EEE-351 Term Project
Electromagnetic Pulse (EMP) Generator

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01. Introduction

Electromagnetic Pulses

- Electromagnetic Pulses, also referred to as transient electromagnetic disturbances, are sudden bursts of electromagnetic fields that disrupt the other electromagnetic devices in its vicinity.

- EMP’s can be both natural and artificial. A common example can be considered a lightning strike which radiates EM-waves along every frequency, causing noise.

EMP Generator

- To create an artificial EMP generator, we will use a 400kV boost converter that will allow us to create sudden bursts of energy. We will use a capacitor to store energy which we will then quickly disperse through a radiating coil.

- We will then test our EMP generator on a calculator to test the electromagnetic interference. We will also test our device with a coherer to see the effects.

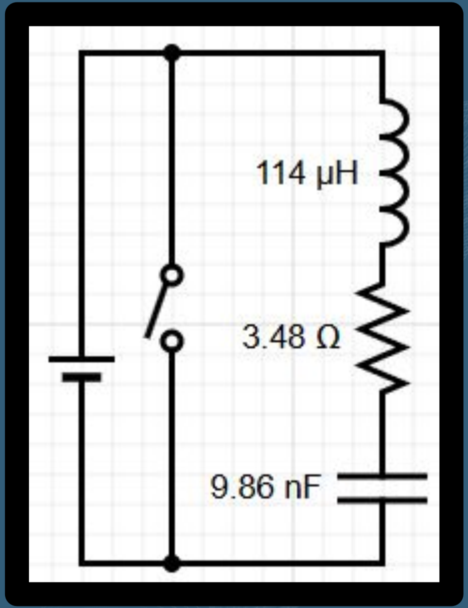
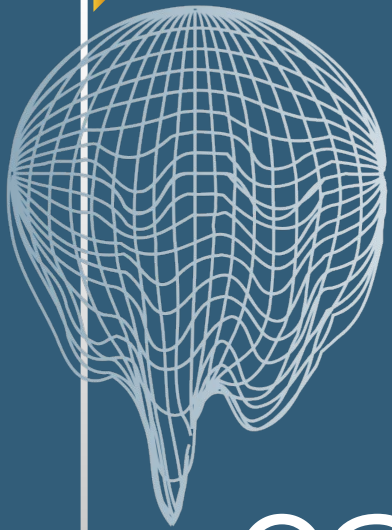


Figure 1: Circuit Schematic

Theory Behind EMP’s



02.

Theory - Field Creation

- To create a sudden burst of EM-fields, we used a radiating coil with a sudden change in current. Where the B-field due to the current is calculated using Biot-Savart law is given as:

$$\bar{B}(z) = \frac{\mu I r^2}{2(r^2+z^2)^{\frac{3}{2}}}$$

- Where r is the radius of the coil and z is the distance away from the coil along its normal direction. We have 80 windings on our coils so we multiply this result by n.

Theory - Current Spike

- In order to obtain a sudden current, we used an RLC circuit with the schematic seen in Figure 1.

- This circuit allows the capacitor to charge until the voltage is enough to ionise the air. Once the air is ionised, resistance drops for a spike in current. This presents a tradeoff between EMP intensity and EMP fire rate.

- Our second order circuit has the transfer function:

$$I(s) = \frac{V_C/s}{\frac{1}{sC}+\frac{1}{R}+sL}$$

Theory - RLC Circuit [1],[2],[3]

- Air ionises at around V=3kV/mm. It has a resistivity of ($1/10^4$) Ω/m when ionised. With the distance between our terminals being 5mm and our terminals having a r=0.5mm. So our RLC circuit has:

$$V_C = 15kV, C = 9.86nF, L = 114\mu H, R = R_L + R_a = 3.86\Omega$$

- Then our initial current spike can be obtained as a damped sinusoidal with the parameters below.

$$\zeta = \frac{1}{2R}\sqrt{\frac{L}{C}} = 0.101, f_n = \frac{1}{2\pi\sqrt{LC}} = 150\mathrm{kHz}$$

$$i(t) = -4310e^{-2.387x}\cos\left(2 \cdot \pi \cdot 150269x\right)$$

Theory - Coherer [4]

