ELEC1200: A System View of Communications: from Signals to Packets
Lecture 1

- **Course Overview and Mechanics**
- **A basic communication system**
  - Bits and Bit Sequences
  - The transmitter
  - The channel
  - The receiver

Who's who

Instructor

- Prof. W.H. MOW

Teaching Associate

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TAs

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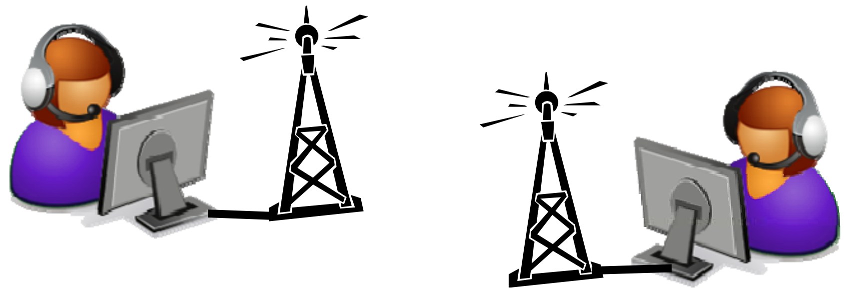
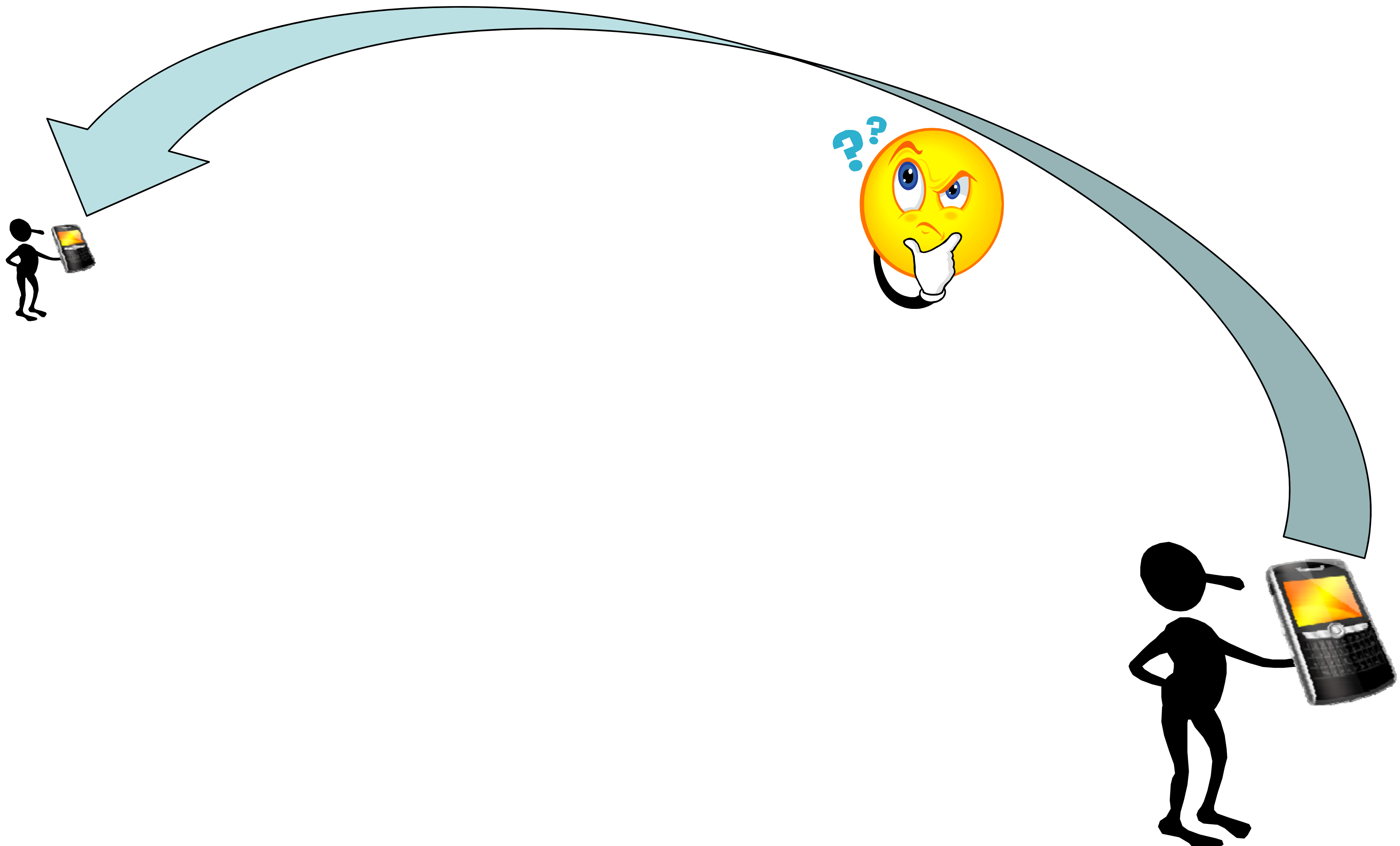
Course Description

- Have you ever wondered what technologies enable you to communicate via your mobile phone?



