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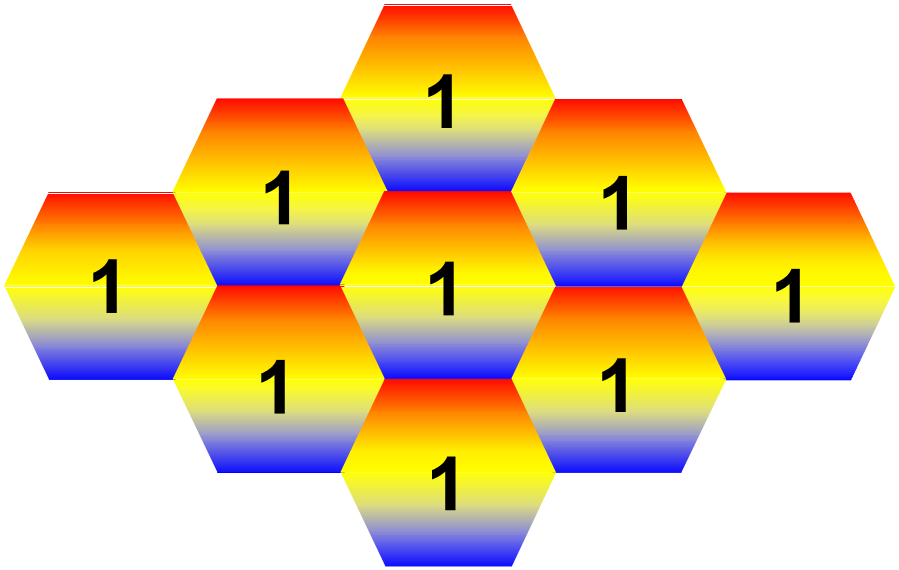
An Overview of cdma2000 Technology Concepts

June 24, 2002 and July 16, 2002

presented by:

Ken Carolus

An Overview of cdma2000 Technology Concepts



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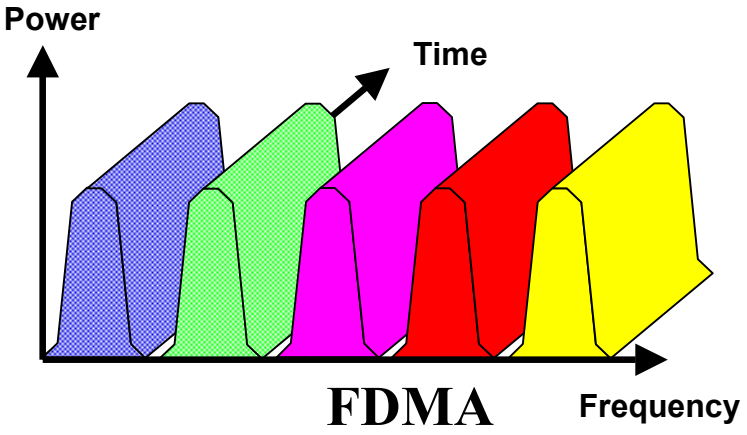
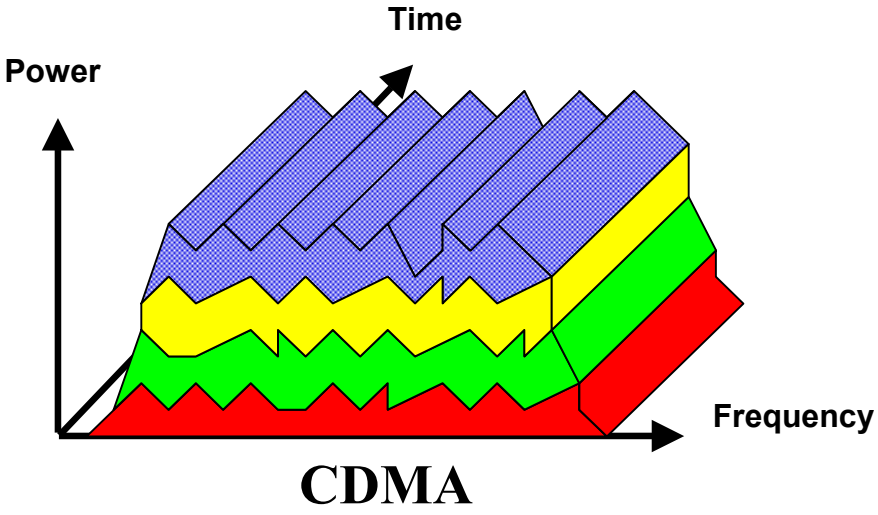
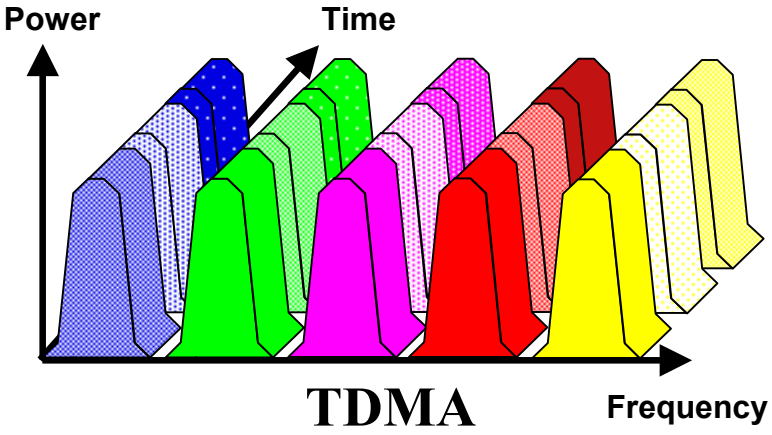
Contents

Cellular Access Methods







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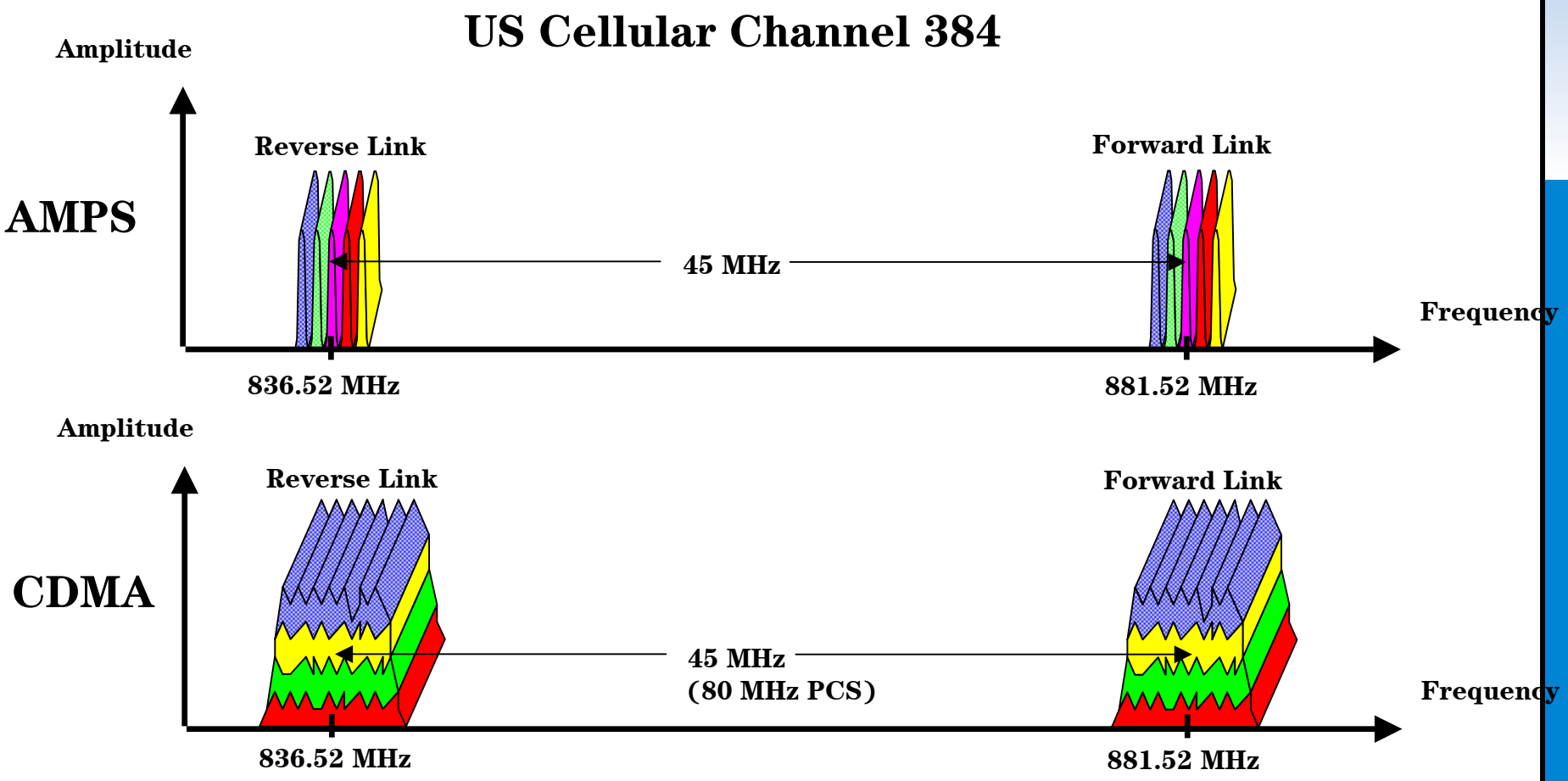
CDMA is Also Full Duplex



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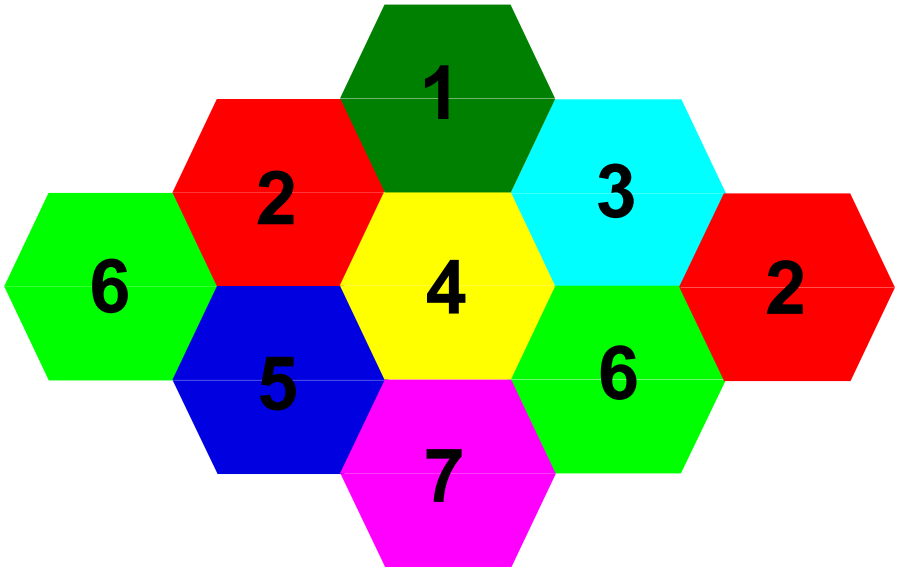
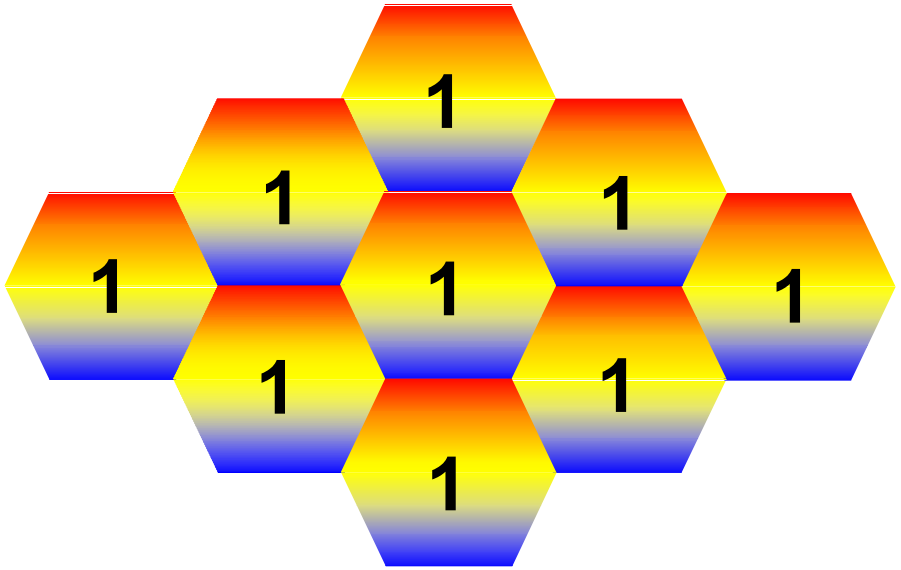
Cellular Frequency Reuse Patterns

