Bits over the Air: Pre-Lab 5

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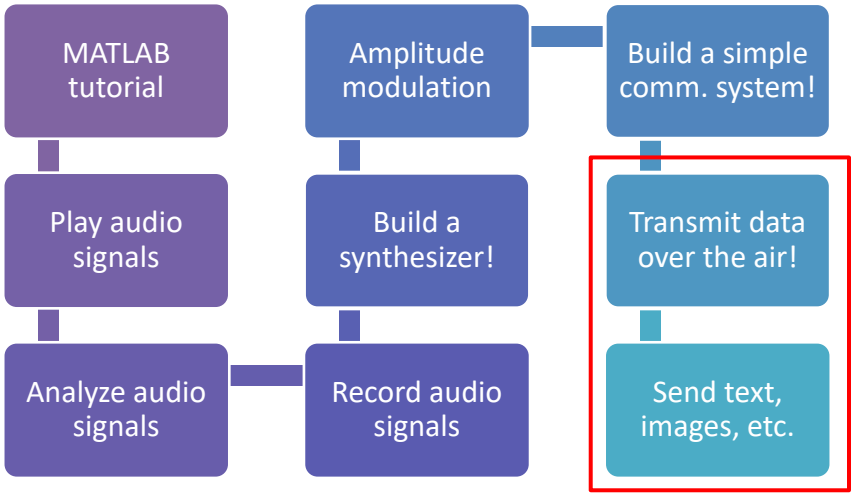
Friday overview

Bits over the air

Today's goals:



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Project schedule

	Monday	Tuesday	Wednesday	Thursday	Friday
1pm-2pm	Pre-Lab 1: Introduction to MATLAB and digital communication	Pre-Lab 2: Signal processing, time-domain, spectrum, and spectrogram	Pre-Lab 3: Generating music with MATLAB and communication system basics	Pre-Lab 4: Communication via amplitude modulation and synchronization	Pre-Lab 5: Bits over the air: transmitting text and images over the air (reliably!)
2pm-3pm	Module 1: MATLAB basics 1	Complete previous modules	Complete previous modules	Complete previous modules	Complete previous modules
	15min break	15min break	15min break	15min break	15min break
3pm-4pm	Module 2: MATLAB basics 2	Module 4: Spectrum and spectrogram	Module 6: Generating music in MATLAB	Module 8: Simple communication system 2	Module 10: Transmitting bits over the air
4pm-5pm	Module 3: Play audio in MATLAB	Module 5: Record audio in MATLAB	Module 7: Simple communication system 1	Module 9: Synchronization	Work on presentations

- Please stay focused—we are almost there!

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Remember: this is group work!

- Help each other, especially the other group you are collaborating with!
- Module 10 is about transmitting data from one computer to another!
- Do not forget the presentation!

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A magic trick

Module 10

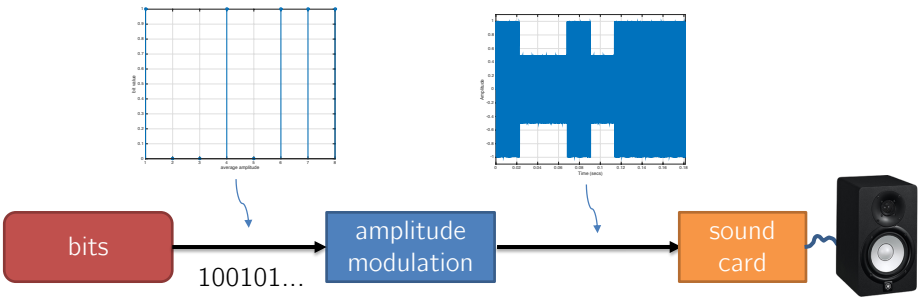
Finally: Bits over the air

Everything is there!

- You have a working transmitter
- You have the ability to play signals from loudspeaker and to record signals
  - Two modes: separately or simultaneously
- You have the ability to synchronize receiver
- You have the ability to demodulate the signal

- Goal: get zero bit errors over the air

Transmitter summary



- We use digital amplitude modulation (AM)
- Use playback function in MATLAB

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Play signal over channel

- Start recording at receiver and then play signal at transmitter (start not immediate)
- Two modes:
  - Simultaneous playback and record at one computer
  - Play from one computer, receive at other computer

