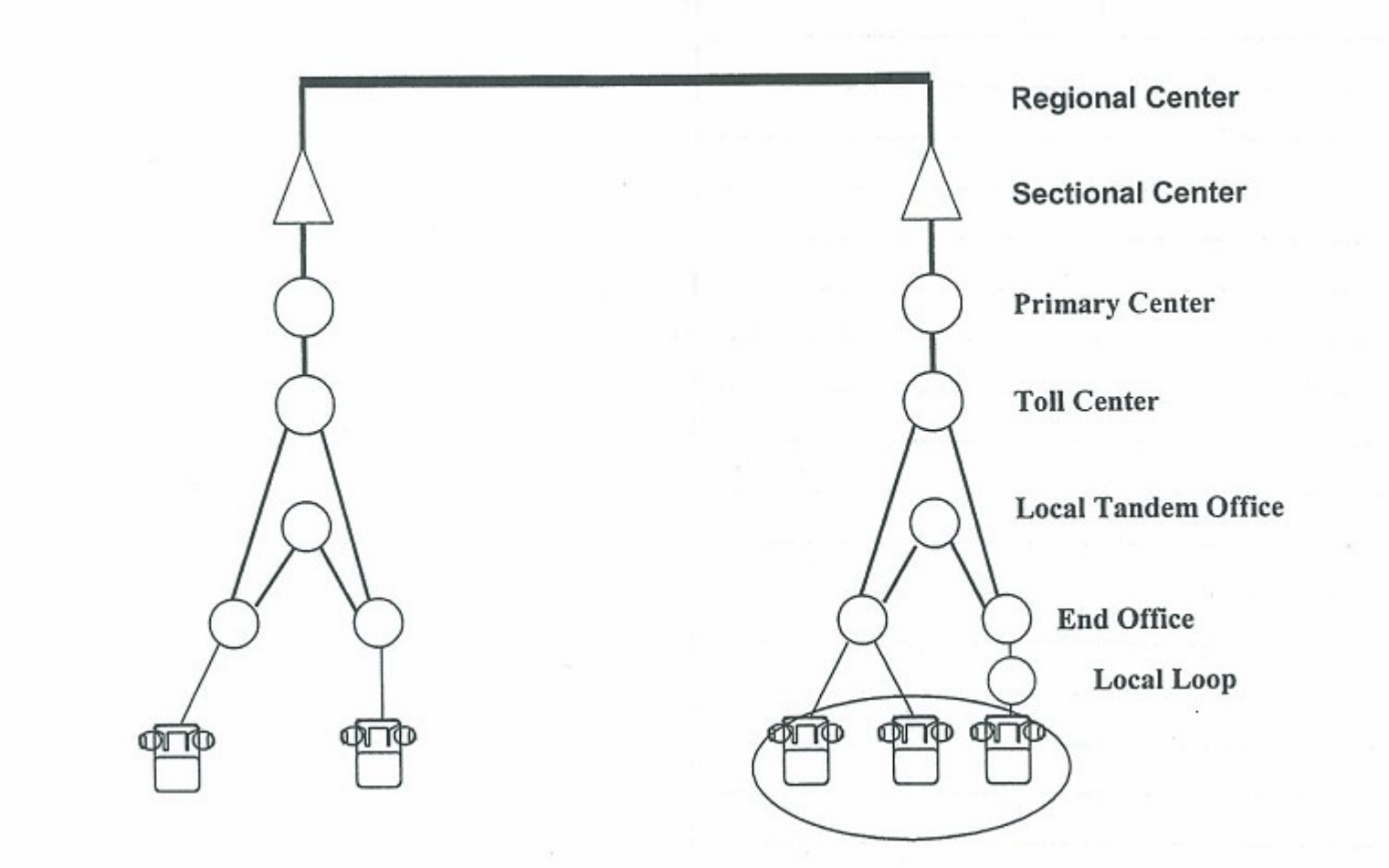
CDMA Wireless Standards

Section 1

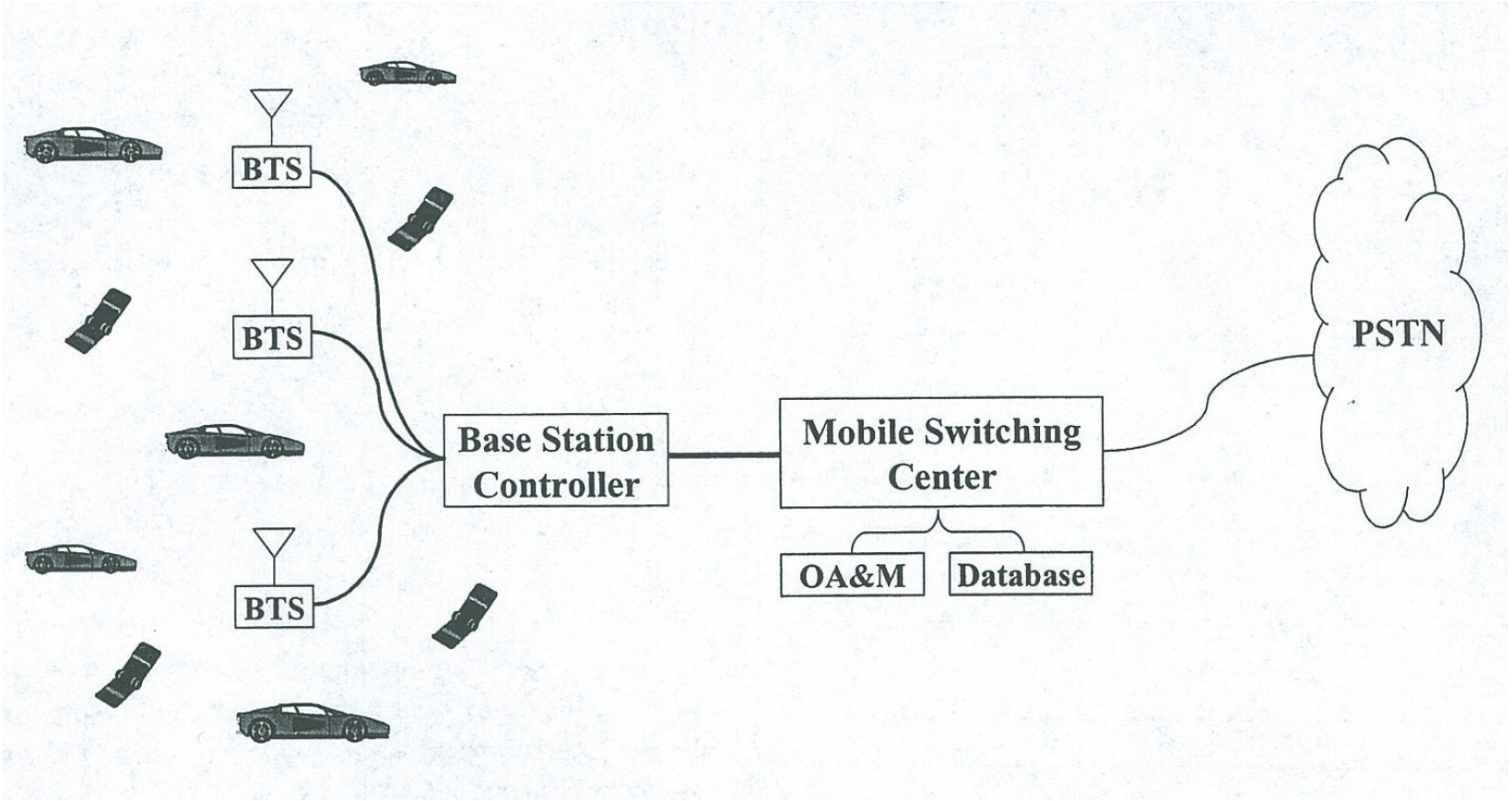
Objectives

- Review the mobile telephone system architecture.
- Review multiple access techniques.
- Describe channel behavior in wireless systems.
- Define requirements for spread spectrum wireless systems.

