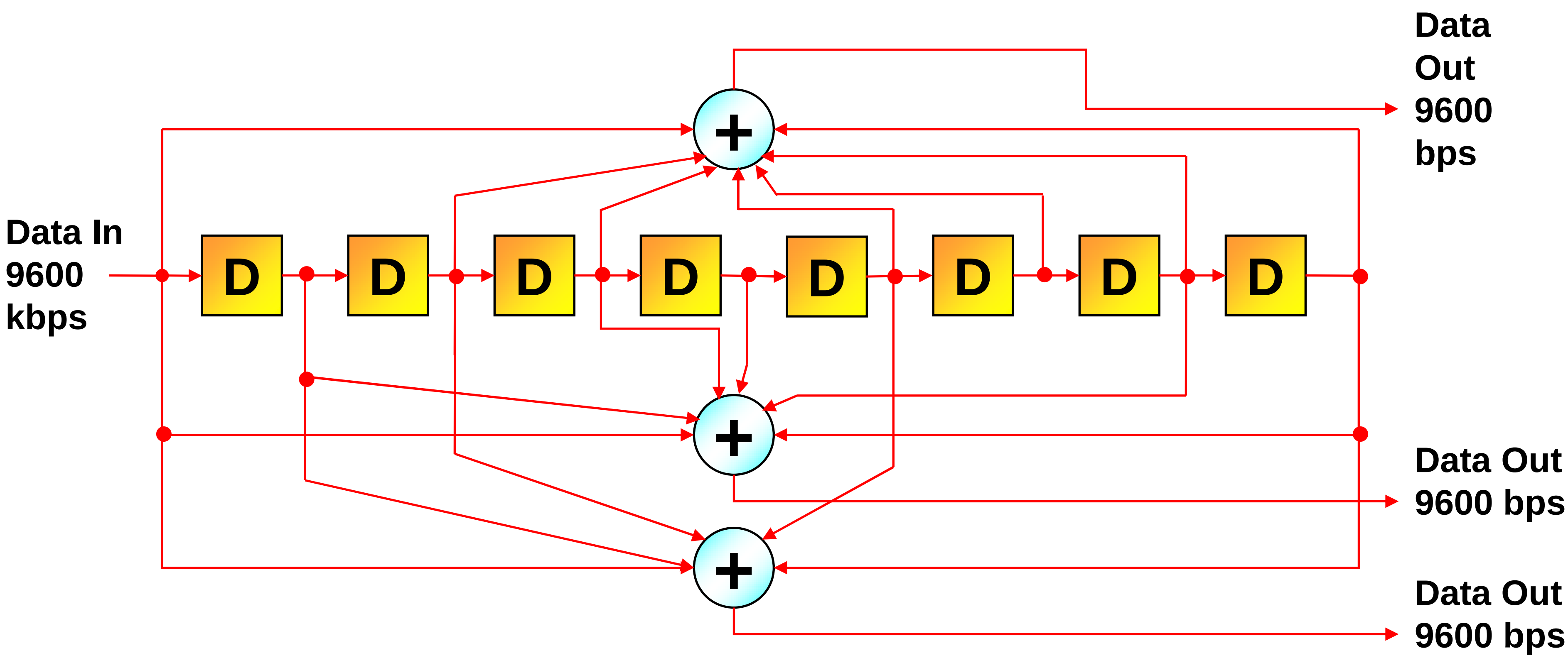


Agilent Technologies

3G

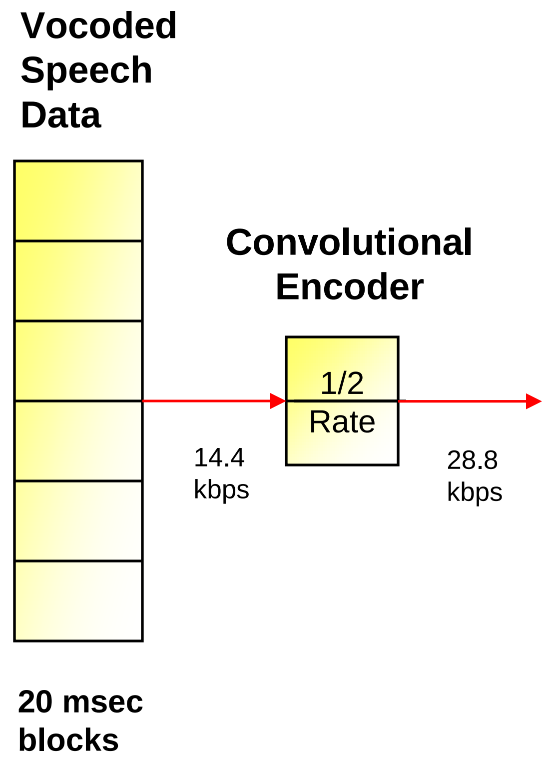
Reverse Error Protection

- Uses Third-Rate Convolutional Encoder
- Outputs Three Bits for Every Input Bit



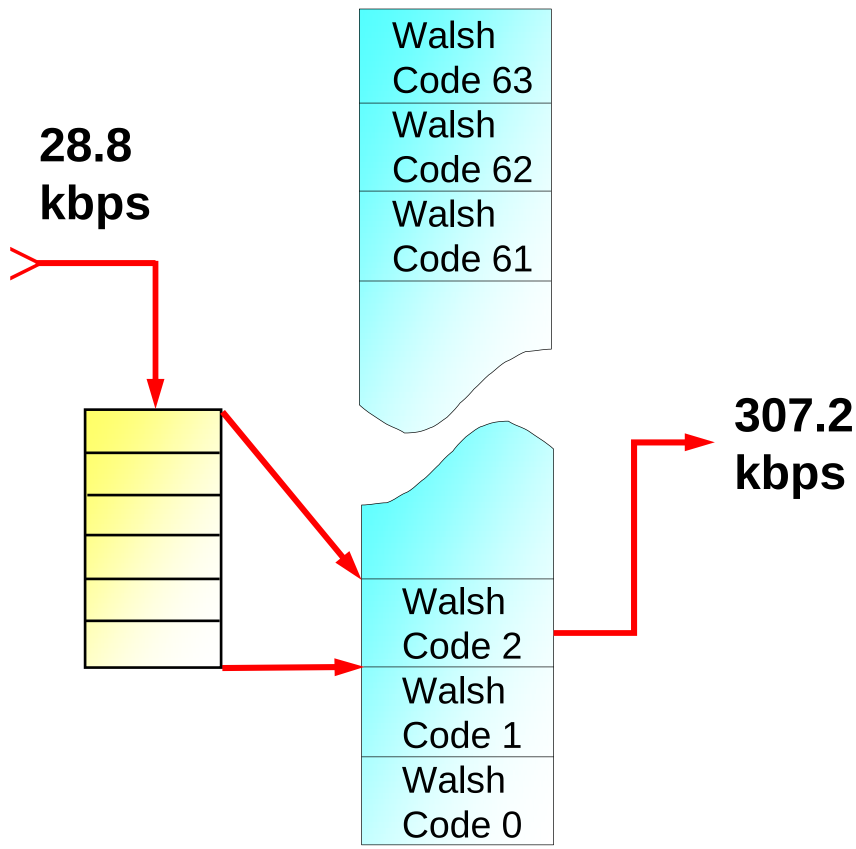
14.4 Traffic Channel Reverse Link Modifications

- Replaces 8 kbps Vocoder with a 13 kbps Vocoder (both Variable Rate)
- Effects:
  - Provides Toll Quality Speech
  - Uses a 1/2 Rate Encoder
  - Reduces Processing Gain 1.76 dB
  - Results in Reduced Capacity or Smaller Cell Sizes



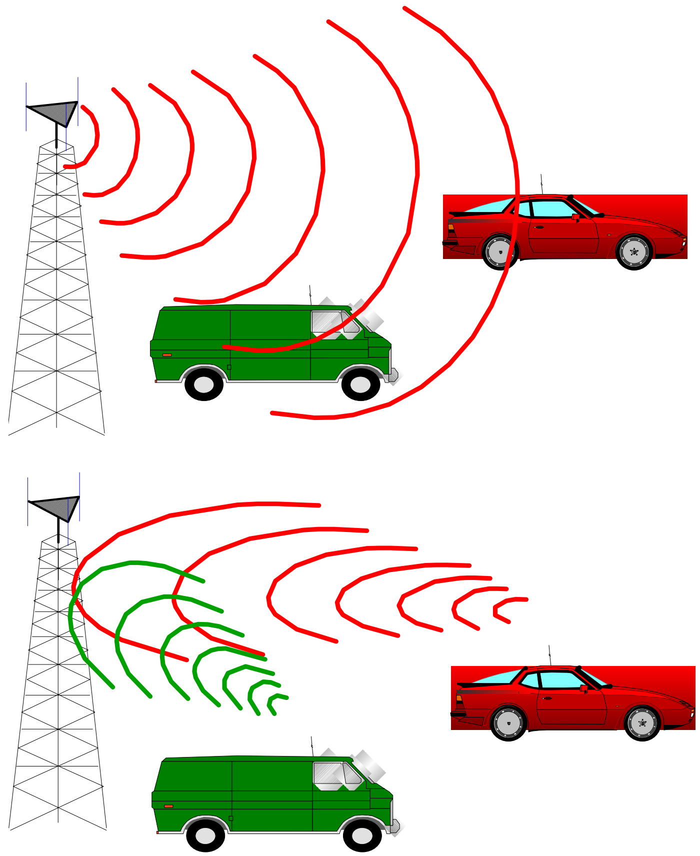
64-ary Modulation

- Every 6 Encoded Voice Data Bits Points to one of the 64 Walsh Codes
- Spreads Data from 28.8 kbps to 307.2 kbps
  - ➢ (28.8 kbps * 64 bits) / 6 bits = 307.2 kbps)
- Is Not the Channelization for the Reverse Link