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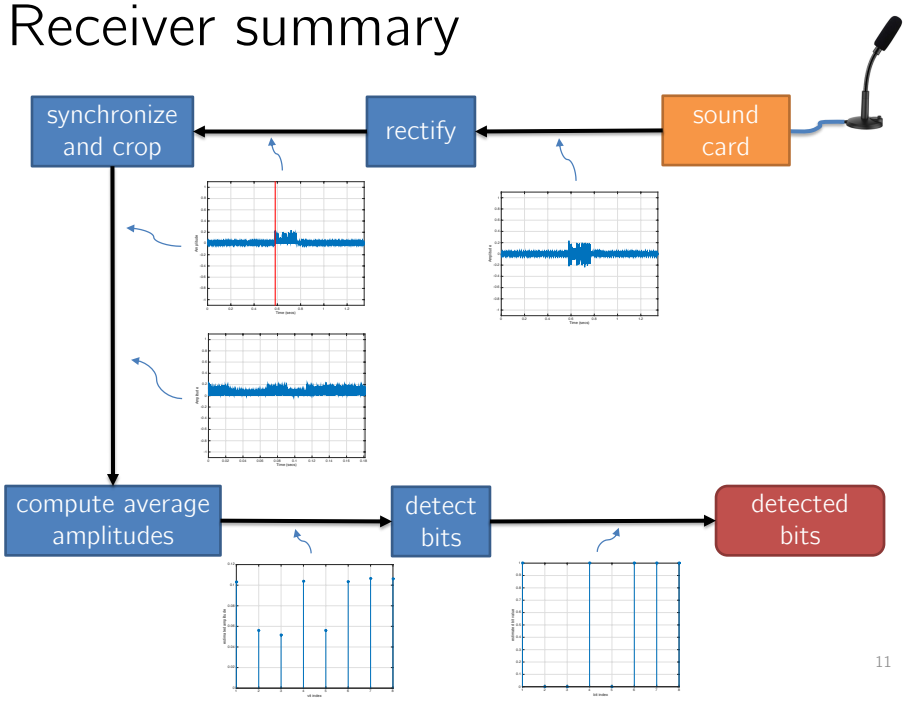
Receiver summary



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Calculate performance metrics

- Bit error rate: Number of wrong bits divided by total number of transmitted bits

$$BER = \frac{\#\ \text{errors}}{\#\ \text{transmitted bits}}$$

- Throughput: bits per second

$$\text{Throughput} = \frac{f_s}{T}$$

f_s=sampling rate, T=duration of sine waves

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If you have time!

More aspects to explore

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Transmit text over the air

- We provide functions that convert strings (text) into bit sequence (and vice versa)

```
bits = string2bits('This is a test!')

string = bits2string(bits)
```

- ASCII defines mapping from characters to bits

This is a test!

0	0011 0000	O	0100 1111	m	0110 1101
1	0011 0001	P	0101 0000	n	0110 1110
2	0011 0010	Q	0101 0001	o	0110 1111
3	0011 0011	R	0101 0010	p	0111 0000
4	0011 0100	S	0101 0011	q	0111 0001
5	0011 0101	T	0101 0100	r	0111 0010
6	0011 0110	U	0101 0101	s	0111 0011
7	0011 0111	V	0101 0110	t	0111 0100
8	0011 1000	W	0101 0111	u	0111 0101
9	0011 1001	X	0101 1000	v	0111 0110
A	0100 0001	Y	0101 1001	w	0111 0111
B	0100 0010	Z	0101 1010	x	0111 1000
C	0100 0011	a	0110 0001	y	0111 1001
D	0100 0100	b	0110 0010	z	0111 1010
E	0100 0101	c	0110 0011	.	0010 1110
F	0100 0110	d	0110 0100	,	0010 0111
G	0100 0111	e	0110 0101	:	0011 1010
H	0100 1000	f	0110 0110	;	0011 1011
I	0100 1001	g	0110 0111	?	0011 1111
J	0100 1010	h	0110 1000	!	0010 0001
K	0100 1011	I	0110 1001	'	0010 1100
L	0100 1100	j	0110 1010	"	0010 0010
M	0100 1101	k	0110 1011	(	0010 1000
N	0100 1110	l	0110 1100	)	0010 1001
				space	0010 0000

Transmit images over the air

- Images are just sampled intensities in 2-dimensional space

- We will transmit binarized (black-white) images over the air

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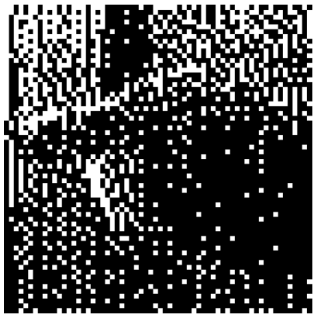
We can see errors happening



- 516 errors occurred (resolution is 64x64)
- BER = 13%

- Zero errors happened (resolution is 64x64)
- BER = 0%

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Many advanced methods

- Map two bits to four amplitudes
- Use better receiver (filters!)
- Use multiple frequencies
- Use cosine and sine carriers
- Encode information in phase
- Detect transmission errors at receiver

- Modern systems use all such tricks!

