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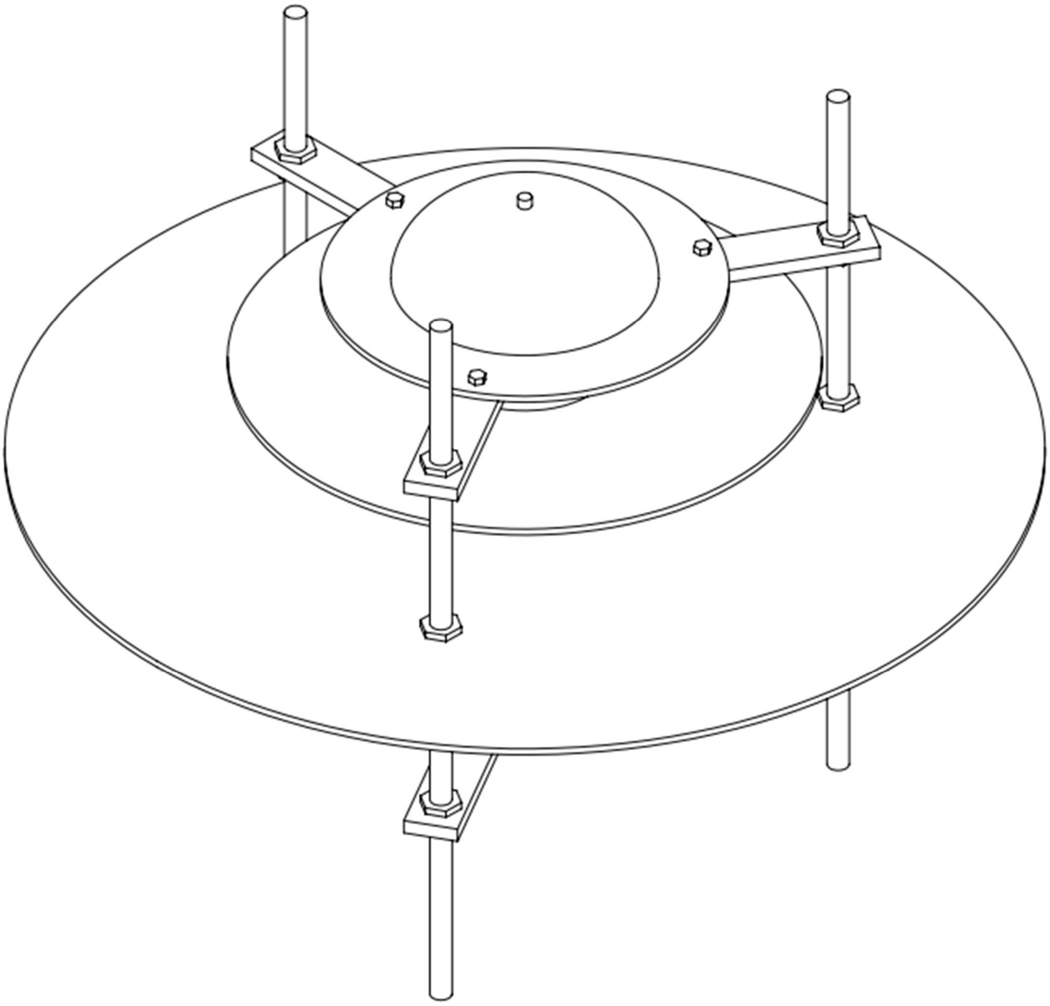

PHYSICS OF THE GRAVIFLYER_-_V1.0

STUDY OF THE PHYSICS

TOMAS ROSICH

REPORT: PHYSICS OF THE GRAVIFLYER_-_V1.0

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1 LIST OF REVISIONS

Date	Revision	Author	Description
04/04/2024	0.1	Tomás Rosich	Initial release
25/04/2024	0.2	Tomás Rosich	Revision of the magnets section: eddy currents
31/05/2024	0.3	Tomás Rosich	Inclusion of the eddy currents simulation.
14/06/2024	0.4	Tomás Rosich	Revision of the Tesla's coil simulation.
17/07/2024	1.0	Tomás Rosich	Last conclusions, report completion and project closure

Electronic sign, by ROSICH PARTE, TOMAS
(FIRMA) on July, 14.