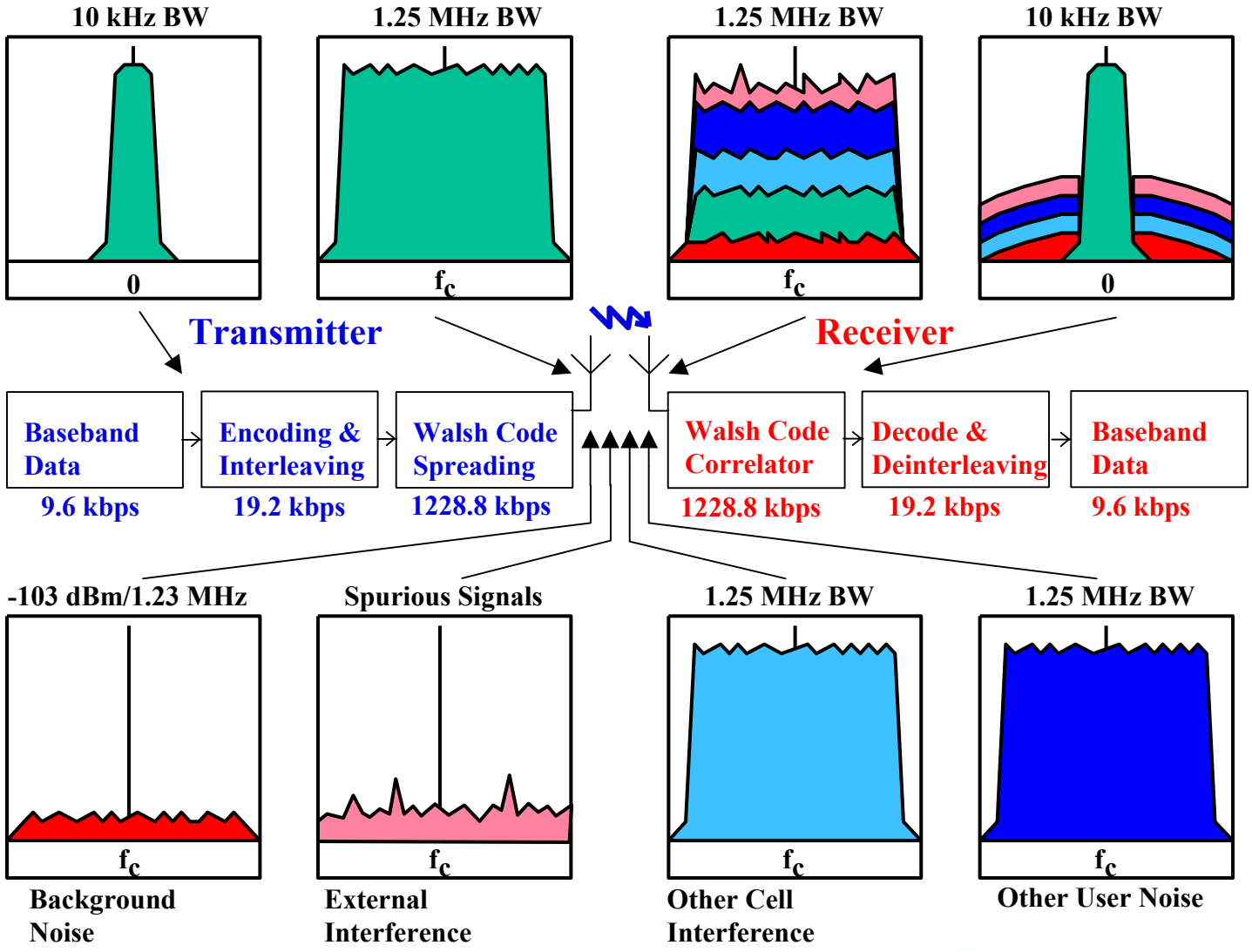


FDMA Reuse



CDMA Reuse

The CDMA Concept



Interference Sources

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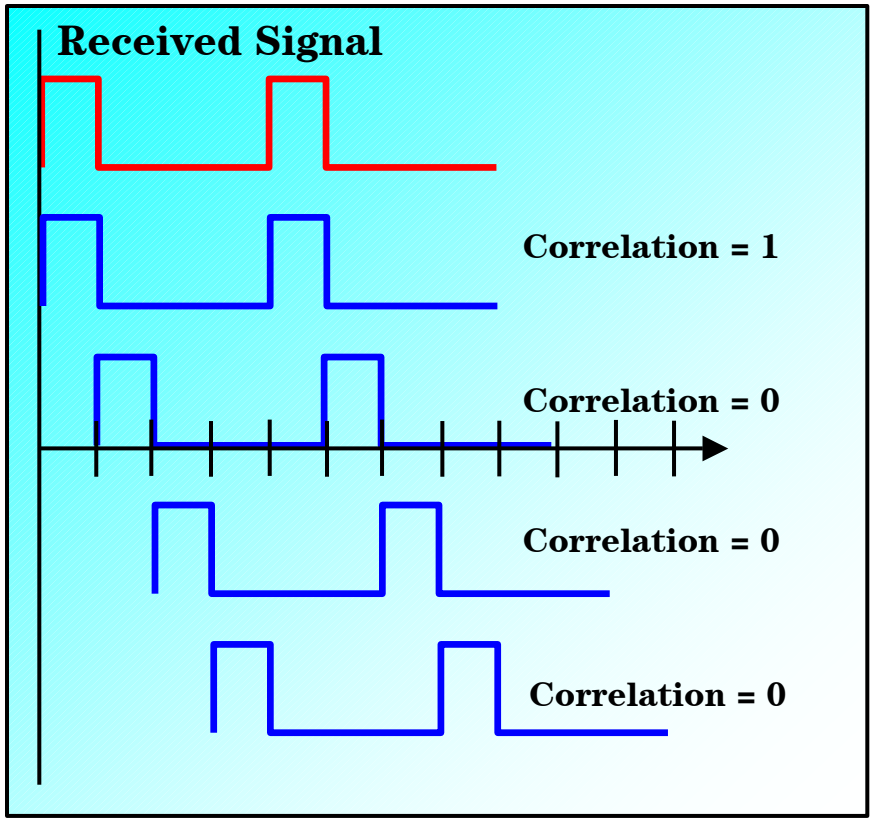
IS-2000 Terms and definitions

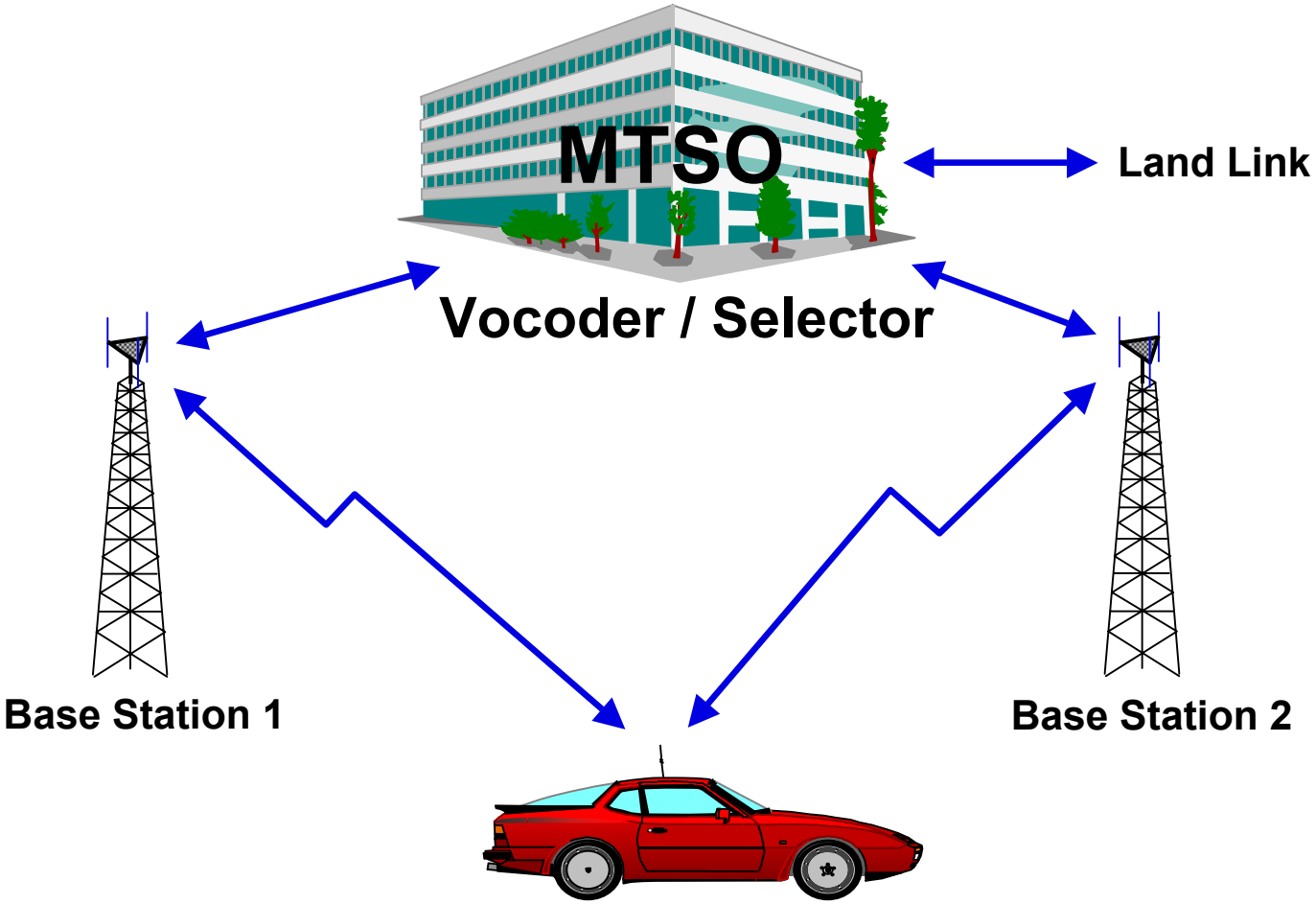
- **Chip**
  - Is the period of a data bit at the final spreading rate
- **SR - Spreading Rate**
  - Defines the final spreading rate in terms of 1.2288 Mcps.
- **RC - Radio Configuration**
  - Defines the physical channel configuration based upon a base channel data rate.
  - RCs contain rates derived from their base rate. For example, RC3 is based on 9.6 kbps and includes 9.6, 19.2, 38.4, 76.8, and 153.6 kbps.

