ELEC353 Lecture Notes Set 1

There is a tutorial THIS week. Attend the tutorial and do the problem.

The first homework assignment is posted on the course web site.

Do it by January 14th.

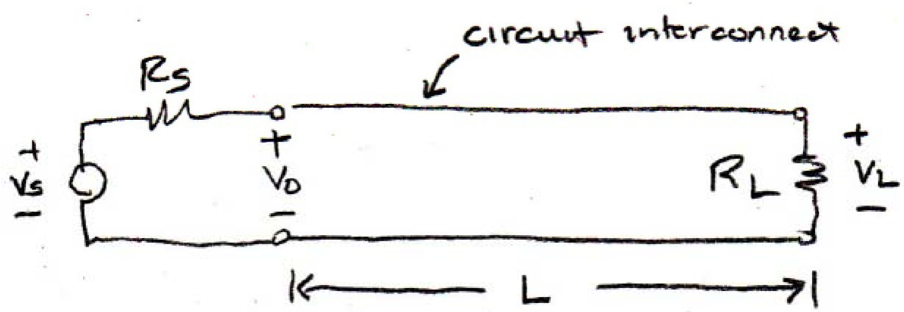
Get the solution from the course web site after January 14th.

From the course web site:

ELEC 353 – Assignment #1

Note: In ELEC353, assignments are not handed in. Do the assignments week-by-week and then evaluate your work in comparison to the solution.