2 LIST OF FIGURES

3 LIST OF TABLES

4 OBJECT OF THE REPORT

The current report will show the analysis of the Graviflyer device, analysing completely the Physical interactions to get the device lifting. The Physics principles will be studied and analysed by a Multiphysics simulator, getting the relationships between them, and proposing a Physical base of the device.

5 MODEL OF THE GRAVIFLYER

The Graviflyer model has been built directly in COMSOL, based on the indications of the documentation shared by the customer. The Graviflyer has three important sections:

- Magnets section: It consists of 6 neodymium magnets placed on a rotating disc driven by a 4250 rpm DC motor.
- Tesla's Coil Section: It consists of a system for generating an intense electromagnetic field based on a Tesla's coil, forming a resonant circuit with the discs of the Graviflyer.
- Ultrasound Section: It consists of an ultrasonic system, which generates a mechanical pressure interaction from an electric cover applied between the electrodes of a piezoelectric ceramic. This section is placed on another rotating disc with other DC motor of 4250 rpm.

All sections have been analysed separately, modelling each device (neodymium and aluminium nitride ceramic, for the magnets and the piezoelectric device). A circuit model has analysed the Tesla's coil, doing a co-simulation between the circuit model and the 3D model.

The semiconductor's devices (transistors and diodes) have been modelled using their SPICE models.

The mechanical model has been modelled in COMSOL in 3D.

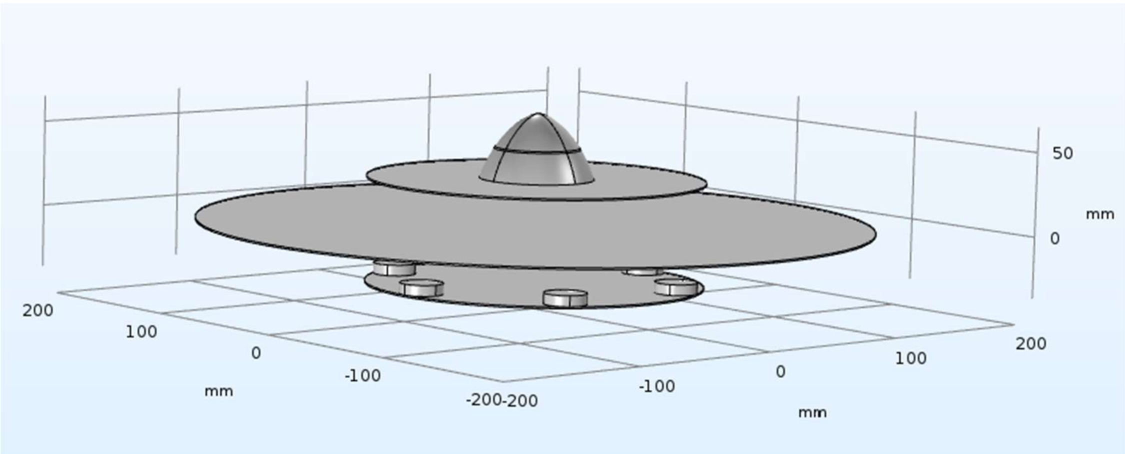

Fig. 1 - 3D Graviflyer model in COMSOL

Each part of the model has been drawn keeping in mind the indications shared by the client. However, there are non-detailed parts that have been modelled in a free form, such as the piezoelectric envelope and its plastic support. The influence of different materials must be analysed in detail when studying this structure, since different materials, with different densities and speed of sound can significantly change the functioning of the piezoelectric, modifying its resonant frequency. Therefore, an eigenmode analysis is performed to check the resonance regions where there are pure non-degenerate modes.

As for the Tesla's coil, to get its equivalent circuit, a 2D simulation has been used to extract the fundamental parameters of the coil, depending on the number of turns and the wire, as well as the coupling between primary and secondary. In this way, we can simplify the 3D model.