Public Switch Telephone Network



Mobile Network Architecture



Multiple Access

- Access to a Resources
  - Communication Channel
  - Reasonable grade of service (GoS) for voice and data
- Coverage
  - Outdoor
  - Indoor
- Flexibility (Voice, Data, Video, & SMS)

Multiple Access Efficiency

- Efficient Use of Channel
  - Minimize bandwidth for narrow -band systems
  - Minimize E_b/N_o for digital system
- Maximize Capacity

Large Scale Fading

- Successful Multiple Access Systems Address
  - Interference
    - System generated (co-channel interference mitigated by frequency planning in narrow-band systems.)
  - Path loss
  - Multipath/Fading (mitigated by equalizers in narrow-band systems and by rake receivers in wide-band systems)

Propagation Models

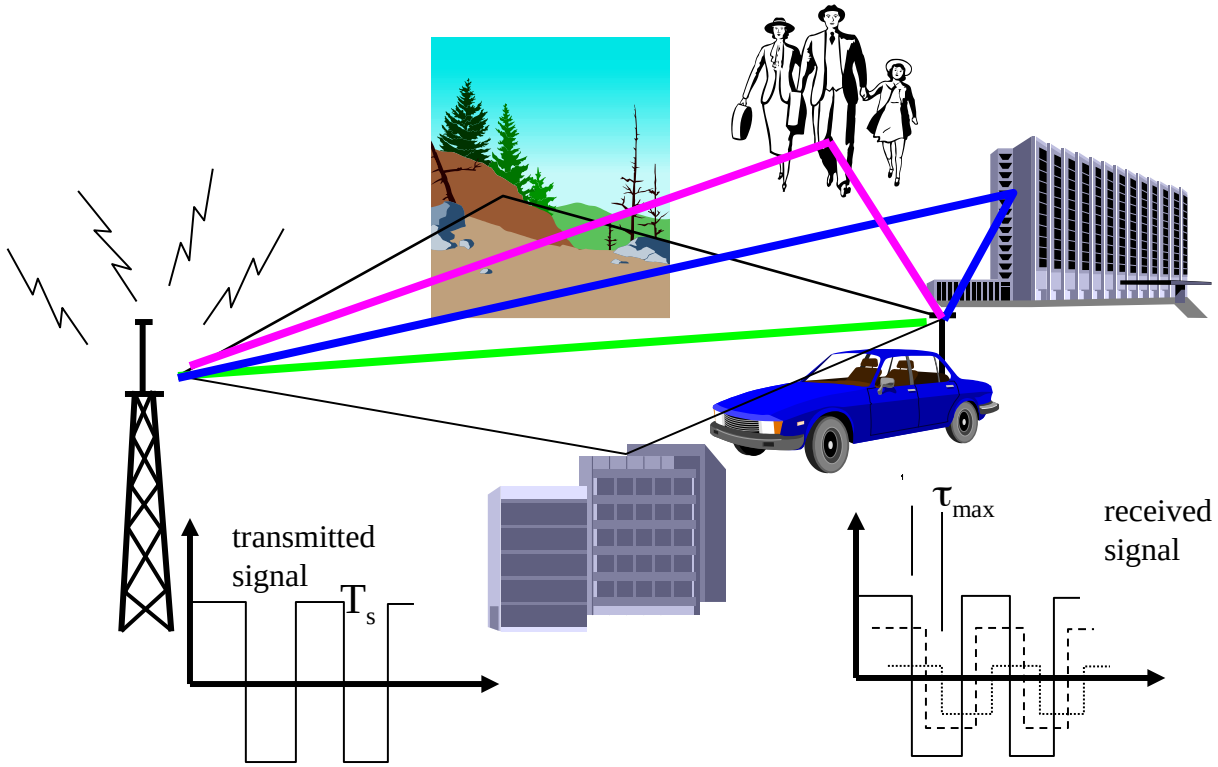
- **Propagation Models** are normally used to predict the average signal strength at a given distance from the transmitter.

  – Propagation models that predict the mean signal strength for an arbitrary T-R separation distance are useful in estimating the radio coverage area. This is called the *Large Scale* or *Path Loss* propagation model (several hundreds or thousands of meters);

  – Propagation models that characterize the rapid fluctuations of the received signal strengths over very shot distance (few wavelengths) or short duration (few seconds) are called *Small Scale* or *Fading* models.

Introduction to Radio Wave Propagation

- Reflection
  - Large buildings, walls, earth surface
- Diffraction
  - Obstacles with dimensions
- Scattering
  - Foliage, lamp posts, street signs, walking pedestrian, etc.



Reflection:

It occurs when propagating electromagnetic waves impinges upon an object which has a large dimension compared to its own wavelength

Reflection occurs from the surface of the earth, buildings and walls

Diffraction:

It occurs when propagation path of an electromagnetic wave is obstructed by a sharp edge.

This gives rise to bending of waves around the obstacles even when there is no line-of-sight present between transmitter and receiver.

Scattering:

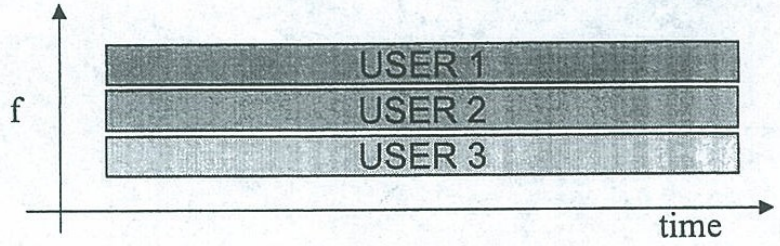
It occurs when small objects with dimensions (small compared with the wavelength) gets in the way of the propagation paths, and when the number of obstacles per unit volume is large.

In general these objects include foliage, pedestrians, street lamps and small particles such as dust etc.