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



Spatial Diversity During Soft Handoff



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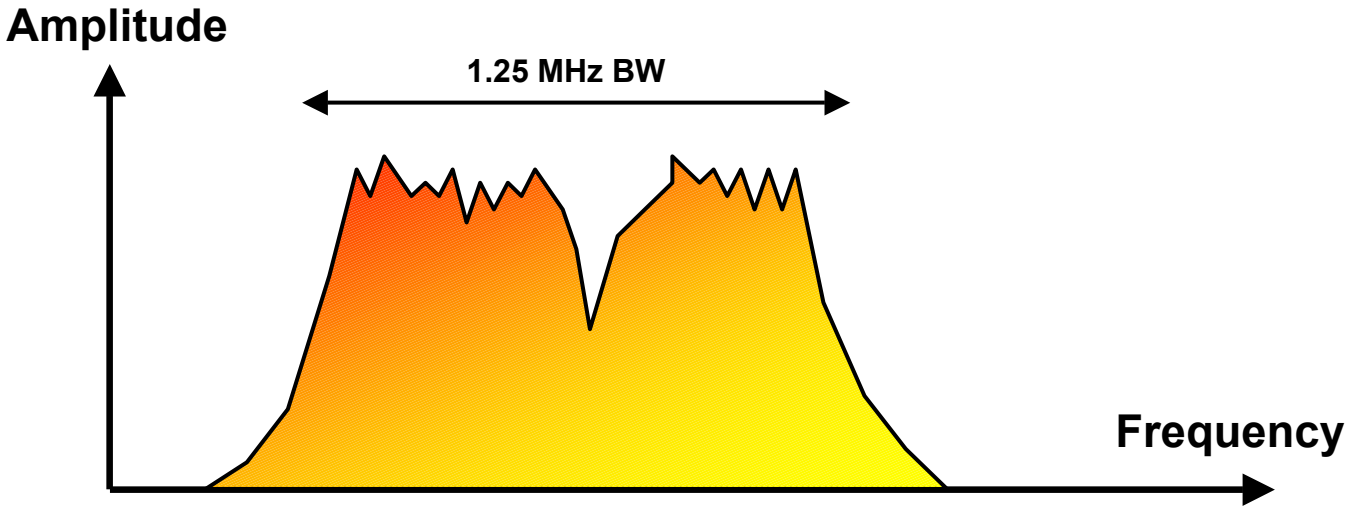
CDMA Frequency Diversity

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



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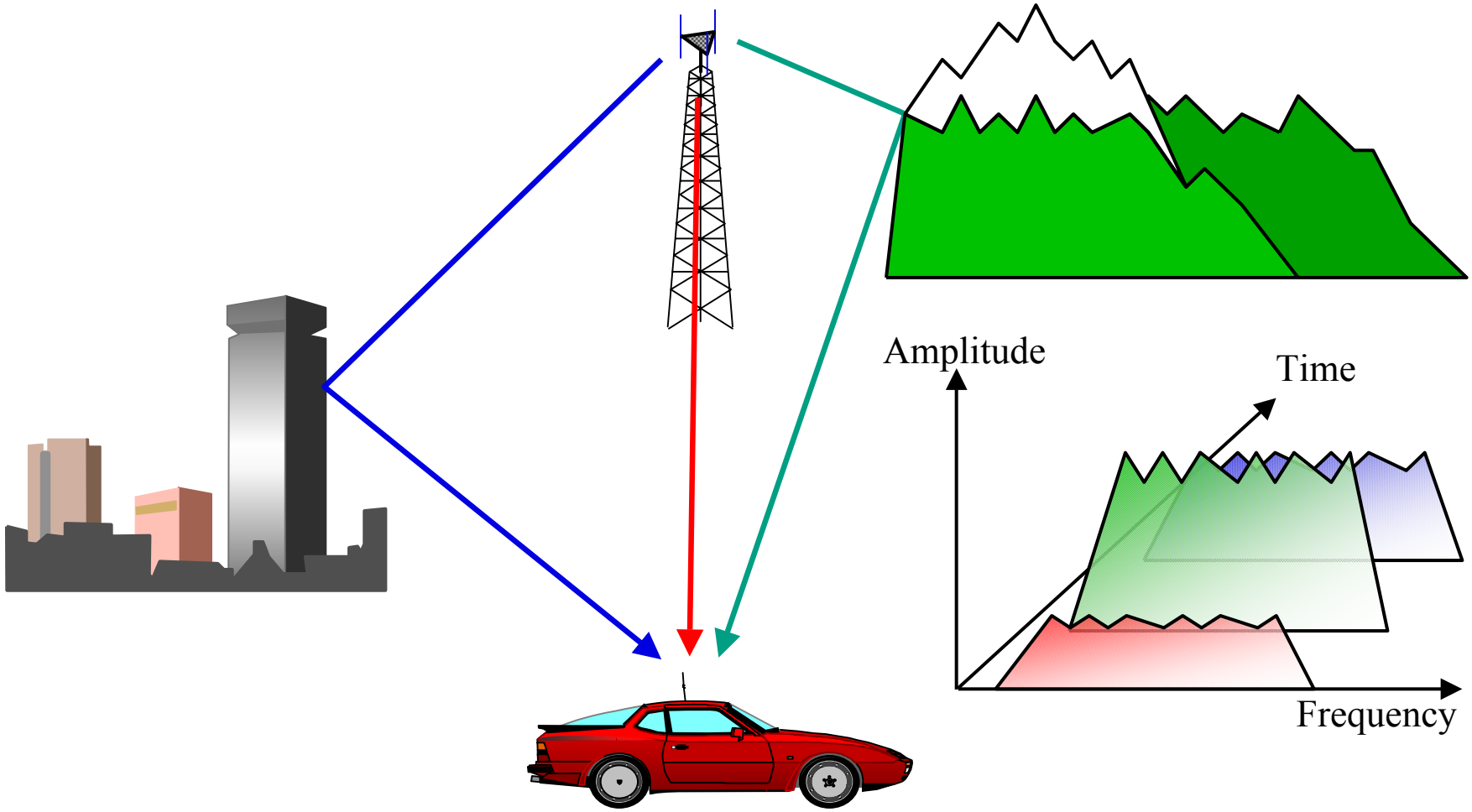
CDMA Time Diversity

- Uses Rake Receiver
- Convolutional Encoding
- Data is Interleaved
- Viterbi Decoding

The Rake Receiver



Power Control

- Important in cdma systems because of frequency reuse of N=1
- The goal is to maintain equal received power at the base station from each mobile
- Affects traffic channels (not pilot signal)

Near-far effect: BS receiver captured by nearby MS

CDMA Power Control (Reverse Link)

- All Mobiles are Received at Base Station at Equal Power
- Two Types of Control
  - Open Loop Power Control
  - Closed Loop Power Control

Open Loop Power Control (Reverse Link)

- Assumes Loss is Similar on Forward and Reverse Paths.
- Receive Power+Transmit Power = -73
  - All powers in dBm
- Example:
  - For a Received Power of -85 dBm (at the mobile)

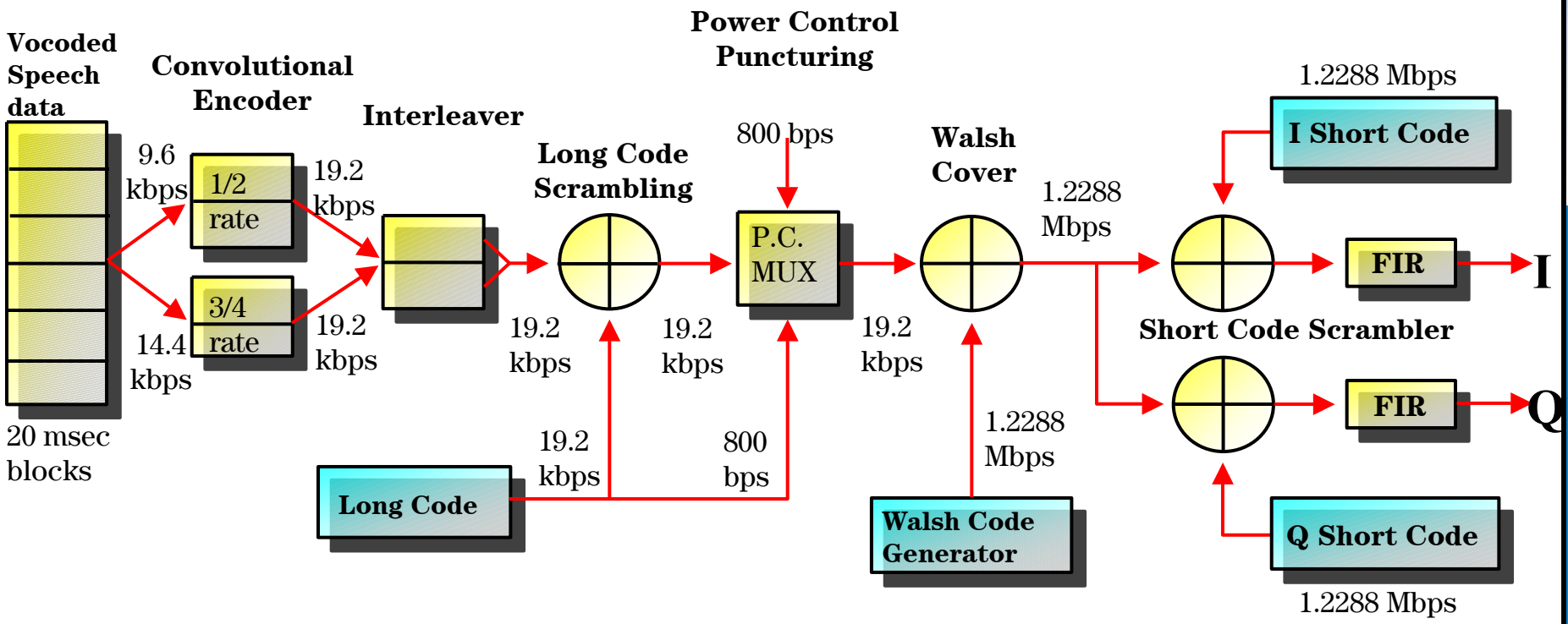
    Transmit Power = (-73) - (-85)

    Transmit Power = +12 dBm

Closed Loop Power Control (Forward & Reverse)

- Directed by Base Station (for the Reverse Link) and by Mobile (for the Forward Link)
- Updated Every 1.25 msec
- 1 dB Step Size (also 0.25 and 0.5 dB)
- Closed Loop Adds to Open Loop Power Estimate on Reverse Link