5.1 MAGNETS SECTION

First, magnets are modeled. Neodymium magnets are used, so the following main features are defined in the material model:

Feature	Units	Value
Relative permeability		12
Relative permittivity		1
Electrical conductivity	S/m	0

Table 1 - Neodymium features

The magnets are mounted on a rotating aluminum base. Aluminum is a characterized material in COMSOL, but to define the magnet it is necessary to insert the features of the remnant flux density, because neodymium has a permanent magnetic field of 1.32 T on the z-axis. This is included by defining the domain of magnets under Ampere's Law, remnant flux density.

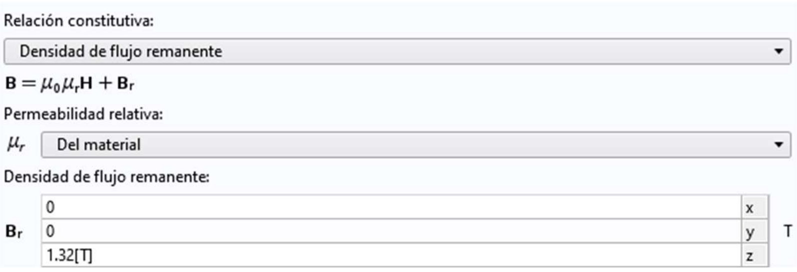

Fig. 2 – Remnant flux density for the neodymium

The domains that are defined with this characteristic are the domains of magnets.

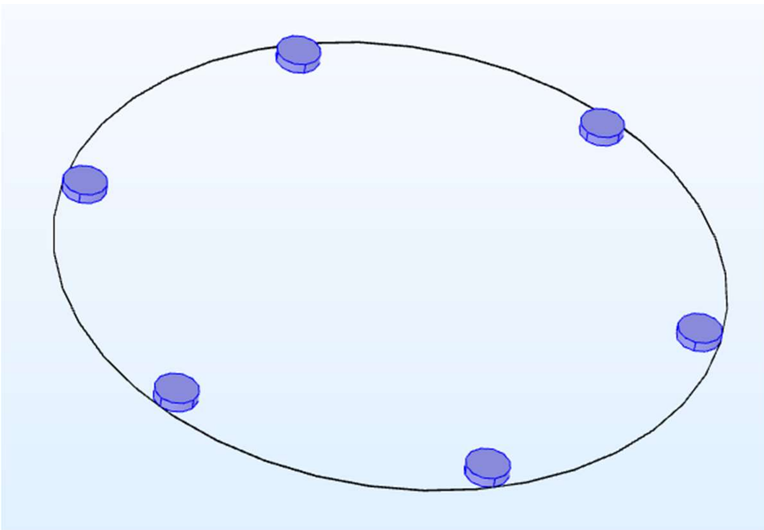

Fig. 3 - Domains of the magnets

And in this way the magnets are fully characterized.

5.2 TESLA'S COIL SECTION

In the case of the Tesla coil, it is a circuit formed by a transistor that couples to a resonant transformer. This resonant transformer is formed by the transformer body, which is connected to the supporting disc, being a capacitor with air as dielectric.

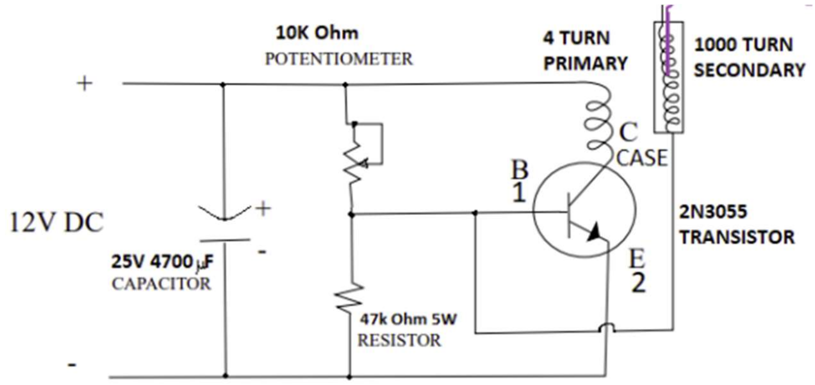

Fig. 4 - Tesla's coil circuit

In this case, the circuit is simulated as a circuit embedded in COMSOL, while the Tesla coil is simulated using COMSOL's axisymmetric system, which allows 2D drawing and revolutionizes the result.

