STEVENS
Institute of Technology

# Code Division Multiple Access (CDMA)

EE583 – Wireless Communications

Nasser Osman

April 8th, 2013

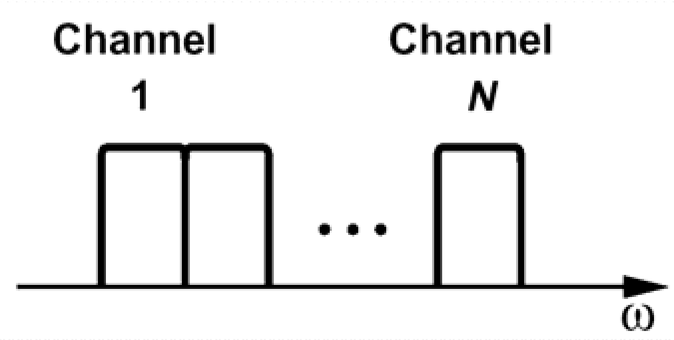
STEVENS
Institute of Technology

# Outline

- Introduction Background
  - 1G –AMPS
  - 2G – GSM, CDMA
- CDMA Transmission
  - Direct Sequence Spread Spectrum
  - PN Code
  - QPSK Complex Modulation
- CDMA Reception
  - RF Demodulation
  - Correlation and Despreading
  - Code Acquisition & Lock
- Near-Far Problem
  - Automatic Power Control
  - Power Control Runaway
- Features
  - Soft Handoff
  - Frequency Reuse
- Industry Standards
  - IS-95
  - IS-2000
  - SVLTE
- Summary

# 1st Generation Cellular Technology- Advanced Mobile System (AMPS)

- During the 1980s cellular networks began to emerge using analog communications as a means, AMPS
- AMPS uses Frequency Division Multiple Access, FDMA, method
- FDMA implies using frequency spectrum such that each user was subjected to a band of frequencies; one for downlink (BS-to-MS) and one for uplink (MS-to-BS) – for this reason occupied greater bandwidth
- System uses a range of frequencies [824MHz-894MHz]



# Issues with AMPS Technology

- Took up greater bandwidth than available radio resources within frequency spectrum
- Susceptible to noise since analog processing
- Dropped calls and busy signals were common

# Cellular Challenge – Solving Capacity Issue

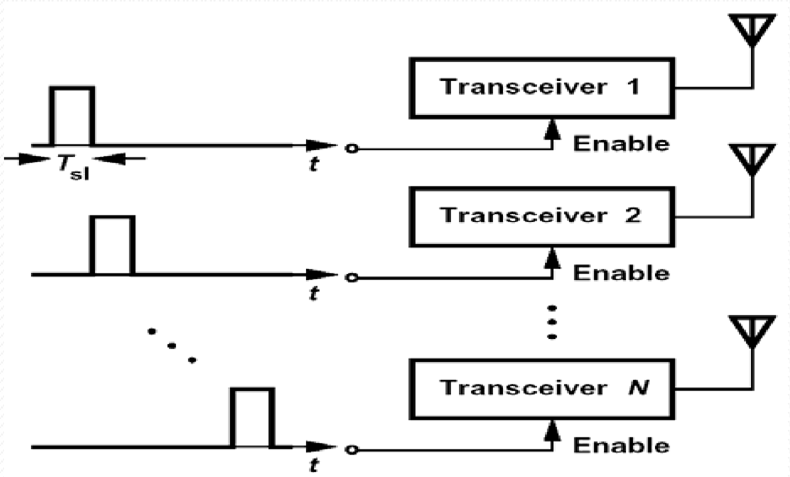
- As more and more users began to hit the cellular market, it became evident that new technology was required to accommodate users within 'limited' available radio spectrum
- Solving this entailed seeking alternate multiple access techniques