1. What is an "ideal" short circuit?

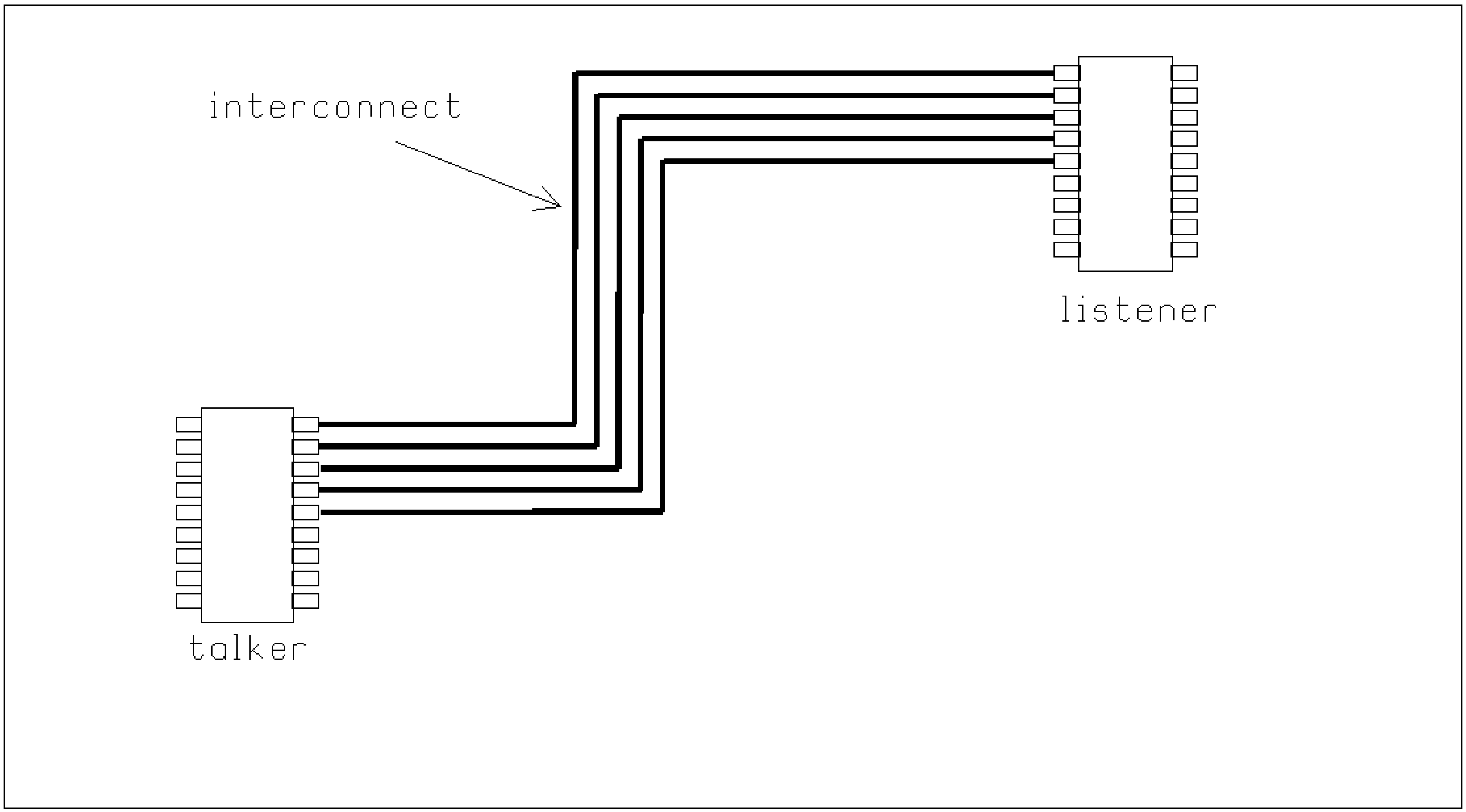


2. In the circuit shown above, V_s and R_s are the Thevenin equivalent circuit for the output of a logic chip. The output of the chip is connected to a load R_L with a circuit interconnect of length L. The load represents the input of another logic chip. The source is step-function generator that steps up from 0 volts to $V_s = 10$ volts at $t = 0$, and has internal resistance $R_s = 30$ ohms. The load resistor is $R_L = 1000$ ohms. Find the voltage across the generator terminals $v_0(t)$ and across the load terminals $v_L(t)$. Treat the circuit interconnect as an *ideal short circuit*. Plot the voltage at the source terminals and at the load terminals as a function of time. This problem is trivially simple and represents the "ideal" behavior of a circuit interconnect.

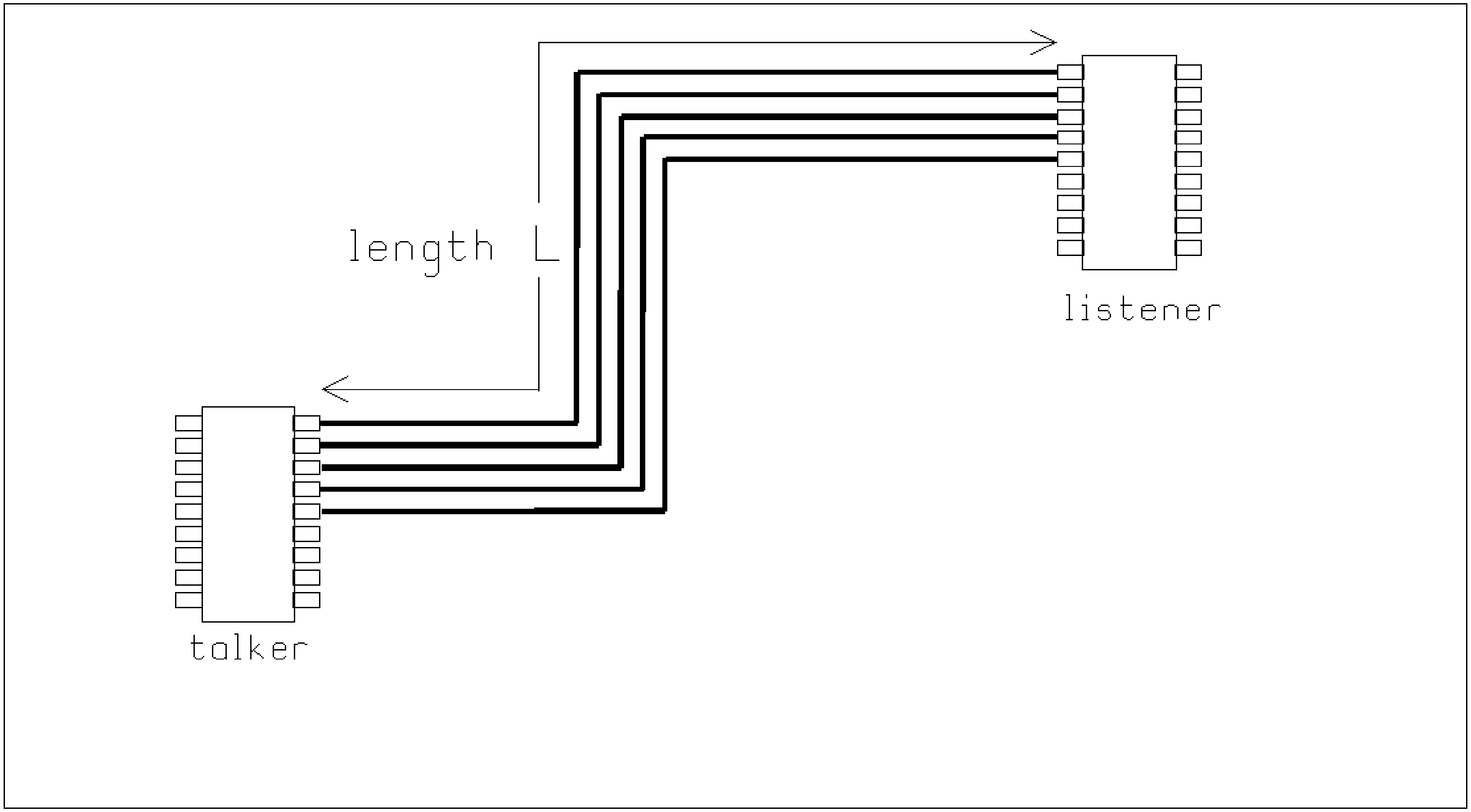
Why do you take this course?

