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The infinite reflexion floating lamp

1. Introduction

Diving into the world where technology meets art, our group of third-year undergraduates studying electronics is working on a cool project: the "Infinite Reflection Floating Lamp." This isn't just a school project; it's our way of pushing the limits of what's possible with electromagnetism and wireless power.

Imagine a lamp shaped like a dodecahedron (that's a fancy word for a 12-sided shape) that floats in the air and lights up without any wires. That's what we're making. It's not just about making something that looks cool; it's about showing off what we can do with technology and getting people excited about science and art.

We're mixing science, engineering, and creativity to make something amazing. By playing with magnetic fields and wireless energy, we're stepping into new territory and challenging ourselves to think outside the box. Our floating lamp is a step towards new inventions that could change how we use energy and make our surroundings more interesting.

2. Objectives of the Proposed System

The Infinite Reflection Floating Lamp achieves levitation and lighting through a smart design in its base, which combines permanent magnets arranged in a circle with embedded position correction coils. These magnets provide the lift, while the correction coils, integral to the magnetic setup, ensure the lamp stays precisely in place by making real-time adjustments to the magnetic field if the lamp drifts. This system allows for a stable hover and is coupled with a transmitter coil for wireless energy transfer, powering the lamp's LEDs. This innovative approach not only highlights the lamp's floating effect but also its seamless, wire-free illumination, showcasing a blend of functionality and aesthetic appeal through advanced engineering !

3. Design Concept and Theoretical Background

3.1 Transmitting Part

A. 13.56MHz oscillator

Our system utilizes a Wien Bridge Oscillator powered by a ±15V DC asymmetric power supply, designed to generate a 13.56 MHz signal for efficient energy transfer.
Through simulations, we optimized the oscillator to produce a stable 30V amplitude signal at the desired frequency, essential for our energy transmission application.
The oscillator operates on feedback principles, with carefully chosen components to achieve the target frequency and amplitude, ensuring a reliable energy transfer process.

B. Transmitter coil

To send a signal to the levitating component for powering the dodecahedron's internal LEDs, it was necessary to create a transmitter coil, excited by a drive loop.
Our project tackles wireless power transmission through magnetically coupled resonators. The system comprises a multi-turn spiral coil as the transmitter antenna and a single-turn driving loop. The transmitter coil, acting like an LC tank, is energized by an oscillating magnetic field when powered by the RF amplifier. On the receiving end, a load replaces the power supply, functioning as a step-down transformer.

The interaction between the transmitter and receiver coils, both high Q-factor LCR tank resonators, is vital. Their mutual inductance, influenced by their geometry and separation, facilitates energy transfer. This setup is modeled in our circuit diagram, representing each antenna element as series resonators linked by mutual inductances, showcasing the system's efficient design for wireless power transmission.

We opted for a 13.56MHz signal for our transmitter coil, necessitating precise design to achieve resonance at this frequency.

C. Levitator

The levitator is the key component that enables the dodecahedron to levitate. It ingeniously uses permanent magnets for repulsion to create lift, complemented by electromagnetic coils for precise position adjustments. These adjustments are controlled by a PID controller, implemented on a microcontroller, which continuously regulates the magnetic field intensity to correct the dodecahedron's position. This setup ensures the dodecahedron remains stably suspended in air, demonstrating a seamless blend of magnetic repulsion and controlled electromagnetic interaction.

3.2 Receiving Part

A. Receiving coil

We placed the receiving coil inside the dodecahedron, alongside its load loop, to showcase our handcrafted coil, a foundational element of this wireless energy transfer project. This coil was designed to resonate at 13.56MHz, enabling it to receive signals from the transmitter coil effectively.

B. AC to DC converter

To illuminate the LEDs, a DC signal is required; however, the signal we receive is AC. Therefore, a conversion to DC is necessary, for which we have chosen to use a buck converter.