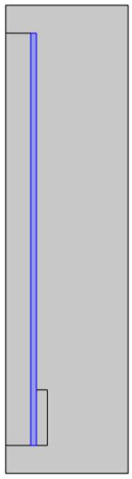

Fig. 5 - Tesla's coil model

The 1000-turn coil (secondary) is modeled in blue, while the outermost rectangle models the 4-turn coil. The 4-turn coil is connected to the electrical circuit, while the 1000-turn coil is connected to the Graviflyer disc.

5.3 ULTRASOUND SECTION

The ultrasonic section is the most complex to model, since it is necessary to add not only electrical characteristics, but also mechanical conditions of the piezoelectric, so after analyzing the manufacturer's datasheet, it has been possible to verify that the material is Aluminum Nitride, with the next features

Feature	Units	Value
Mass density	kg/m^3	3300
Elasticity matrix	Pa	$\begin{pmatrix} 4.1 & 1.49 & 0.99 & 0 & 0 & 0 \\ 0.99 & 4.1 & 0.99 & 0 & 0 & 0 \\ 0.99 & 0.99 & 3.89 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1.25 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1.25 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1.31 \end{pmatrix} \cdot 10^{11}$
Coupling matrix	C/m^2	$\begin{pmatrix} 0 & 0 & 0 & 0 & -0.48 & 0 \\ 0 & 0 & 0 & -0.48 & 0 & 0 \\ -0.58 & -0.58 & 1.55 & 0 & 0 & 0 \end{pmatrix}$
Relative permittivity		9

Table 2 – Aluminum Nitride piezoelectric features

The domains are simple, as it is a discoid system in which two terminals envelop the piezoelectric material.

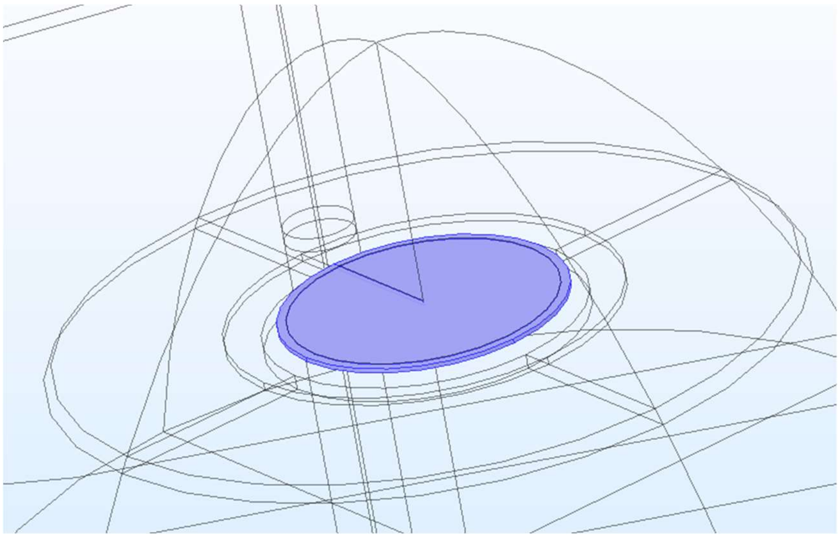

Fig. 6 - Piezoelectric domain inside the Graviflyer

6 RELATED PHYSICS

Related Physics is defined by the Physical Theories, Laws, and Principles that will drive the device. All the principles described below must be accepted as Physical principles by Physics, since what this report aims to do is to show the scientific conditions that explain the device lifting, so that it can be reproduced repetitively, and in the future, that it has industrial scale.

6.1 MAGNETOSTATICS, ELECTROSTATICS AND ELECTROMAGNETIC THEORY

One of the Physical Theories involved in the device is Electromagnetics, within three disciplines: magnetostatic, electrostatic and electromagnetism itself. It should be noted that magnetostatic and electrostatic do not refer, in this case, to classical magnetostatic and electrostatics, but that the equations that govern both disciplines can also be applied to the stationary conditions of an electromagnetic wave.