Multiple Access Techniques

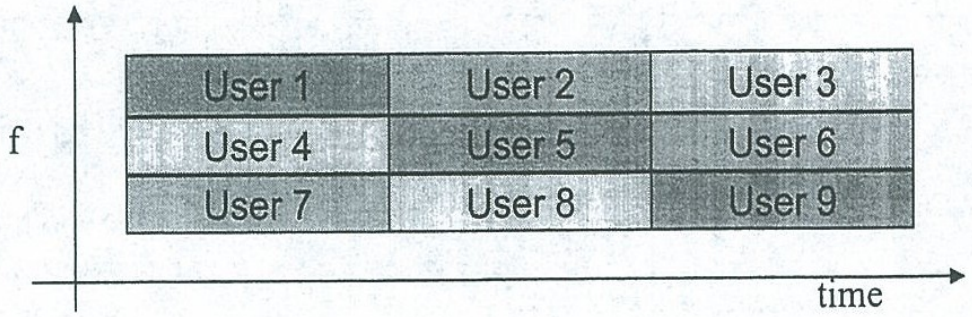
- FDMA
  - Separate the users in frequency domain (Spectral) (AMPS, TACS, NAMP)
- TDMA
  - Separate the users in time and frequency domain (Temporal)(GSM, IS-136)
- CDMA
  - Separate the users by codes (Spatial) (IS-95, W-CDMA)

Frequency Division Multiple Access



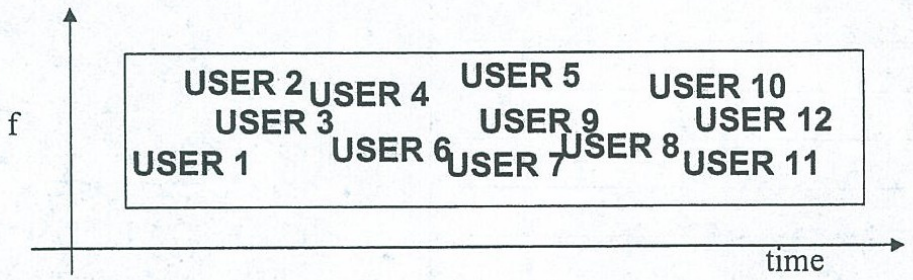
- FDMA was the 1st generation (main objective: mobility)
  - AMPS (USA 2 x 30kHz Bandwidth)
  - TACS (UK 2 x 25 kHz Bandwidth)
  - JTACS (Japan 2 x 25 kHz Bandwidth)
- Advancements
  - NAMPS (USA 2 x 10 kHz Bandwidth)

Time Division Multiple Access



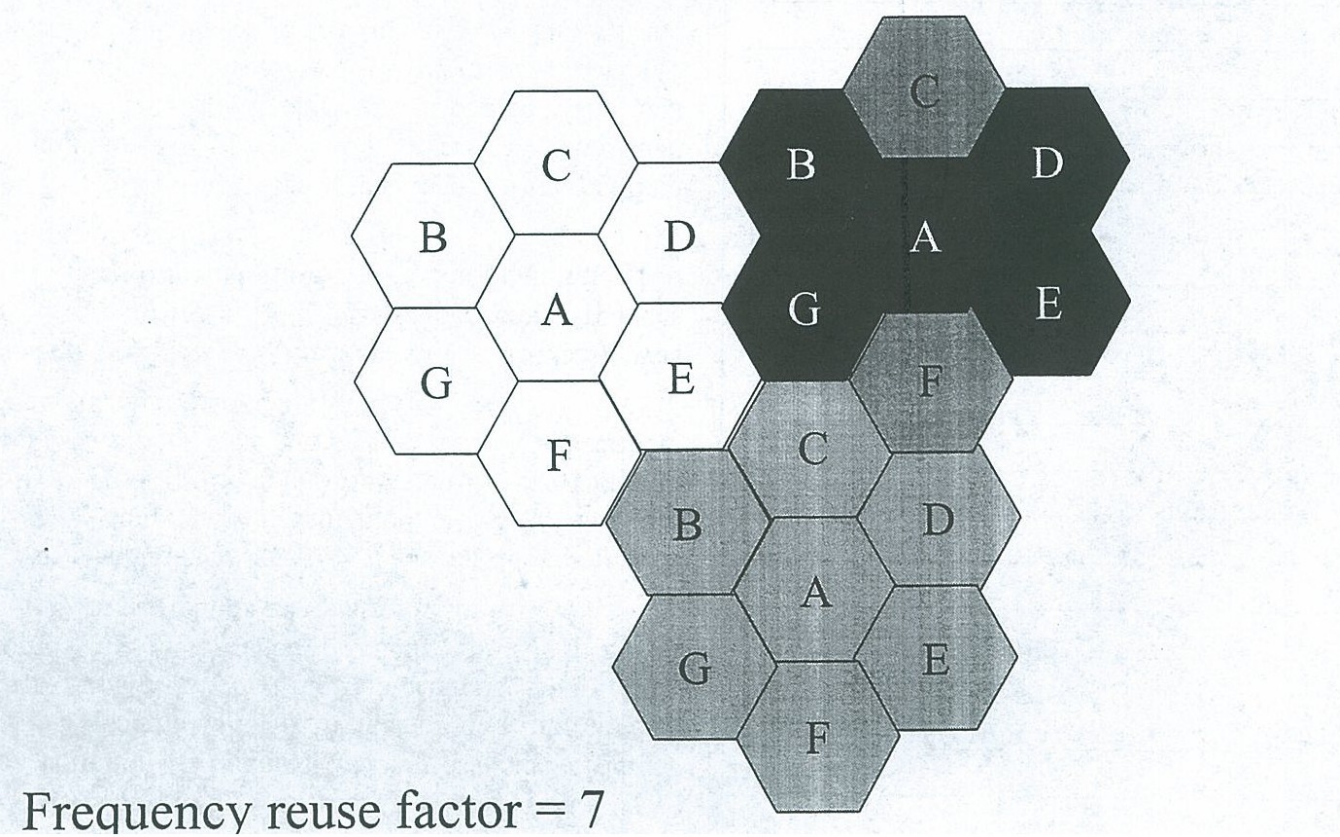
- TDMA was the 2nd Generation (objective: roaming, capacity)
  - GSM (Europe, 200kHz Bandwidth, 8 users multiplexed)
  - IS-54, IS-136 (USA, 30 kHz Bandwidth, 3 or 6 users multiplexed)
  - Typical SNR, 10 dB