C. LED

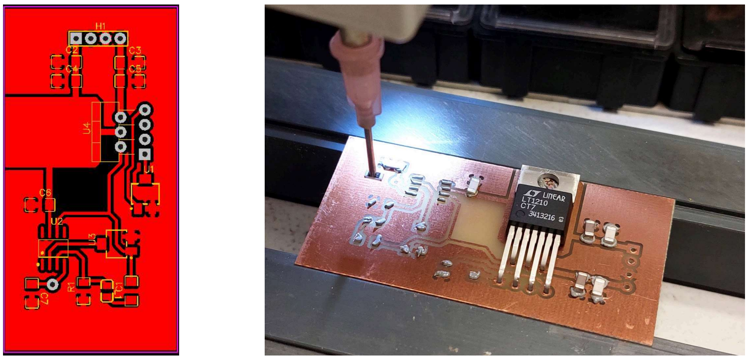
Inside the dodecahedron, we've integrated Filament LEDs, akin to the type encountered in modern light bulbs, for their exceptional lighting capabilities. Unlike standard LEDs, Filament LEDs offer a unique aesthetic that closely resembles the warm glow of vintage incandescent bulbs, while providing the energy efficiency and longevity associated with LED technology. This choice not only ensures an even dispersion of light, enhancing the visual appeal and luminosity across the dodecahedron's facets, but also contributes to an ambient atmosphere. The use of Filament LEDs aligns with our objective to merge traditional aesthetics with cutting-edge technology, creating a mesmerizing visual experience that is both environmentally friendly and visually striking.

4. Prototype and Results

4.1 Transmitting Part

A. 13.56MHz oscillator

For the oscillator board we were able to realize the routing, the manufacture of the PCB and braze the components on the PCB.



(a) (b)

Fig. 4.1.A.1.a *: Routing PCB oscillator.*
Fig. 4.1.A.1.b *: Deposit of oscillator PCB components.*

Following this, we had a little trouble adapting our system to the desired frequency due to the elements that influence our oscillator such as the coil and measuring devices.
Finally our oscillator system can supply our exciting loop with a sinusoidal signal of 13.56 MHz ± 0.50 MHz and peak to peak amplitude of 30 V ± 1 V (for a power supply of ± 15 V).

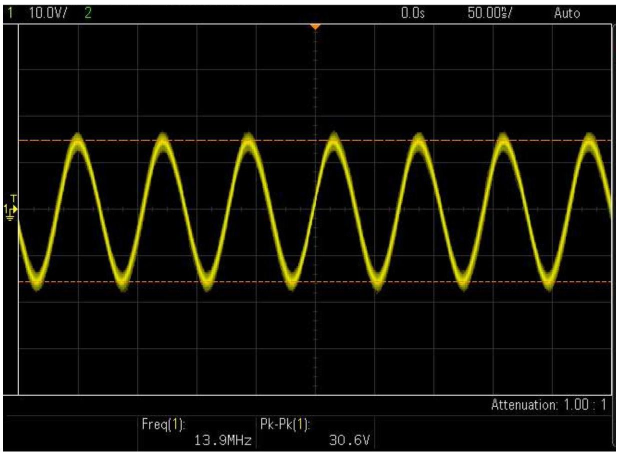


Fig. 4.1.A.2 *: Measure voltage of the oscillator in the emitting coil.*

B. Transmitter coil

Were initially part on the design of an emitting coil of the same diameter as the receiver, but given the possibility of making a wider one, the design of a coil was made with the following parameters:

Resonant coil:

Tinned copper diameter: 1.6 mm
Coil diameter: 240 mm
Coil spacing: 10 mm
Number of turns: 9

Loop Exciter:

Tinned copper diameter: 1.6 mm
Coil diameter: 200 mm
Coil spacing: 10 mm
Number of turns: 2

A first prototype was then produced :

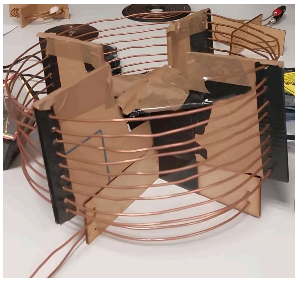
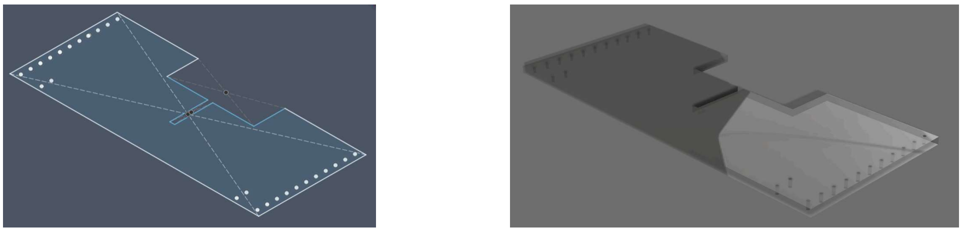