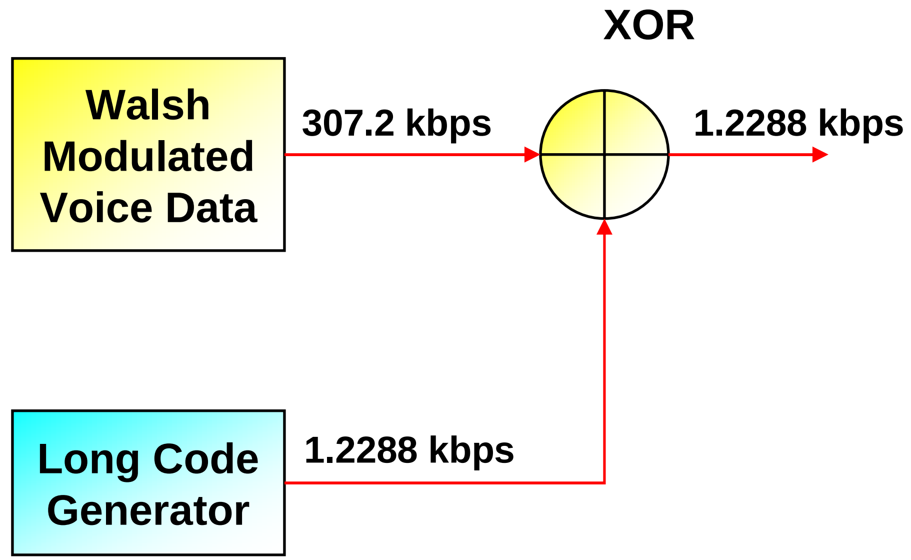
Why Aren't Walsh Codes Used for Reverse Channelization ?

- All Walsh Codes Arrive Together in Time to All Mobiles From the Base Station
- However, Transmissions from Mobiles DO NOT Arrive at the Same Time at the Base Station

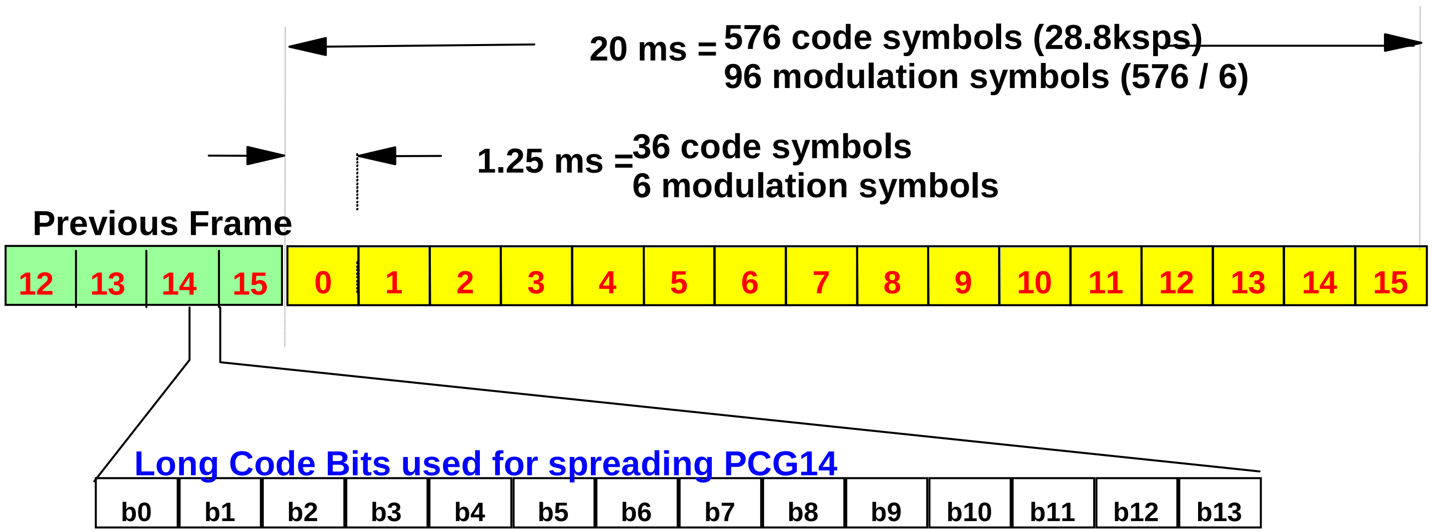


Reverse Channel Long Code Spreading

- Long Code Spreading Provides Unique Mobile Channelization
- Mobiles are Uncorrelated but not Orthogonal with Each Other



Data Burst Randomizer



Algorithm

At 4800 bps rate,

Transmission should occur on the PCG's numbered:

b0, 2 + b1, 4 + b2, 6 + b3, 8 + b4,10 + b5, 12 + b6, 14 + b7

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

(Example)

(50% Gated-On, 50% Gated-Off)

Agilent Technologies

Data Burst Randomizer

Algorithm

At 2400 bps rate ,

Transmission should occur on the PCG's numbered:

b0 if b8 = 0, or 2 + b1 if b8 = 1 (i.e. 1 out of PCG 0...3)
4 + b2 if b9 = 0, or 6 + b3 if b9 = 1 (i.e. 1 out of PCG 4...7)
8 + b4 if b10 = 0, or 10 + b5 if b10 = 1 (i.e. 1 out of PCG 8...11)
12+b6 if b11 = 0, or 14 + b7 if b11 = 1 (i.e. 1 out of PCG 12..15)

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	**(Example)**

(25% Gated-On, 25% Gated-Off)

At 1200 bps rate ,

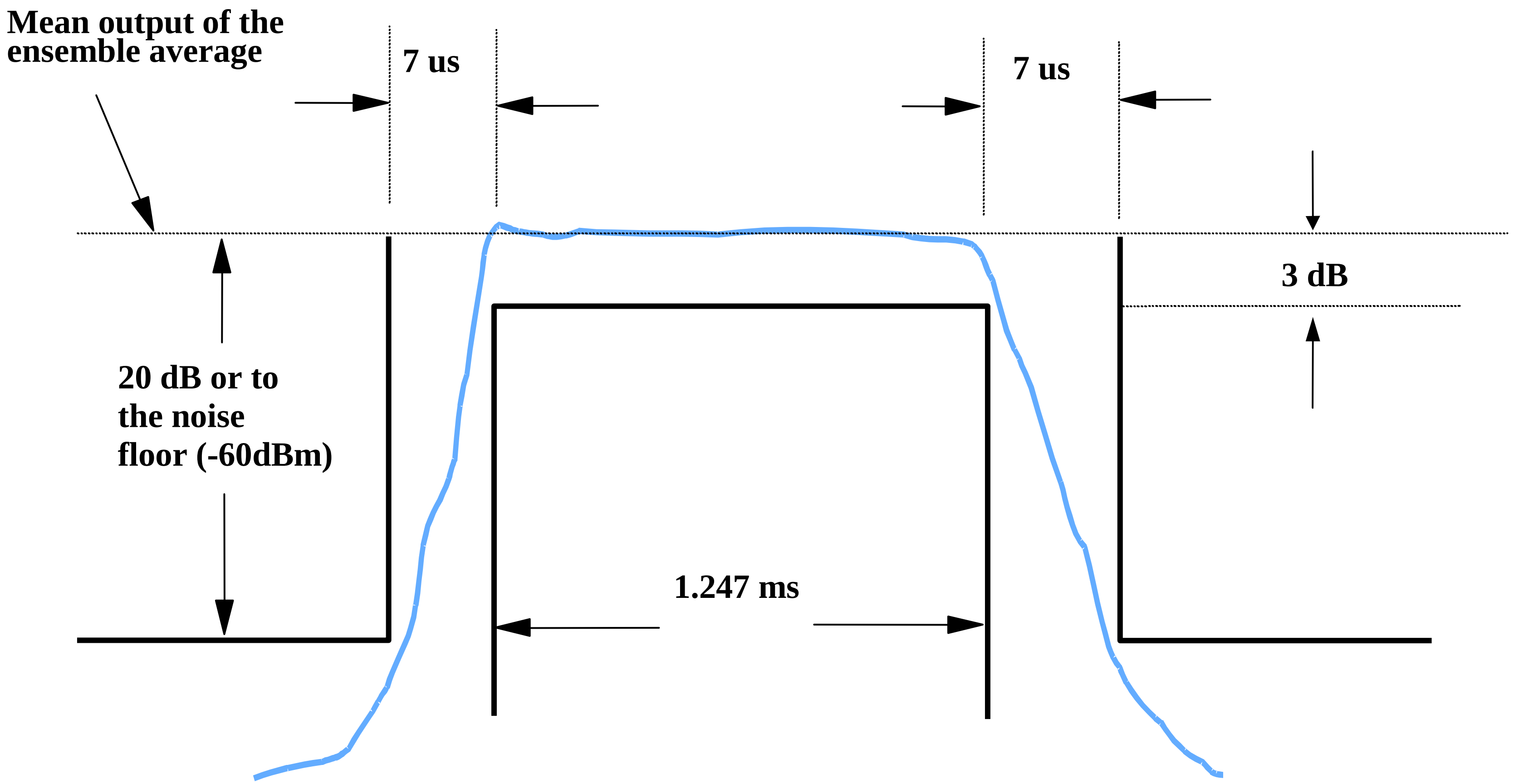
Transmission should occur on the PCG's numbered:

b0 if (b8 = 0 and b12=0), or 2 + b1 if (b8 = 1 and b12=1)
or 4 + b2 if (b9 = 0 and b12=0), or 6 + b3 if (b9 = 1 and b12=1) (i.e. 1 out of PCG 0...7)
8 + b4 if (b10 = 0 and b13=0), or 10 + b5 if (b10 = 1 and b13=1)
or 12 + b6 if (b11 = 0 and b13=0), or 14 + b7 if (b11 = 1 and b13=1) (i.e. 1 out of PCG 8..15)