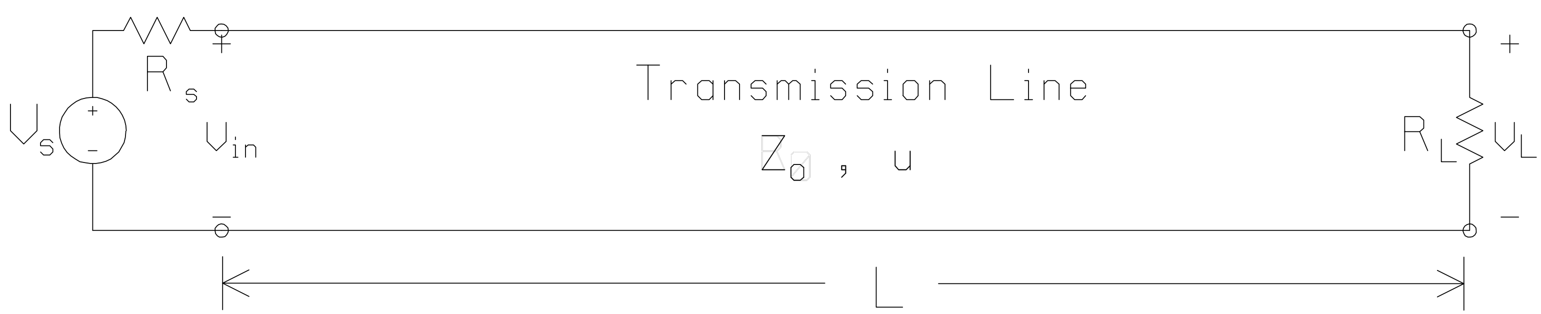
- Unexpected problems occur with high-speed logic circuits!
  - expect to receive a logical 0 but instead receive a logical 1.
- Circuit interconnects introduce:
  - time delay
  - intersymbol interference
- This course allows us to understand these problems:
  - Fundamental cause: travelling wave behaviour
  - Learn about *distributed circuit analysis*
  - Reflections: arise because of impedance mismatch between the “line” and the “load”
  - How to diagnose problems with a circuit
  - How to build circuits that work correctly

Interconnection Paths on a Logic Board



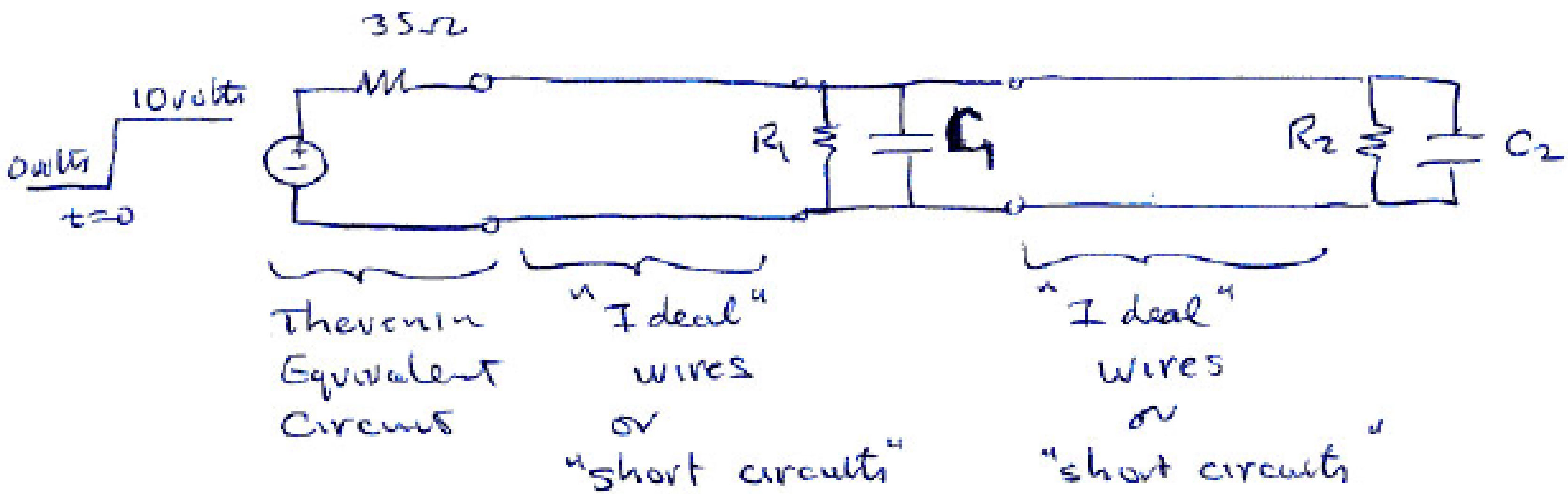
Equivalent Circuit for an Interconnection