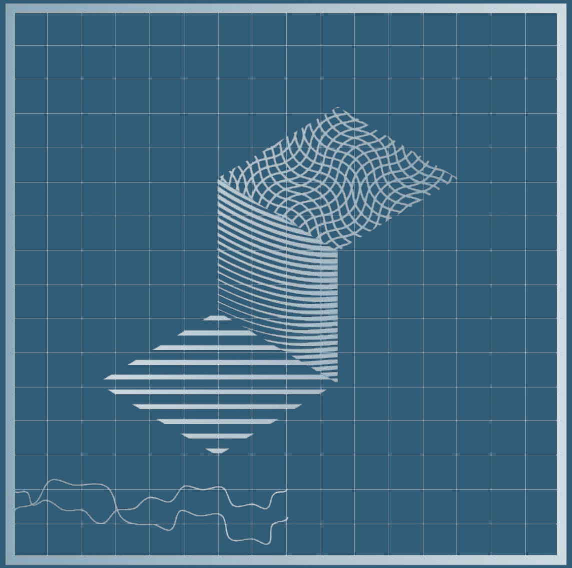
- Coherers are primitive radio wave detectors that we primarily used in the beginning of 20th century.

- It consists of loose metal particles between two terminals. These metal particles become much more conductive in the presence of EM-waves. Therefore, the coherer’s resistance is correlated with the amount of EM-Fields

- This contraption will also detect the radiating EM-fields from our EMP generator.

03.

Process, Cost & Safety



Development Process

1. Building the Capacitor
2. Making the Spark Plug
3. Winding the Radiating Coil
4. Making the Coherer

Building the Capacitor

We used cellulose acetate sheets whose relative permittivity is $\varepsilon=4.87$ and width = 120µm. We used two A4 acetate cellulose sheets which resulted in d=240µm.And left a margin of 0.5cm from each edge while making the aluminium layers which results in $A=0.0574m^2$.

$$C = \varepsilon A/d = 10.30nF$$

Our results were 9.86nF which has an error of 4.2%. This is probably due to the dust stuck between the layers and some other factors that increased our leakage.

Figure 2: Capacitance Measurement

Making the Spark Plug

While making the spark plug the the distance between the wires (spark gap) has a crucial role. As discussed in the “Theory” part the spark gap determines the trade off between pulse intensity and pulse firing rate. Therefore, we optimized our spark plug with this in mind.

We also designed a closed enclosure in order to keep the sparks isolated from the rest of the circuit and the potential users.

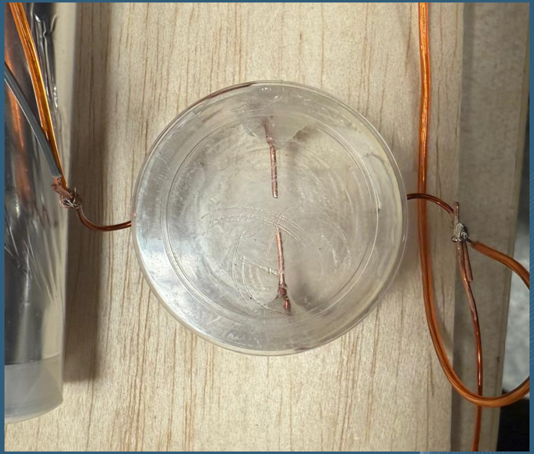


Figure 3: Spark Plug Mechanism

Winding the Radiating Coil

We wind the radiating coil by using a empty tape slot and a copper wire. In this process we made sure that the windings are neat and tight to reduce B-field leakage. After winding we, went over it with a layer of electric tape for better insulation and mechanical stability.

Our final coil has 80 windings.