Code Division Multiple Access

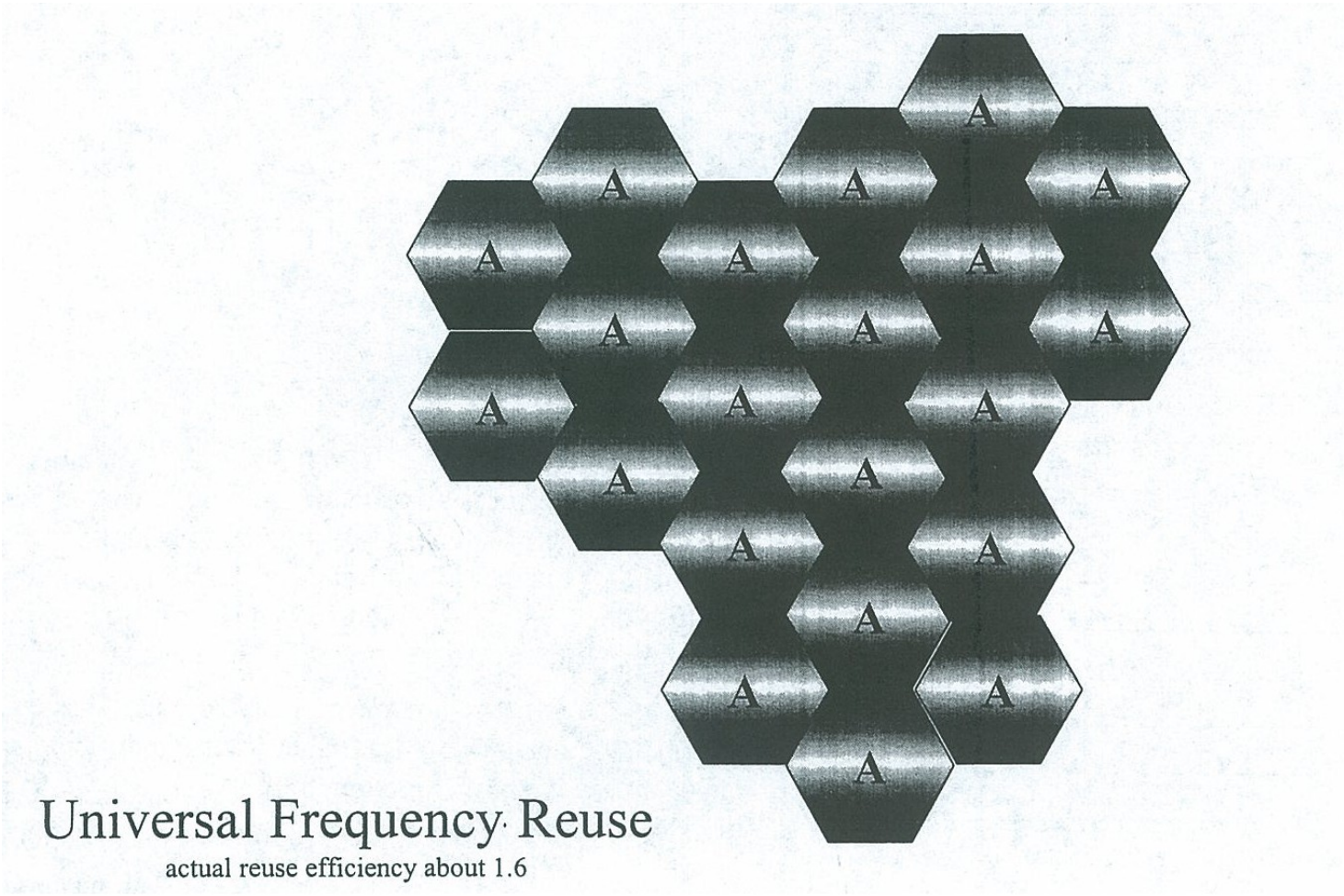


- CDMA (IS-95) was 2nd Generation (main technology objectives: capacity & coverage)
  - TIA/EIA-95 (USA)
  - 1.25 MHz Bandwidth
  - Soft capacity depends on many parameter such as VOCODER rate, sectorization, and effectiveness of power control.

Frequency Reuse for FDMA and CDMA

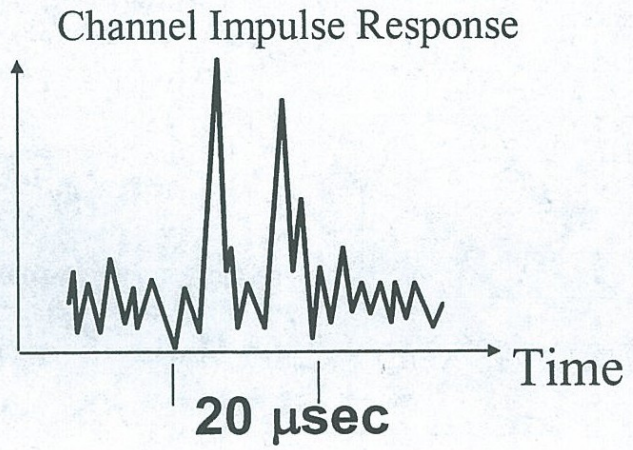


Universal Frequency Reuse in CDMA

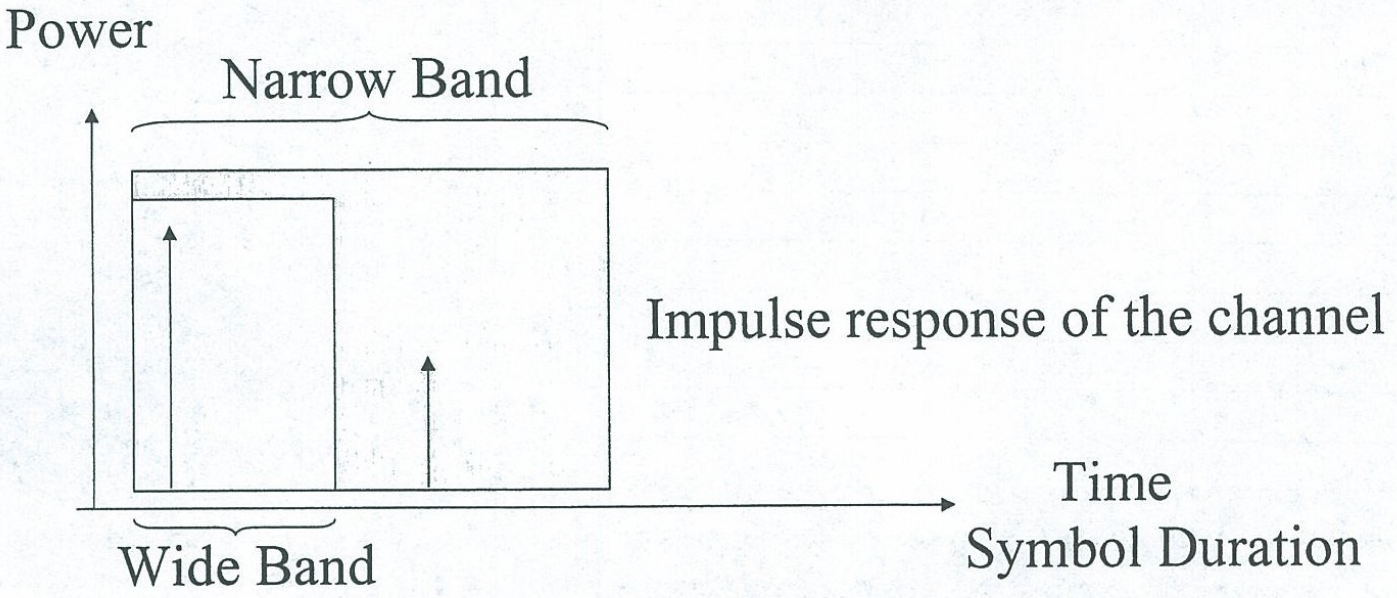


Multiple Access Issues
Small Scale Fading

- Multipath is the primary channel degrading factor
- Reflected signals arrive with different path delay, attenuation and phase
- Such Reflected signals sometimes add destructively producing "Rayleigh" Fading



Delay Profiles



Delay Profiles of a Multipath Channel

Coherence BW= 1/(Delay Spread)