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How to detect transmission errors?

- How can a receiver detect transmission errors (without knowing the bit sequence)?

- Assume: bits = [1,0,0,1,0,1,1,1]
- Is number of 1's even or odd?
- Parity bit p=1 if odd and p=0 if even
- Transmit: bits_p = [1,0,0,1,0,1,1,1,p]
- If one bit error happens, we can detect it!

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Example: one parity bit

- bits = [1,0,0,1,0,1,1,1]
- p = 1 (since number of 1's is odd)
- bits_p = [1,0,0,1,0,1,1,1,1] — # of ones will be even!
- Assume received bits are [1,0,1,1,0,1,1,1,1]
- Number of ones is odd → ERROR!
- An example of coding: real systems use this to detect and correct transmission errors

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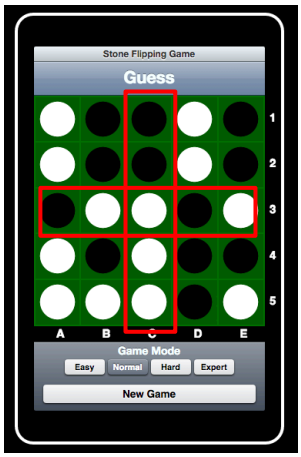
I cheated with parity checks!



- Parity bits added to right column and bottom row so that # black stones is odd
- One stone flip violates check on one row and one column
- Flipped stone is at intersection ☺

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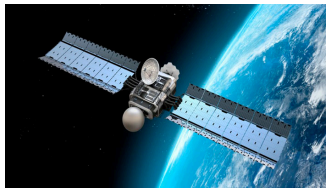
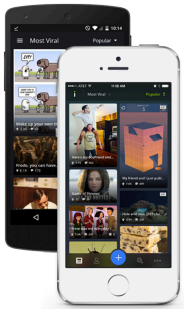
Error protection and correction is everywhere!





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Some updates

Organization

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Research presentations

- Saturday 9:30am-11:30am in RPCC
- Group presentation with assigned team
- 10 teams in 2 hours → 10 minutes presentation plus 2 minutes Q&A
- Present what you have done this week
  - Music synthesizer, transmitter/receiver, achieved data rate, special tricks, etc.
  - About 7-8 slides (only 10 minutes time)

SATURDAY 20

8:00-8:45 am
RPCC Dining Hall

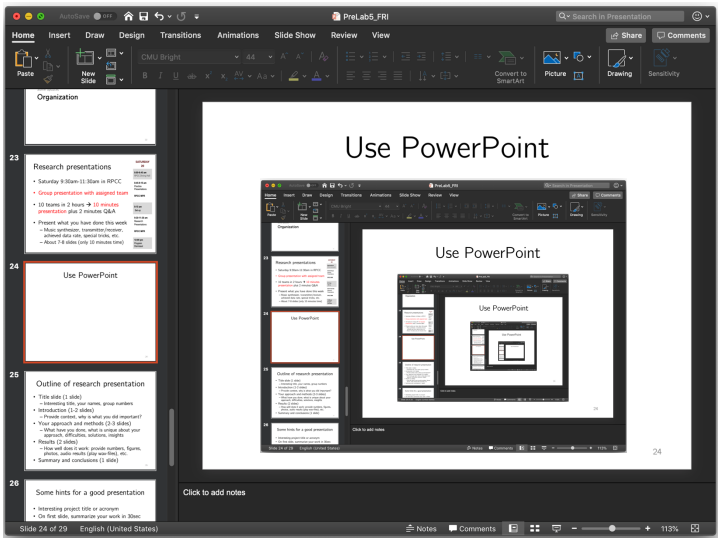
8:45-9:15 am
Practice Presentations
RPCC MPR

9:15 am
Set-up

9:30-11:30 am
Research Presentations
RPCC MPR

12:00 pm
Program Dismissal

Use PowerPoint



*save presentation in box folder: presentations/group-numbers.pptx

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Outline of research presentation

- Title slide (1 slide)
  - Interesting title, your names, group numbers
- Introduction (1-2 slides)
  - Provide context, why is what you did important?
- Your approach and methods (2-3 slides)
  - What have you done, what is unique about your approach vs. that of other groups
- Results (2 slides)
  - How well does it work: provide numbers, figures, photos, audio results (play wav-files), etc.
- Summary and conclusions (1 slide)

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Some hints for a good presentation

- Interesting project title or acronym
- On first slide, summarize your work in 30sec

- Surprise audience
- Use short and clear explanations
- Practice many times!

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Important

- Some groups did NOT upload their music
  - Please do that right away (before you forget)
  - Next slide shows groups who didn't upload
  - Upload to Songs/ folder
- Sit next to your collaborating team
- Please stay focused

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