- Course Features
  - **Hands on:** You work with a simple but fully functional wireless communication system to understand the basic technology in these systems.
  - **Broad perspective:** We cover all aspects of the system from end to end.
  - **Fundamental:** All concepts introduced from first principles. No prior ECE background required.

Our Question: How to transmit information wirelessly?



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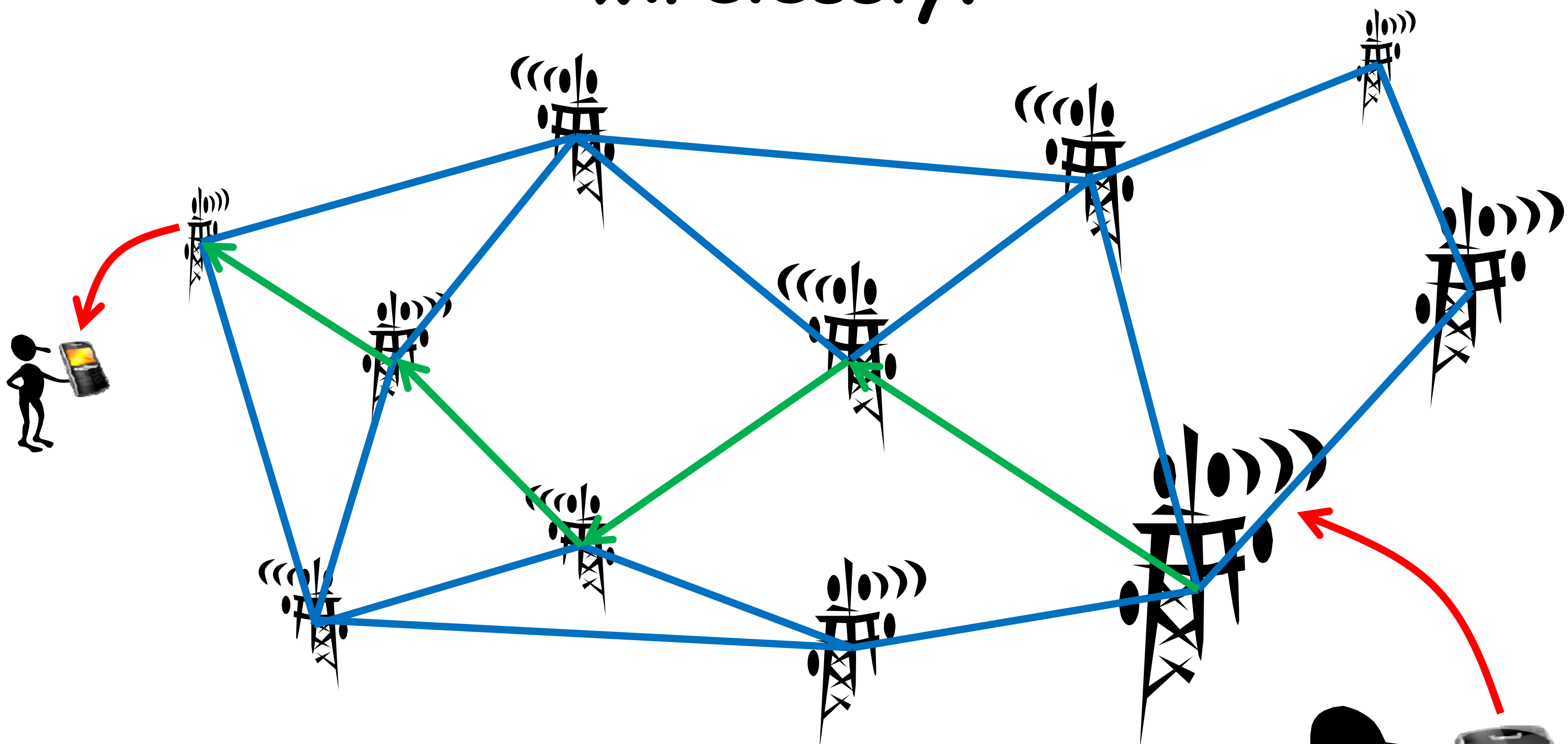
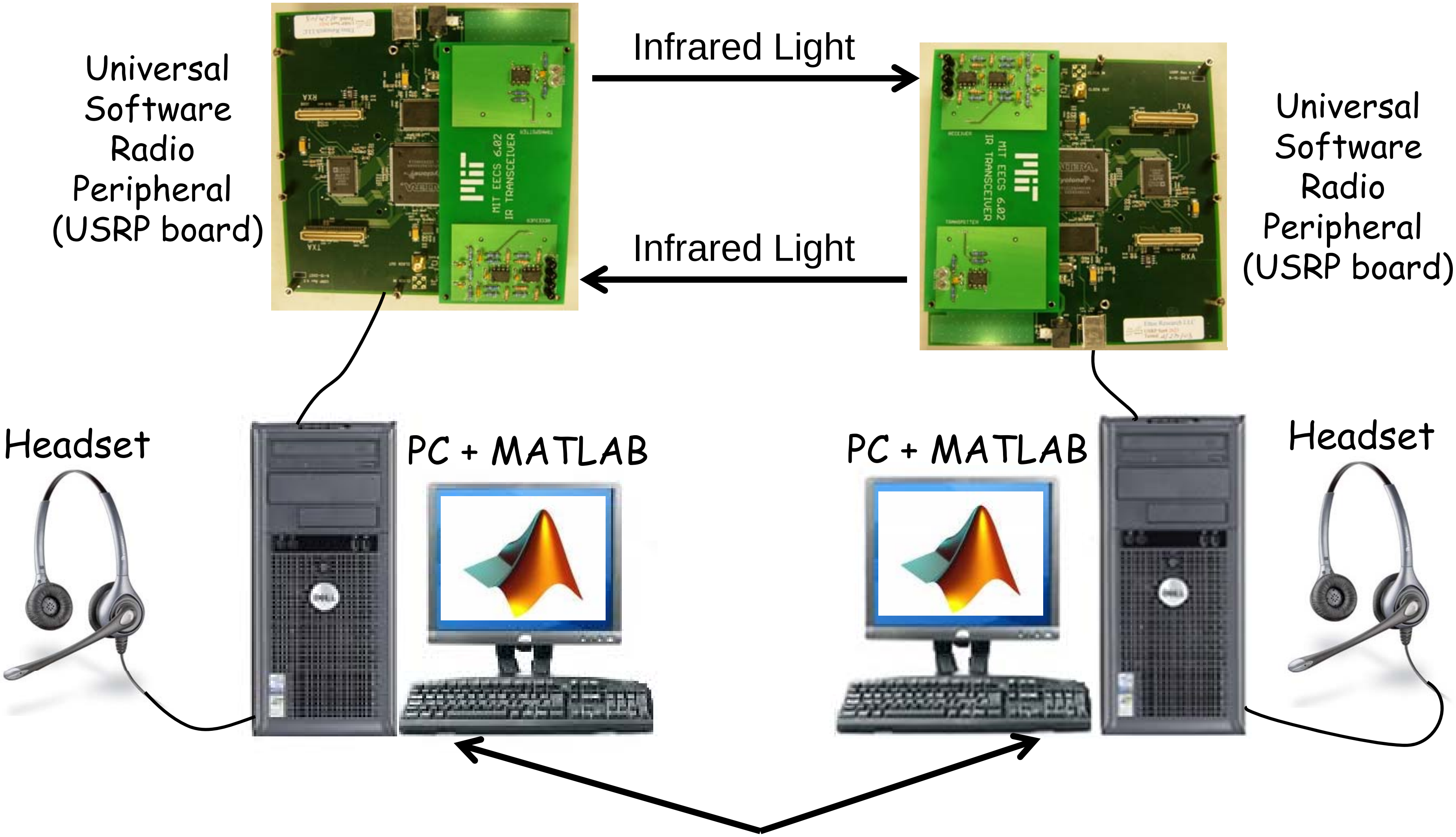


Point-to-point: link from phone to base station
first 2/3 of this course
Network: links between base stations
last 1/3 of this course

Our Laboratory Work



Most of your work will involve programming in MATLAB

Provides the context for:

- **Foundation course:**
  - ELEC2100: Signals and Systems
- **Area courses:**
  - ELEC3100: Signal Processing and Communication
  - ELEC3200: System Modeling, Analysis and Control
- **Depth Courses**
  - ELEC41XX
    - Digital Communication, Computer Communication Networks, Digital Image Processing, Speech and Image Compression, Information Theory and Error-Correcting Codes, Digital Speech Recognition, Digital Media and Multimedia Applications, Wireless Communication Engineering
  - ELEC42XX
    - Digital Control Systems
  - ELEC48XX
    - Medical Imaging