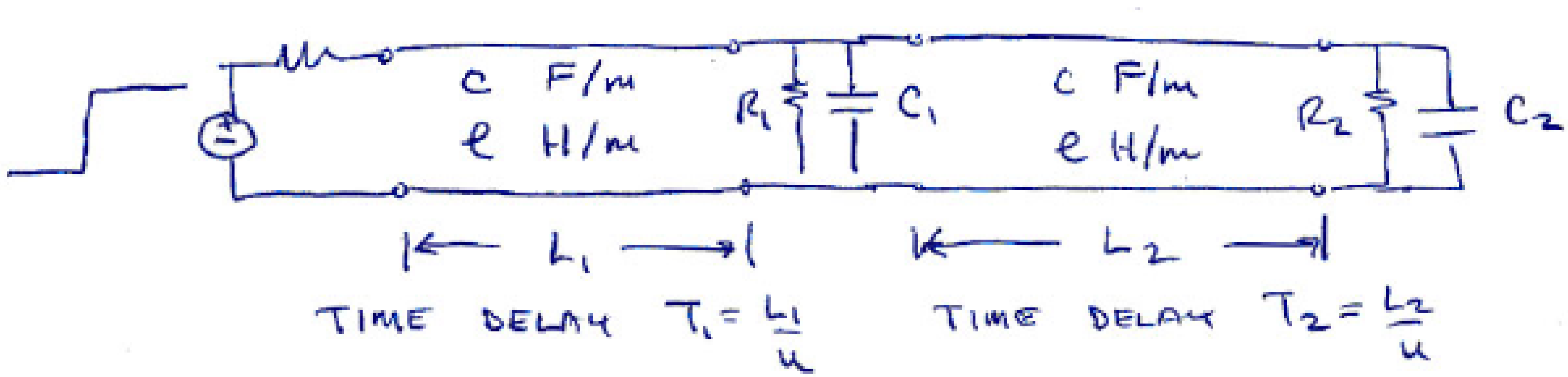


Lumped circuit analysis or distributed circuit analysis?

Lumped circuit analysis:



- R, L and C are discrete components.
- Circuit paths are "ideal" short circuits.
- There is *zero time delay* for a voltage to go from one end of a circuit to the other.



Distributed circuit analysis:

- Circuit paths are *not ideal short circuits*.
- Circuit paths have capacitance-per-unit-length and inductance-per-unit length
- Consequently circuit paths have a propagation velocity u m/s and so have *time delay* $T = \frac{L}{u}$, where L is the length of the circuit path.

- Voltages and currents behave as "traveling waves".
- These circuits are called "transmission line circuits".
- **Homework:** read about "distributed circuit analysis" in Inan and Inan.

On a computer circuit board, circuit paths that connect the various chips have inductance-per-unit-length and capacitance-per-unit-length and therefore may have to be analyzed by distributed circuit analysis.

Learning objectives:

- Learn *when* we can use lumped circuit analysis and when we must use distributed circuit analysis.
- Learn about distributed circuit analysis:
  - How is the capacitance-per-unit-length found?
  - How is the inductance-per-unit-length found?
  - How do capacitance-per-unit-length and inductance-per-unit-length give rise to time delay?
  - How do we solve “distributed” circuits?
  - What are “traveling waves”?