# 2nd Generation - Digital Multiple Access Methods

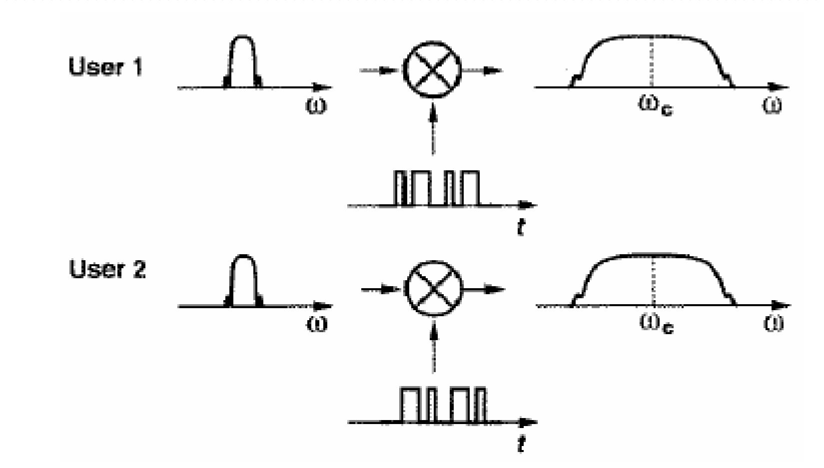
- In the late 1980s, digital access communications techniques came to realization as R&D efforts prevailed
- In 1989, the Telecommunications Industry Association (TIA) endorsed a digital technology called Time Division Multiple Access (TDMA ) – giving birth to Global System for Mobile Communications (GSM)
- Just three months later, Qualcomm introduced Code Division Multiple Access (CDMA)

# Digital Multiple Access Methods contd…

GSM (TDMA) – Each user is assigned ‘time slots’ Ts




CDMA – Each user uses same frequency band of 1.25MHz BW but with different codes



STEVENS Institute of Technology

# Multiple Access Techniques Analogy

- An analogy to multiple access techniques is a room (channel) in which people talk to one another simultaneously. To avoid confusion, people could take turns speaking (time division), speak at different pitches (frequency division), or speak in different languages (code division).
- CDMA is analogous to the last example where people speaking the same language can 'understand one another; others treated as noise'.
- In CDMA, each group of users is given a shared code. Many codes occupy the same channel, but only users associated with a particular code can communicate.

# Spread Spectrum Technique

- CDMA is a "spread spectrum" technology, allowing many users to occupy the same time and frequency allocations in a given band/space.
- Assigns unique codes to each communication to differentiate it from others in the same spectrum.
- CDMA uses Direct Sequence Spread Spectrum, DSSS.

STEVENS Institute of Technology

# Direct Sequence Spread Spectrum

- The signal occupies a bandwidth much greater than that which is necessary to send the information. Bandwidth is 1.25MHz.
- The bandwidth is spread by means of a code which is independent of the data.
- The receiver synchronizes to the code to recover the data.

# PN Code

- In order to protect the signal, the code used is pseudo-random.

- It appears random, but is actually deterministic, so that the receiver can reconstruct the code for synchronous detection.

- This pseudo-random code is also called pseudo-noise (PN).

# Properties of PN code

- It must be deterministic. The subscriber station must be able to independently generate the code that matches the base station code.
- It must appear random to a listener.
- The cross-correlation between any two codes must be small
- The code must have a long period (i.e. a long time before the code repeats itself)

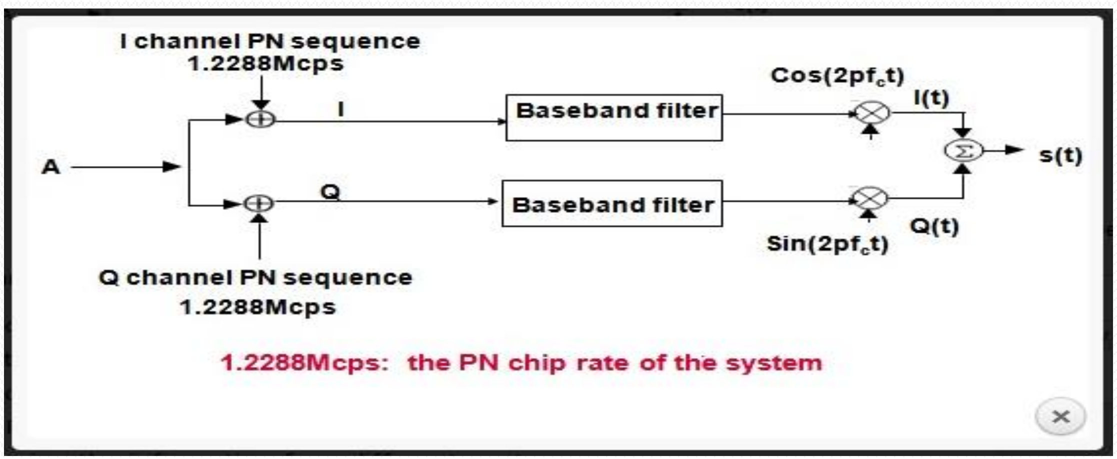
# RF Modulation

- QPSK digital modulation technique used primarily in CDMA mobile phones and IEEE 802.11b