Prerequisites

- **Math (one of the following)**
  - AL Pure Mathematics or AL Applied Mathematics
  - MATH 1003/1014/1018/1020/1024
- **Programming**
  - COMP 1004/1021/1022P/1022Q

Course Objectives

- **CO1 - Through the study of a voice communication system, students will understand the real-life context of the concepts that they study in more theoretical detail in other classes**
- **CO2 - Students will be able to explain typical problems and tradeoffs encountered in electronic and computer engineering systems**
- **CO3 - Students will be able to analyze simple approaches to deal with these problems and tradeoffs.**
- **CO4 - Students will be able to use software tools, such as MATLAB, to investigate potential solutions to these problems/tradeoffs in order to validate the above analysis, as well as handle cases not amenable to simple analysis.**
- **CO5 - Students gain experience working and learning in a cooperative setting on real hardware where the simplifying assumptions used in theoretical analysis may be violated, and gain an understanding of the both the benefits and limitations of such analysis.**

Course vs Program Objectives

COURSE OUTCOMES	**PO1** – An ability to apply knowledge of mathematics, science and Electronic and Computer Engineering.	**PO2** – An ability to design and conduct experiments, as well as to analyse and interpret data.	**PO3** – An ability to design efficient and economical Electronic and Computer Engineering systems, components or process subject to practical constraints.	**PO4** – An ability to function in a multi-disciplinary environment through teamwork.	**PO5** – An ability to identify, formulate and solve Electronic and Computer Engineering problems.	**PO6** – An ability to understand professional practices and ethical responsibilities.	**PO7** – An ability to communicate effectively.	**PO8** – An ability to understand contemporary global, regional, economic, environmental, and social issues, and the corresponding role and the impact of Electronic and Computer engineers.	**PO9** – An ability to recognize the need for, and to engage in life-long learning.	**PO10** – An ability to use current techniques, skills and engineering tools necessary for solving Electronic and Computer Engineering problems.	**PO11** – An ability to use the computer/IT tools relevant to the Electronic and Computer Engineering along with an understanding of their processes and limitations.
CO1- Through the study of a voice communication system, students will understand the practical context of the concepts that they study in more theoretical detail in other classes.	1		1		1				1	1	
CO2 - Students will be able to explain typical problems and tradeoffs encountered in electronic and computer engineering systems.			2				3				
CO3 -Students will be able to analyze simple approaches to deal with these problems and tradeoffs.	2				2						
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CO5 - Students gain experience working and learning in a cooperative setting on real hardware where the simplifying assumptions used in theoretical analysis may be violated, and gain an understanding of the benefits and limitations of such analysis.				3			2		1		

3 = Significant, 2 = Good, 1 = Basic

A week in the life of ELEC1200

MON	*TUE*	*WED*	*THU*	*FRI*
Lecture A 16:00-16:50 Room 2302	Tutorial 18:00-18:50 Room 2302	LA1 10:00-12:50 Room 2133 LA2 16:30-19:20 Room 2134	LA3 13:30-16:20 Room 2134	Lecture B 11:30-12:20 Room 2302

- Lecture A:
    -Cover concepts to be studied in the lab
- Tutorial:
    -discussion and laboratory preparation
- Lab:
    -3-hour section, work with partner
- Lecture B:
    -Extend concepts from lab, introduce next topic

Assessment

- Pre-lab exercises (10%)
  - Handed in at the start of the lab.
- Lab Check-off Points (10%)
- Post-lab interviews (15% total)
  - Each lab group (2 students) meets with teaching staff to discuss questions about the material in the lab.
  - No lab reports are required
- Homework (10%)
  - Reinforce concepts learned during the lab
- Midterm Exam (20%)
- Final Exam (35%)

