Matthew Spencer – Fall 2023

Lab 4: Near Field Measurements

In this lab you are going to use near filed probes to measure electromagnetic fields.

After this lab, you will be able to:

1. Calculate magnetic fields around some common structures.
2. Use near field electromagnetic pre-compliance measurements to infer circuit behaviors.

Practical Questions

1. What is a Helmholtz coil?
2. What is the Biot-Savart law?
3. What is the magnetic field strength (H) in a Helmholtz coil?
4. What is the magnetic field distribution around an infinite current carrying wire?
5. What is pre-compliance electromagnetic testing?

Theory Questions

1. A sinusoidal voltage source with a 50 Ohm output impedance is used to drive a Helmholtz coil with 75 turns and a radius of 1cm. What is the coil magnetic flux density, B, as a function of voltage amplitude, Vzp, and frequency, f? You will need to look up a expression for the flux in the Helmholtz coil to answer this question, and you should find an expression that assumes flux in the coil is constant (though technically it varies a little with position). Don't forget to account for the inductance of the coil, which you can readily calculate as flux/current once you've looked up a flux expression.

Lab Instructions

This lab doesn't require any circuit simulations. Instead of comparing measurement, simulation and analysis for each problem, just compare measurement and analysis. We will use the HP 8665B signal generator, Agilent N9320B spectrum analyzer, Tekbox TBPS01 near field probes and Tekbox TBWA1 wide band amplifier. Datasheets are below:

- https://www.tekbox.com/product/TBPS01_TBWA1_Manual.pdf
- https://us.rs-online.com/m/d/72ff981d3a2821471f9c138fdea78d94.pdf
- https://www.keysight.com/us/en/product/8665B/highperformance-signal-generator-6-ghz.html

1. Familiarize yourself with the HP 8665B RF signal generator and the N9320B spectrum analyzer.
    a. Turn on both devices.
    b. Set the span of the spectrum analyzer to 2MHz and the center frequency to 4MHz.
    c. Set the output of the signal generator to the following settings, VERIFY THAT THE POWER LEVEL IS NEGATIVE DBM, connect the signal generator to the spectrum analyzer, enable RF signal output, and record the resulting spectra.

        i. -50dBm at 4MHz
        ii. -40dBm at 4MHz
        iii. -40dBm at 5MHz
    d. As a note: We'll dig into this more in a future lab, but beware that the spectrum analyzer is trickier than it looks. Keep your span fairly narrow (500kHz-2MHz, narrower if you are working at very low frequency), and ensure that you are only viewing positive frequencies on the screen (set center > span/2).

2. Calibrate the near field probes
    a. Connect the near filed probe to an SMA cable using a type-B to SMA adapter. Connect the SMA cable to the pre-amplifier (which should be powered by a USB connection) and connect the amplifier output to your measurement instrument. You may use whatever tools you like to drive signals and receive them, but the signal generator and spectrum analyzer from section 1 work well.
    b. Use the Helmholtz coil and the parallel plate setup pictured in Figure 1 to calibrate your near field probes. Your calibrations should include the following relationships listed below. You are expected to calculate the field induced in the coil in order to make this calibration.
        i. a relationship between received power and measured field at 100kHz and 5MHz. (Note: our setup probably can't handle >30MHz well.)
        ii. a replication of the calibration curve on pages 2 and 3 of the near field probe datasheet, which is linked above. You probably won't be able to replicate the whole curve because we are frequency limited by our setup. Feel free to stop in the 10's of MHz region, wherever the data gets dicey.
    c. A few notes about our Helmholtz coils
        i. The Helmholtz coil in Figure 1 has 75 turns on each side.
        ii. A second (possibly more reliable) set of Helmholtz coils is also available in lab, and I'd be eager to see students explore their use. Include a picture of them in your report if you give them a try. These have 100 turns and nicer connectors.

3. Measure field around an "infinite" wire
    a. Use your calibrated probes and the function generator to measure the B field around the long wire on this breadboard. Compare your measured results to theory. You can measure the current in the wire using a sense resistor on the breadboard.
    b. The E field around this wire is poorly controlled, so we're not going to try to measure it. What do you expect the E field to look like from theory?

4. Observe near field behavior in an example circuit
    a. Find the test circuit pictured in Figure 3. It is comprised of a voltage regulator, a ring oscillator, a buffering inverter and a load resistor as shown in the schematic in Figure 3. It should be powered with at least 7V. Inspect the circuit with your near field probes and use your measurements to answer the following questions.
        i. What nodes emit strong B fields? What nodes emit strong E fields? Why?
        ii. What is the frequency of the ring oscillator? Are there other frequency components in your measured spectrum? Why?
        iii. Use your measurements to determine the value of the load resistor (which is currently hidden by tape).