Forward Link Traffic Channel IS-95 Physical Layer



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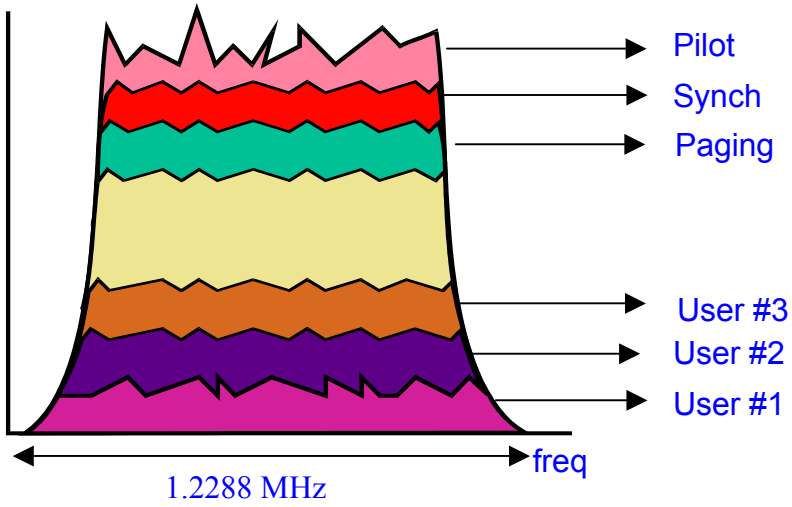
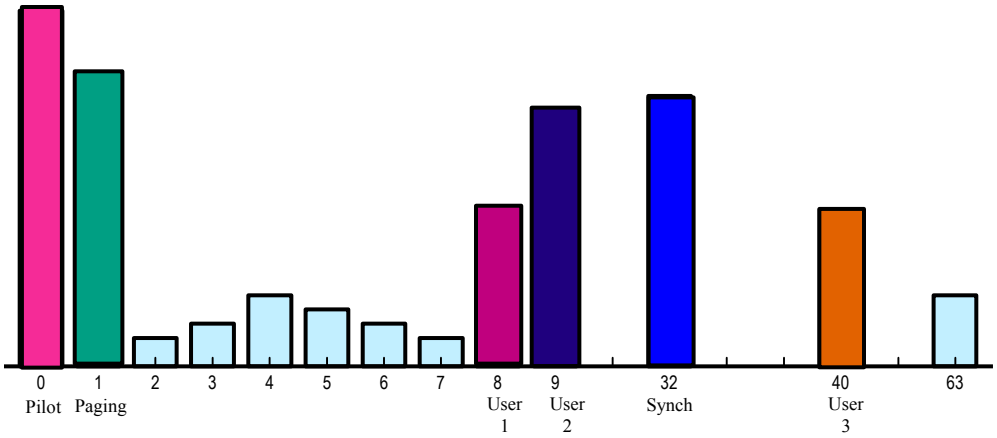
Code Domain Power (IS-95)



Frequency Domain



Code Domain

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Contents

- Review of IS-95 CDMA Concepts
- cdma2000 Improvements
- cdma2000 Concepts
- cdma2000 Network Architecture

IS-2000 Improvements vs. IS-95

- **2X Voice Capacity**
  - Reverse Link Pilot for Each Mobile
  - Fast Forward (new) and Reverse Link Power Control
- **QPSK Modulation**
- **Improved Convolutional Channel Encoding for 14.4 kbps Voice Channels**
- **Supports Auxiliary Pilots for Beam Forming, Multi-Antennas, and many other options**

cdmaOne to cdma2000 1xRTT

- **1xRTT keeps same chip rate and carrier bandwidth**
- **Splits the data into I and Q (QPSK Modulation vs. P-BPSK)**
- **Keep existing IS-95-based channels for backwards compatibility with IS-95 mobiles**
  - IS-95B enhancements retained
- **Adds new radio configurations, adds new FWD and REV channels**
  - New optional control channels
  - New fundamental traffic channels
  - New supplemental traffic channels for faster data
  - New turbo codes and spreading techniques
- **~35 max users/sector/carrier for IS-95, ~70 max for IS-2000**

cdma2000 to Achieve 3G Data Rates (cont.)

- New transmission modes offer faster data rates

Technology	Data Capabilities
IS-95A/J-Std008	Up to 14.4 kbps using one traffic channel for supplemental data
IS-95B	Up to 115.2 kbps using 1 traffic channel and up to 7 supplemental code channels supporting 14.4 kbps each
1xRTT	Up to 153.6 kbps (RC3) or 307.2 kbps (RC4) per SCH (one deployed today); RC3 avail. today; Uses fundamental & supplemental channels, advanced rate and QoS management
3xRTT	Up to 1.0386 Mbps (RC9) using fundamental channel for voice and supplemental channel(s) for data; 2 Mbps using 2 SCH

- 1xEV-DO and 1xEV-DV: 2.4 Mbps and higher

The CDMA Technology Path to 3G

		cdmaOne		cdma2000/IS-2000		
Generation	**1G**	**2G**	**2G**	**2.5G or 3**	**3G**	**3G**
Technology	**AMPS**	**IS-95A/J-Std008**	**IS-95B**	**IS-2000: 1xRTT**	**IS-2000: 3xRTT**	**1xEV-DO/DV**
Signal Bandwidth, #Users	30 kHz. 1	1250 kHz. 20-35	1250 kHz. 25-40	1250 kHz. 50-80 voice and data	F: 3x 1250k R: 3687k 120-210 per 3 carriers	1250 kHz. Many packet users
Data Capabilities	None, 2.4K by modem	14.4K	64K	**153K 307K 230K**	**2.0 Mb/s**	**2.4 Mb/s** (1xEV-DO) **3.864 Mb/s** (1xEV-DV)
Features: Incremental Progress	First System, Capacity & Handoffs	First cdma, Capacity, Quality	•Improved Access •Smarter Handoffs	•Enhanced Access •Channel Structure	Faster data rates on shared 3-carrier bundle	Faster data rates on 1x carrier

Differences Between W-CDMA and cdma2000

W-CDMA	cdma2000
New Spectrum only	Overlay IS-95
3.84 Mcps	1.2288 Mcps
New equipment	Upgrade existing
3GPP	3GPP2

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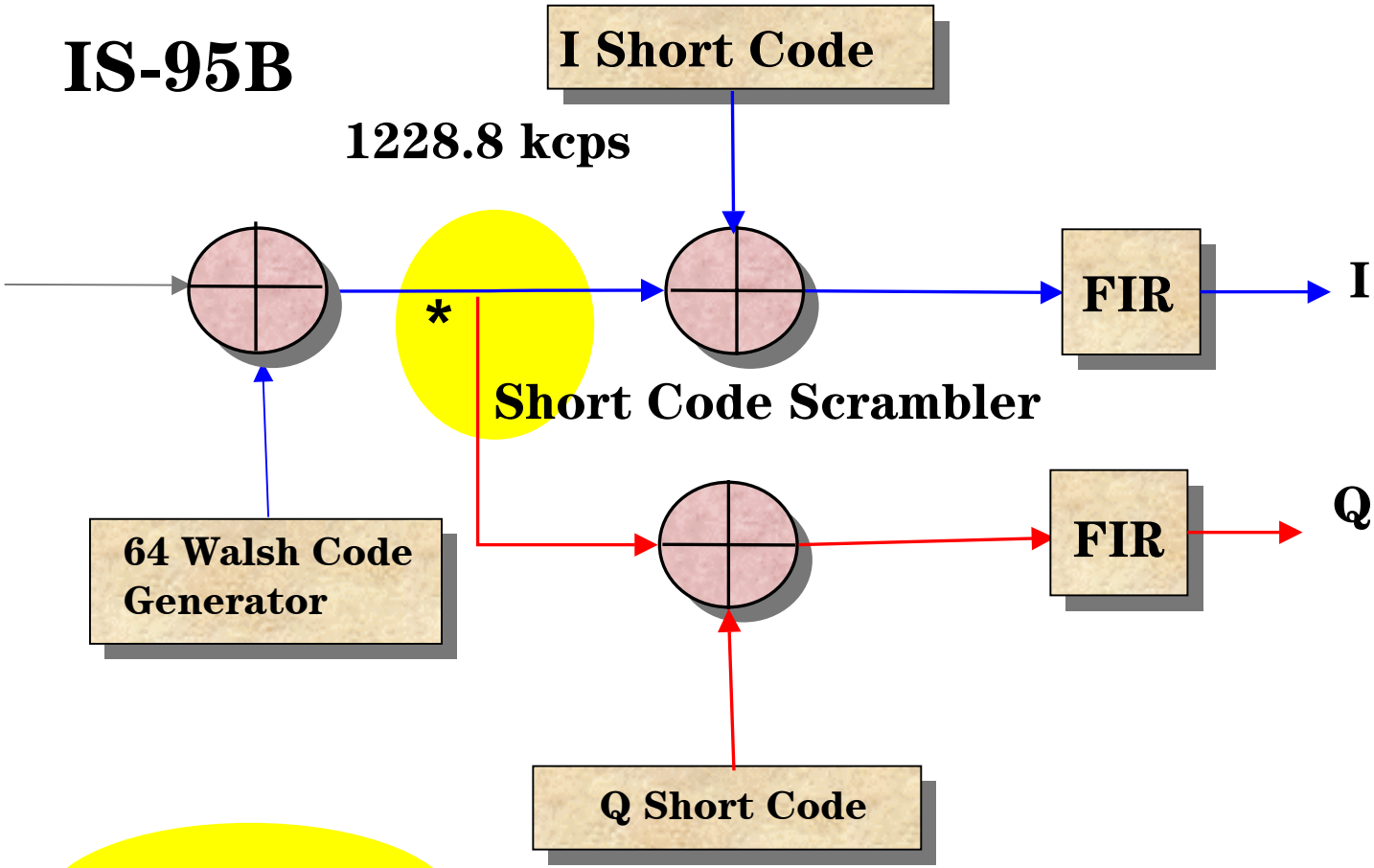
IS-95A/B (9.6 kbps)

Traffic Channel (F-FCH)