Level Crossing

$$N_R = \sqrt{2\pi}\, f_D \rho e^{-\rho^2}$$

Average Number of Fades in One Second

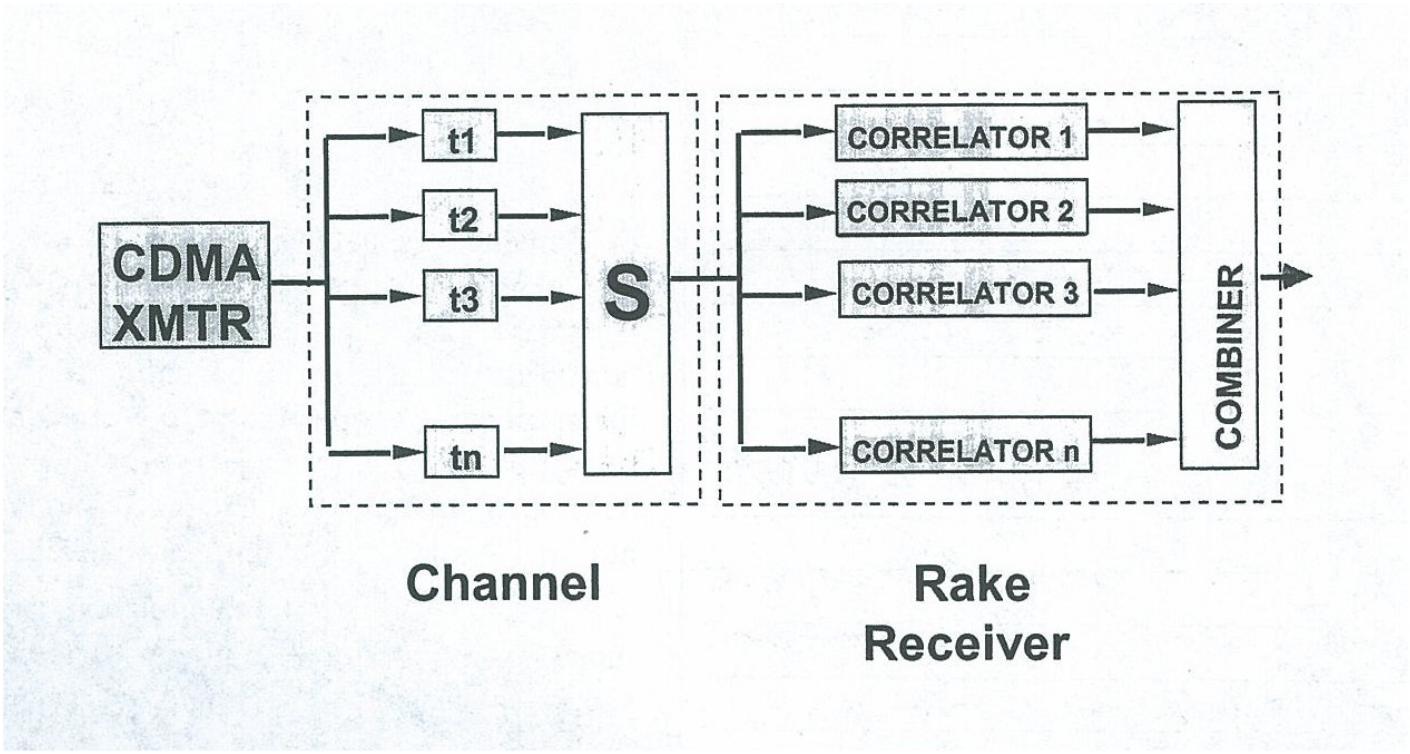
$$\tau = \frac{e^{\rho^2} - 1}{\rho f_D \sqrt{2\pi}}$$

Average Duration of A Fade in One Second

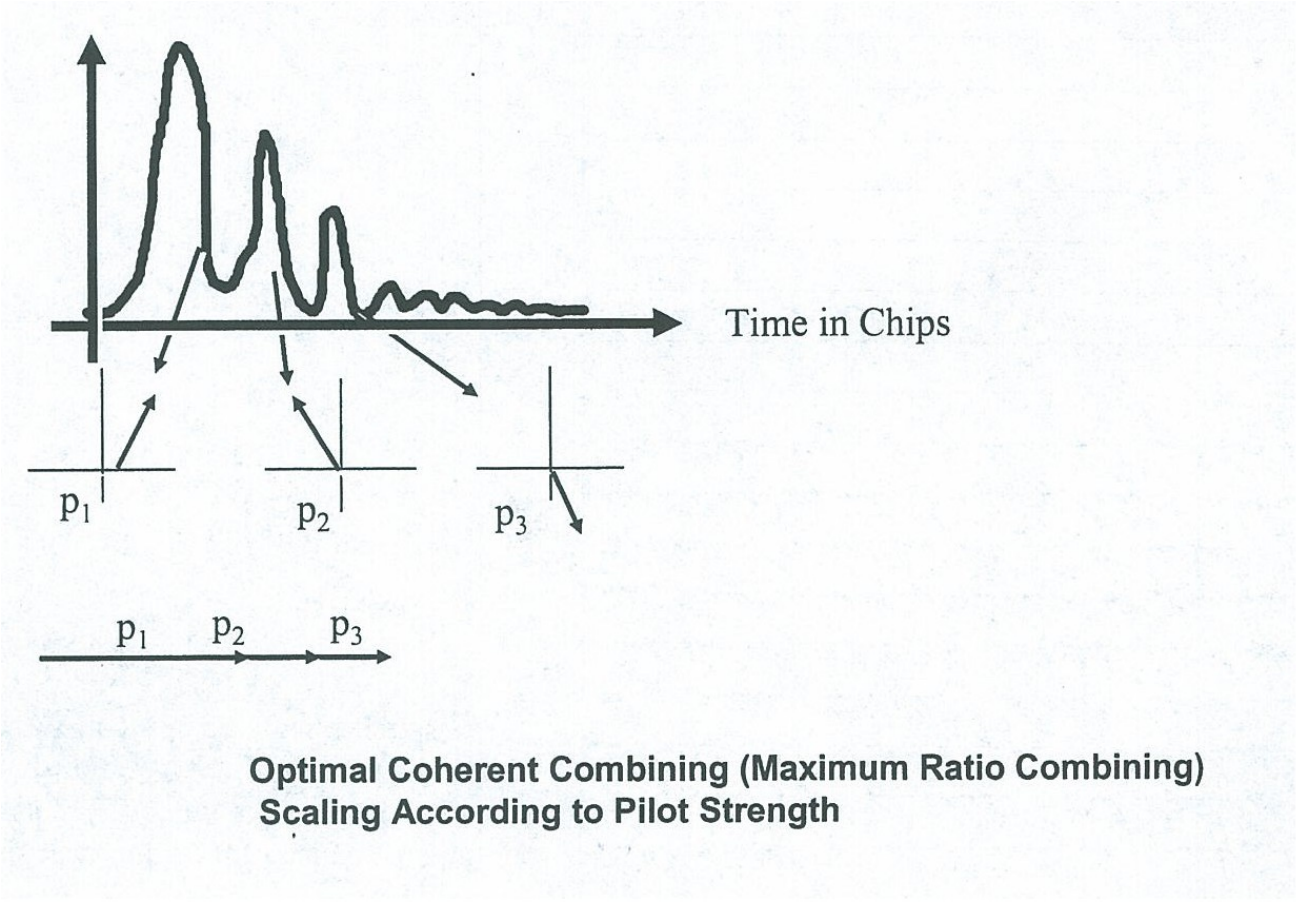
Multipath in Mobile Communications

- In FDMA/TDMA, multipath can only be overcome by equalizers and high C/I which reduces capacity due to high frequency reuse requirement .
- CDMA separates the arriving signals by using correlators (rake receivers, hence no need for equalizers)
- This results in more path diversity, higher signal quality, and higher capacity