Fig. 4.1.B.1 *: Prototype transmitter coil.*

Then we modeled in 3D our emitting coils to cut them in acrylic with the laser machine :



(a) (b)

Fig. 4.1.B.2.a *: Modeling of the dimensions of the transmitting coil.*
Fig. 4.1.B.2.b *: Rendering of acrylic emitting coil.*

We were then able to produce our final transmitting coils :

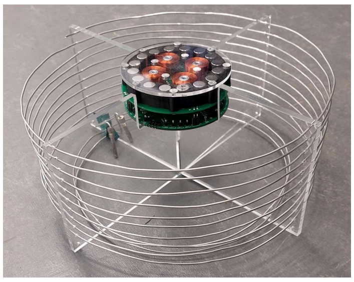


Fig. 4.1.B.3 *: Final emitting coil.*

C. Levitator

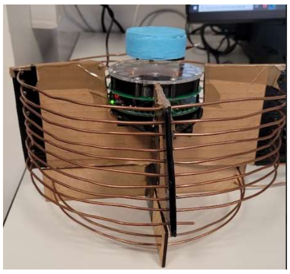


Fig. 4.1.C.1 : Levitator in the coil.

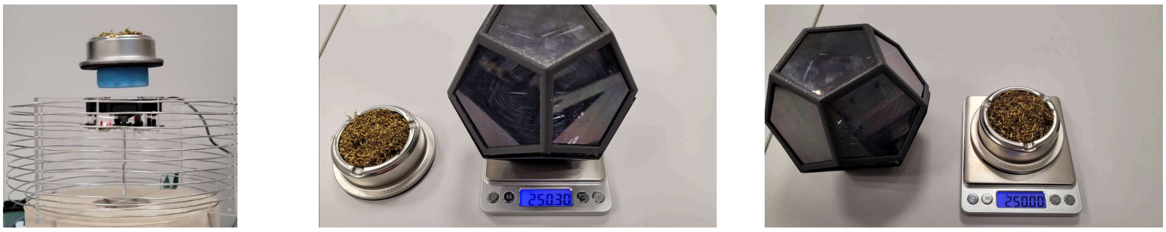
The development of the levitator involved two phases.

Initially, we used less powerful permanent magnets, which were adequate for levitating our main magnet (wrapped in a blue rubber layer to prevent damage in case it fell and collided with the levitator). However, once the dodecahedron was placed atop the magnet, the assembly collapsed due to the excessive weight.

Consequently, we switched to stronger magnets to ensure the dodecahedron's levitation. This change led to two challenges.

First, the dodecahedron-plus-blue-magnet system was unstable because the blue magnet was not fixed to the dodecahedron, and the dodecahedron itself was not securely closed.

Second, with the more powerful magnets, the impact force between them and the blue magnet increased, raising concerns that the dodecahedron might break given its instability. To mitigate this, we replaced the dodecahedron with an object of equivalent weight for our tests. The trials with the new magnets were highly successful, demonstrating their efficacy in supporting the levitation system.



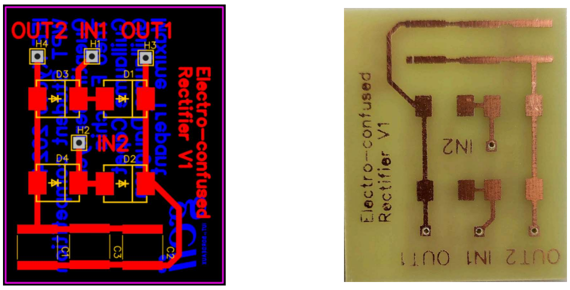
(a) (b) (c)

Fig. 4.1.C.2.a *: Levitation of weight equivalent to the dodecahedron.*
Fig. 4.1.C.2.b *: Measure the weight of the dodecahedron.*
Fig. 4.1.C.2.b *: Measure of the weight equivalent to the dodecahedron.*

4.2 Receiving Part

A. AC to DC converter

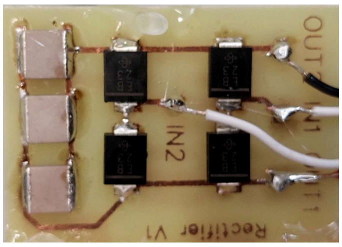
In order to power the leds of our receiving part, we needed to design a rectifier adapted to our system.
Thanks to the adapted component, we carried out the routing, manufactured the PCB and brazed the components.