- Learn to solve distributed circuits in the **time domain.**
- Learn to solve distributed circuits in the **frequency domain.**

- **Learn that the voltages on a circuit interconnect behave as travelling waves.**

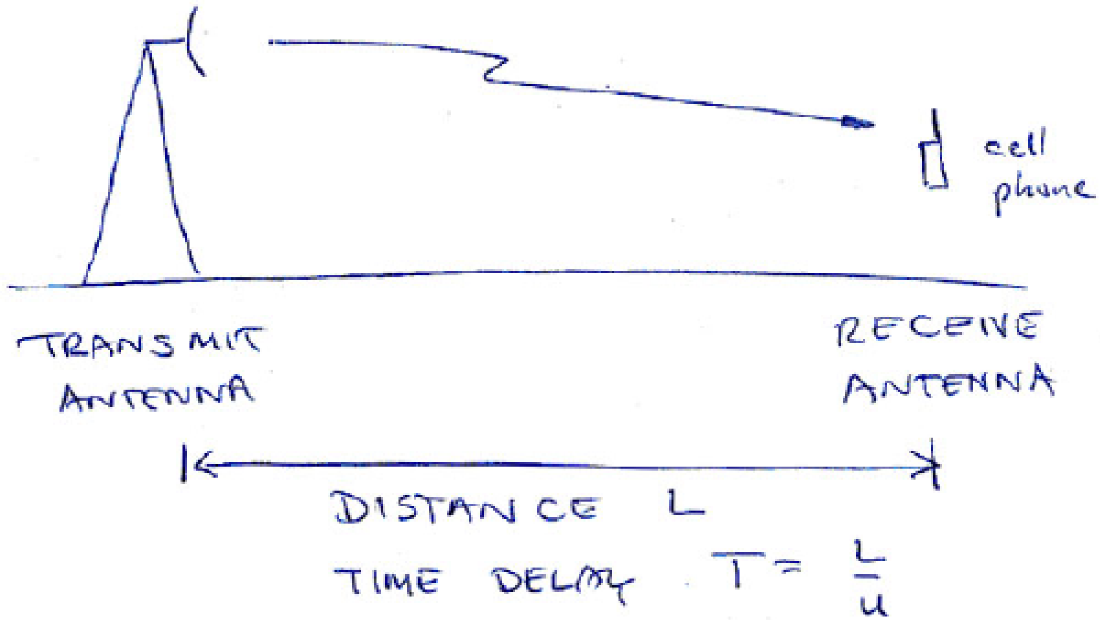
Learning objectives:

- **Apply travelling wave concepts:**
  - **to circuits**
  - **to waves travelling in space**

- Learn about electromagnetic waves travelling through space.

- Learn about antennas and wireless links.

Wireless Links



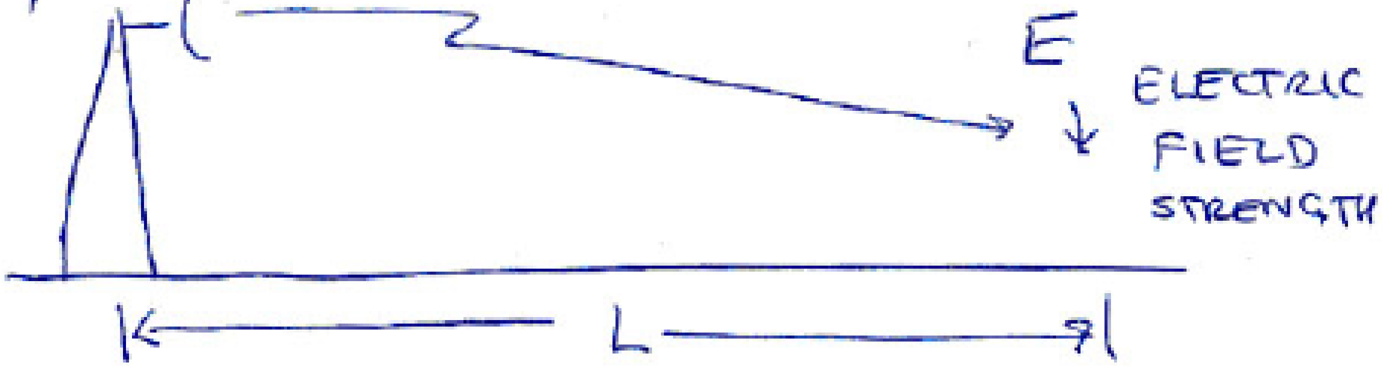
- In a communication system, a "transmitter" talks to a "receiver" that may be many, many miles away. This is a desirable interaction!
- The time delay for propagation from the transmit antenna to the receive antenna is $T = \frac{L}{u}$ where u is the speed-of-travel of the wave in free space.
- For waves in air, the speed-of-travel is usually denoted by c (instead of u) and is

