ELEC 361 Measurement and Analysis
Lab 3. Near Field Electrostatic Communicator

This lab investigates the performance of short-range wireless communication using medium frequency amplitude modulation (AM) in the "near field". This is a 2-week lab.

Pre-Lab Homework
1. Assigned reading:
   - Read section 13.15 in The Art of Electronics – Horowitz and Hill (2nd edition). Just read the parts about amplitude modulation and detection. The section on PWM will be used in a future lab.
   - Look over the data sheets for the LF356 (JFET input OpAmp) and LM386 (audio amp). Things to note about LF356 are the input impedance and gain-bandwith product. For the LM386 look over the typical applications – you will be using one of these.
2. Review the formula for capacitance between two parallel wires. How does capacitance depend on distance between the wires? (See background section.)

Background
The transition between near-field and far-field distance d is typically quoted as

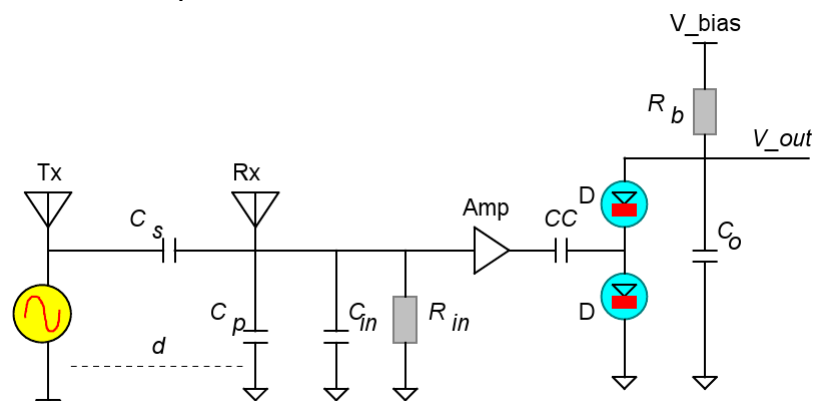$$d < \frac{\lambda}{2\pi} \quad \text{near field}$$

$$d > \frac{\lambda}{2\pi} \quad \text{not near field}$$

$$d > 3\lambda \quad \text{far field}$$

Here $\lambda = c/f$ is the wavelength for frequency f with propagation speed c. For example, assuming a $f = 1$ MHz electromagnetic signal is transmitted "over the air", then $c = 3 \times 10^8 ms^{-1}$ and the wavelength is $\lambda = 300$ m; near field occurs for distances $d < 48$ m. The transition between near- and far-field is imprecise, and depends on the application.

The block model for the completed Near Field Electrostatic Communicator is:

Electrical model of near-field transmitter and receiver

Electrical coupling through the air is represented by the series capacitance *Cs* , while

stray capacitance to ground is represented by *Cp* . Since a JFET input op-amp has a (incredibly) high input impedance *Rin,* its input primarily presents a capacitive load, shown as *Cin* . The series capacitance *Cs* forms a capacitive voltage divider with *Cp//Cin,* with the voltage ratio being frequency independent for frequencies

$$f < \frac{1}{2\pi\, Rin(Cp + Cin)}$$

The value of *Cs* follows the standard capacitor equation

$$Cs = \varepsilon_0 \frac{A}{d} \quad .$$

Here A = the effective antenna area and ε_0 = permittivity (of air). This simple analysis does not completely determine how the path loss depends on distance, since the voltage ratio is actually caused by a distributed capacitance. You will investigate the actual dependence.

Lab tasks

Transmitting a carrier and AM signal
1. Set FGEN to 100 kHz and use 2 resistor leads as antennas. Use scope inputs (AI inputs may no be sensitive enough) to measure the path loss voltage ratio as a function of distance d . Does the path loss follow an inverse law as predicted by the simple model?
2. Build a voltage gain block with voltage gain of 11, using the LF356 JFET op-amp. Plan your component layout on paper before you build it on the breadboard. Be careful not to 'zap' your op-amp as JFET input op-amps are sensitive to static. Use the following resistor values:
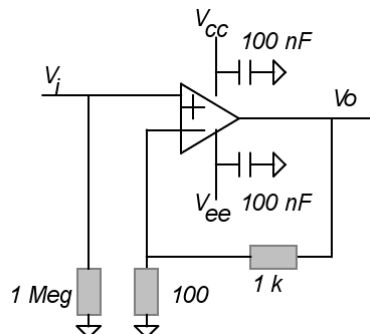
3. Confirm that the OpAmp is stable (use the 100 MHz scope). You will need a tidy layout with short signal paths.
4. Connect the Rx (receiving) antenna to the input and measure the improvement in voltage ratio. Is it greater than 11? If so can you explain why?
5. Construct the diode detector, and connect to the output of the gain stage. Use diode D = 1N4148, Rb = 100k, Cc = 1 nF and Co = 10 nF. Observe the output using AI 0. Check that the output voltage increases with signal level. Relate the signal peak voltage to the detected voltage.
6. Use the ARB (arbitrary waveform) generator to produce a 1kHz sine wave, and use it to AM modulate the carrier signal produced by FGEN. (FGEN has an AM input.) Trace the signal through the generation and circuit stages, and ensure you understand the signal at each stage.
7. Use the DSA to observe the spectrum before demodulation and after demodulation.

Explain the spectrum you see. What is the maximum distance before the 1kHz audio component is lost in noise?

Voice communication

8. Build an audio amplifier in one corner of the breadboard, using an LM386N-4. Plan your layout before you build the circuit (see handout on circuit layout with an example using the LM386.) You will reuse this audio amplifier for another lab. Check that your audio amplifier functions correctly.
   Sometimes the LM386 amplifier can be tricky to lay out, because it can go unstable. A sample layout and circuit can be found at
   http://arduino.cc/en/Tutorial/SimpleAudioPlayer#.Ux5_FfgXsx4 (link on 361 page)
9. Use the PC to record a segment of your voice, and save as a .wav file. (Or find a snippet of voice elsewhere.)
10. Convert the file in MATLAB and waveEditor to a format suitable for ARB.
11. Generate an AM stimulus from FGEN (reduce the level to 5 V) and apply to the Tx antenna
12. Apply the audio output to the audio amplifier and speaker. Confirm that the snippet of voice can be heard.
13. Try different distances d . What distance can you send the voice before it is unintelligible?
14. Relate this to your result from task 7. Can you explain in terms of relative bandwidth of the DSA and the human ear? (This is optional.)

Lab report
Present clearly all your results. Include all set-ups and measurements, and results derived from measurements. Describe how you made estimates from your measurements, and give the basis of calculations or code that you used. We want to see that you have understood how AM transmission of signals works, and how the circuits work.

Please note: Your lab book needs to me marked as 'completed' before you can hand in your lab report. You can only have one lab report outstanding (not graded as 'passed') to be able to start another lab.