Lecture #8
10/5/2016

Last Class
2G Wireless (GSM / CDMA)
Spread Spectrum Techniques
Direct Sequence Spread Spectrum

Today
Orthogonal Codes
CDMA

Next Class
CDMA
Error Correcting Codes

Announcements
Homework #4 Due (Late Penalty after Sunday 10/9)
Homework #5 Posted, Due Next Week
Exam #1 Week of 10/24

Code Division Multiple Access (CDMA)

Code Division Multiple Access

Everyone talks simultaneously but users share medium via codes

Code Division Example: 8 people in a room Talking Simultaneously

4 Speak English

3 Speak Spanish

1 Speaks Chinese

Who understands what the English speakers are saying?

Who understands what the Spanish speakers are saying?

Who understands what the Chinese speaker is saying?

This concept realized digitally via <u>orthogonal codes</u>

Orthogonality

Ex: 4 Linear Simultaneous Equations

Equations can be re-written as linear combination of 4 vectors

Results of 'chipping' data can be mapped into this form

Solution for x vector exists if solutions are independent (i.e. Equations can be broken up into independent columns)

For this to be true the code vectors must be orthogonal

Orthogonality

Orthogonal Basis Vectors

Orthogonal → Dot Product of Row vector (a_i) and Column Vector (a_j) = 0

Orthogonal → Dot Product of Row vector (a_i) and Column Vector (a_j) = 0

Orthogonal Codes and Bit Symbols

In communication theory, often data is represented as bit "symbols":

Code Division Multiple Access

Transmit Using Orthogonal Codes

Assign each user an orthogonal code

Users transmit data simultaneously

Transmitted bits are is ‘chipped’ in time by length of codes

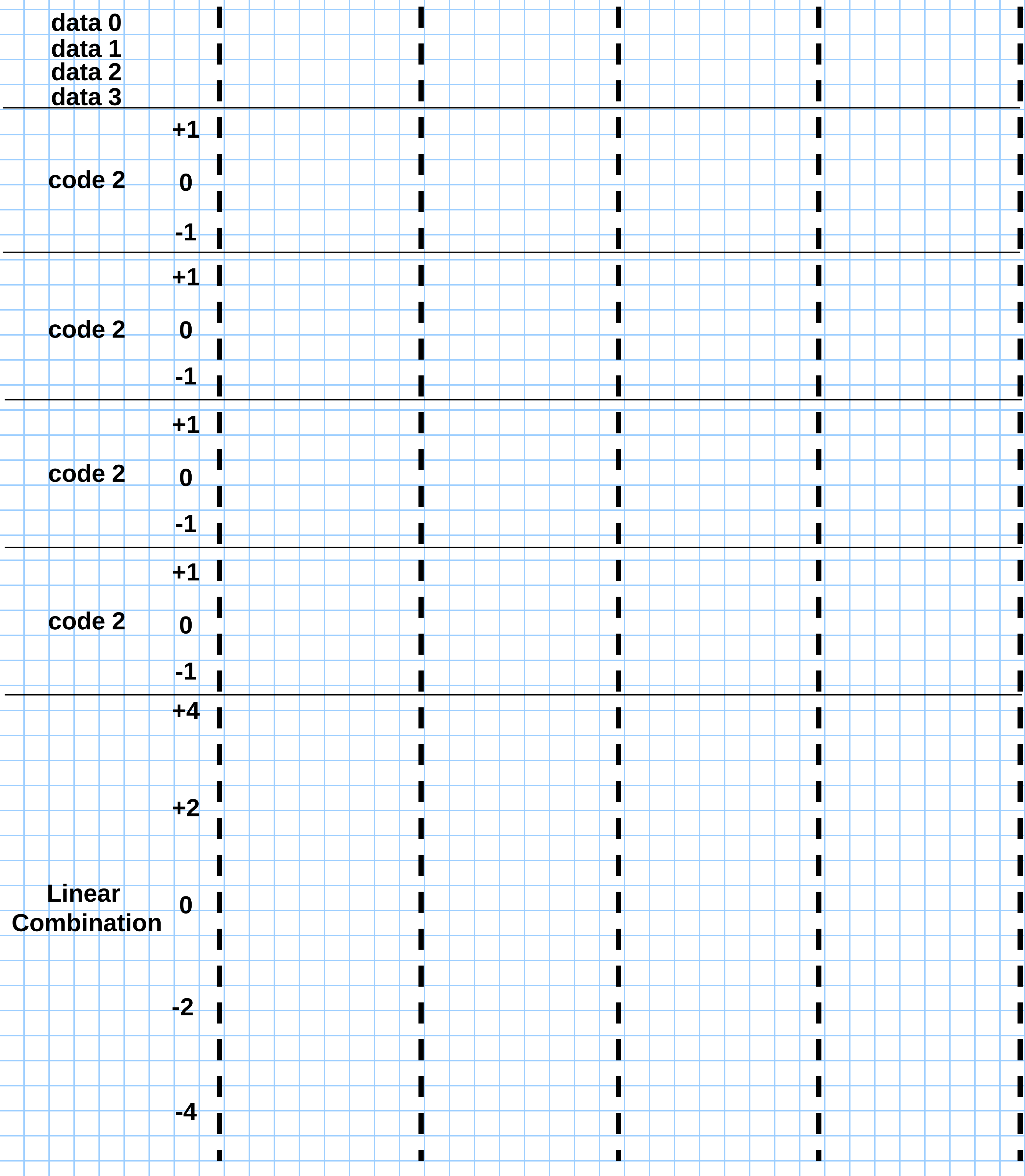
Transmitted signal consists of a linear combination orthogonal codes and data for all users