- Shown below:

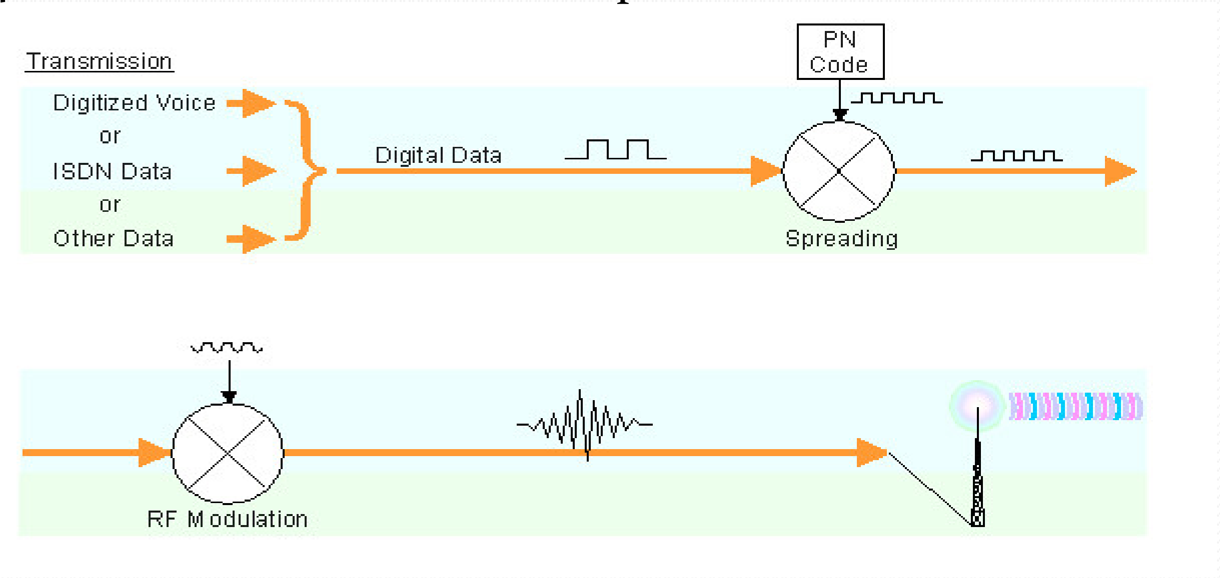
I and Q channel sequences in the figure represent two channels of cyclic PN short code sequences

$$A(t)Cos(\omega_o t + \varphi(t)) = I(t)Cos(\omega_o t) + Q(t)Sin(\omega_o t)$$



# CDMA Transmission

Signal transmission consists of the following steps:
1. A pseudo-random code is generated
2. The Information data modulates the pseudo-random code (the Information data "spreads")
3. The resulting signal modulates a carrier.
4. The modulated carrier is amplified and broadcast.



STEVENS
Institute of Technology

# RF Demodulation

- The receiver generates two reference waves, a Cosine wave and a Sine wave.
- The receiver extracts I(t) and Q(t).
- Analog to Digital converters restore the 8-bit words representing the I and Q chips.

# Code Acquisition and Lock

- The receiver, as described earlier, generates its own complex PN code that matches the code generated by the transmitter.
- Local code must be phase-locked to the encoded data.