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	**(Example)**

(12.5% Gated-On, 12.5% Gated-Off)

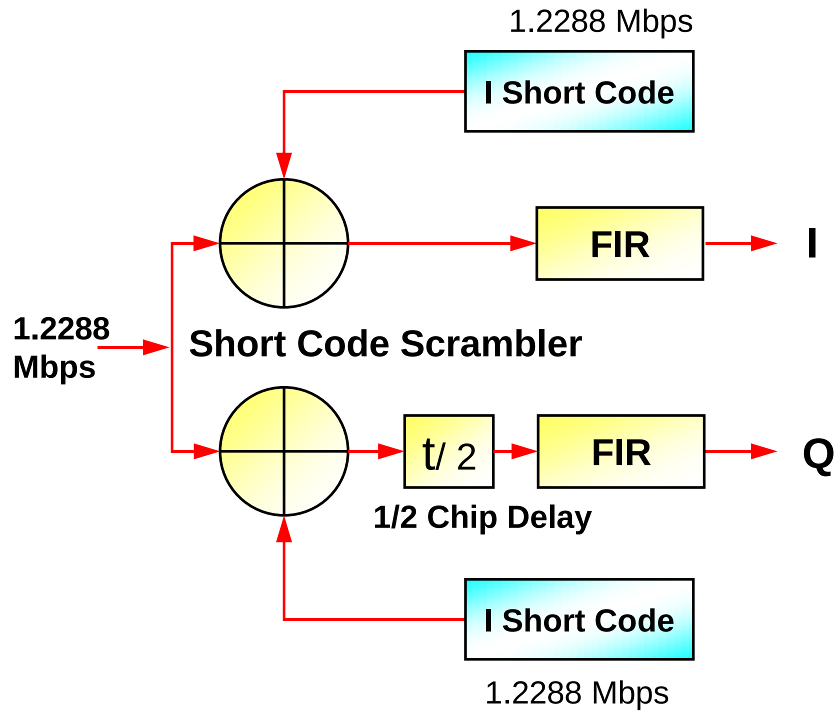
Gated-On and Gated-Off Power



Ensemble average: Average of power control groups,
all with the same output power

Reverse Channel Short Sequence Spreading

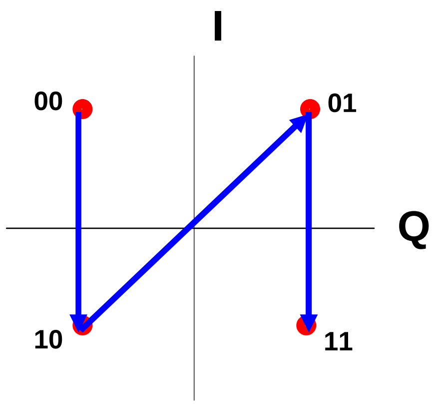
- Same PN Short Codes Are Used by Mobiles
- Short Sequence spreading Aids Base Station Signal Acquisition
- Extra 1/2 Chip Delay is Inserted into Q Path to Produce OQPSK Modulation to Simplify Power Amplifier Design

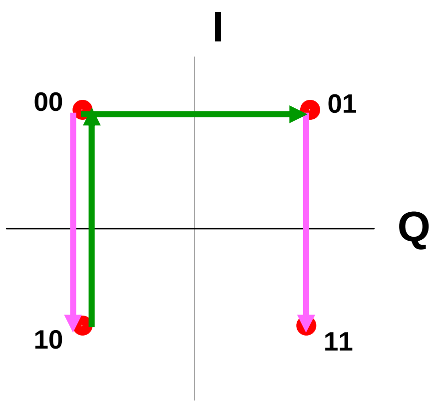


OQPSK Modulation

- QPSK Makes one Symbol Change Every Period
- OQPSK Makes two Symbol Changes Every Period if Q Data Changes
- Example Symbol Pattern is:

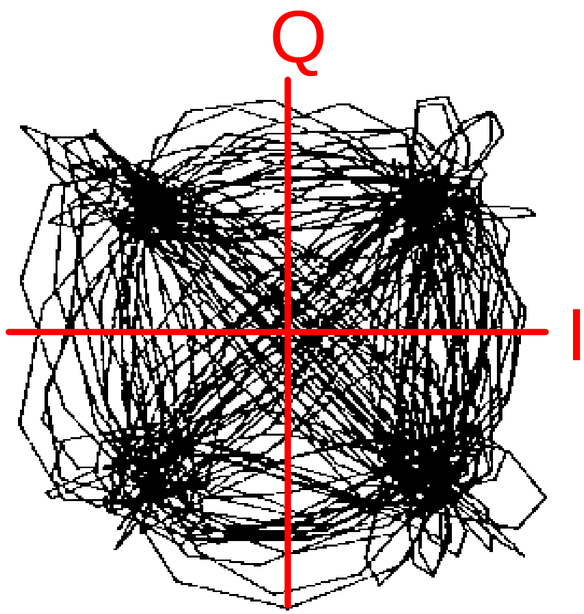
  - 00,10,01,11





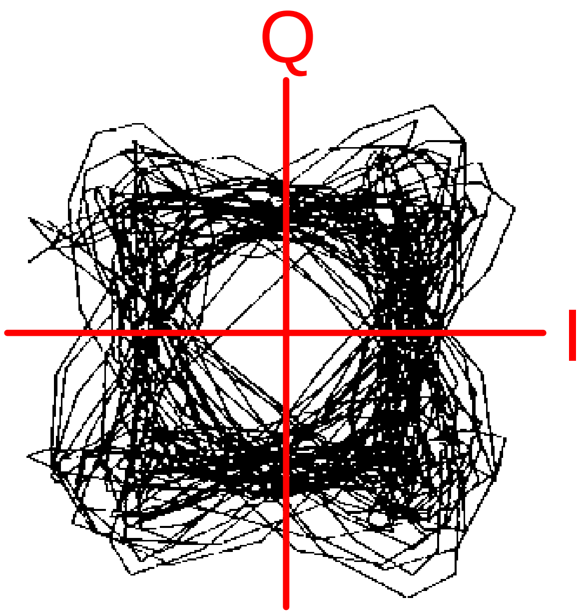
CDMA Modulation Formats

Base Station
Pilot Channel TX



Filtered QPSK

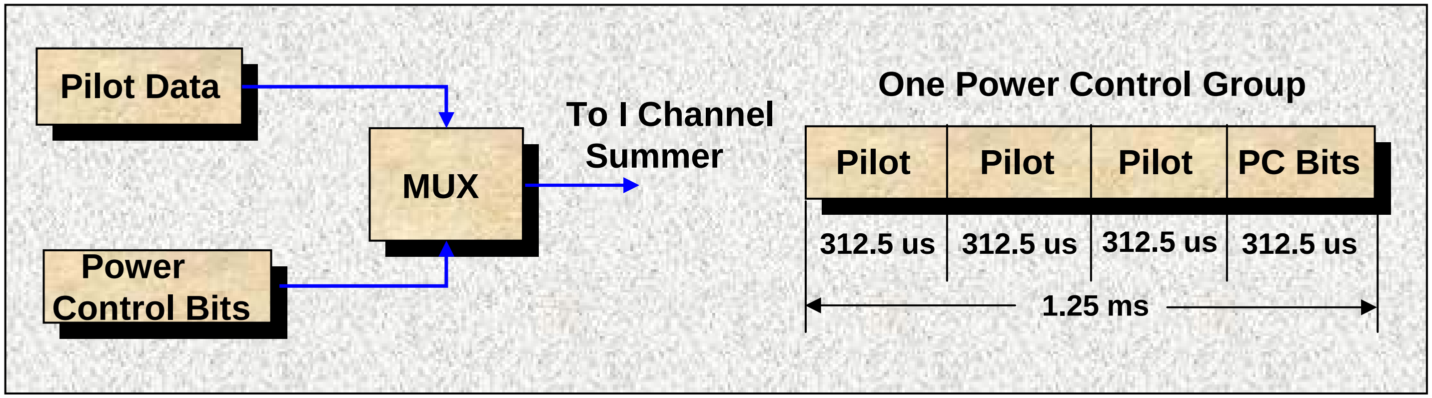
Mobile Station TX



Filtered Offset QPSK

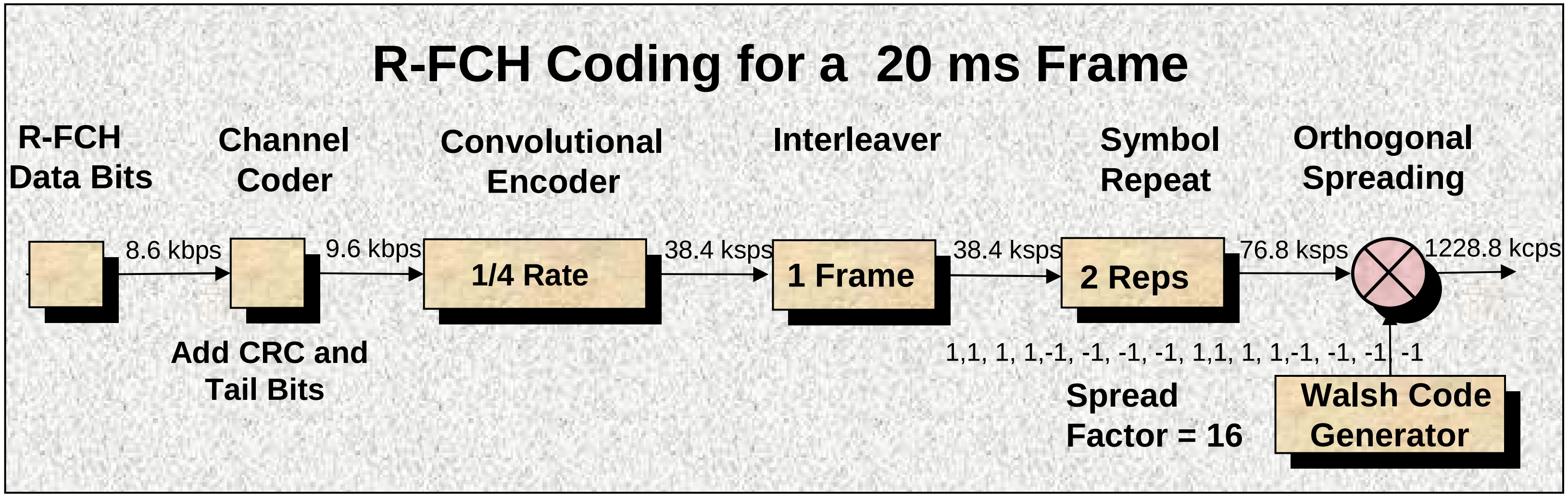
Reverse Pilot/Power Control Multiplexing (RC3,4)

- There are 16 Power Control Groups per 20 ms Frame
- Each Power Control Group is Split into 4 Sub-Groups
- 1 Power Control Bit is Sent per Power Control Group
- Pilot and Power Control are Multiplexed Together

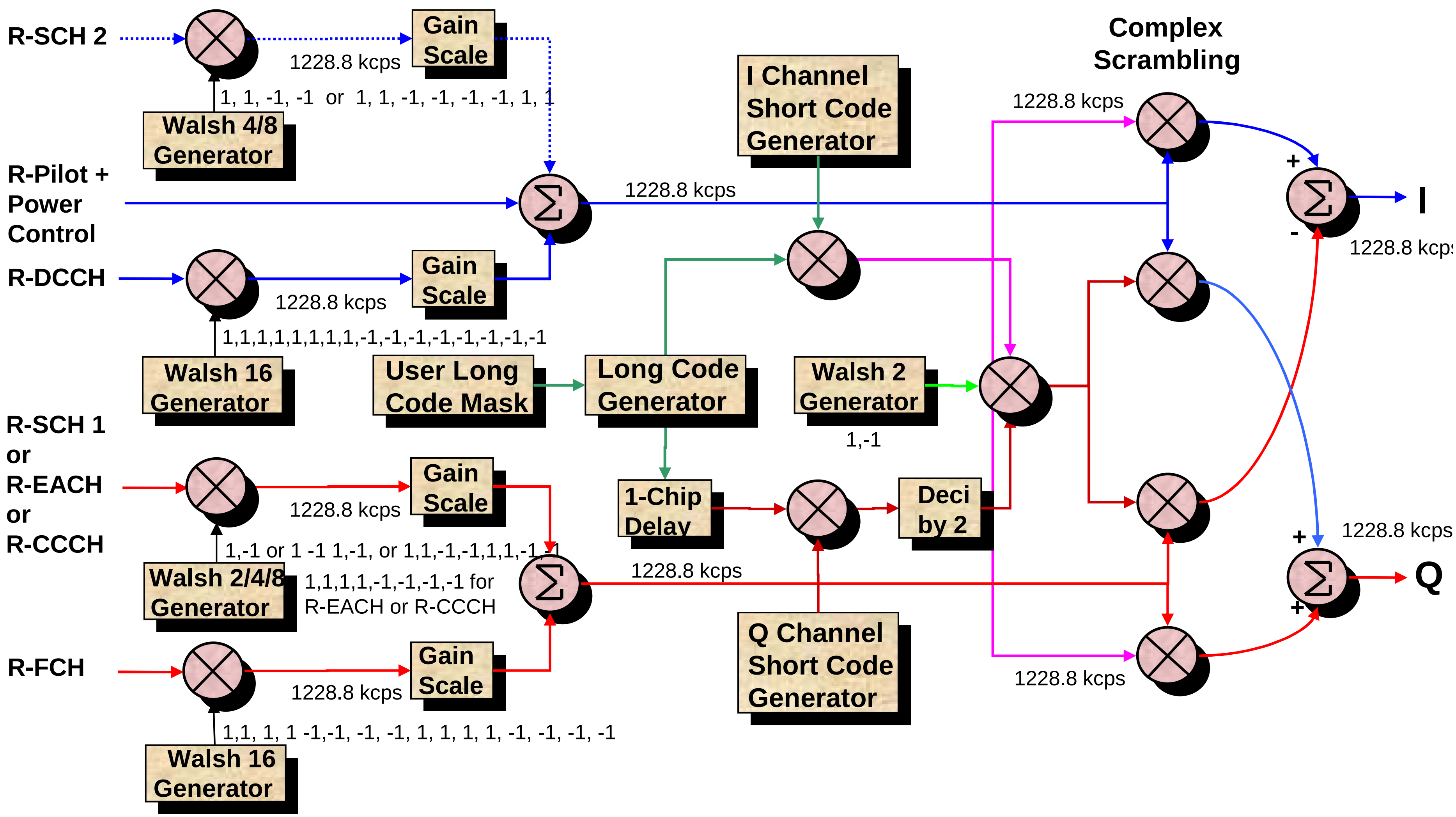


SR1, RC3 R-FCH Coding(RC3,RC4)

- R-FCH Carries Voice Information
- Uses a 20 ms Frames Length
- Using ¼ rate convolutional coding



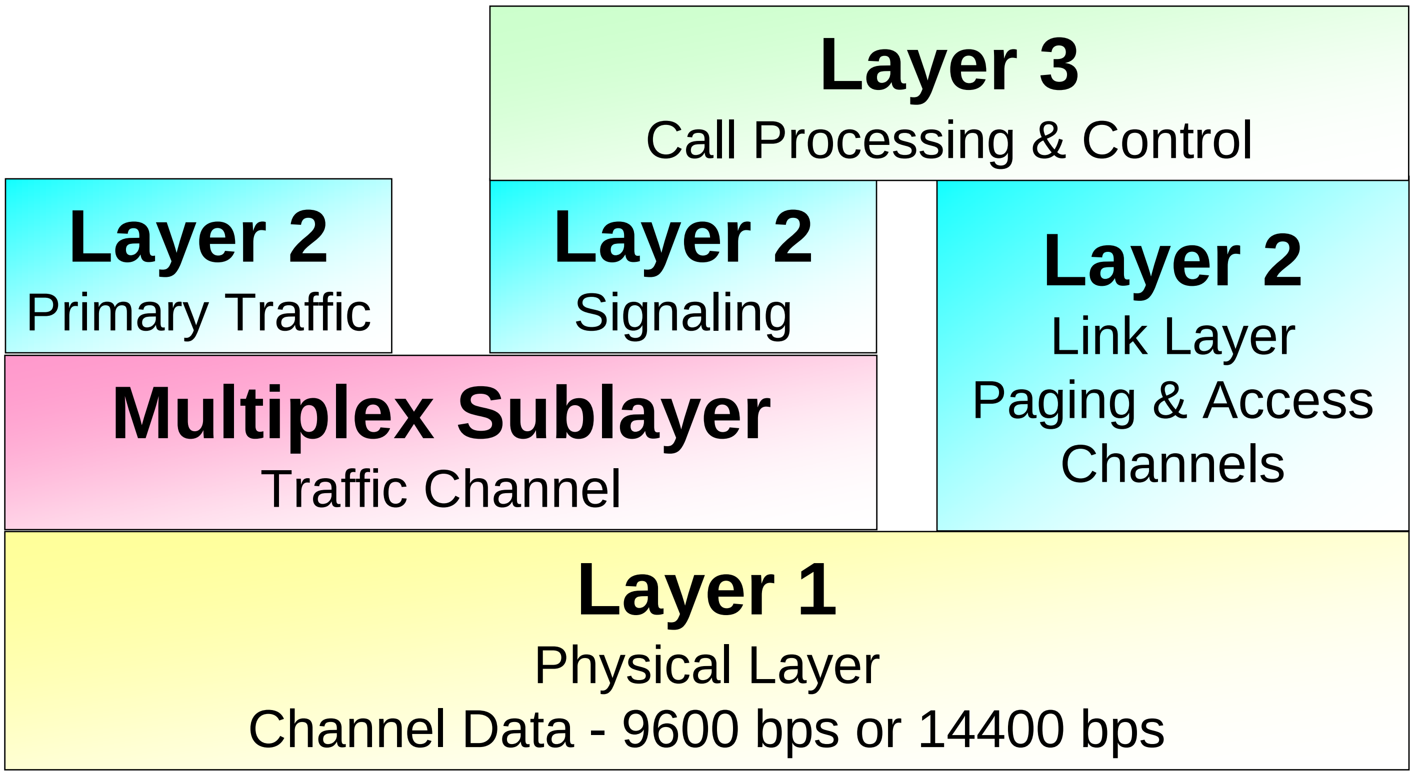
SR1 Reverse Channel Spreading(RC3,RC4)