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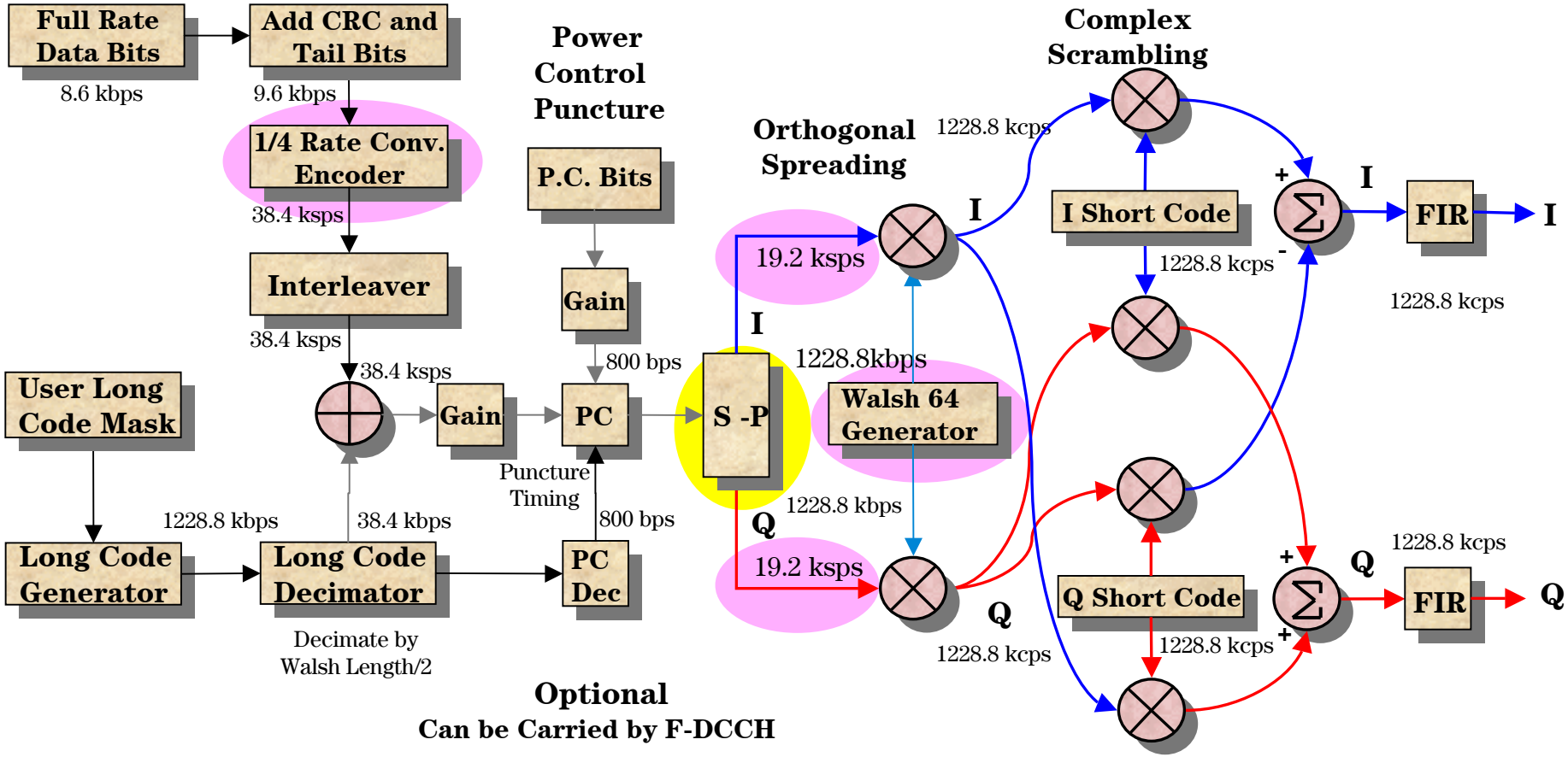
IS-2000 SR1, RC3 (9.6 kbps) (cont.)

Traffic Channel (F-FCH)



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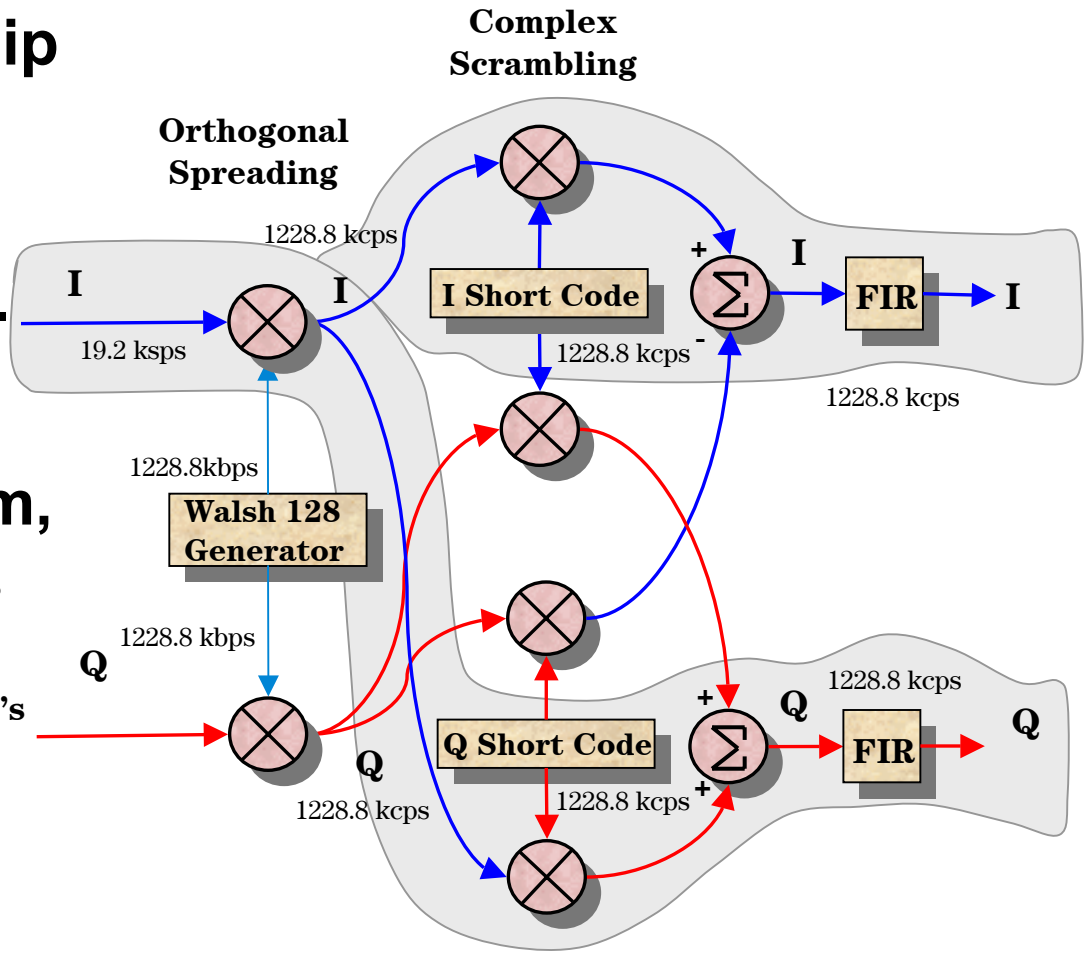
Forward Common Pilot

- Equivalent to IS-95 pilot (Walsh 0 with chip offsets identifying BSs)
- 512 total PNs with 64-chip offsets
- Provides synchronism, signal measurements and phase reference
- Pilot, Paging, Sync applied only to in-phase channel



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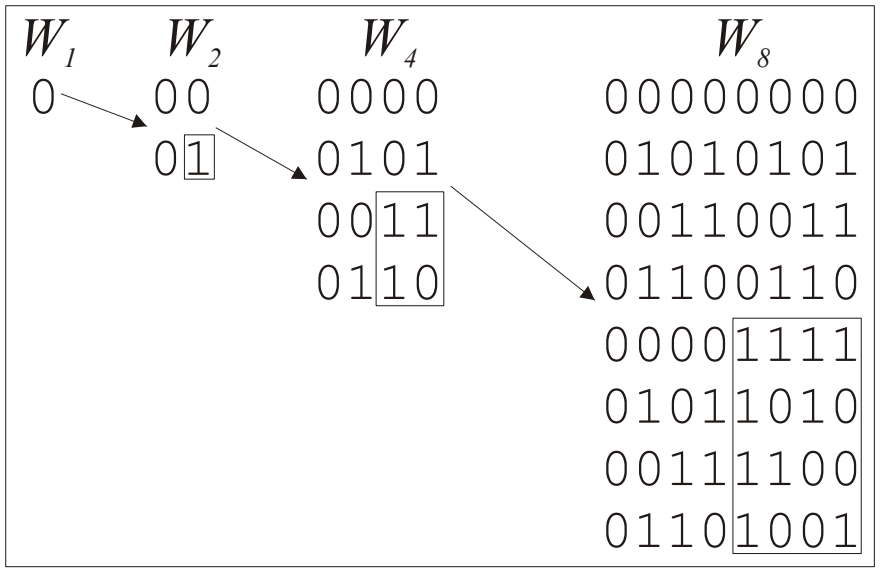
Creating a Walsh Code Matrix

$$W_1 = [0] \quad W_2 = \begin{bmatrix} W_1 & W_1 \\ W_1 & \overline{W}_1 \end{bmatrix} \quad W_4 = \begin{bmatrix} W_2 & W_2 \\ W_2 & \overline{W}_2 \end{bmatrix} \quad \cdots \quad W_{2n} = \begin{bmatrix} W_n & W_n \\ W_n & \overline{W}_n \end{bmatrix}$$