Messages decoded via linear combination of resultant signal with individual codes

Code Division Multiple Access

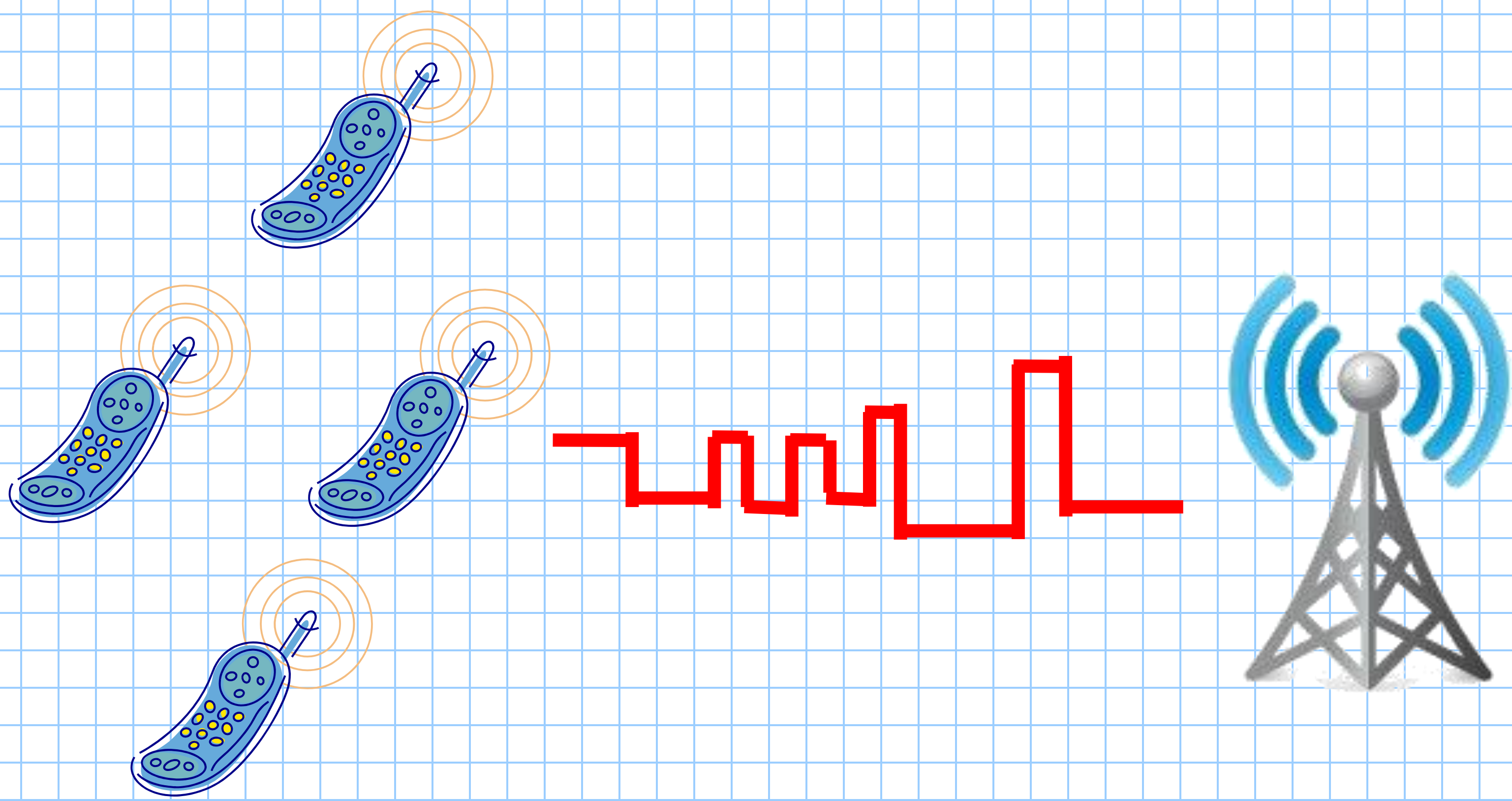
Ex: CDMA Transmission with 4 Users

4 users are to transmit the following data: 1101 (user 0, code 1111), 0111 (user 1, code 1010), 1011 (user 2, code 1100), 0011 (user 3, code 1001) .