Channelization Summary

Function	Forward Link (Base to Mobile)	Reverse Link (Mobile to Base)
9.6 kbps Convolutional Encoder	1/2 Rate (9600 in 19200 out)	1/3 Rate (9600 in 28800 out)
14.4 kbps Convolutional Encoder	3/4 Rate (14400 in 19200 out)	1/2 Rate (14400 in 28800 out)
Walsh Coding	Channelization	64-ary Modulation
Long Code Spreading	Voice Privacy	Channelization
Short Code Spreading	Base Station Identification	Aid Base Station Searching

CDMA Multiplex Sublayer



Station Class Mark (SCM)

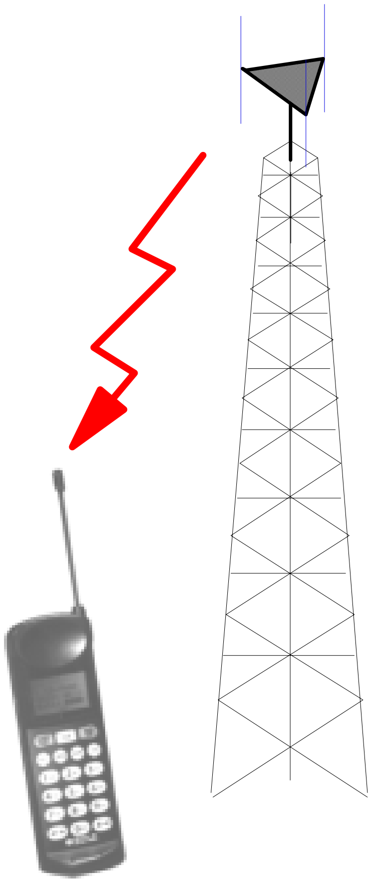
Function	Bit(s)	Setting	
Extended SCM Indicator	7	Band Class 0 Band Class 1	0 XXXXXXX 1 XXXXXXX
Dual Mode	6	CDMA Only Dual Mode	X0 XXXXXX X 1XXXXXX
Slotted Class	5	Non-Slotted Slotted	XX0XXXXX XX1XXXXX
IS- 54 Power Class	4	Always 0	XXX0XXXX
25 MHz Bandwidth	3	Always 1	XXXX1XXX
Transmission	2	Continous Discontinous	XXXXX0XX XXXXX1XX
Power Class for Band Class "0" Analog Operation (For CDMA only "00")	1- 0	Class I Class II Class III Reserved	XXXXXX00 XXXXXX01 XXXXXX10 XXXXXX11

Ten Minutes in the Life of a CDMA Mobile Phone

- Turn-on
  - System Access
- Travel
  - Idle State Hand-Off
- Initiate Call
- System Access
- Continue Travel
  - Initiate Soft Handoff
  - Terminate Soft Handoff
- End Call

CDMA Turn On Process

- Find All Receivable Pilot Signals
  - Choose Strongest One
- Establish Frequency and PN Time Reference (Base Station I.D.)
- Demodulate Sync Channel
- Establish System Time
- Determine Paging Channel Long Code Mask



Agilent Technologies

Sync Channel Message

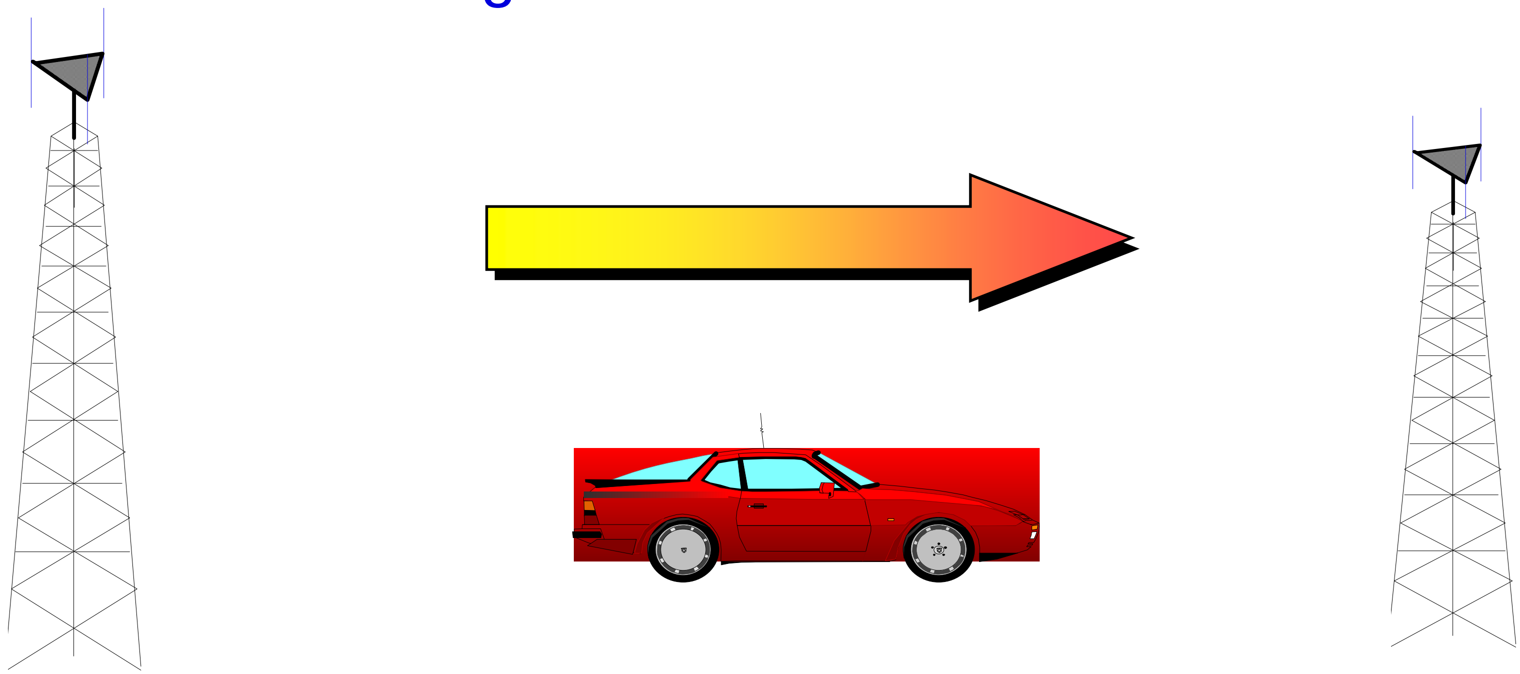
- Contains the Following Data:
  - Base Station Protocol Revision
  - Min Protocol Revision Supported
  - SID, NID of Cellular System
  - Pilot PN Offset of Base Station
  - Long Code State
  - System Time
  - Leap Seconds From Start of System Time
  - Local Time Offset from System Time
  - Daylight Savings Time Flag
  - Paging Channel Data Rate
  - Channel Number

Read the Paging Channel

- Demodulate the Paging Channel:
  - ➢ Use Long Code Mask Derived from the Pilot PN Offset Given in Sync Channel Message
- Decode Messages
- Register, if Required by Base Station
- Monitor Paging Channel

CDMA Idle State Handoff

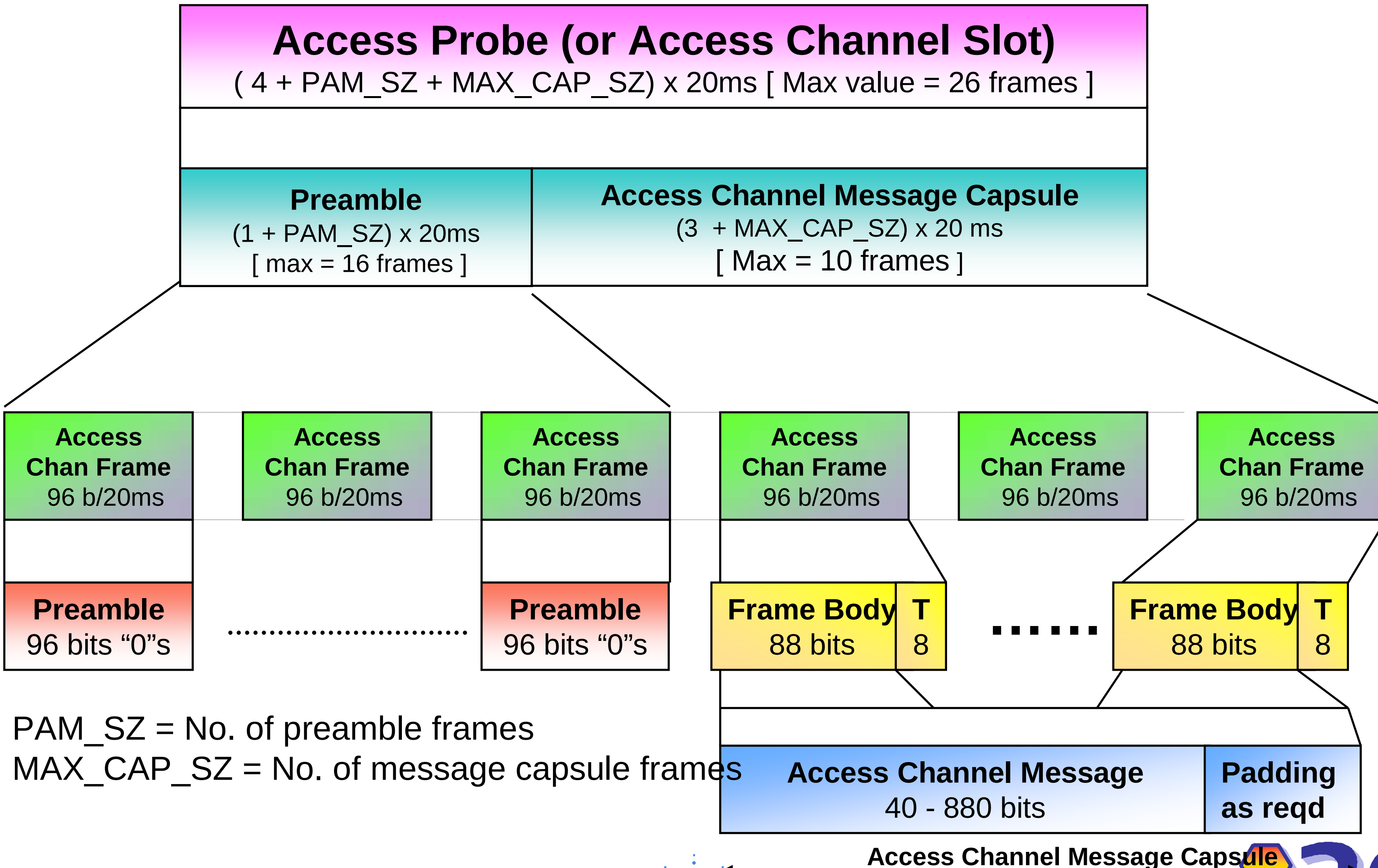
- No Call In Progress
- Mobile Listens to New Cell
- Move Registration Location if Entering a New Zone