Example



Referencing Walsh Codes

$W_4[2] = 0011$

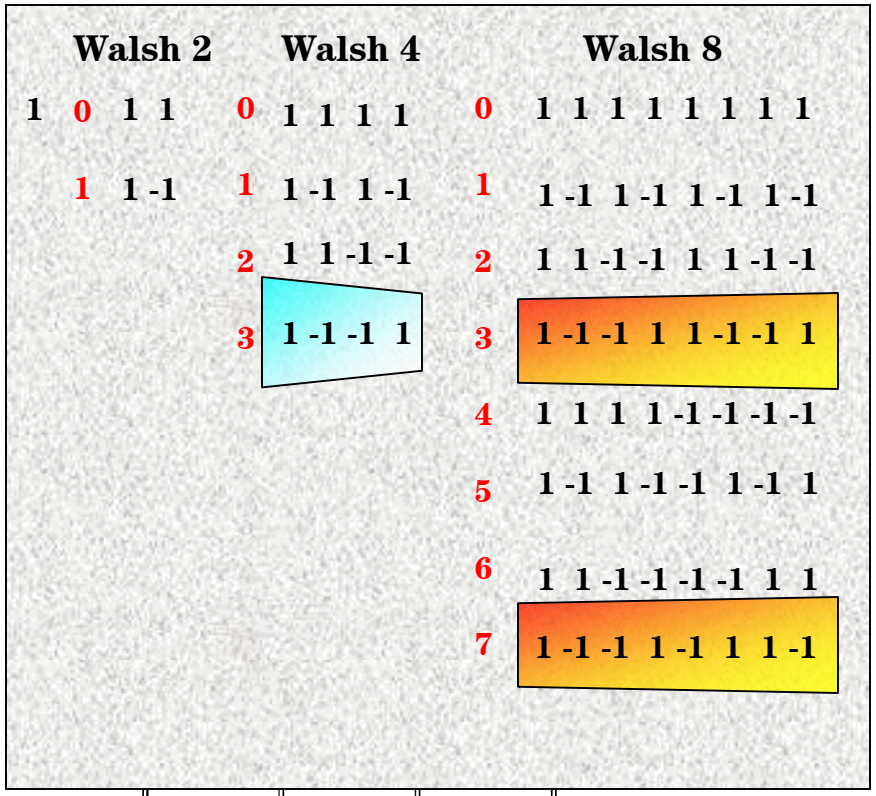
$W_8[7] = 01101001$

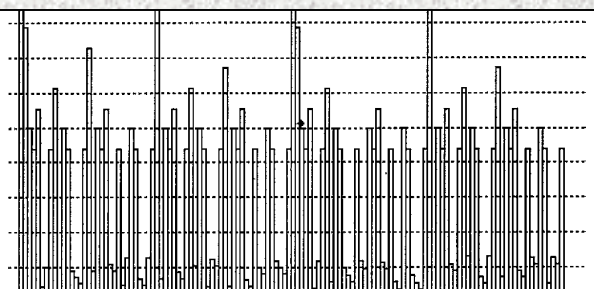
$W_2[0] = 00$

W_7^8 = Walsh Set 8
Walsh Code 7

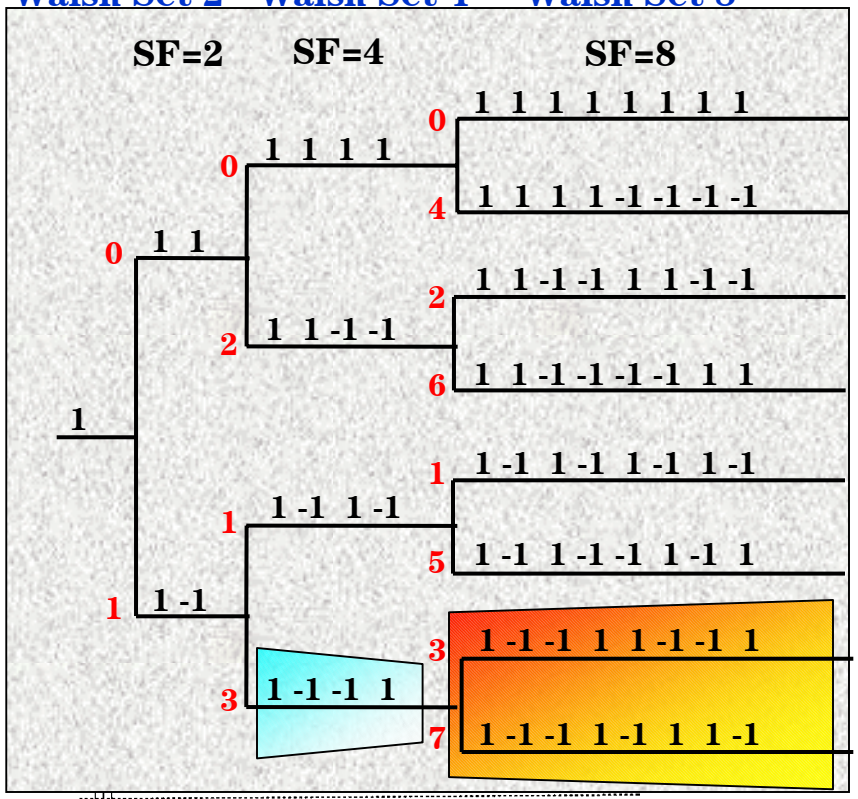
IS-2000 Walsh Code Tree

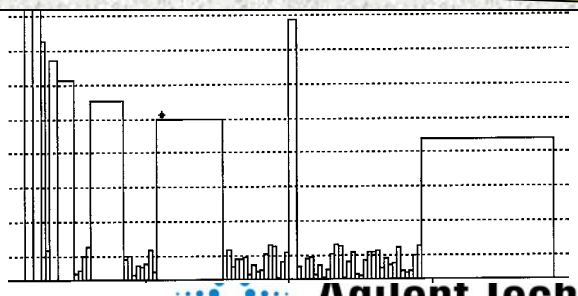
Hadamard Sequence





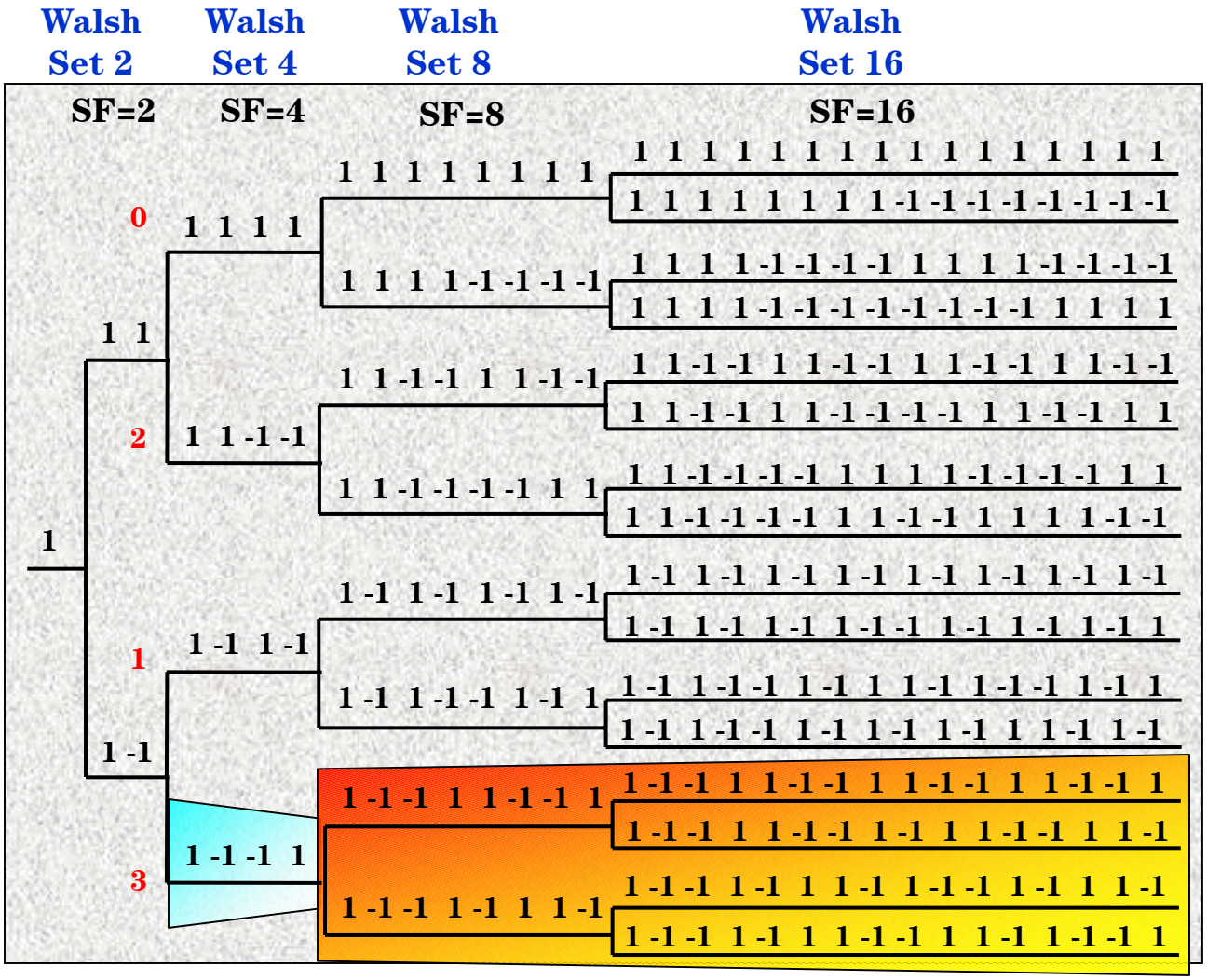
Bit Reversed Sequence





Effects of Using Variable Length Walsh Codes

- Logical 1's and 0's can be represented as physical -1's and 1's in the modulation domain
- Shorter Codes on a Branch map into Longer Codes
- Using Shorter Walsh Codes Precludes Using all Longer Codes Derived from the Original



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Orthogonality of Walsh Codes

- Walsh codes are:
  - Orthogonal with each other and their inverses:
    - *Orthogonality = Equal Number of Matches and Mismatches*

Walsh Codes with SF=8

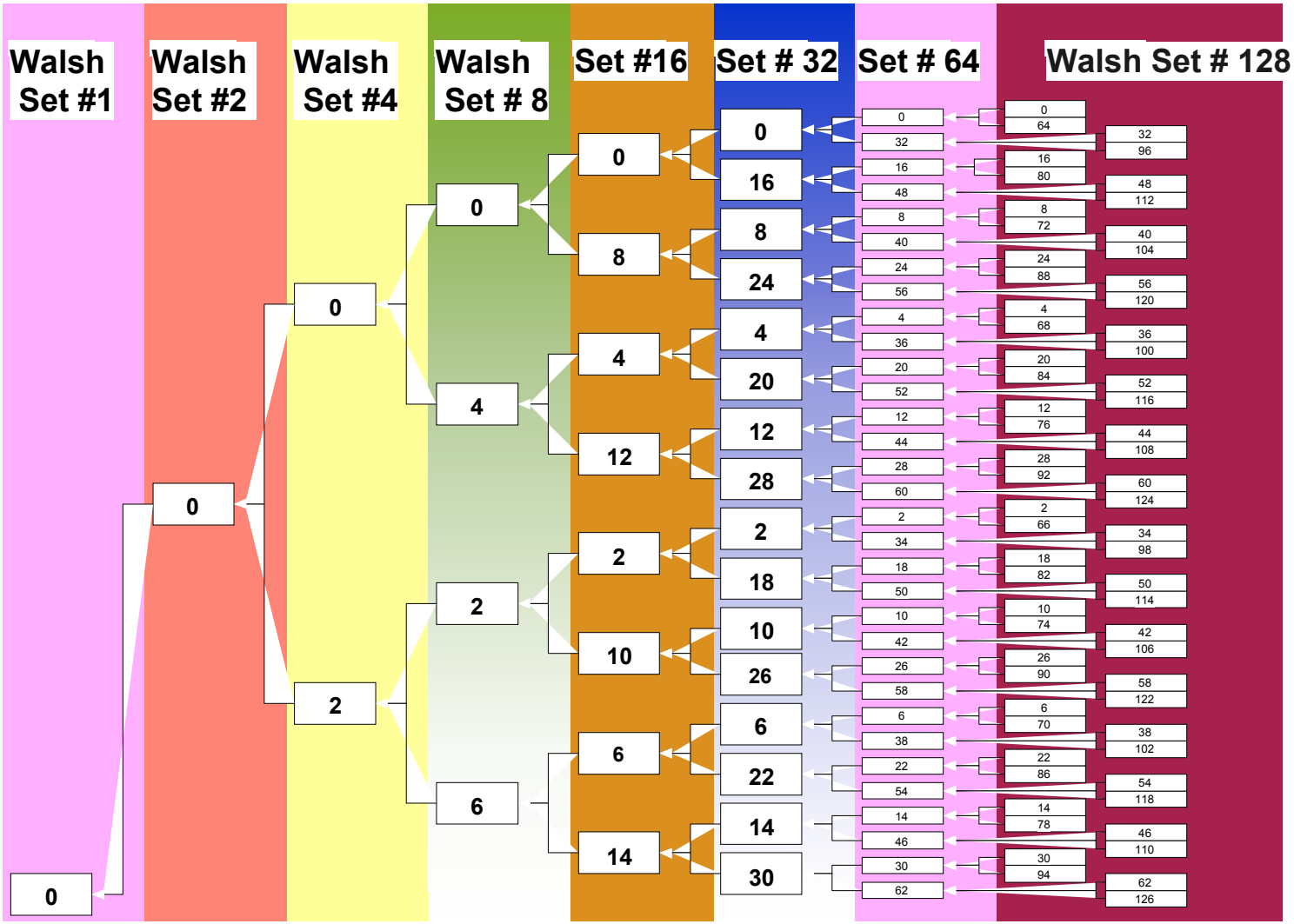
Code	1	1	1	1	1	1	1	1
Code	1	-1	-1	1	1	-1	-1	1
Match?		Y	N	N	Y	Y	N	N	Y