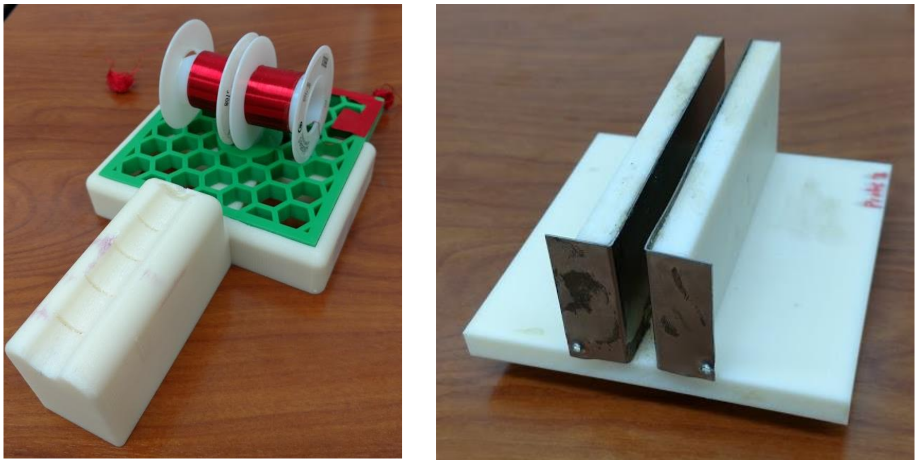

Fig 1

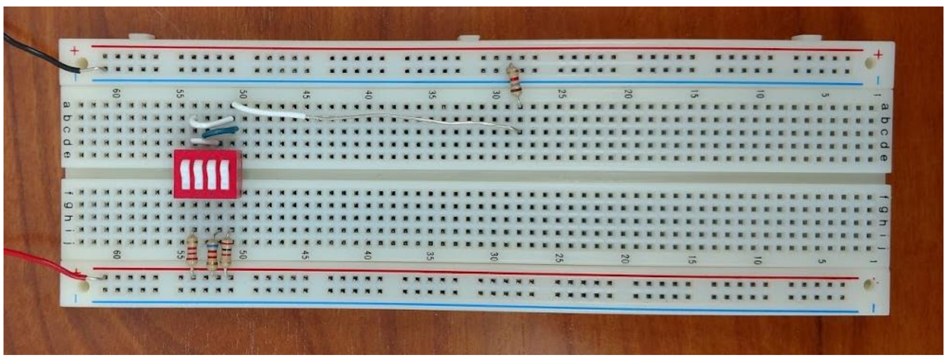

Fig 2

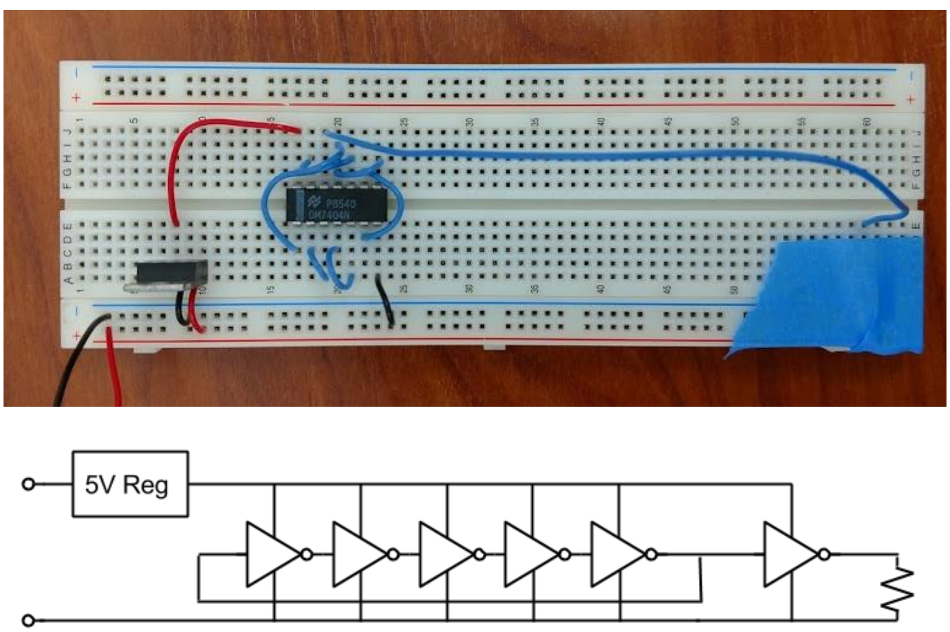

Fig 3

Required data in lab notebook:

- Spectra from familiarization exercise
- Power vs. Field calibration curve curves for each near field probe, including calculations that relate voltage applied to Helmholtz coil to field strength.
- Power vs. frequency calibration curves for each near field probe
- B Field vs. distance measurements for infinite wire. E field discussion for infinite wire.
- Representative field spectra for a few nodes in the example circuit
- Detailed explanation of oscillator frequency extraction, with calculations if necessary
- Spectra and calculations for load resistor extraction