$c = 2.9979x10^8$ meters per second

$c = 299.79$ meters per microsecond/s

$c = 29.979$ centimetres per nanosecond

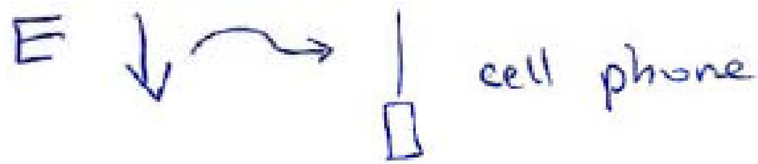
(1)



Engineers solve this problem in two steps with the "electric field" $\overline{E}$ and the "magnetic field" $\overline{H}$ as intermediate parameters:

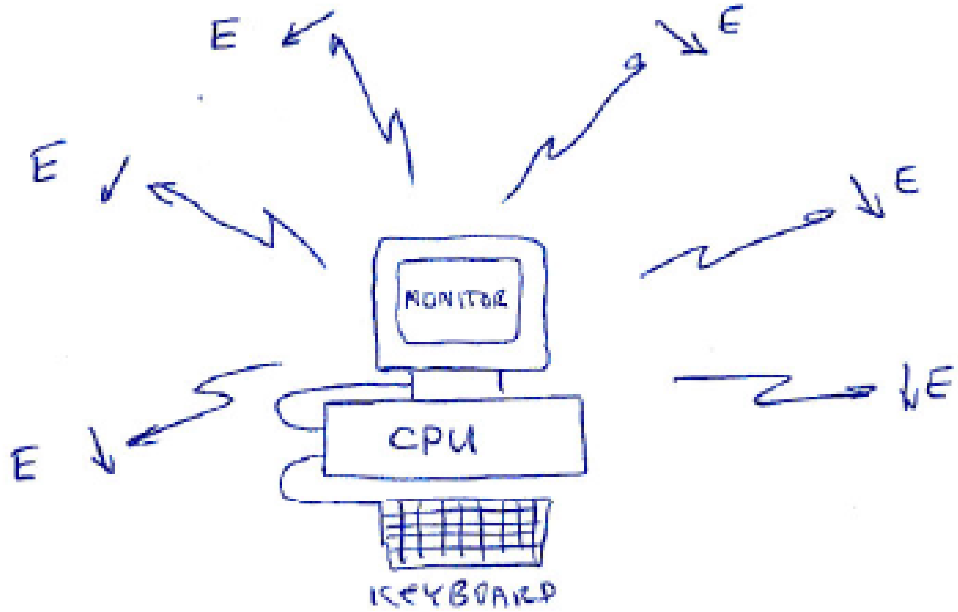
- First, the transmit antenna is studied to find the value of the electric field $\overline{E}$ at the location of the receiver

(2)