Access Procedures

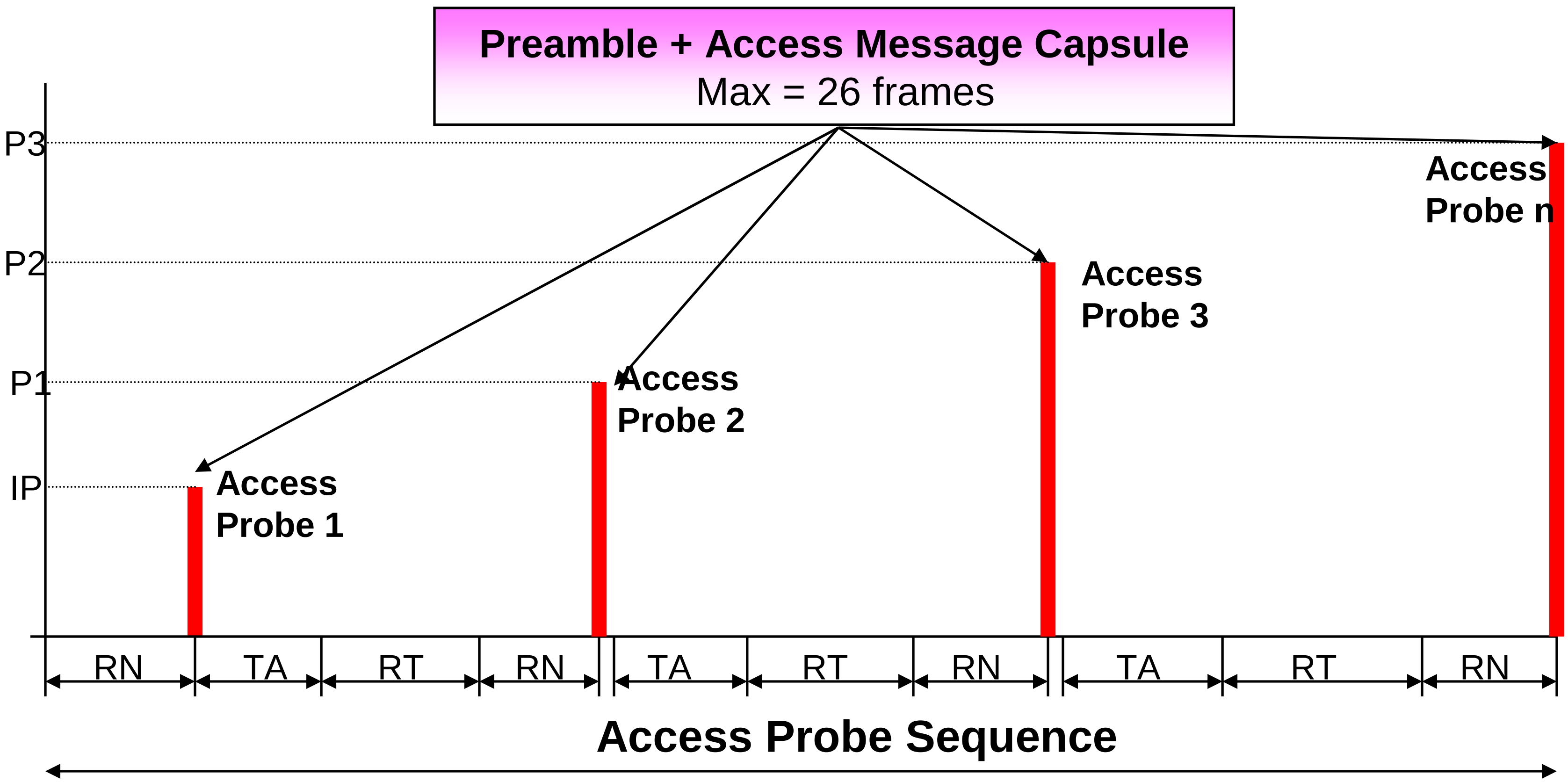
- Controlled by BS by broadcasting Access Parameters Message on the paging channel
- Access attempt is the process of sending one message and receiving (or failing to receive) an ACK for that message = groups of access probe sequence
- Access probe sequence = groups of access probes
- Access probe = each transmission in an access attempt