The Electromagnetic Theory is condensed in the Maxwell's equations:

$$\vec{\nabla}\cdot\vec{D}=\rho$$
$$\vec{\nabla}\cdot\vec{B}=0$$
$$\vec{\nabla}\times\vec{E}=-\frac{\partial\vec{B}}{\partial t} \qquad \textbf{6-1}$$
$$\vec{\nabla}\times\vec{H}=\vec{J}+\frac{\partial\vec{D}}{\partial t}$$

These equations must be related to the Charge's Conservation Law

$$\vec{\nabla}\cdot\vec{J}+\frac{\partial\rho}{\partial t}=0 \qquad \textbf{6-2}$$

It should also be added to these equations that fields derive from potentials: the magnetic field of a magnetic vector potential, and the electric field of a scalar potential and the magnetic vector potential.

$$\vec{B}=\vec{\nabla}\times\vec{A}$$
$$\vec{E}=-\frac{\partial\vec{A}}{\partial t}-\vec{\nabla}\Phi \qquad \textbf{6-3}$$

We also have to keep in mind the Ohm's Law for conduction phenomena in conductive materials.

$$\vec{J}_T=\left(\sigma+\frac{1}{\varepsilon_0}\frac{\partial}{\partial t}\right)\vec{E} \qquad \textbf{6-4}$$

The electromagnetic wave is a specific case of an electromagnetic field, when a field is produced that varies over time on a periodic basis. However, electromagnetic impulses or EMPs produce strong electromagnetic fields that generate pressure on surfaces causing bodies to move. One of the best-known applications is known as the "solar sail", a type of harnessing of a solar electromagnetic impulse that causes radiation known as the "solar wind". In the following sections, we will study the pressure interactions generated by electromagnetic phenomena, which are essential to understanding the device lift.

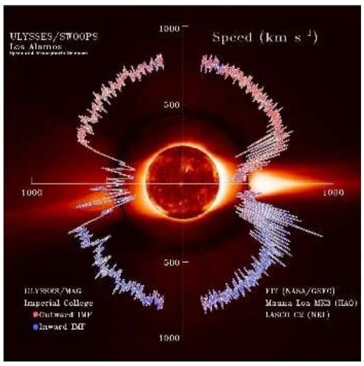

Fig. 7 - Image of solar wind

6.2 SOLID MECHANICS

Piezoelectric materials are electromechanical devices. When a sound pressure is applied on the device, an electrical voltage is generated. And by reciprocity, when an electrical voltage is applied, an acoustic pressure is generated.

Piezoelectric materials have multiple applications in the field of electronics. Therefore, they are easy devices to find, as they are used as buzzers, resonant filters, or resonators. The most common piezoelectric are Aluminum Nitride, Quartz, and Zirconate Titanate.

Physics related to piezoelectric devices is based on the so-called constitutive relationships, which are those that relate the electric field to mechanical pressure.

$$\begin{cases} T = c^E S + \varepsilon_{33} E \\ D = \varepsilon_{33} S + \varepsilon^S E \end{cases} \tag{6-5}$$

Where ***T*** is the stress generated on the surface of the material, ***S*** is the deformation, ***D*** is the electrical displacement and ***E*** is the electric field.

The application of an electric field, through a potential, is described by equation6-3, and this causes a periodic acoustic deformation of the type

$$u = \hat{u} e^{jk(r + c_p t)} \tag{6-6}$$

Where ***k*** is the wavenumber and ***c_p*** is the propagation speed of sound in the material. Therefore, ***c_p*** should not be confused with the speed of light in a vacuum.

Solid mechanics solves generic expression

$$\rho \frac{\partial^2 u}{\partial t^2} = \nabla \cdot (F \cdot S)^T + F_v \\ F = \nabla u + I \tag{6-7}$$

where ***F*** is the deformation gradient.

Almost all the materials that will be used in the study are linearly elastic (metals and plastics), while piezoelectric adds the ratios described in 6-5 to calculate the deformation. Therefore, it is important to know the ceramic that the device uses, to get the desired result.