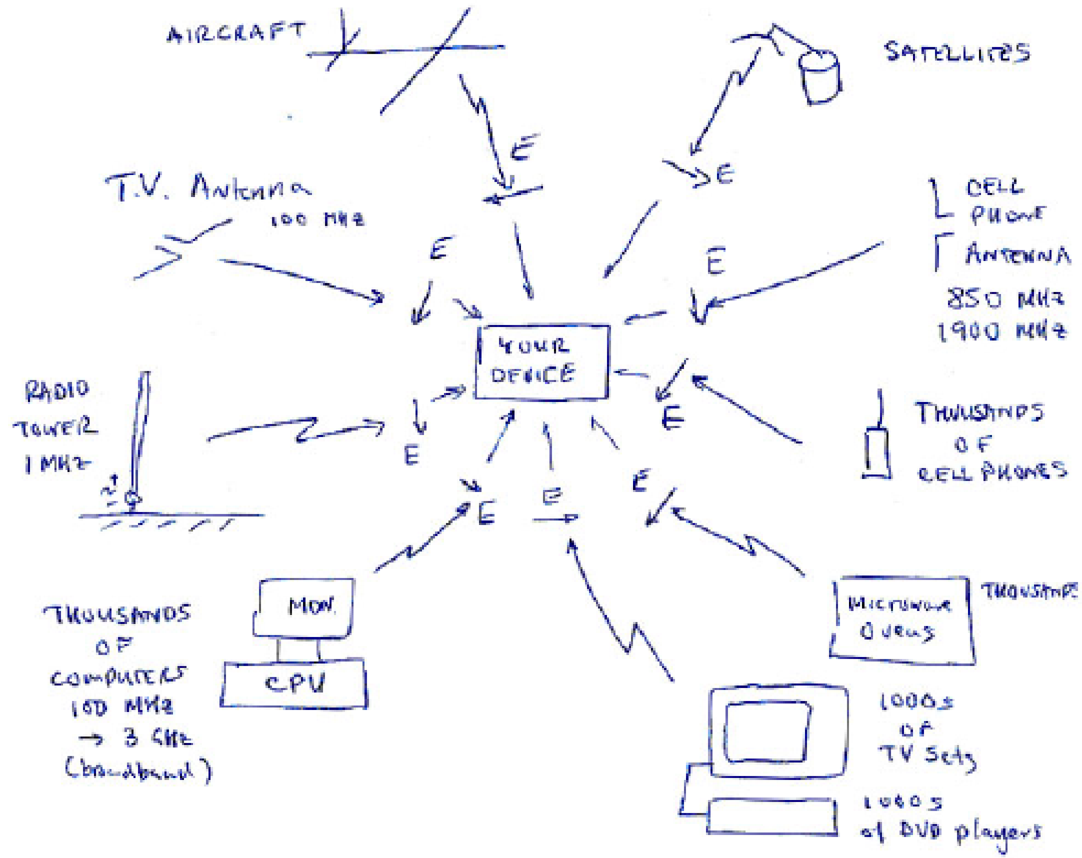
- Then receive antenna is then studied to find the voltage it delivers due to the electric field of the transmitter.

Electromagnetic Compatibility



- Every circuit or device radiates a certain amount of unwanted electric field.
- These fields are called "radiated emissions".
- Government regulations limit the field strength that a computer device (or any commercial electrical product) is permitted to radiate.