Multipath Channel Rake Receiver



Multipath Signal Combining



Optimal Coherent Combining (Maximum Ratio Combining)
Scaling According to Pilot Strength

Diversity Elements

The number of diversity elements (correlators) for a digital system of pulse width BW is given by

$$M = \frac{\delta + \frac{1}{BW}}{\frac{1}{BW}} = BW * \delta + 1$$

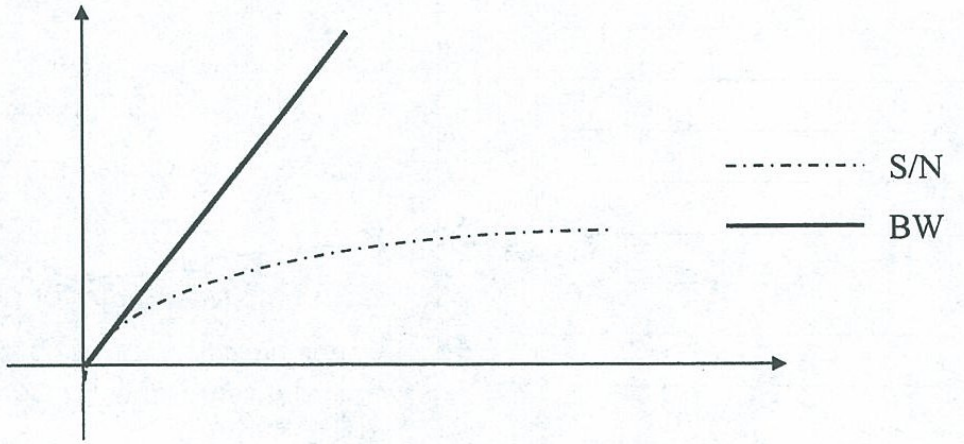
Where δ is the time delay spread of channel. The table below gives a comparison between AMPS and CDMA cellular systems.

Environment	δ	BW=30 KHz	BW=1.25 MHz
Suburban	0.5 μ sec	1.015	1.625
Urban	3 μ sec	1.09	4.75