Matches = 4

Mismatches = 4

Net Correlation = 0

IS-2000 Walsh Code Tree (Top Half)



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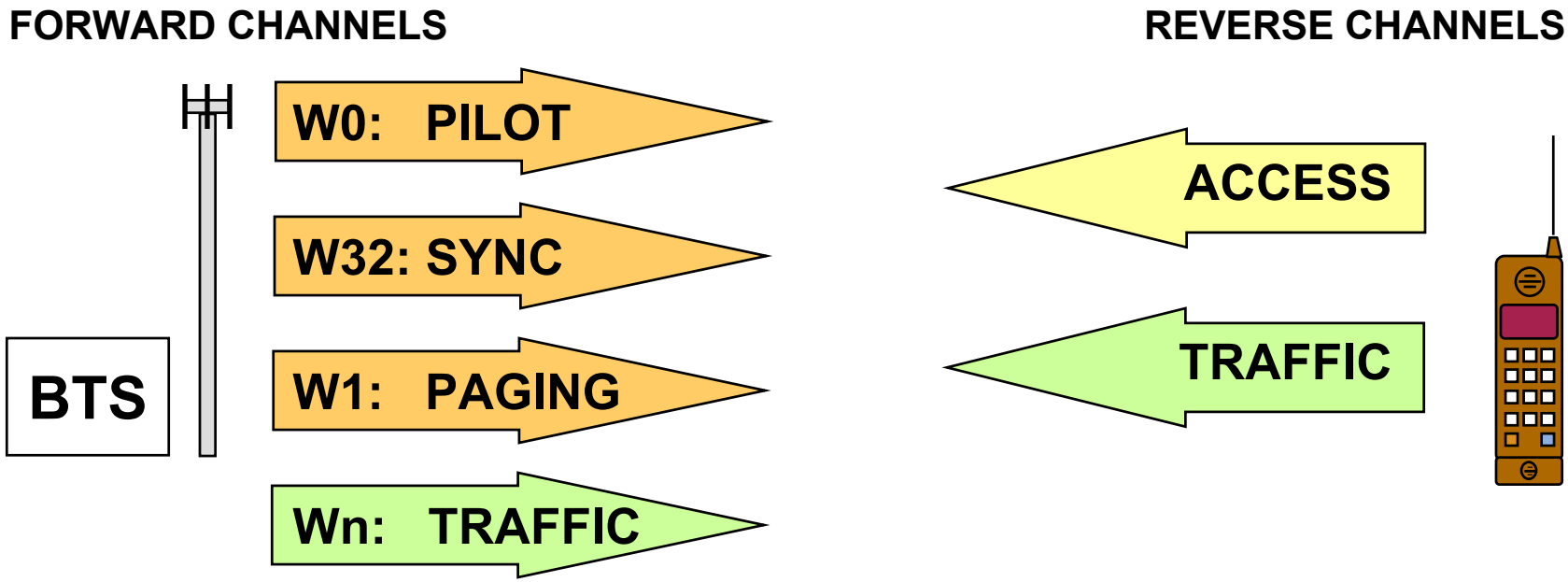
IS-2000 Forward Radio Configurations

- **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, 4, and 5**
  - All use new IS-2000 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

Data Rates & Radio Configurations

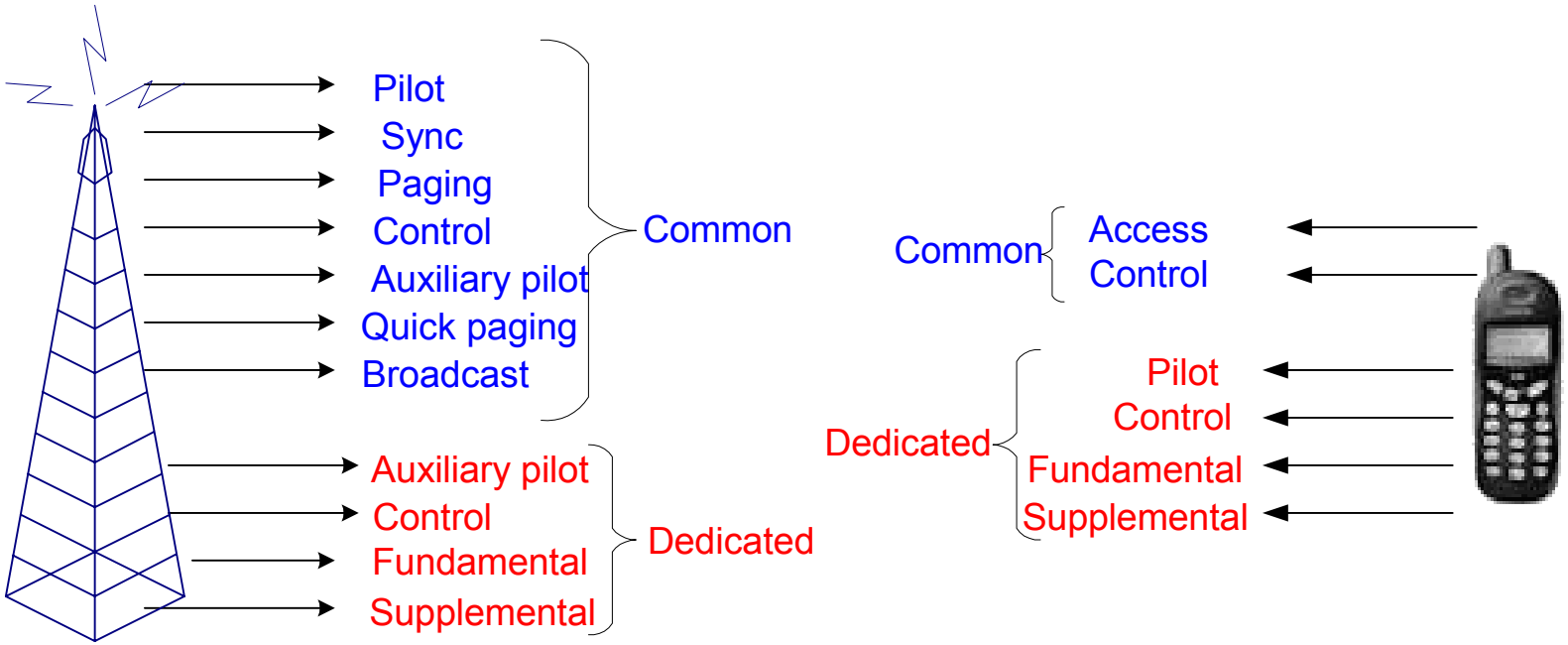
Spreading Rate	Radio Configuration	Forward Link	Data Rates	Radio Configuration	Reverse Link	Data Rates
SR1 1 carrier 1.2288 MCPS	RC1	Required. IS-95B Compatible No cdma2000 coding features	9600 variable	RC1	Required. IS-95B Compatible No cdma2000 coding features	9600 variable
	RC2	Compatible with IS-95B RS2 No cdma2000 coding features	14400 variable	RC2	Compatible with IS-95B RS2 No cdma2000 coding features	14400 variable
	RC3	Quarter-rate convolutional or Turbo Coding, base rate 9600	9600 153600	RC3	¼ rate conv or Turbo coding, 9600 ½ rate conv or Turbo coding, 9600	9600 153600 307200
	RC4	Half-rate convolutional or Turbo Coding, base rate 9600	9600 307200			
	RC5	3/8 rate convolutional or Turbo Coding, base rate 14400	14400 230400	RC4	¼ rate convolutional or Turbo Coding, base rate 14400	14400 230400
SR3 3.6864 MCPS as 3 carriers 1.2288 MCPS	RC6	1/6 rate convolutional or Turbo coding, base rate 9600	9600 307200	RC5	Required. ¼ or 1/3 convolutional Or Turbo coding, base rate 9600	9600 307200 614400
	RC7	Required. 1/3 rate convolutional or Turbo coding, base rate 9600	9600 614400			
	RC8	¼ or 1/3 rate convolutional or Turbo coding, base rate 14400	14400 460800	RC6	¼ or ½ convolutional or Turbo encoding	14400 460800 1036800
	RC9	½ or 1/3 rate convolutional or Turbo encoder, base rate 14400	14400 1036800			

2G Today: IS-95 CDMA Channels



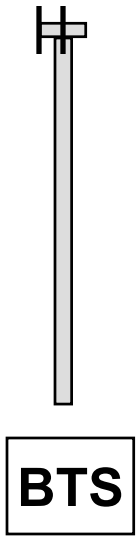
- Existing IS-95A/JStd-008 cdma offers one physical structure using just the channels shown above
- IS-2000 cdma is backward-compatible with this IS-95, but offers additional radio configurations with additional channels

cdma2000 Channels



- Dedicated: Point-to-point, single BS → single MS
- Common: Shared information for/from multiple MS

cdma2000 SR1 CDMA Channels

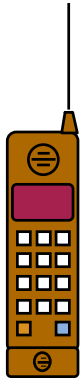


FORWARD CHANNELS

1	F-Pilot	Same coding as IS-95B, Backward compatible
1	F-Sync	Same coding as IS-95B, Backward compatible
1 to 7	PAGING	Same coding as IS-95B, Backward compatible
0 or 1	F-BCH	Broadcast Channel
0 or 1	F-QPCH	Quick Paging Channel
0 or 1	F-CPCCH	Common Power Control Channel
0 or 1	F-CACH	Common Assignment Channel
0 to n	F-CCCH	Common Control Channels
0 to many	F-TRAFFIC	Forward Traffic Channels
0 or 1	F-FCH	Fundamental Channel
0 or 1	F-DCCH	Dedicated Control Channel
0 to 7	F-SCCH *IS-95B only*	Supplemental Code Channels IS-95B only
0 to 2	F-SCH	Supplemental Channels RC3,4,5

REVERSE CHANNELS

Includes Power Control Subchannel	R-Pilot	1
Access Channel (IS-95B compatible)	R-ACH or	1
Enhanced Access Channel	R-EACH	
Common Control Channel	R-CCCH	0 or 1
	R-TRAFFIC	
Reverse Fundamental Channel (IS95B comp.)	R-FCH	0 or 1
Dedicated Control Channel	R-DCCH	0 or 1
Reverse Supplemental Channel	R-SCH	0 to 2



- IS-95 or cdma2000 Rev 0 or Rev A
- cdma2000 Rev A
- cdma2000 Rev 0 or Rev A
- cdma2000 Rev 0 or Rev A (related to traffic)
- IS-95 or cdma2000 Rev 0 or Rev A (related to traffic)
- IS-95B only
- IS-95 or cdma2000 Rev 0

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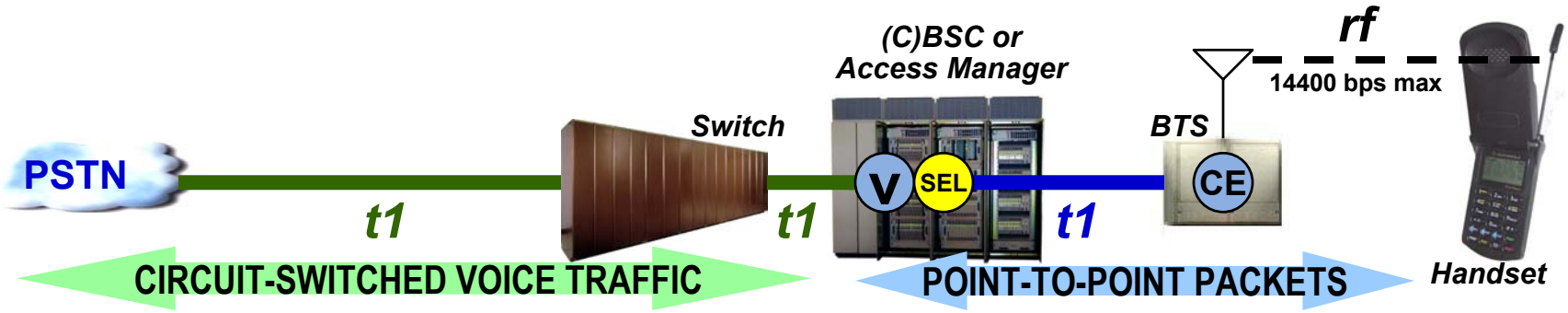
Existing CDMA Voice Networks

- **The cdma voice conversation's 20-ms frames are carried as packets between mobile and the Selector**
  - The selector assembles frames being sent to the mobile and disassembles frames coming from the mobile
  - Frame contents normally include voice and occasional signaling; may also include data if additional equipment is included (not shown)
- **The vocoders in the BSC and the mobile convert the packet stream into continuous DS-0 audio for the end-users**
  - The MSC makes a circuit-switched connection for call

Existing CDMA Voice Networks (cont.)