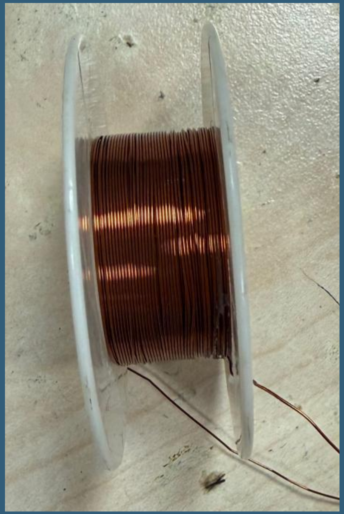


Figure 4: Coil Windings

Figure 5: Taped Coil

Making of Coherer

- For the metal filings, we made small balls out of aluminium foil.
- We then took a cylinder and attached two terminals made out of aluminium sheets.
- Finally we attached our multimeter and measured the resistance across our terminals.

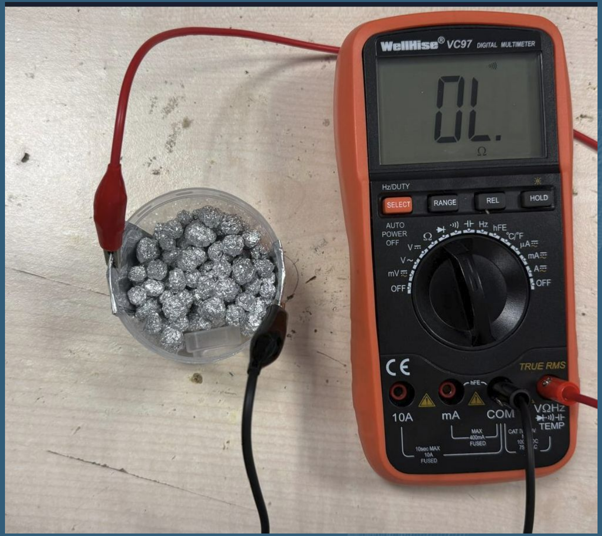


Figure 6: Taped Coil

Cost

68 TL — ACETATE SHEET → 4 acetate sheets are used for capacitor. Each costs 17 TL.

362 TL — BOOST CONVERTER → A boost converter is bought to obtain high voltage supply

0 TL — OTHER EQUIPMENTS → Aluminum sheet, plastic container, wooden base, extra cables, glue, scissors, empty tape slot and copper wire are already obtained

Total cost is 430 TL

Safety

High Voltage Safety: This device uses 400kV which is highly dangerous. To ensure no accidents occur, the spark gap was placed in a special enclosure.

Electromagnetic Safety: This device's main purpose is to cause electromagnetic interference. Thus, it should be kept away from electronic devices.

04. Results

Assembling and Testing

In this part we realised the circuit diagram that was previously discussed.