Access Probe



PAM_SZ = No. of preamble frames
MAX_CAP_SZ = No. of message capsule frames

Access Probe Sequence

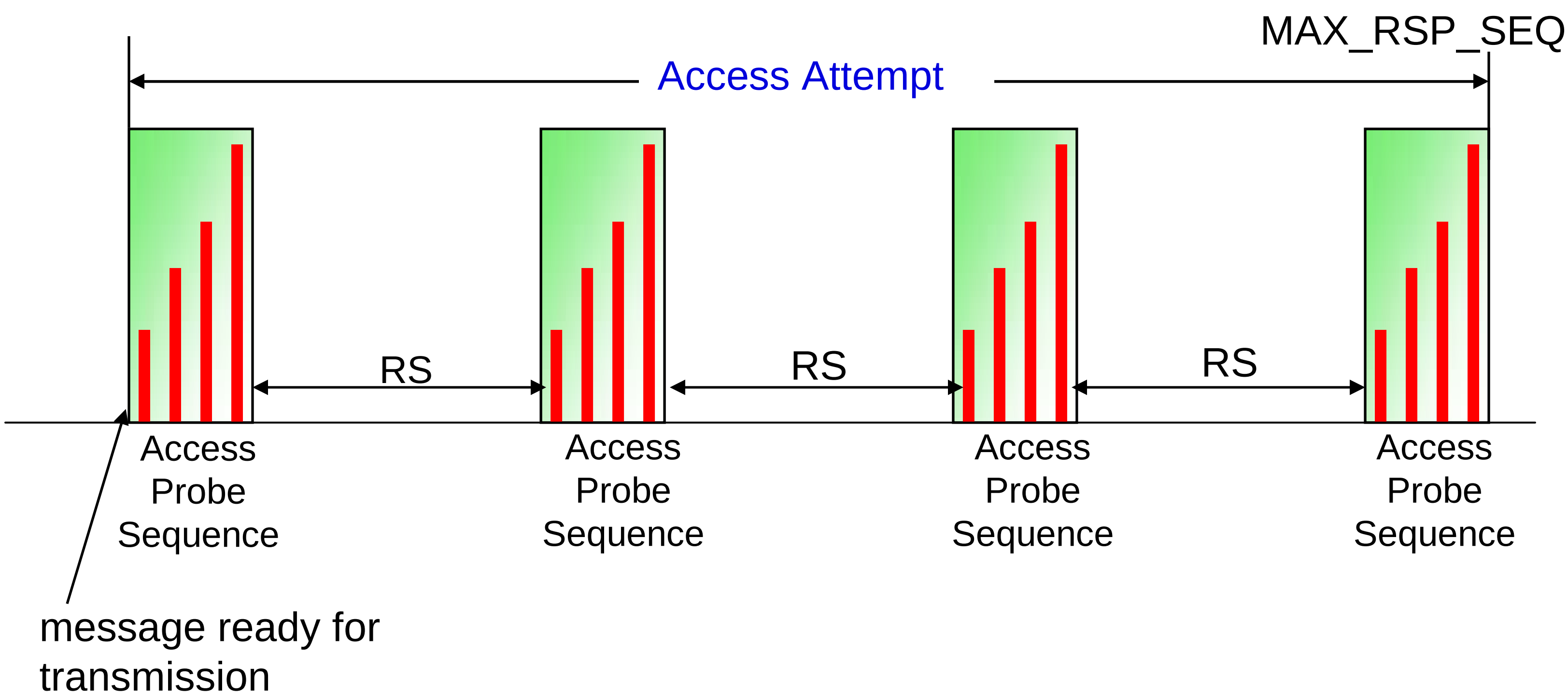


IP = Open Loop Power + NOM_PWR + INIT_PWR

where Open Loop Power = -(Received Power) - 73

Access Attempt

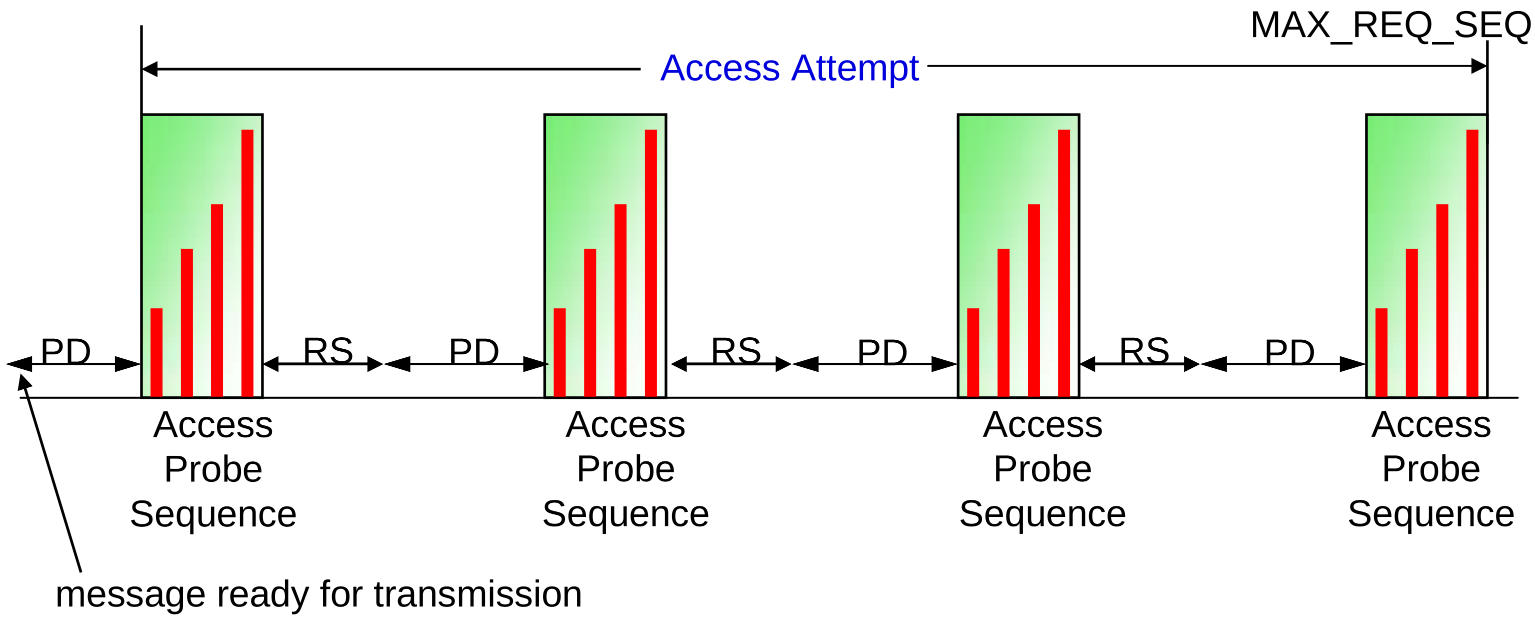
Process for Response Messages



RS : Backoff delay, which is random value between 0 to BKOFF slots

Access Attempt

Process for Request Messages



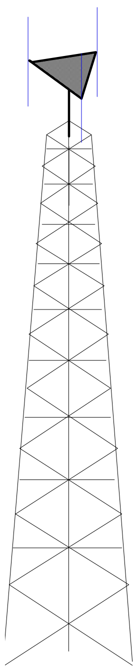
PD: (Persistence Delay) resulted from a pseudo-random test by MS; the first access probe of the sequence begins in the slot only if the test passes within that slot

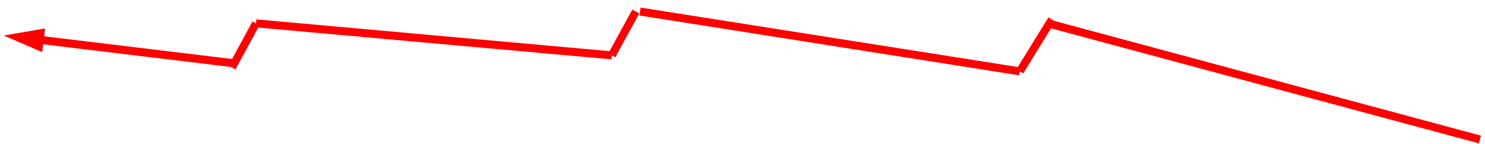
The test result depends on the ESN, reason for attempt (call origination, register, etc.) and the access overload class of the MS, and a PSSIST value broadcasted by BS for that access class. If the PSSIST is all "1"s for some access class, the test for that access class will always fail

Access Channel Messages

- **Registration Message** - for registration as well as Global Challeng Authentication Process
- **Order Message** - for transmission of order messages (e.g., BS challenge order, SSD update confirmation, MS acknowledgement order, etc.)
- **Data Burst Message** - to get a trigger from the user to send a message to BS (information message like SMS)
- **Origination Message**-MS information
- **Page Response message**
- **Authentication Challenge Response Message**
- **Status Response Message** - response to BS status request order which may include MS terminal information, station class mark, service option supported, multiplex option support, IMSI, ESN, etc.

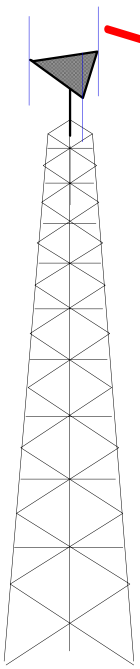
CDMA Call Initiation

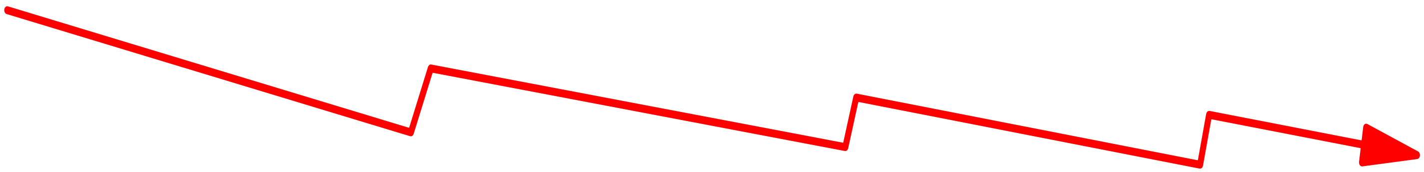




- Dial Numbers, Then Press Send
- Mobile Transmits on a Special Channel Called the Access Channel
- The Access Probe Uses a Long Code Mask Based On:
  - ✓ Access & Paging Channel Numbers
  - ✓ Base Station ID
  - ✓ Pilot PN Offset

CDMA Call Completion





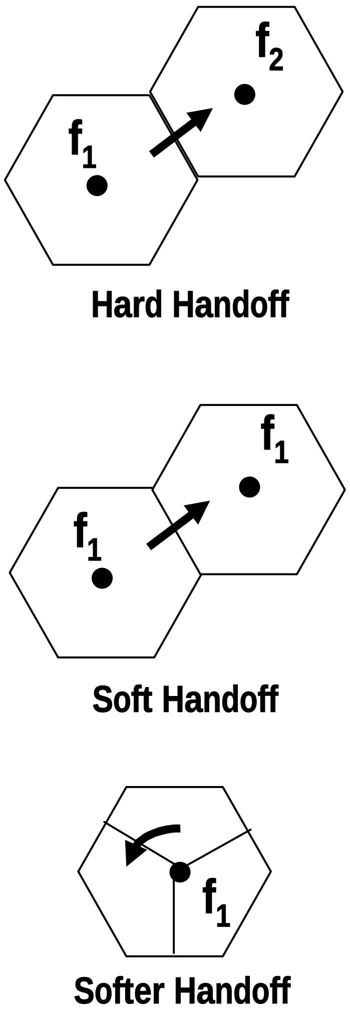
- Base Answers Access Probe using the Channel Assignment Message
- Mobile Goes to A Traffic Channel Based on the Channel Assignment Message Information
- Base Station Begins to Transmit and Receive Traffic Channel

CDMA Soft Handoff Initiation

- Mobile Finds Second Pilot of Sufficient Power (exceeds T_add Threshold)
- Mobile Sends Pilot Strength Message to First Base Station
- Base Station Notifies MTSO
- MTSO Requests New Walsh Assignment from Second Base Station
- If Available, New Walsh Channel Info is Relayed to First Base Station