Code Division Multiple Access

CDMA Implementation



All users transmit simultaneously

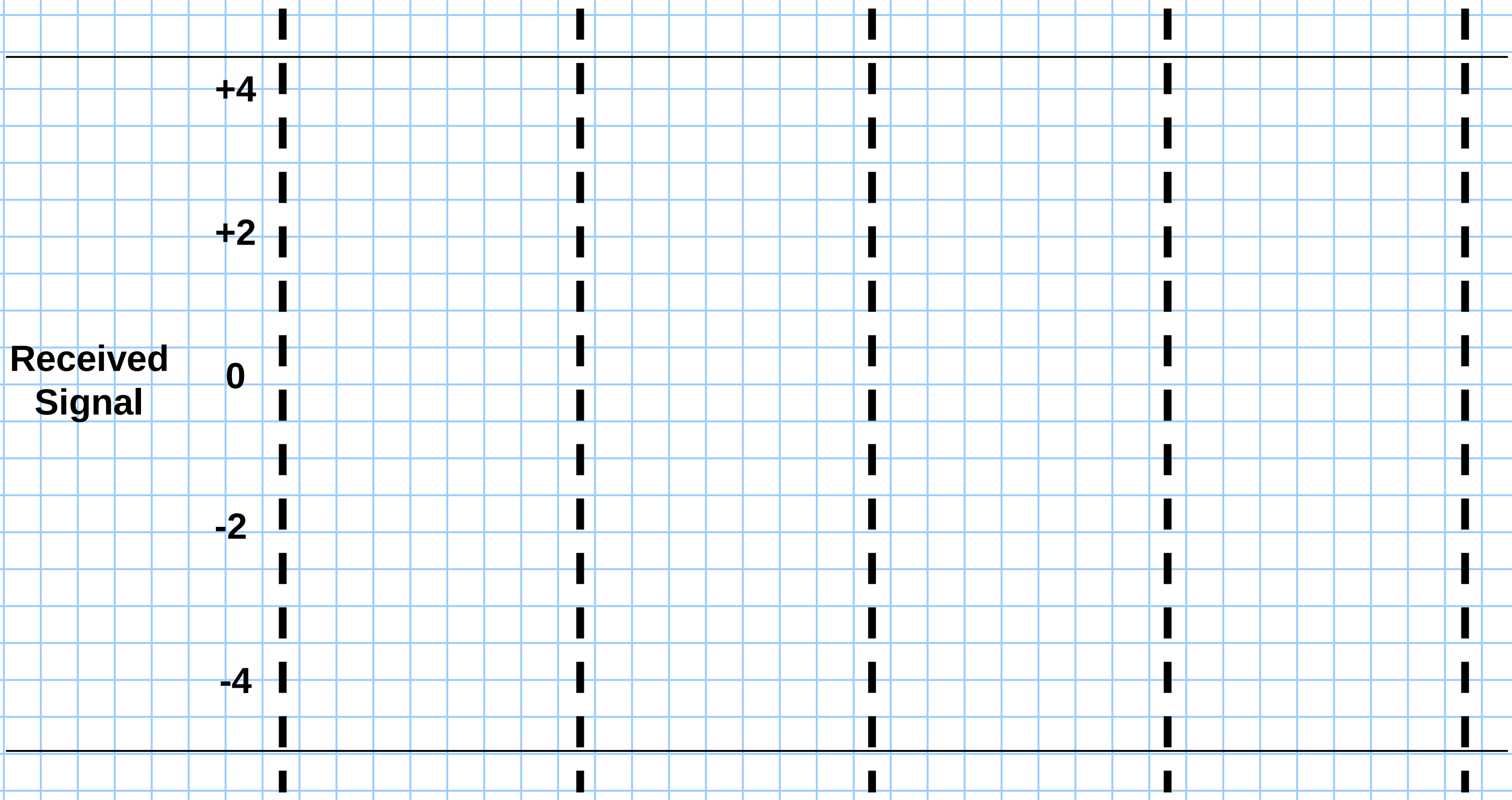
Linear combination of transmitted signals occurs via addition of power levels

Receivers sees combined signal

Decodes each user message via linear combination with senders orthogonal code

Code Division Multiple Access

Ex: CDMA Decoding



Code Division Multiple Access

CDMA Implementation: Power Levels

Encoded Signal Transmitted As Power Level at a Given Frequency

Problem → Cant transmit Negative Power

How can various signal levels still be transmitted accurately?