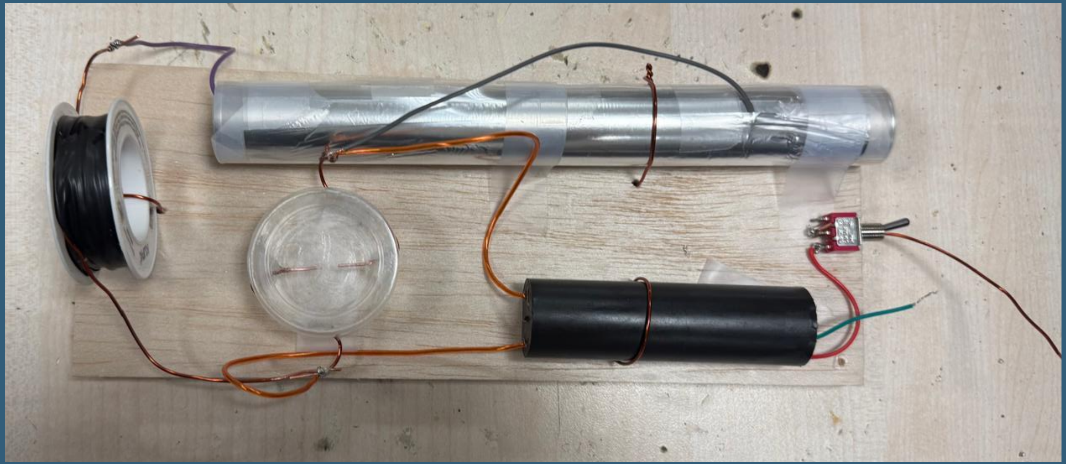


Figure 7: Assembled Circuit

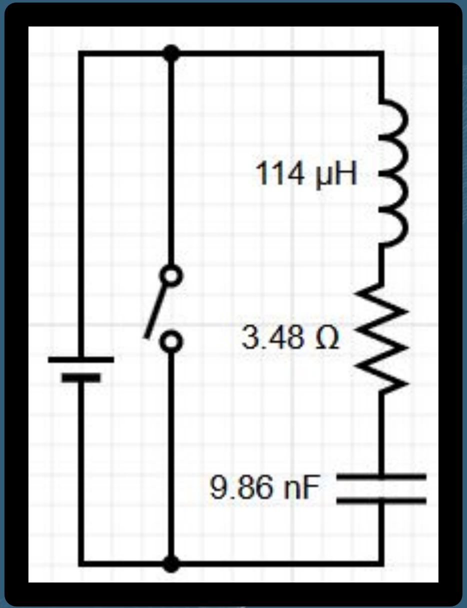


Figure 8: Circuit Schematic

Measured Induced Voltage

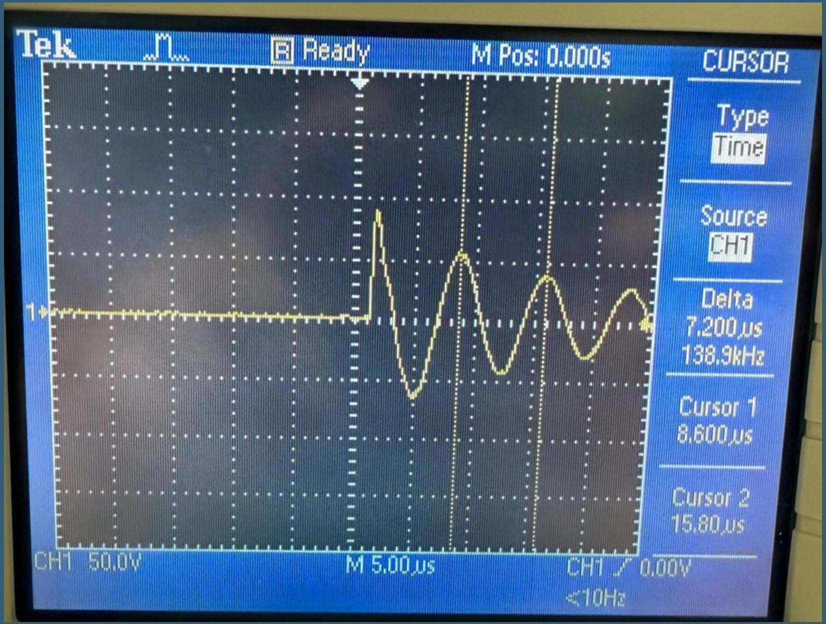


Figure 9: Oscilloscope Image

The frequency of the observed signal is 139 kHz while our theoretical frequency was 150kHz yielding an error of just 7.3%.

The experimental damping ratio was around 0.2 while the theoretical value was 0.1.

Possible reasons for this is the parasitic inductances, resistances, and capacitances; also measurement errors.