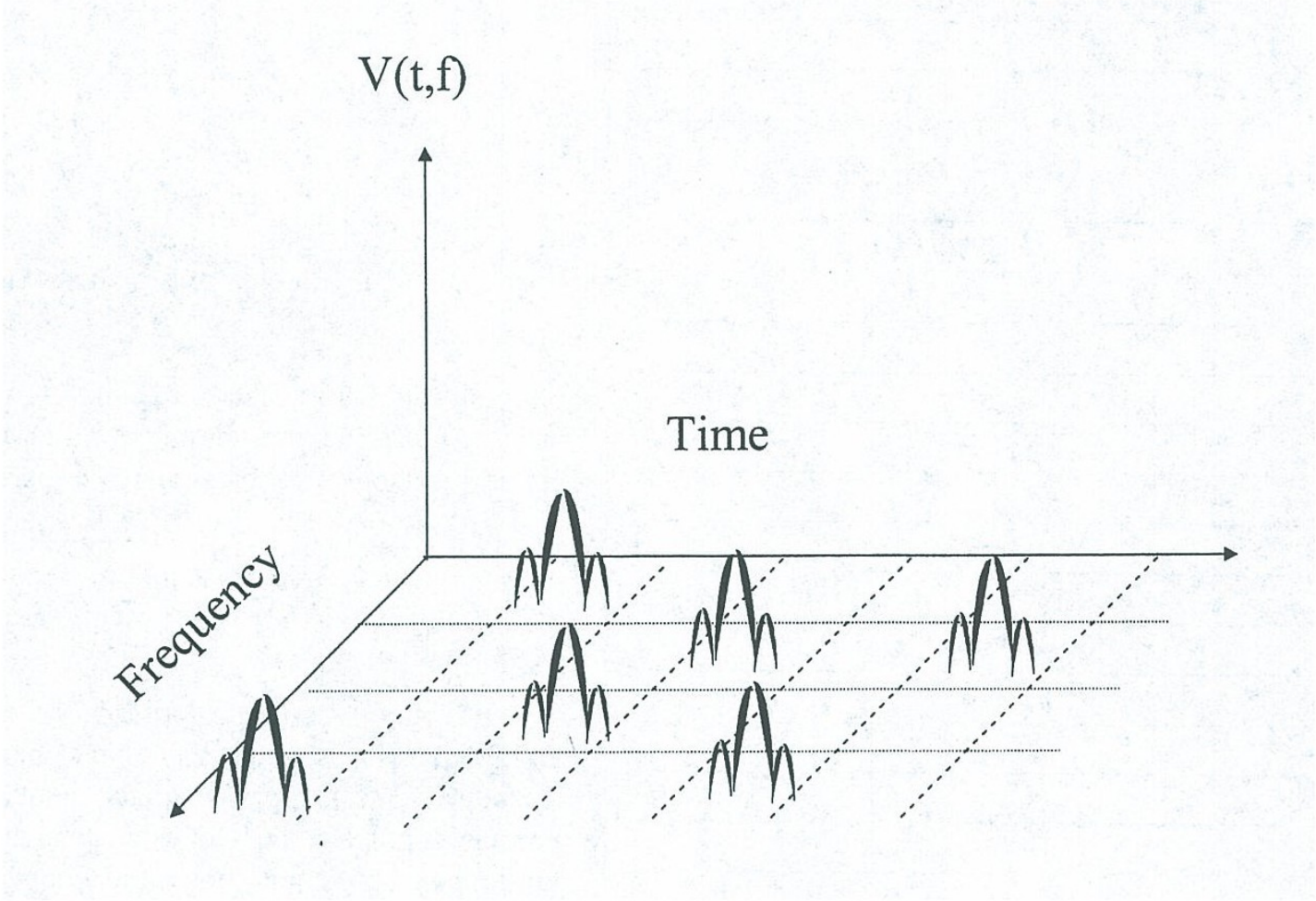
Shannon Theorem

$$C = (BW)\log_2(1 + S/N)$$

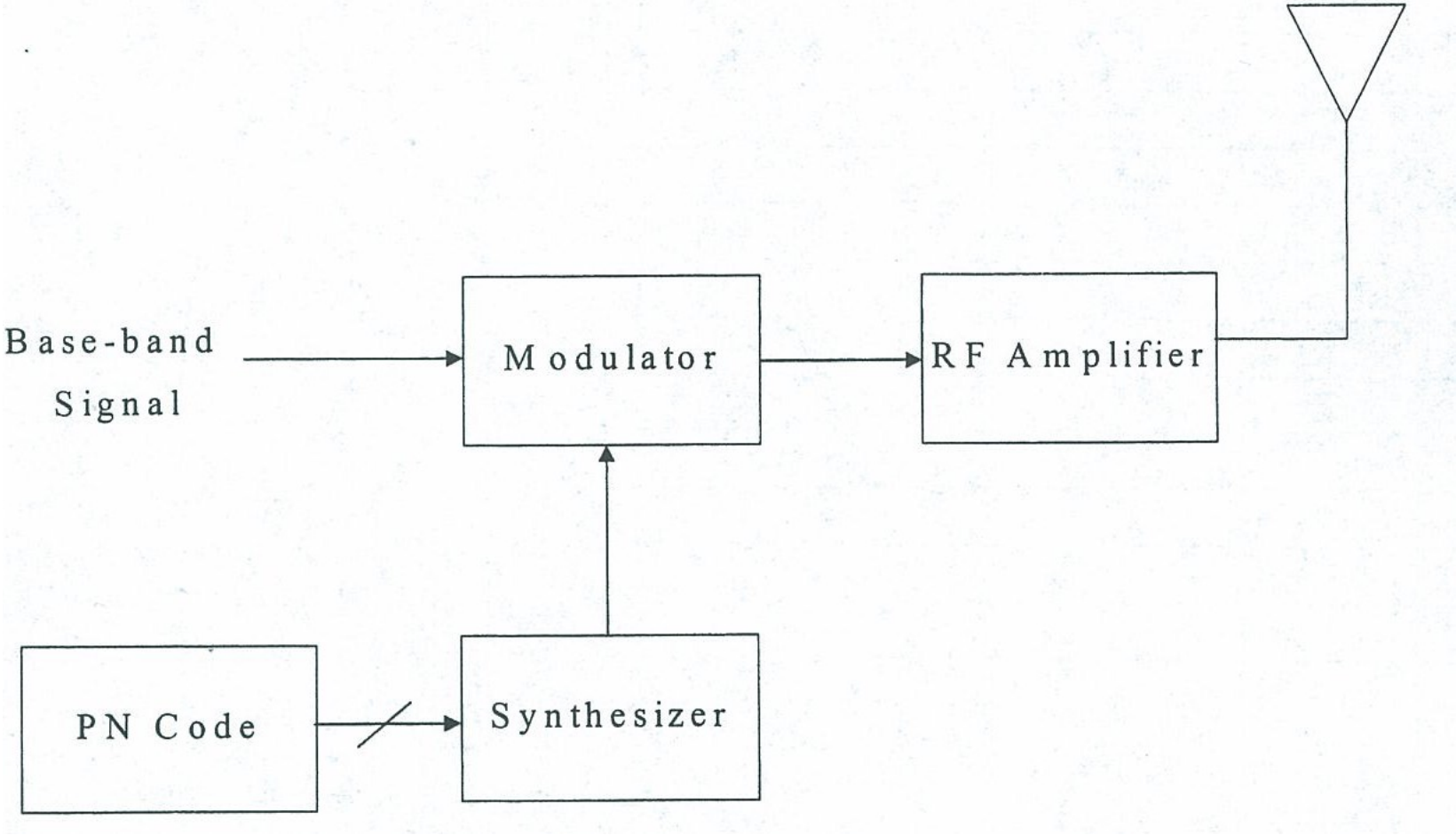
C = Capacity (Max error free bps through the channel)
BW = Bandwidth of the channel
S/N = Signal to Noise Ratio at the receiver