CDMA Implementation

Generating more codes to add more users

Derived from Hadamard Matrix

Each row is mutually orthogonal

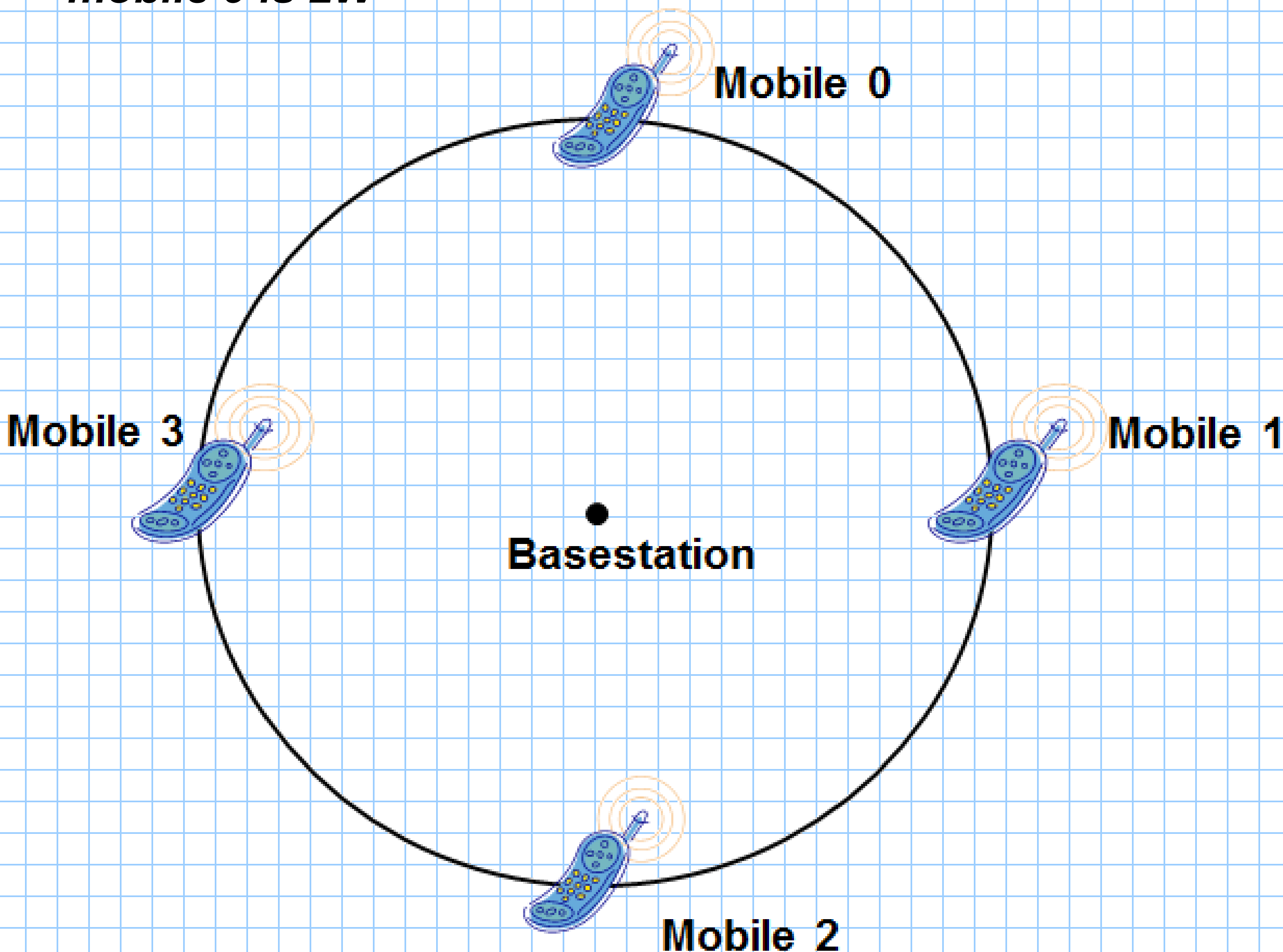
Replication of Matrices, where A = -B

n = 1 **n = 2** **n = 4** **n = 8**

More codes means more simultaneous users!

CDMA Implementation
CDMA Near-Far Problem

Scenario 1: All mobiles are equidistant from the base
Assume the power received by the basestation from mobile 0 is 1W