Measured Induced Voltage

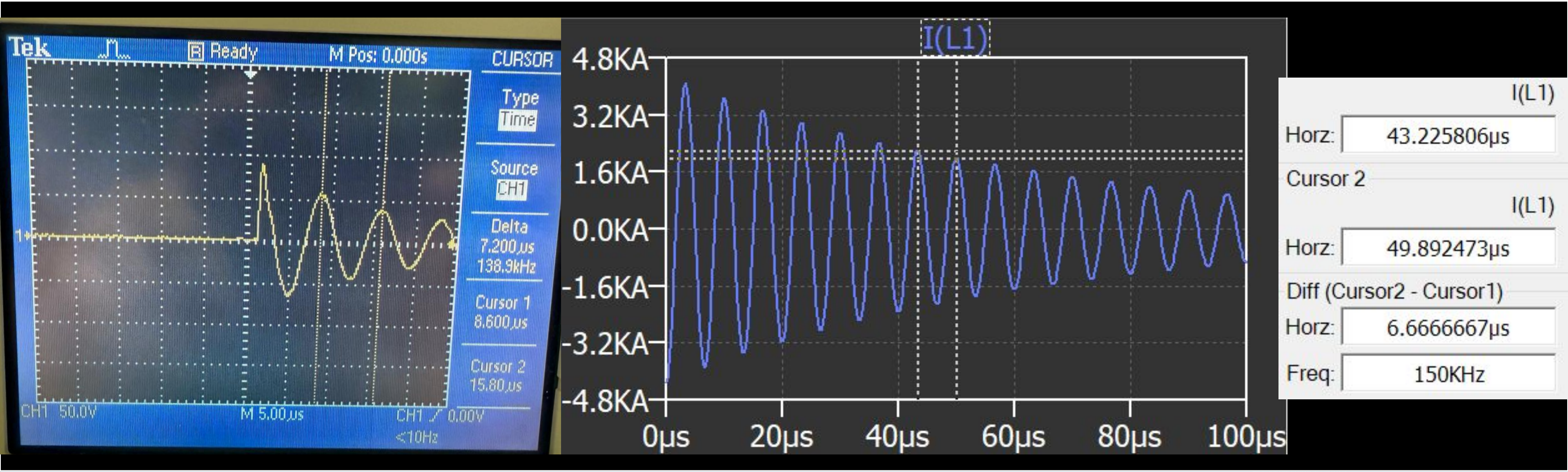
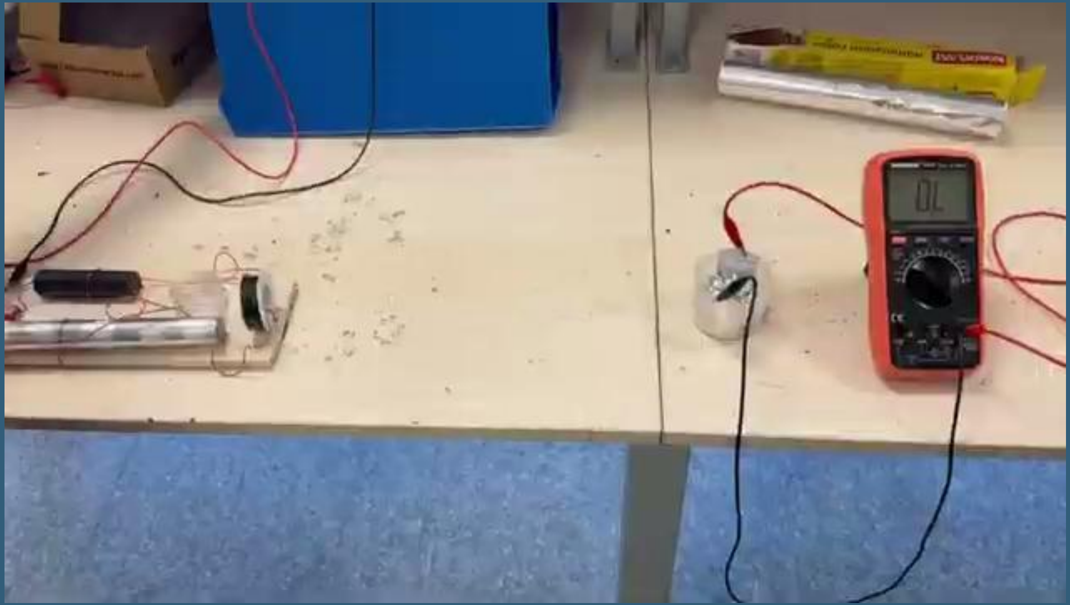


Figure 10: Experimental and the LTSpice Comparison

Tests With a Calculator

Video 1: EMP Generator Interfering With Our Calculator

Tests With a Coherer



Video 2: Coherer Resistance with Distance

05.

References

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[3] R. E. Thomas, A. J. Rosa, and G. J. Toussaint, The Analysis and Design of Linear Circuits, 7th ed. Hoboken, NJ, USA: Wiley, 2011.

[4] "High voltage," Wikipedia, Wikimedia Foundation, Apr. 25, 2025. [Online]. Available: https://en.wikipedia.org/wiki/High_voltage

Thank You for Listening