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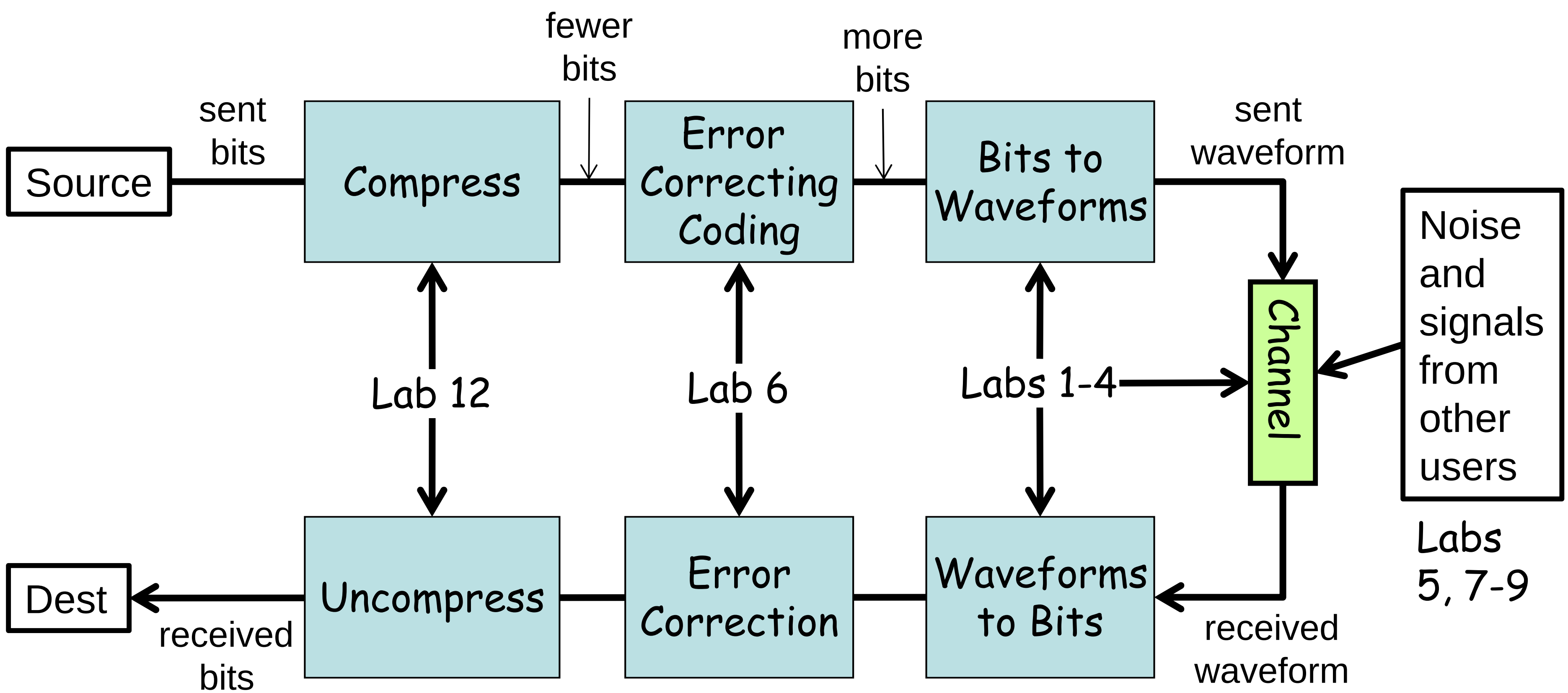
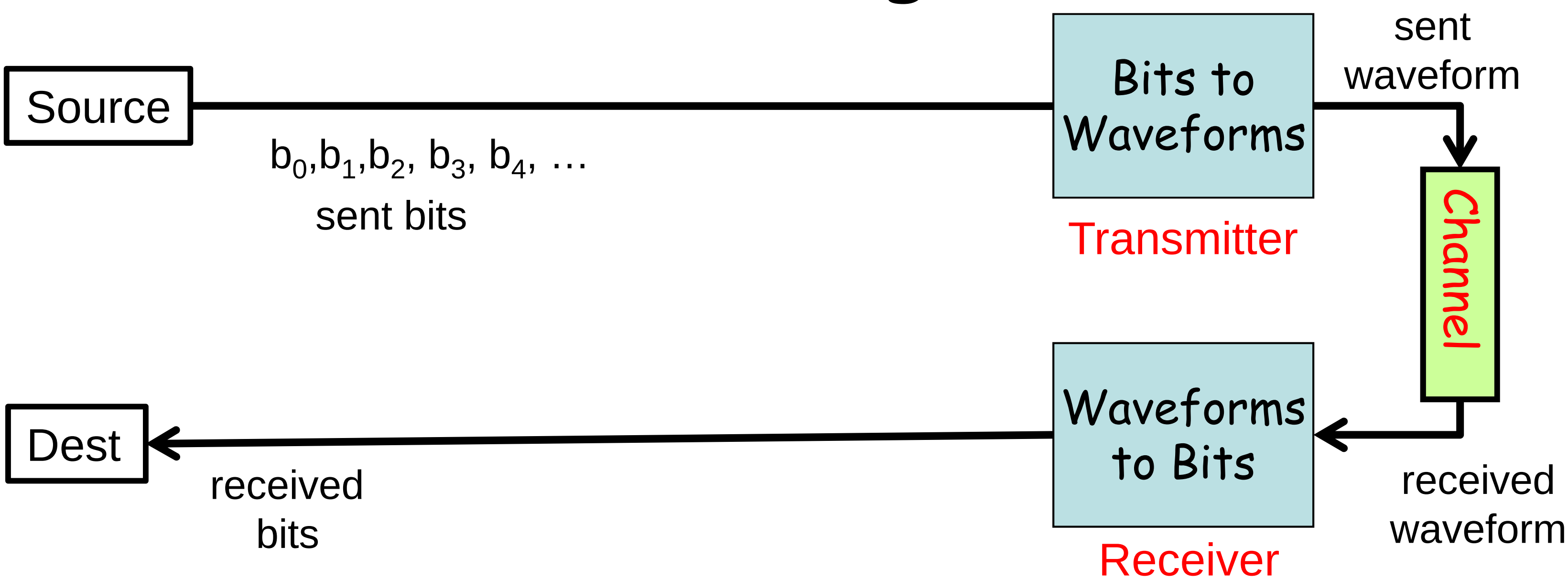
Point-to-Point Communication:



Ideally, “sent bits” = “received bits”
However, this is not always the case. Usually, we want to avoid this.

Our Starting Point



- The **transmitter** takes a sequence of bits and creates a physical waveform (e.g. time varying voltage or light intensity) that is carried over a channel.
- The **channel** (a wire, the air, a fiber optic cable) may modify the signal as it carries it.
- The **receiver** tries to figure out what the transmitted bits were from the received waveform.

Bits

- A bit is the basic unit of information used in modern computers and communication systems.
- A bit is a variable that can assume only two possible values or "states", commonly denoted by 0 or 1.
- Variables that can assume more than two possible values can be represented by combinations or sequences of bits, e.g.
  - binary numbers
  - ASCII codes for letters and text

Binary Numbers

- **We can use N bits $b_{N-1}, \ldots, b_1, b_0$ to represent integers from 0 to $2^N - 1$**
- **For example, if N = 3,**

$$x = b_2 \cdot 2^2 + b_1 \cdot 2^1 + b_0 \cdot 2^0$$

x	b_2	b_1	b_0
0	0	0	0
1	0	0	1
2	0	1	0
3	0	1	1
4	1	0	0
5	1	0	1
6	1	1	0
7	1	1	1

- **More generally,**

$$x = \sum_{i=0}^{N-1} b_i \cdot 2^i$$

- **Notation:**
  - **b_{N-1} = Most Significant Bit (MSB)**
  - **b_0 = Least Significant Bit (LSB)**

ASCII Codes

- ASCII = American Standard Code for Information Exchange
- A 7-bit code that can represent 128 text symbols

Example:

E = 1000101

MSB b_6 LSB b_0

- Often, a zero is put at the start to create an 8 bit code,e.g.,

E = 01000101

MSB b_7 LSB b_0

USASCII code chart

Bits				$b_6 b_5 b_4$	0 0 0	0 0 1	0 1 0	0 1 1	1 0 0	1 0 1	1 1 0	1 1 1
b_3	b_2	b_1	b_0	Column → / Row ↓	0	1	2	3	4	5	6	7
0	0	0	0	0	NUL	DLE	SP	0	@	P	`	p
0	0	0	1	1	SOH	DC1	!	1	A	Q	a	q
0	0	1	0	2	STX	DC2	"	2	B	R	b	r
0	0	1	1	3	ETX	DC3	#	3	C	S	c	s
0	1	0	0	4	EOT	DC4	$	4	D	T	d	t
0	1	0	1	5	ENQ	NAK	%	5	E	U	e	u
0	1	1	0	6	ACK	SYN	&	6	F	V	f	v
0	1	1	1	7	BEL	ETB	'	7	G	W	g	w
1	0	0	0	8	BS	CAN	(	8	H	X	h	x
1	0	0	1	9	HT	EM	)	9	I	Y	i	y
1	0	1	0	10	LF	SUB	*	:	J	Z	j	z
1	0	1	1	11	VT	ESC	+	;	K	[	k	{
1	1	0	0	12	FF	FS	,	<	L	\	l	|
1	1	0	1	13	CR	GS	−	=	M	]	m	}
1	1	1	0	14	SO	RS	.	>	N	^	n	~
1	1	1	1	15	SI	US	/	?	O	_	o	DEL

Bit Sequences

- Information we want to send is typically encoded as long bit sequences created by concatenating binary code words.
- In this class, we will assume that the LSB appears first in the sequence.
- Thus, ECE would be transmitted as the bit sequence