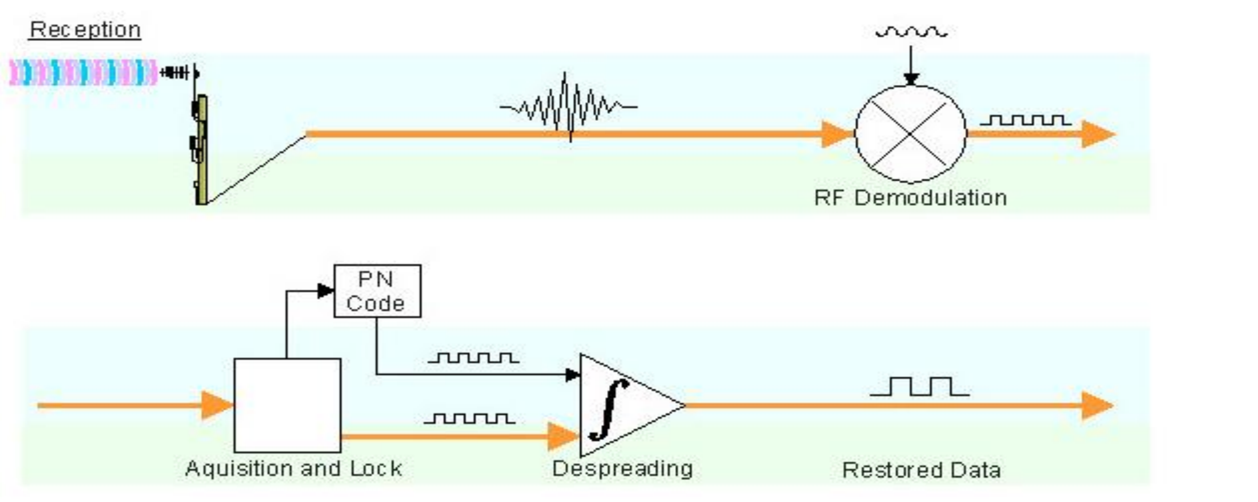
# Correlation and Despreading

- Once the PN code is phase-locked to the pilot, the received signal is sent to a correlator that multiplies it with the complex PN code, extracting the I and Q data meant for that receiver.
- The receiver reconstructs the Information data from the I and Q data.

# CDMA Reception

Signal reception consists of the following steps:

- The carrier is received and amplified.
- The received signal is mixed with a local carrier to recover the spread digital signal.
- A pseudo-random code is generated, matching the anticipated signal.
- The receiver acquires the received code and phase locks its own code to it.
- The received signal is correlated with the generated code, extracting the Information data.



# Multipath Interference

- Multi-path interference is caused by the broadcast signal traveling over different paths to reach the receiver.
- The receiver then has to recover the signal combined with echoes of varying amplitude and phase.

# Rake Filter

- In order to combat multipath interference, a rake filter is employed; correlators are set up at appropriate time intervals to extract all the echoes.

- The relative amplitude and phase of each echo is measured, and each echo signal is phase corrected and added to the signal.

STEVENS
Institute of Technology

# Near-Far Problem

- Because the cross-correlation between two PN codes is not exactly equal to zero, the system must overcome what we call the Near/Far problem.

- Consider a receiver and two transmitters, one close to the receiver, the other far away. If both transmitters transmit simultaneously and at equal powers, then due to the inverse square law the receiver will receive more power from the nearer transmitter. Since one transmission's signal is the other's noise, the signal-to-noise ratio (SNR) for the farther transmitter is much lower.

- This makes the farther transmitter more difficult, if not impossible, to understand. If the nearer transmitter transmits a signal that is orders of magnitude higher than the farther transmitter then the SNR for the farther transmitter may be below power threshold levels to detect

STEVENS Institute of Technology

# Near-Far Analogy

- Imagine talking to someone 20 feet away. If the two of you are in a quiet, empty room then a conversation is quite easy to hold at normal voice levels.
- In a loud, crowded place, it would be impossible to hear the same voice level, and the only solution is for both you and your friend to speak louder.
- By talking louder others would have to talk louder as well; making it very difficult for all parties

# Automatic Power Control

- In CDMA systems, the problem is commonly solved by output power adjustment of the transmitters.
- That is, the closer transmitters' power is adjusted such that they use less power hence the SNR for all transmitters at the receiver is roughly the same.
- In high-noise situations, however, closer transmitters may boost their output power, which forces distant transmitters to boost their output to maintain a good SNR.

STEVENS Institute of Technology

# Power Control Runaway

- Other transmitters react to the rising noise floor by increasing their output.
- This process continues, and eventually distant transmitters lose their ability to maintain a usable SNR and drop from the network.
- This process is called *power control runaway*.

# Benefits in CDMA

- Greater system capacity - squeezing multiple users in just a single 1.25 MHz bandwidth – equivalent to 35 simultaneous voice calls!

- Better call quality, almost no noise when making a call.

- Usage of soft handoff feature yields less dropped calls in the field

# Drawbacks in CDMA

- Main drawback is capacity (number of active users at any instant of time) is limited by the access interference
- Near-Far Problem