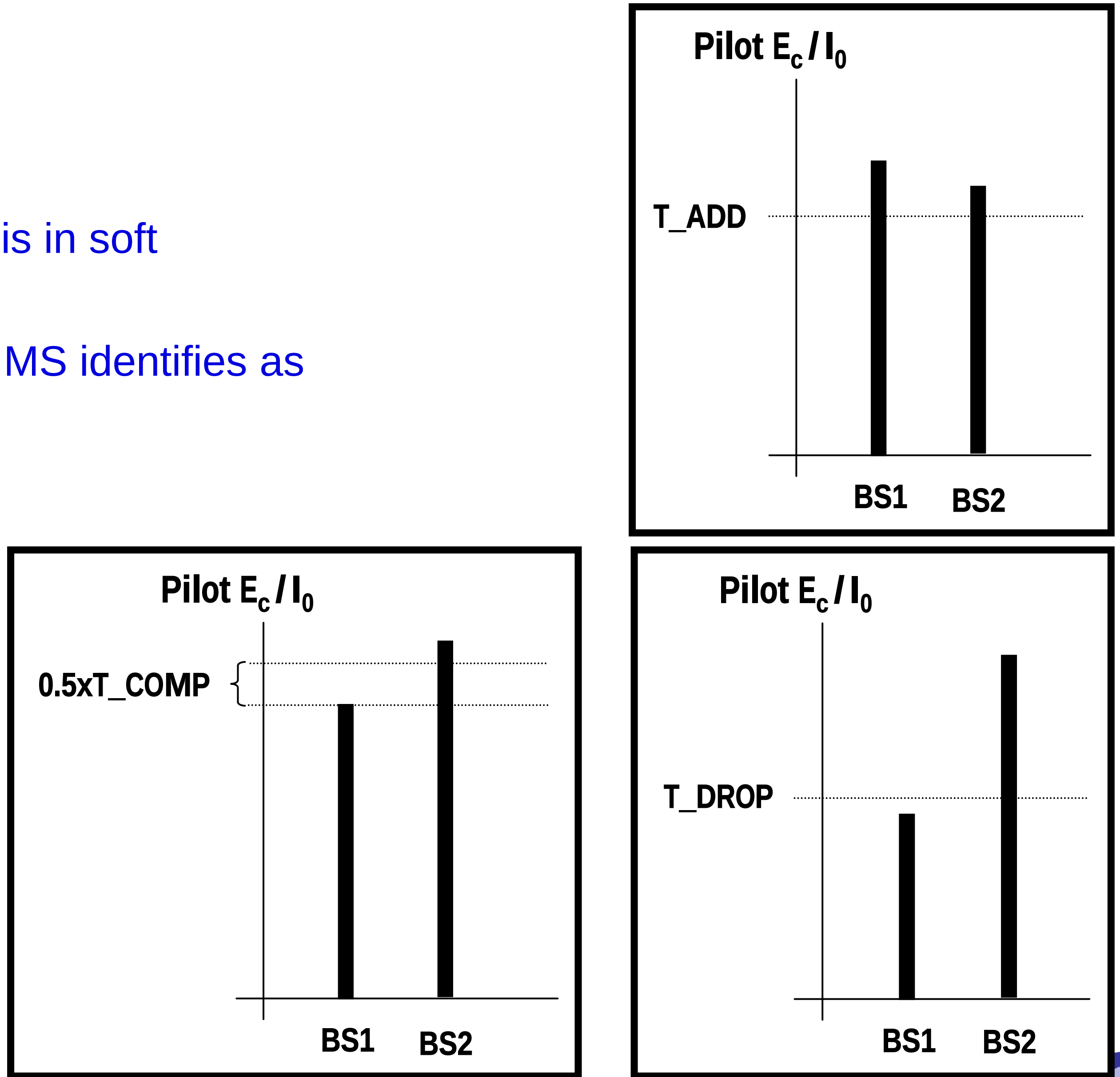
Hard, Soft, and Softer Handoffs

- Hard Handoff
  - “Break before make.”
- Soft Handoff
  - “Make before break.”
  - MS communicates with more than one BS at a time.
  - Improves reception on cell boundaries.
  - MS will receive different power control from the two BSs.
- Softer Handoff
  - MS communicates with more than one sector of a cell.
  - MS will receive identical power control from both sectors.



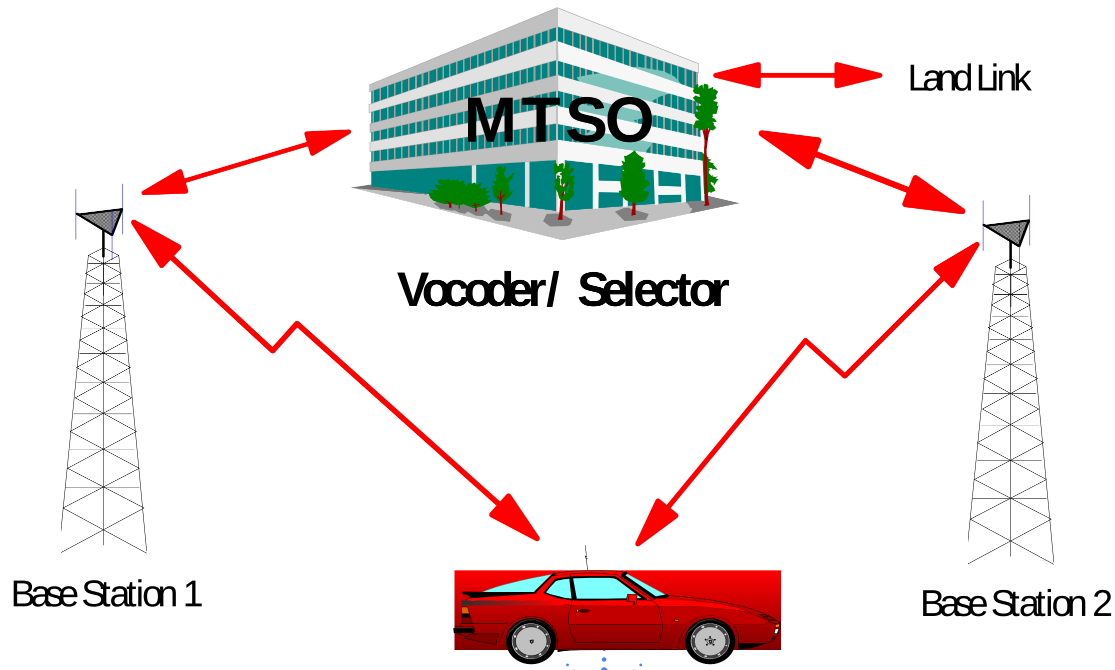
cdma2000 CONCEPT: Soft Handoff

- Terms:
  - ➢ Active Set: MS is in soft handoff.
  - ➢ Candidate Set: MS identifies as strong.
- Parameters:
  - ➢ T_ADD
  - ➢ T_COMP
  - ➢ T_DROP
  - ➢ T_TDROP



CDMA Soft Handoff Completion

- First Base Station Orders Soft Handoff with new Walsh Assignment
- MTSO Sends Land Link to Second Base Station
- Mobile Receives Power from Two Base Stations
- MTSO Chooses Better Quality Frame Every 20 Milliseconds



Agilent Technologies

Ending CDMA Soft Handoff

- First BS Pilot Power Goes Low at Mobile Station (drops below T_drop)
- Mobile Sends Pilot Strength Message
- First Base Station Stops Transmitting and Frees up Channel
- Traffic Channel Continues on Base Station Two

CDMA End of Call

- Mobile or Land Initiated
- Mobile and Base Stop Transmission
- Land Connection Broken

cdma2000 Standards Overview - TIA/EIA-98-D/E

- I.e.3GPP2 C.S0011-A/B:
  - “Recommended Minimum Performance Standards for cdma2000 Spread Spectrum Mobile Stations.”

- Important test sections:
  - 2 Standard Radiated Emissions Measurement Procedure
  - 3 CDMA Receiver Minimum Standards
  - 4 CDMA Transmitter Minimum Standards

- Covers both SR1 and SR3
  - No Minimum Standards specified for SR3.
  - This presentation only covers SR1 testing.

SR1

CDMA Service Options

- Service Options Are:
  - ✓ ***1- Voice Using 9600 bps IS-96-A Vocoder***
  - ✓ ***2- Rate Set 1 Loopback (9600 bps)***
  - ✓ ***3- Voice Using 9600 bps (EVRC)***
  - ✓ ***4- Asynchronous Data Service (circuit switched)***
  - ✓ ***5- Group 3 Fax***
  - ✓ ***6- Short Message Service (9600 bps)***
  - ✓ ***7- Internet Standard PPP Packet Data***
  - ✓ ***8- CDPD Over PPP Packet Data***
  - ✓ ***9- Rate Set 2 Loopback (14400 bps)***
  - ✓ ***14-Short Message Service (14400 bps)***
  - ✓ ***32,768- Voice Using 14400 bps (CDG)***

Section 3 - Receiver Test

Receiver Test

Transmitter Test

- 4.1 Frequency Accuracy
- 4.2 Handoff
- 4.3 Modulation Requirements
- 4.4 RF Output Power Requirements
  - ***4.4.1 Range of Open Loop Output Power***
  - ***4.4.2 Time Response of Open Loop Power Control***
  - ***4.4.3 Access Probe Output Power***
  - ***4.4.4 Range of Closed Loop Power Control***
  - ***4.4.5 Maximum RF Output Power***
  - ***4.4.6 Minimum Controlled Output Power***
  - ***4.4.7 Standby Output Power and Gated Output Power***
  - ***4.4.8 Power Up Function Output Power***
  - ***4.4.9 Code Channel to Reverse Pilot Channel Output Power Accuracy***
  - ***4.4.10 Reverse Pilot Channel Transmit Phase Discontinuity***
  - ***4.4.11 Reverse Traffic Channel Output Power During Changes in Data Rate***

CDMA Conclusions

- New Access Method
  - ➢ Code Based
- Designed for Use in Interfering Environment
- Uses Multipath to Improve Reception in Fading Conditions
- cdma2000 is Backwards Compatible with TIA/EIA-95-B
- Provides 2x Capacity Improvement Over TIA/EIA-95-B
  - ✓ ***Improved Coding***
  - ✓ ***Improved Modulation***
  - ✓ ***Coherent Reverse Link Demodulation (Mobile Pilot)***
  - ✓ ***Fast Forward Link Power Control***
- Has Options for Green Field and Overlay Operation:
  - ✓ ***Direct Spread for Green Field Spectrum Applications***
- Supports High Speed Data for New Applications