(a) (b)

Fig. 4.2.A.1.a *: The PCB routing of the rectifier.*
Fig. 4.2.A.1.b *: The PCB of the rectifier.*

We have also added a step down voltage regulator (BUCK) that regulates our output voltage to 3V.
After testing our system, we established that we would ideally need a signal with a minimum amplitude of 6 V to properly supply our LEDs in reception.

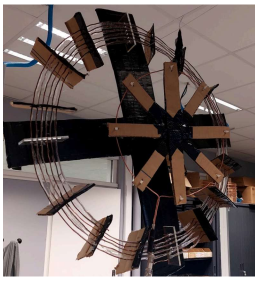


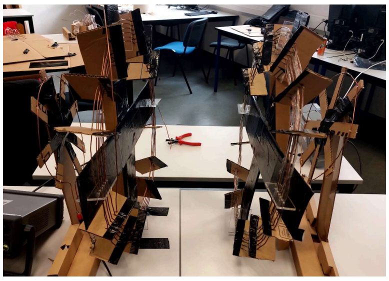
(a) (b)

Fig. 4.2.A.2.a *: The rectifier.*
Fig. 4.2.A.2.b *: The step-down regulator (BUCK).*

B. Receiving coil

For the receiving resonant coil, we made a lot of prototypes, because we did not have any modeling software, so it allowed us to determine which one is best suited to our situation.
We first realized a Magnetically Coupled Resonators thesis from Joshua Smith that inspired us a lot for this project:

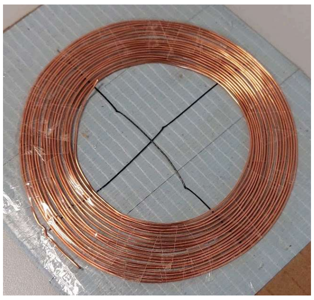


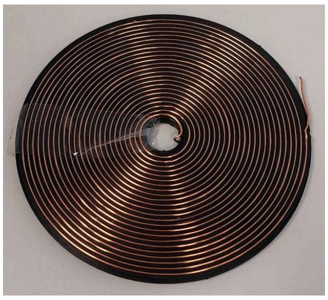


(a) (b)

Fig. 4.2.B.1.a *: The receiving part of the prototype reproduction of the starting thesis.*
Fig. 4.2.B.1.b *: Prototype reproduction of the starting thesis.*

Then we made prototypes adapted to the size of our system, but the copper wires was too thin :

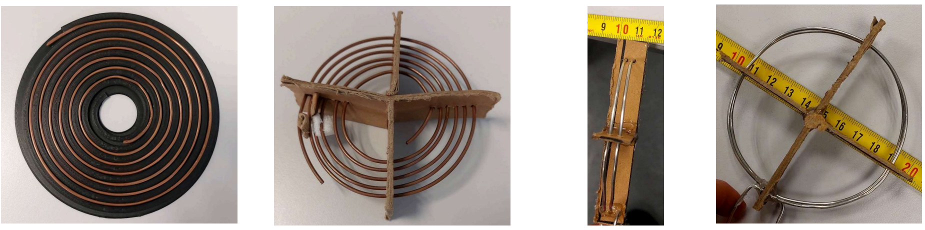




(a) (b)

Fig. 4.2.B.2.a *: Prototype 1 receiving resonant coil.*
Fig. 4.2.B.2.b : *Prototype 2 receiving resonant coil.*

So we changed the copper wire to a thicker wire:



(a) (b)

Fig. 4.2.B.3.a *: Prototype 3 and 4 receiving resonant coil.*

Fig. 4.2.B.3.b : *Prototype 2 receiving resonant loop.*

Then we chose to make a flat coil with two layers:

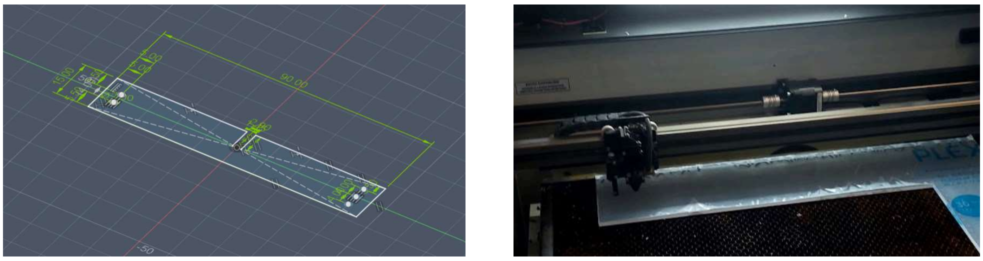
Resonant coil:

Tinned copper diameter: 1.6 mm
Coil diameter: 100 mm
Coil spacing: 5 mm
Number of turns: 2 x 6

Receiving loop:

Tinned copper diameter: 1.6 mm
Coil diameter: 80 mm
Coil spacing: 4 mm
Number of turns: 2

We modeled in 3D our receiving coils for laser machine cutting in acrylic:



(a) (b)

Fig. 4.2.B.4.a *: Modeling of receiving coils.*

Fig. 4.2.B.4.b *: The laser cutting machine.*

We were then able to realize our final receiving coil :

Fig. 4.2.B.5 *: Final receiving resonant coil.*

C. Structure of the dodecahedron

For the outer structure of the dodecahedron, we chose to print it in 3D.
For this, we have therefore carried out 3D models:

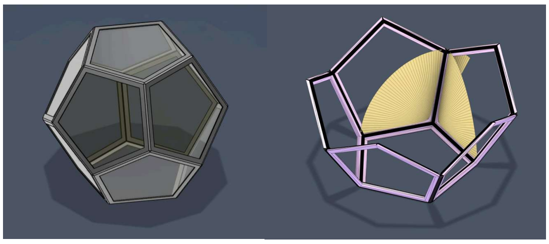


Fig. 4.2.C.1 *: 3D modeling of the dodecahedron.*

We were then able to print several parts to have this final rendering:

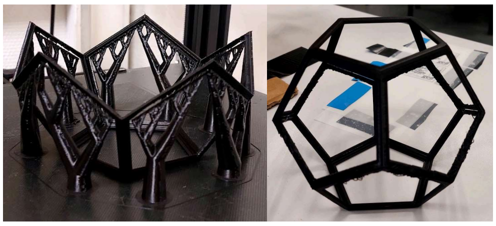
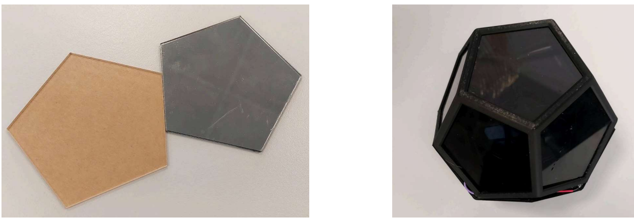


Fig. 4.2.C.2 *: 3D printing of the dodecahedron.*

We were then able to cut the sides of the dodecahedron in acrylic with the laser cutter and we applied a mirrored film on it to create the final optical illusion.



(a) (b)

Fig. 4.2.C.3.a *: Acrylic plate of dodecahedron.*
Fig. 4.2.C.3.b *The assembled dodecahedron.*

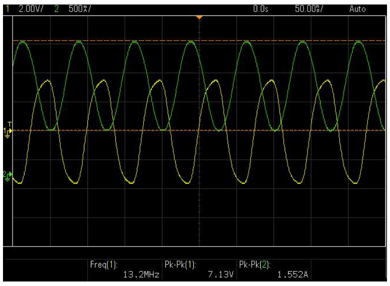
D. LED

For the interior lighting of the dodecahedron that achieves the optical illusion, we used special led strips that diffuse the light better and are very thin on the other hand are very fragile and can break when touched.
The welding of these LEDs was then a meticulous work :

(a) (b) (c)

Fig. 4.2.D.1.a *: Welding of LEDs.*
Fig. 4.2.D.1.b *: Set of LEDs on.*
Fig. 4.2.D.1.b *: The optical illusion created by the LEDs.*

4.3 Final Result



We were able to establish the voltage performance of our coils, we were able to measure the voltage, but we had a lot of difficulty measuring the current, because our oscillator and coils emitted such a strong field that the measuring devices did not work properly (for example, the screens flash when approaching the coil).