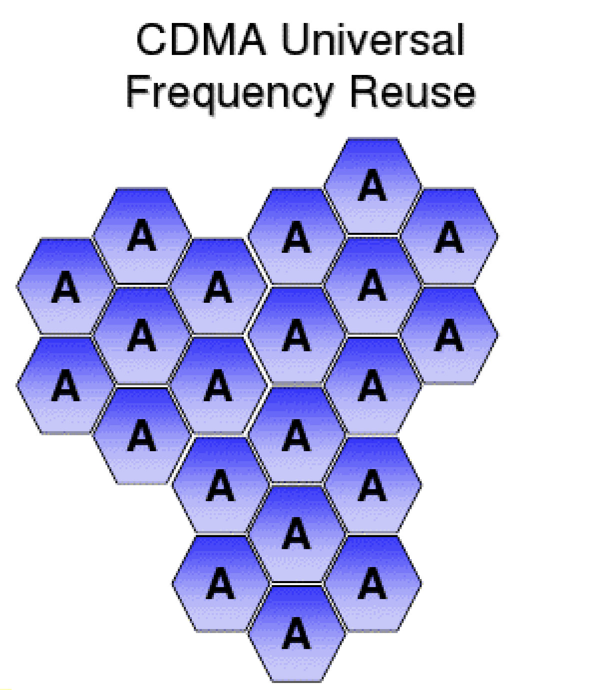
# Frequency Bands

- Cellular (824-894 MHz)

- PCS (1850-1990 MHz)

# Frequency Reuse

Frequencies may be reused in adjacent cell sites



# Soft Handoff Feature

- An attractive feature in CDMA systems is the use of *soft handoff*
- In this, an MS may be actively connected to multiple base stations simultaneously, possibly for a considerable length of time using the same channel.
- MS accomplishes this in a *make-before-break* fashion, i.e. making connection with the new BS before breaking connection with old BS
- In Non-CDMA systems a break is implemented before the connection

STEVENS
Institute of Technology

# CDMA Standards & Protocol

- Development of CDMA systems made clear the necessity of standards.

- Mobile devices can only communicate with one another if they are compatible, and each receiver can “understand” each transmitter – i.e. if they follow the same rules and protocols.

# 2G - Industry Standard IS-95

- First digital standard for CDMA developed by Qualcomm
- Direct Sequence Spread Spectrum
- Soft handoff supported

STEVENS Institute of Technology

# 3G - Industry Standard IS-2000

- Successor of IS-95
- Family of 3G standards adopted by Telecommunications Industry Association, TIA
  - CDMA2000 1xRTT
  - CDMA2000 1xEV-DO: Release 0, Revision A, Revision B
  - CDMA2000 1xEV-DO Revision C or Ultra Mobile Broadband (UMB)
  - CDMA2000 1xEVDV
- 1xRTT
  - Almost doubles the capacity of IS-95 by adding 64 more traffic channels
- Evolution-Data Optimized
  - Supports forward link throughput speeds of 2.4 Mbps with Rev. 0 and up to 3.1 Mbps with Rev. A

# 4G Industry "*De Facto*" Standard - *SVLTE*

- When LTE is an overlay to a CDMA/EV-DO network, the current de facto standard for voice delivery is Simultaneous Voice and LTE (SVLTE).

- In this arrangement, voice service is deployed as a CDMA service running in parallel with LTE data services.

- For this solution to work, the handset needs to have two radios that are on simultaneously.

STEVENS
Institute of Technology

# Summary

- CDMA drastically evolved from older technology and is currently most widely-used technology in North America
- CDMA uses Spread Spectrum multiple access technique
- Transmitting and receiving voice/data is concatenated with unique codes, called Pseudo-random codes (PN codes), spread and despread respectively within a 1.25 MHz signal bandwidth
- CDMA signal bandwidth can hold multiple users without interfering with one another since they offset by PN codes
- Automatic Power Control is necessary in CDMA technology
- The features and benefits of CDMA outweigh drawbacks
- Currently CDMA is still being used by wireless operators and is the *de facto* standard for voice delivery while on a 4G LTE network

# Reference List


- <http://www.bee.net/mhendry/vrml/library/cdma/cdma.htm>
- Molisch, Andreas F.. *Wireless Communications*. 2nd ed. Chichester, West Sussex, U.K.: Wiley :, 2011. Print.
- Groe, John B., and Lawrence E. Larson.*CDMA mobile radio design*. Boston: Artech House, 2000. Print.
- "Introduction to CDMA." *Chester County Website Hosting, Chester County Web Hosting, Chester County Hosting, Chester County Internet Services,Chester County ISP*. N.p., n.d. Web. 23 Mar. 2013.
- Industry. "History of CDMA | CDMA Technology | Qualcomm." *Qualcomm*. N.p., n.d. Web. 25 Mar. 2013. <http://www.qualcomm.com/who-we-are/history/story>.
- "How Modulation-QPSK in CDMA ?."*Telecom Techniques Guide*. N.p., n.d. Web. 9 Apr. 2013. <http://www.teletopix.org/cdma/how-modulation-qpsk-in-cdma>.