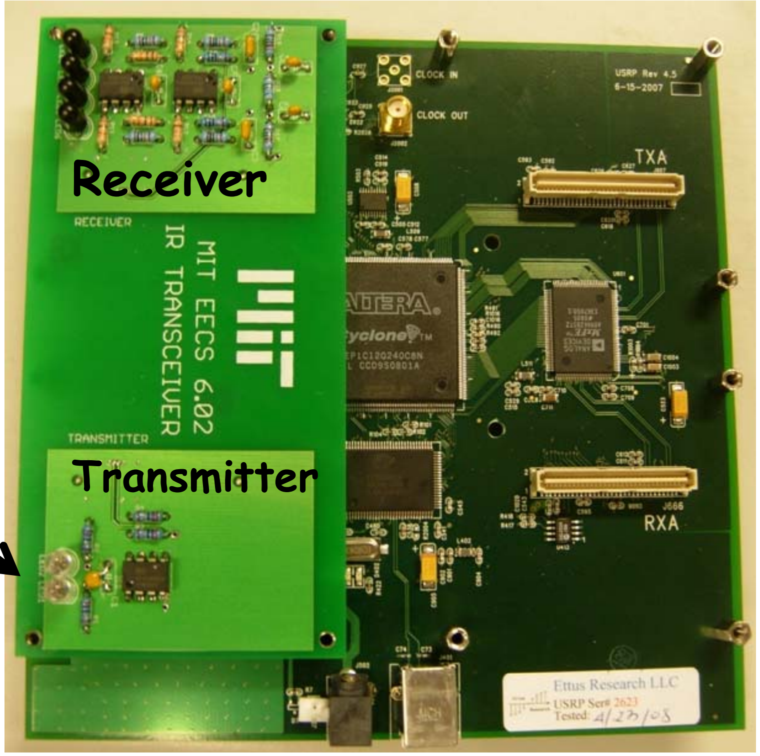
$$\begin{matrix} b_0 & b_1 & b_2 & b_3 & b_4 & b_5 & b_6 & b_7 \end{matrix}$$

$$\underbrace{1\ 0\ 1\ 0\ 0\ 0\ 1\ 0}_{E}\ \underbrace{1\ 1\ 0\ 0\ 0\ 0\ 1\ 0}_{C}\ \ldots$$

$$\underbrace{1\ 0\ 1\ 0\ 0\ 0\ 1\ 0}_{E}$$

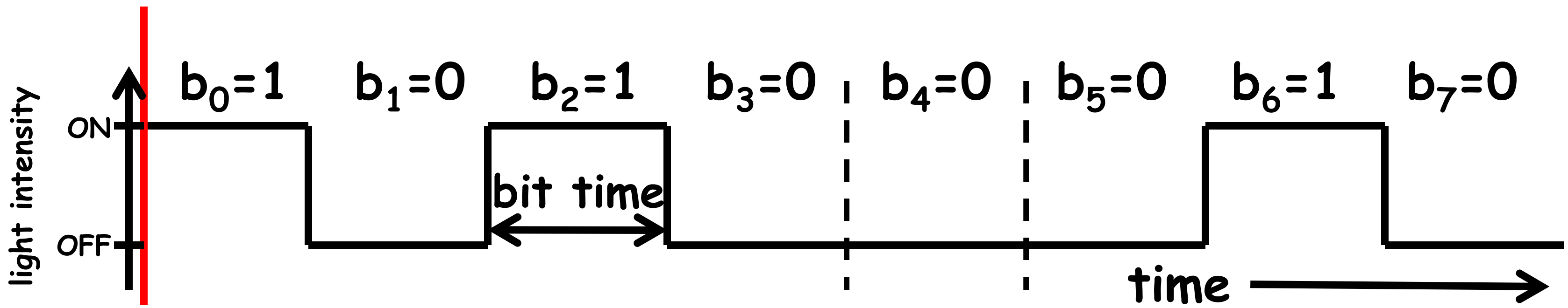
Representing Bits

- Physically, bits can be represented as two distinct states of a physical variable, e.g.
  - voltage (1 = high / 0 = low)
  - current (1 = positive / 0 = negative)
  - light (1 = on / 0 = off)