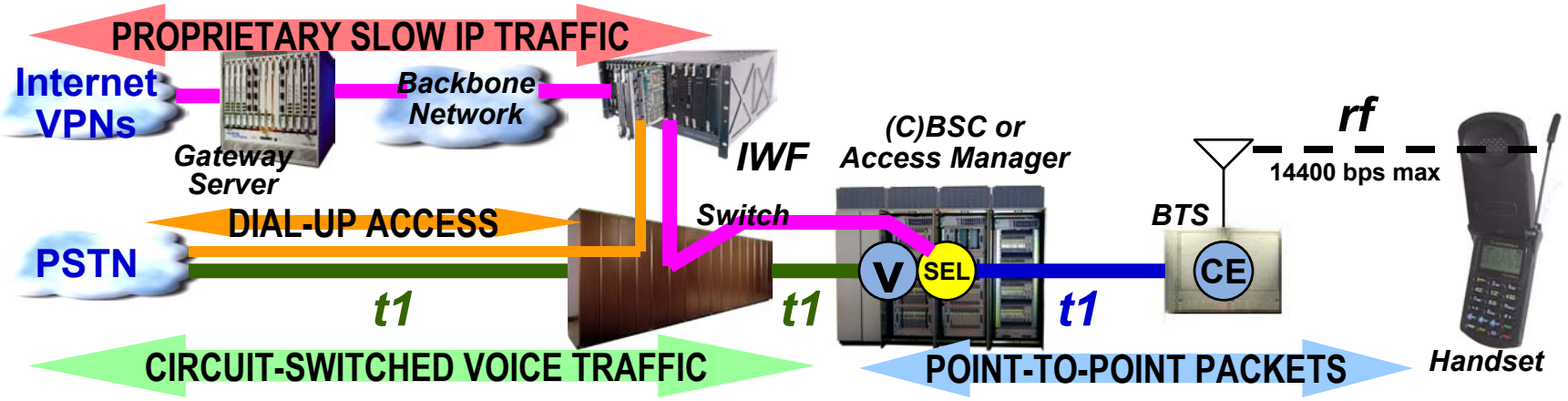


2nd Generation cdma Networks were designed primarily to handle voice

Data Capability Today on a CDMA Network

- **Data to/from the user connects near the selector in the BSC**
  - Passed through the switch as 56kb/s data links in 64kb/s DS-0s
- **Data connection to outside world handled by IWF InterWorking Function**
  - Includes modems to convert data stream into DS-0 for dial-up uses
  - Can contain data routers to access IP or PPP networks
  - May include capability for FAX and other communications modes

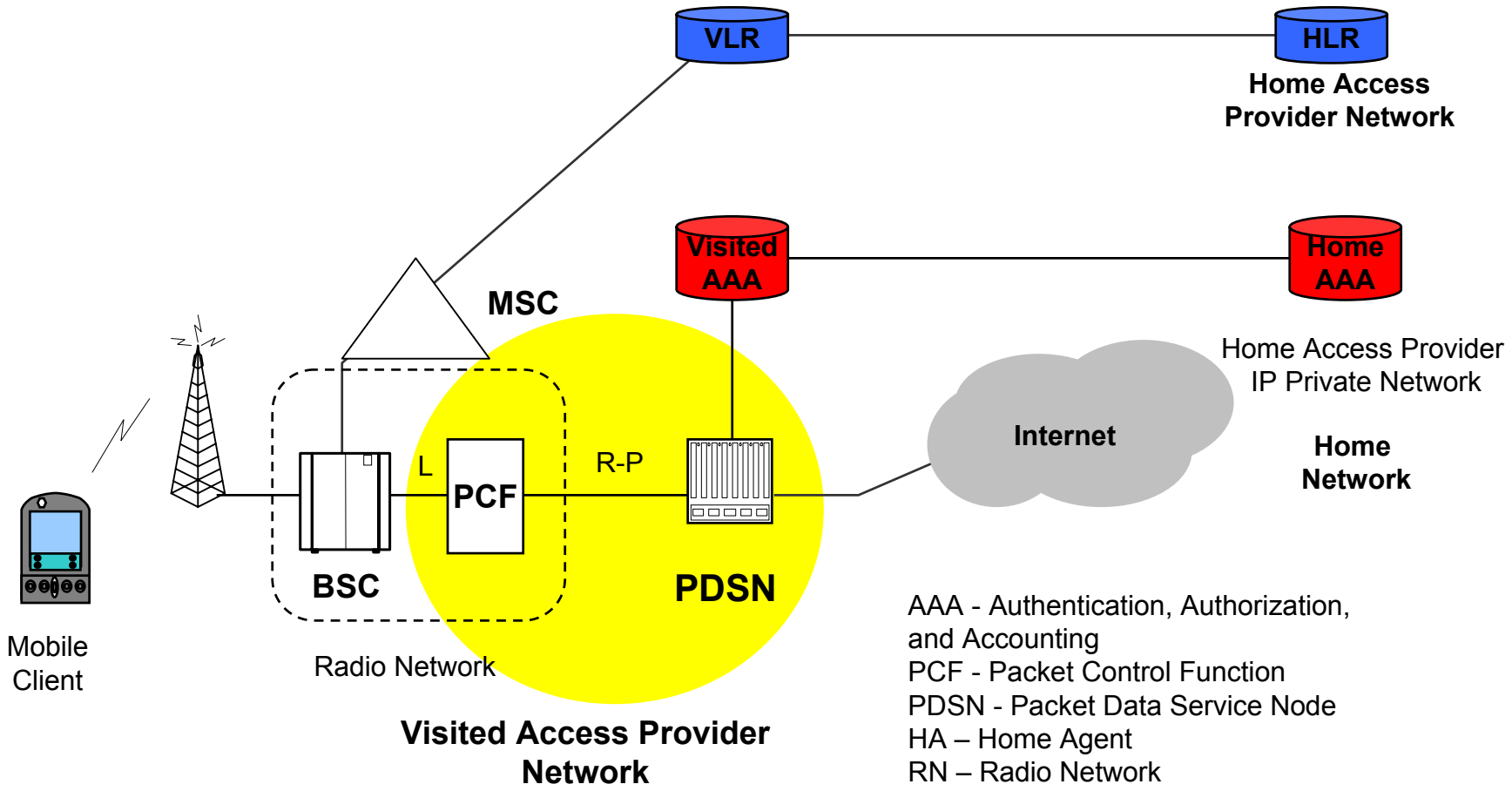
Data Capability Today on a CDMA Network (cont.)



Additional hardware was needed to carry data on a 2G network

cdma2000 Network

Packet Data Requires New H/W including PCF and PDSN



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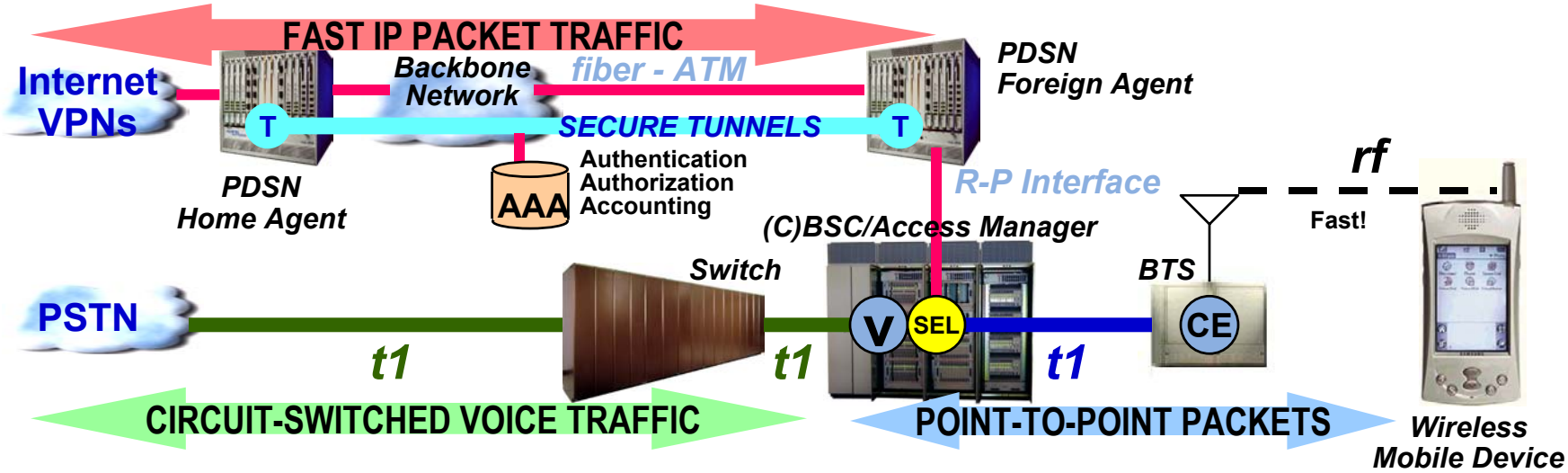
3G Data Capabilities: 1xRTT CDMA Network

- **This requires a Packet Data Serving Node**
  - ISP and operator-provided services are provided by external Home Network and Home Agent servers
  - Authentication, Authorization, and Accounting provided by external server
- **The IWF (InterWorking Function) is still maintained to allow old mobiles to use dial-up and WAP/wireless web keypad access**

3G Data Capabilities: 1xRTT CDMA Network (cont.)



For full-featured data access over a 3G network, a true IP connection must be established to outside Packet Data Networks

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Conclusions

- **IS-2000 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
- **Supports High Speed Data for New Applications**

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  - *Scott Baxter and Associates, Nashville, TN*
- ***3GPP2 web site: www.3gpp2.org***