Fig. 4.3.1 *: Current in the transmitting coil.*

We therefore estimated a voltage output of 24% (± 1%)

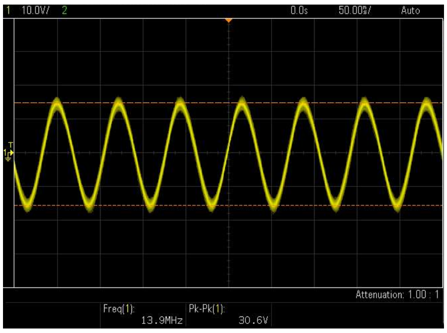


Fig. 4.3.2 *: Voltage in the transmitting coil*

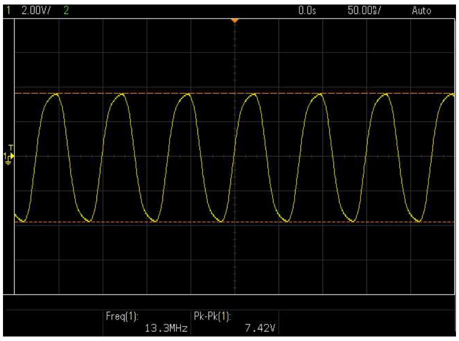
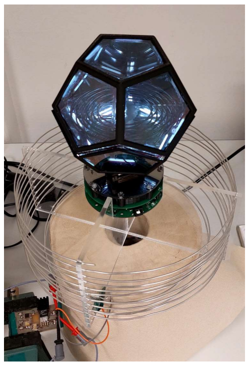


Fig. 4.3.3 *: Voltage in the receiving coil*

The received voltage is more than enough to power our LEDs.
So the system is working.

(a)

(b)



(c)

Fig. 4.3.4.a *: The dodecahedron in the dark.*
Fig. 4.3.4.b *: The inside of the dodecahedron.*
Fig. 4.3.4.c *: The final complete system.*

5. Conclusion and future work

As this project was conducted alongside our three-year Bachelor of University Technology (BUT) program, we had limited time allocated to it. Consequently, we somewhat ran short of time and are thus not yet fully satisfied with certain aspects. We plan to address these issues over the coming days/weeks.

5.1 External structure for the transmitting part

Initially, our plan includes constructing a transparent external structure crafted from Acrylic. This enclosure is intended to encompass the entire transmitting section of our project, aligning with the vision we set out in the first stage.

The choice of Acrylic as the material is deliberate; it allows for full visibility of the project's internal components. This transparency is particularly important for showcasing the transmitting coil, among other elements, enabling viewers to appreciate the intricacies of our design and the functionality of the system as a whole.

Fig. 5.1.1 *: The external structure.*

5.2 Redo the oscillator's circuit board

As we initially experienced, when we first tested the oscillator board, it heats up excessively, and we are concerned that this could cause the board to malfunction. This board is of critical importance since it provides the signal we wish to transmit. Therefore, we would like to rebuild it, taking these considerations into account, and allowing more space for the component responsible for the heating. This would enable us to attach a heat sink or employ other means to reduce the heating, such as placing it in a case equipped with a fan.

5.3 Optimize the levitation

As previously observed, we have managed to levitate an object with the same weight as the dodecahedron. The challenge in achieving stable levitation of the dodecahedron itself stems from its current lack of stability. This instability is partly because the levitating magnet has not yet been securely attached to the dodecahedron. Furthermore, the dodecahedron's upper and lower sections have not been adhered together, leaving it unfixed and unstable. To resolve this, our next steps include firmly gluing the dodecahedron's sections and securely attaching the magnet to ensure overall stability. After these adjustments, we should be capable of levitating the dodecahedron successfully.

References

[1] Alanson P. Sample, David T. Meyer, and Joshua R. Smith, "Analysis, Experimental Results, and Range Adaptation of Magnetically Coupled Resonators for Wireless Power Transfer", June 04,2010, IEEE.

[2] Rozman, M.; Fernando, M.; Adebisi, B.; Rabie, K.M.; Kharel, R.; Ikpehai, A.; Gacanin, H. Combined Conformal Strongly-Coupled Magnetic Resonance for Efficient Wireless Power Transfer. Energies 2017, 10, 498. https://doi.org/10.3390/en10040498

[3] Pham, T.S., Nguyen, T.D., Tung, B.S. et al. Optimal frequency for magnetic resonant wireless power transfer in conducting medium. Sci Rep 11, 18690 (2021). https://doi.org/10.1038/s41598-021-98153-y

[4] Component link and other files :
https://drive.google.com/drive/folders/1wp72Ved3cmJdb8b-pmBo59Tzywvh5ofF?usp=drive_link