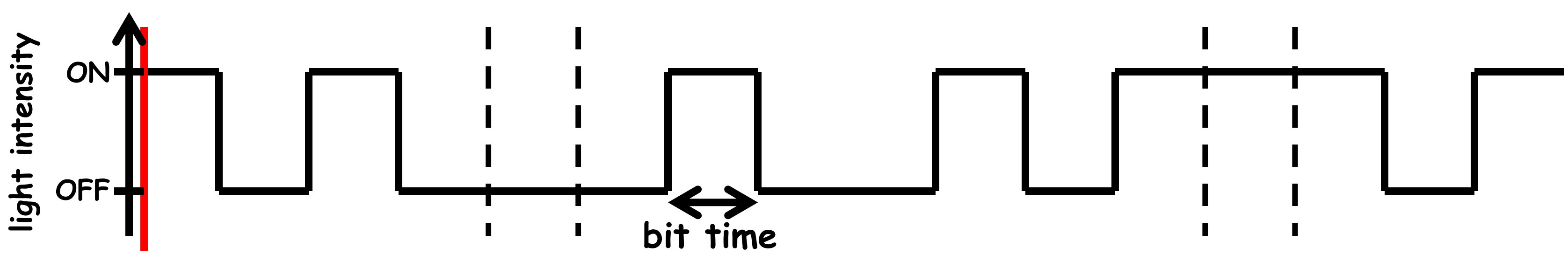


Representing Bit Sequences as Waveforms

- A bit sequence can be encoded by changing the value of the physical variable over time.



- Each bit is encoded by holding the state constant over a length of time, known as the bit time.
- The shorter the bit time, the faster we can transmit information (bits)

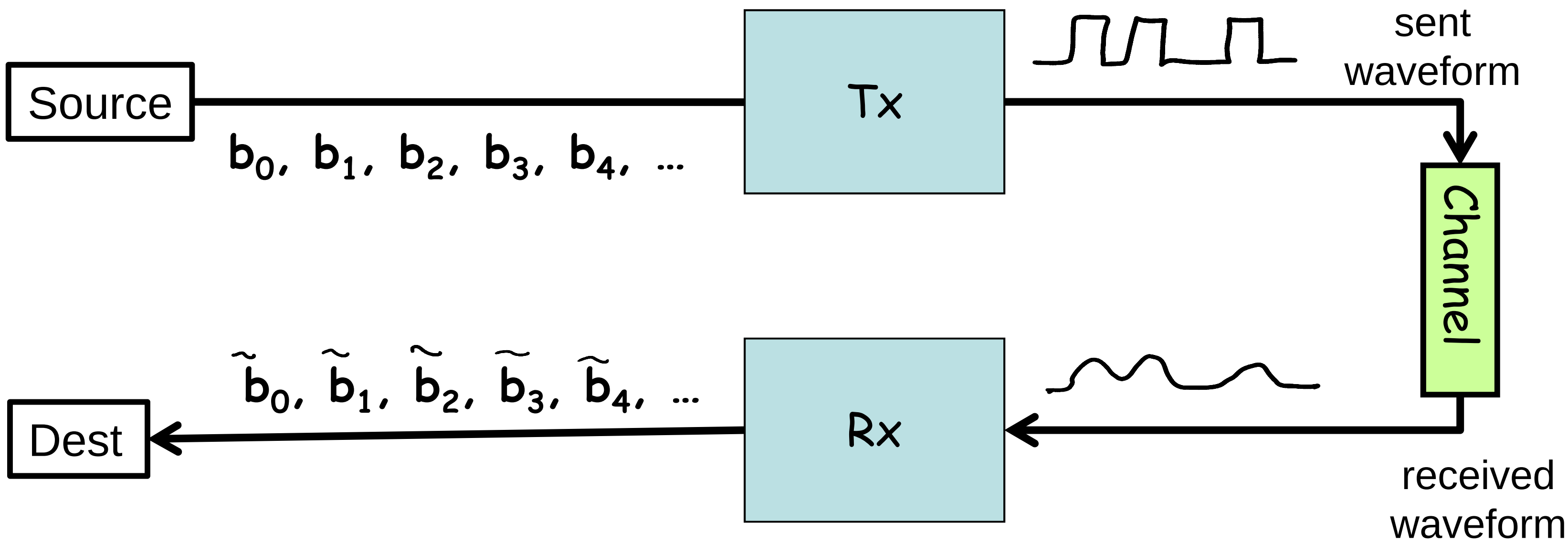


The channel

- The transmitter sends the waveform representing the bit sequence to the receiver over a channel.
- For example,
  - A voltage or current waveform might be sent over a wire.
  - A light waveform might be sent over a fiber optic link (e.g. the internet) or over plain air (e.g. a TV remote)
- Due to various factors, the channel may distort the waveform, so that the waveform at received by the receiver is not the same as the one sent by the transmitter.

Receiver

- The receiver's job is to take the possibly distorted signal it receives and figure out what the original transmitted bit sequence was.



- Common Abbreviations
  - Tx = transmitter
  - Rx = receiver

Key Questions for Next Lecture

- **How do we describe the physical waveforms sent by the transmitter and sensed by the receiver using mathematical equations?**
- **How do we describe (model) the effect of the channel on the physical waveform?**