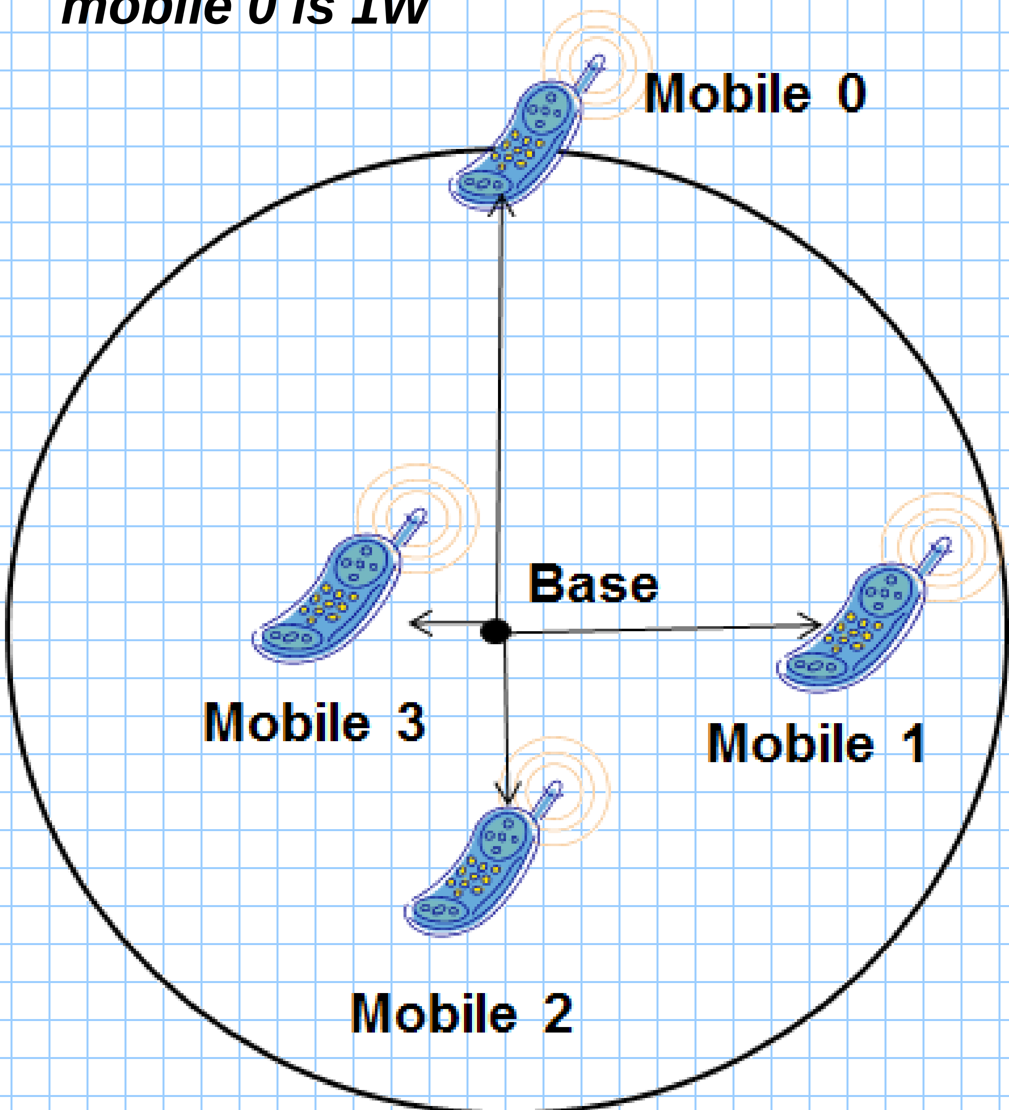


Is this a practical assumption to make when implementing CDMA?

CDMA Implementation

CDMA Near-Far Problem

Scenario 2: ***Distance to base differs for each mobile. Assume the power received by the basestation from mobile 0 is 1W***



Is this a practical assumption to make when implementing CDMA?

CDMA Implementation
CDMA Near-Far Problem

In order to overcome the Near-Far Problem:

Transmit Power of mobiles are dynamically adjusted

Mobile has choice of 6 discrete transmit power levels to choose from

8 dBm	12 dBm	16 dBm	20 dBm	24 dBm	28 dBm	32 dBm	36 dBm
6.3 mW	15.8 mW	39.8 mW	100 mW	251.2 mW	630 mW	1,584 mW	3,981 mW

CDMA Power Levels for Mobile Devices

Basestation listens to all devices and makes power level decision for each mobile, then normalizes the received levels

Adjustment to occur periodically due to mobility