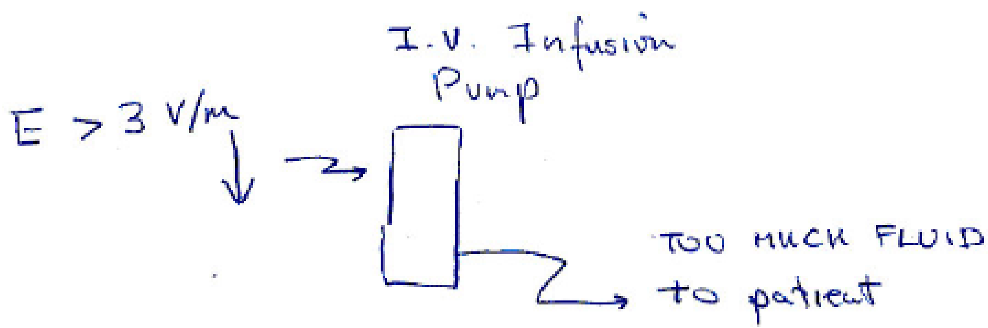
The Electromagnetic Environment



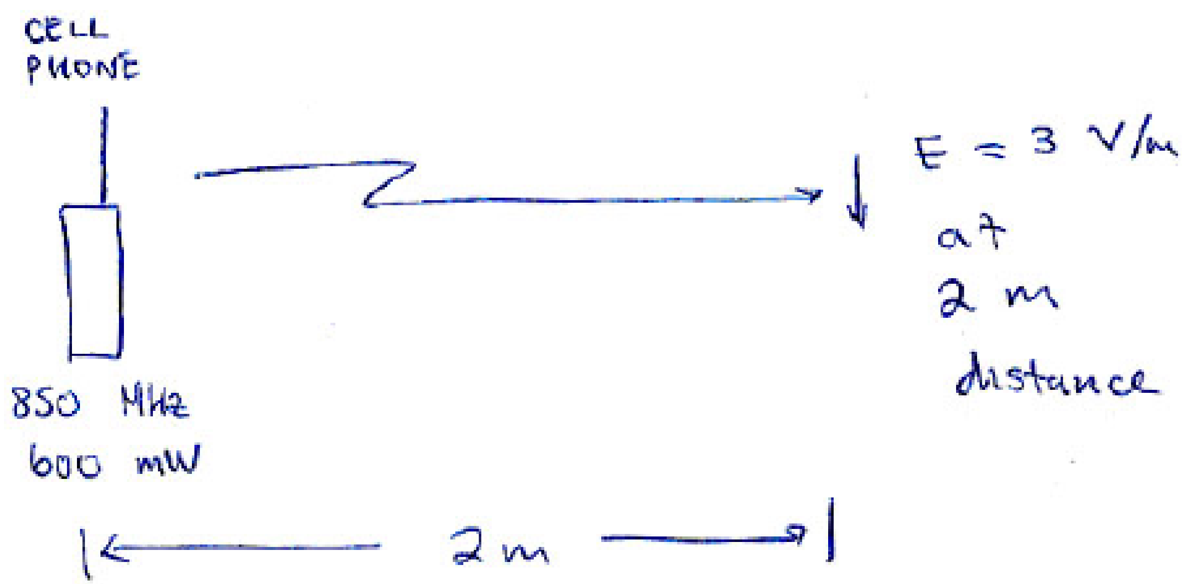
- The "electromagnetic environment" consists of:
  - all the fields radiated by antennas for various purposes (radio, TV, cell phone, radar, …)
  - all the unwanted "radiated emissions" from thousands of TV sets, radio sets, computers, cars, …
  - Your computer device or logic circuit MUST operate correctly in the presence of the electromagnetic environment

Immunity

- The "**immunity**" of a device is the electric field strength at which the device malfunctions, and is a function of the frequency.



  - For older medical devices, typically the immunity is 3 V/m.

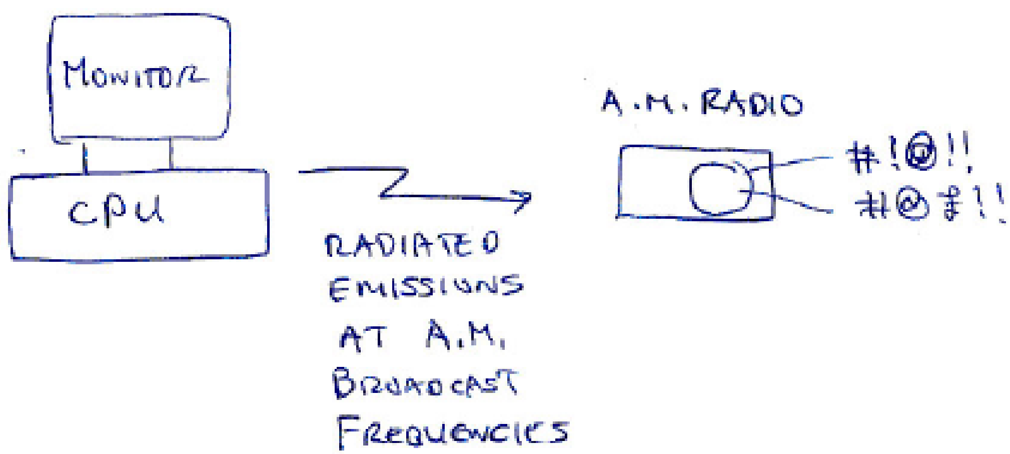


  - Thus a 600 mW cell phone operating near a medical device creates fields in excess of 3 V/m if it is closer than 2 m.

Interference

Interference occurs when:

- your device malfunctions because of the fields radiated by some other device; or
- some other device malfunctions because of the unwanted fields radiated by your device.



- Example: put an AM radio near a computer. The radio will whine when it is close enough. The computer interferes with the radio.

Electromagnetic Compatibility

- **"Electromagnetic Compatibility"** or **EMC** refers to the ability of devices to operate together without malfunction.
- EMC Testing: Computers and other equipment are often tested for emissions and susceptibility.
  - Emission testing determines the electric field strength of the radiated emissions.
  - Susceptibility testing determines the immunity of the device.
- Designing for EMC:
  - Identify circuit configurations that radiate as little as possible.
  - Design "shielding" to prevent radiated emissions from circuit boards getting out of the computer box.

Learning objectives:

- Learn about the electric field and the magnetic field:
  - What is the electric field of a wire at a voltage V?
  - What is the magnetic field of a wire carrying a current I?
- What principles or "Laws" in physics govern $\overline{E}$ and $\overline{H}$?
  - Answer: Maxwell's Equations.

- Learn about how "waves" of electric field and magnetic field propagate through space.
- Learn about how waves interact with materials.
- **Homework:** read about "electric field" and "magnetic field" in Inan and Inan.