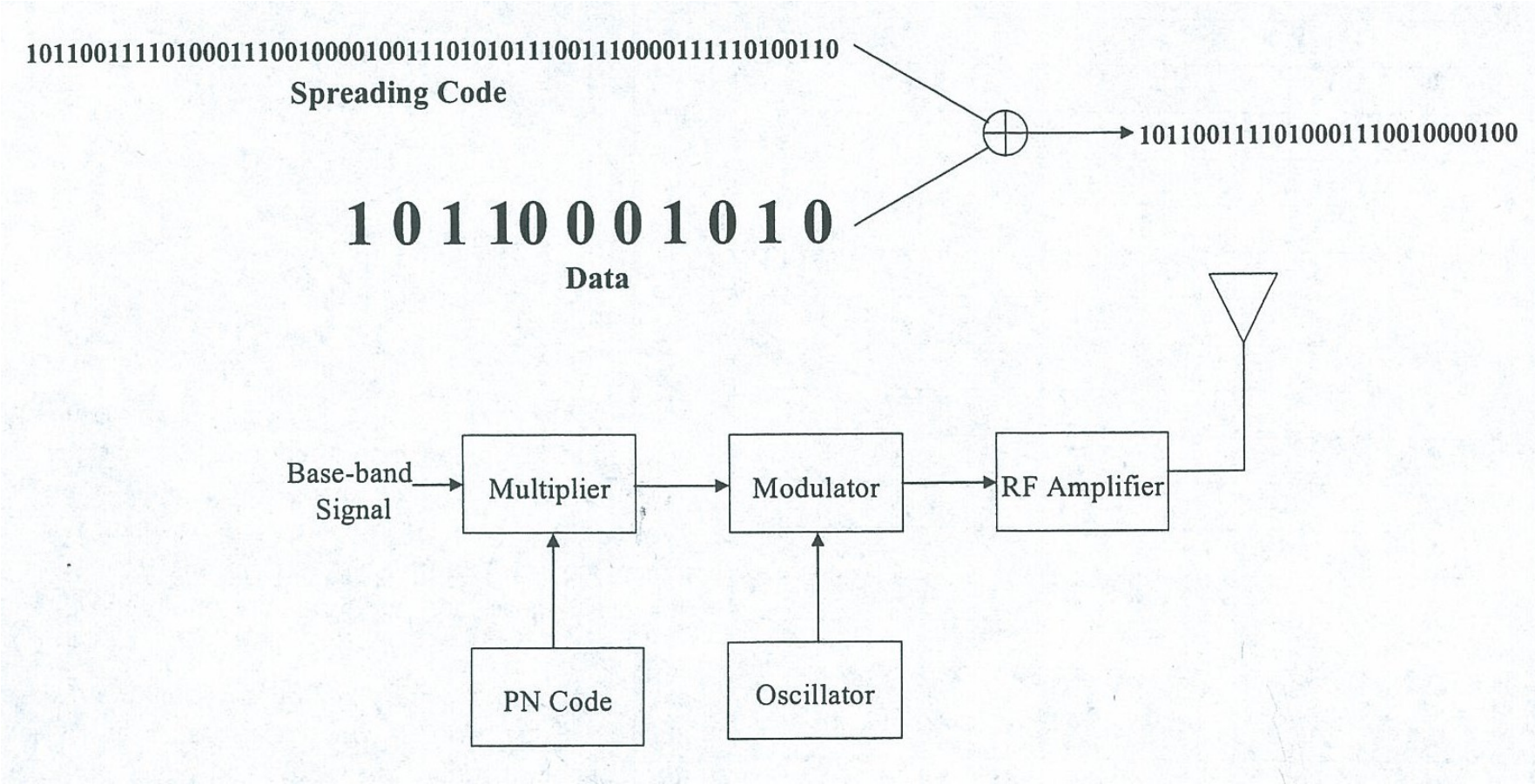
Frequency Hopping Spread Spectrum



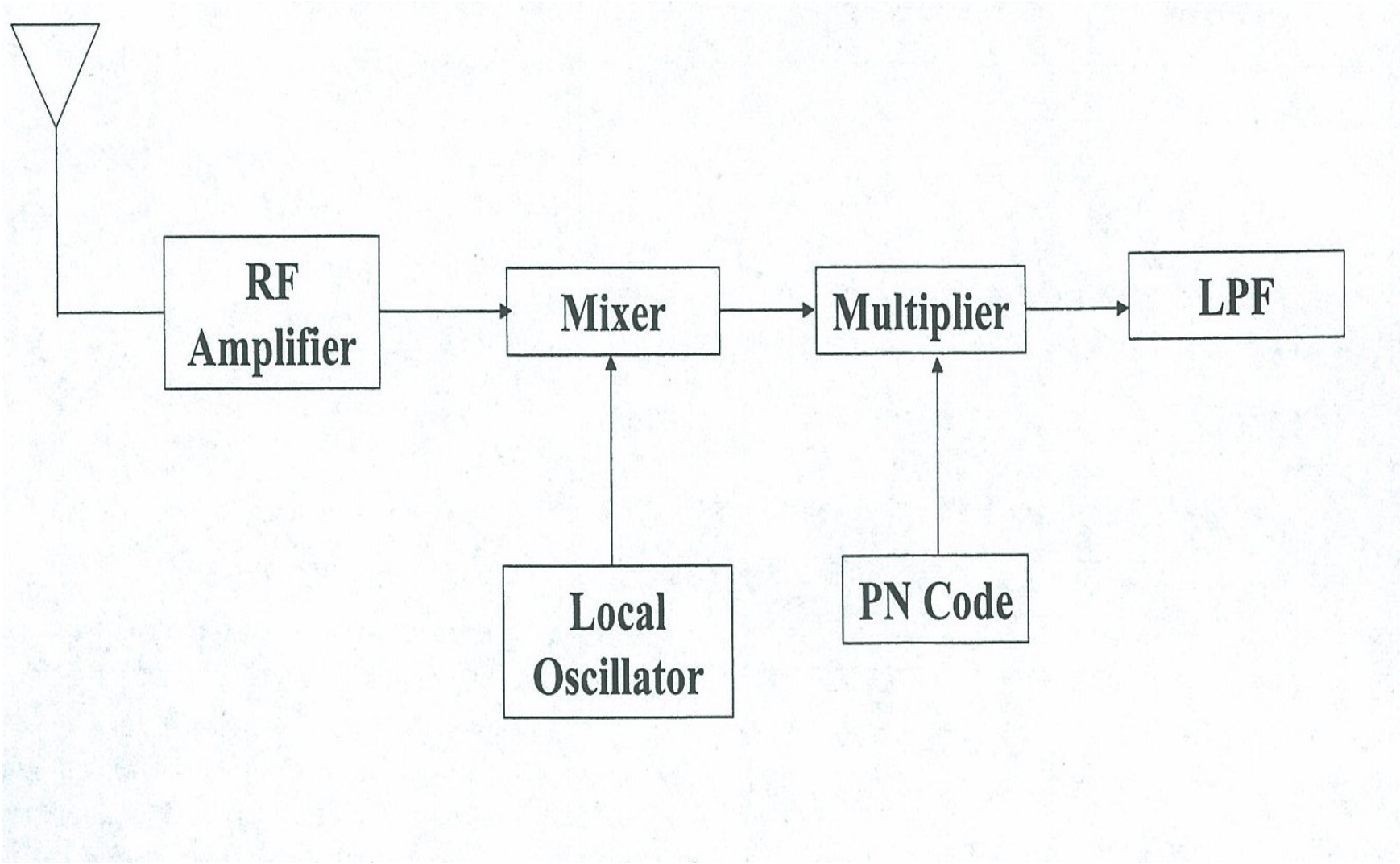
Basic Fast Hopping Transmitter Block Diagram



Basic Direct Sequence Transmitter Block Diagram



Basic Receiver Block Diagram



Cellular Frequencies

System	Valid CDMA Frequency Assignments	CDMA Channel Number	Transmitter Frequency Assignment (MHz)	
			Mobile	Base
A" (1MHz)	///////	991	824.040	869.040
		1012	824.670	869.670
	CDMA	1013	824.700	869.700
		1023	825.000	870.000
A (10 MHz)	CDMA	1	825.030	870.030
		311	834.330	879.330
	///////	312	834.360	879.360
		333	834.990	879.990
B (10 MHz)	///////	334	835.020	880.020
		355	835.650	880.650
	CDMA	356	835.680	880.680
		644	844.320	889.320
	///////	645	844.350	889.350
		666	844.980	889.980
A' (1.5 MHz)	///////	667	845.010	890.010
		688	845.640	890.640
	CDMA	689	845.670	890.670
		694	845.820	890.820
	///////	695	845.850	890.850
		716	846.480	891.480
B' (2.5 MHz)	///////	717	846.510	891.510
		738	847.140	892.140
	CDMA	739	847.170	892.170
		777	848.310	893.310
	///////	778	848.340	893.340
		799	848.970	893.970

PCS Frequencies

Block Designator	Valid CDMA Frequency Assignments	CDMA Channel Number	Transmit Frequency Band (MHz) Personal Station	Base Station
A (15 MHz)	Not Valid	0–24	1850.000–1851.200	1930.000–1931.200
	Valid	25–275	1851.250–1863.750	1931.250–1943.750
	Cond. Valid	276–299	1863.800–1864.950	1943.800–1944.950
D (5 MHz)	Cond. Valid	300–324	1865.000–1866.200	1945.000–1946.200
	Valid	325–375	1866.250–1868.750	1946.250–1948.750
	Cond. Valid	376–399	1868.800–1869.950	1948.800–1949.950
B (15 MHz)	Cond. Valid	400–424	1870.000–1871.200	1950.000–1951.200
	Valid	425–675	1871.250–1883.750	1951.250–1963.750
	Cond. Valid	676–699	1883.800–1884.950	1963.800–1964.950
E (5 MHz)	Cond. Valid	700–724	1885.000–1886.200	1965.000–1966.200
	Valid	725–775	1886.250–1888.750	1966.250–1968.750
	Cond. Valid	776–799	1888.800–1889.950	1968.800–1969.950
F (5 MHz)	Cond. Valid	800–824	1890.000–1891.200	1970.000–1971.200
	Valid	825–875	1891.250–1893.750	1971.250–1973.750
	Cond. Valid	876–899	1893.800–1894.950	1973.800–1974.950
C (15 MHz)	Cond. Valid	900–924	1895.000–1896.200	1975.000–1976.200
	Valid	925–1175	1896.250–1908.750	1976.250–1988.750
	Not Valid	1176–1199	1908.800–1909.950	1988.800–1989.950

Capacity of Cellular FDMA & TDMA

$$m = \frac{\frac{B_t}{B_c}}{\sqrt{\frac{2}{3}\left(\frac{C}{I}\right)}}$$

m = Number of channels per cell
Bt = Total bandwidth
Bc = Channel bandwidth
C/I = Min required Carrier to Interference ratio per channel or per time slot

Reversal Link Pole Capacity

$$N \approx \frac{\left(\frac{W}{R}\right)(1-\eta)}{\left(\frac{E_b}{I_0}\right)(1+f)\upsilon} G_s$$

Pole capacity of a sectorized CDMA cell

Capacity Comparison with AMPS

System	Radio Capacity/Sector	Erlang Capacity/Sector
AMPS	19	12.3
CDMA	216	202
CDMA/AMPS	11.4 times	16.4 times

Summary

- Wireless Architecture
- Multiple Access Techniques
- Multi-path Channel
- Coherence Bandwidth
- Spread Spectrum Principle
- Capacity Comparison

END OF SECTION