In solid mechanics, boundary conditions are essential and must be well defined. The most important boundary condition to be applied is the fixed constraint, in those contours where deformation cannot happen. This condition should be applied to the edges of the piezoelectric support.

It is important to note that piezoelectric material can see its characteristics modified depending on this support. This piezoelectric material will be modeled on a Teflon-type plastic support.

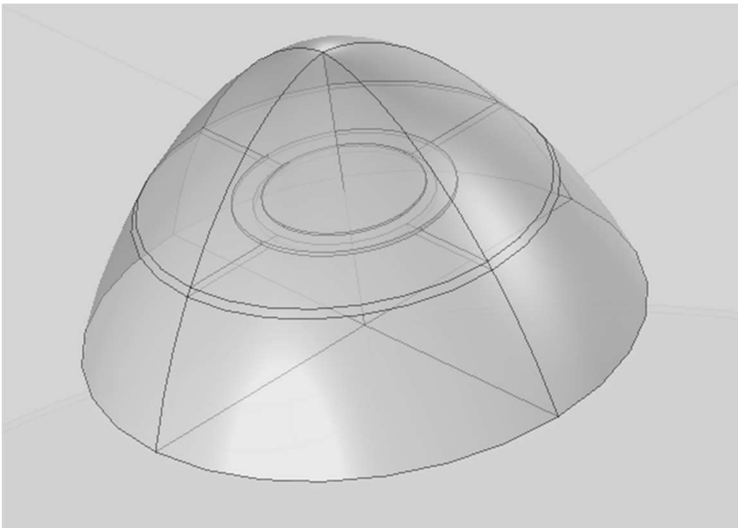

Fig. 8 - Piezoelectric model

6.3 PHYSICAL INTERFACES IN COMSOL: MULTIPHYSICS

The Graviflyer generates a series of interactions that must be combined with each other. In the case of electromagnetic fields, pressure interactions must be studied. In the case of piezoelectric materials, electrical and mechanical interactions, and mechanical interactions with pressure interactions, must be used. This section will detail the interactions and the use of COMSOL's Multiphysics couplings to resolve these interactions.

6.3.1 MULTIPHYSICS ELECTRIC AND MAGNETIC FIELDS

COMSOL solves electromagnetic problems in different ways: such as electric and magnetic fields, with application in 2D and 3D models, using the next expressions:

$$\begin{gathered}\vec{\nabla}\times\vec{H}=\vec{J}\\ \vec{E}=-\frac{\partial\vec{A}}{\partial t}-\vec{\nabla}\mathrm{V}\\ \vec{B}=\vec{\nabla}\times\vec{A}\\ \frac{\partial\rho}{\partial t}+\vec{\nabla}\cdot\vec{J}=0\end{gathered} \tag{6-8}$$

It also solves electromagnetic fields using Helmholtz's equation

$$\nabla^2\vec{E}+k_0^2\left(\varepsilon_r-\frac{j\sigma}{\omega\varepsilon_0}\right)\vec{E}=0 \tag{6-9}$$

Due to the combination of electric and magnetic fields and mechanical couplings, the most suitable solver is the one that solves the equations 6-8, since MultiPhysics can be used to achieve coupling with other Physical solvers.

6.3.2 SOLID MECHANICS, AC/DC SOLVERS AND CIRCUITS

In solid mechanics, the equation is solved directly 6-7, while AC/DC solvers combine electrical and magnetic effects with solids or circuit mechanics.

Circuits cannot be drawn directly. It is necessary to describe the circuit by knots. Nonlinear components, such as transistors, use the models defined for simulators such as SPICE.

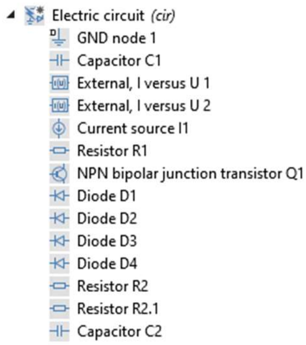

Fig. 9 – Circuit description in COMSOL

PARAMETER	DEFAULT	DESCRIPTION
B_F	100	Ideal forward current gain
B_R	1	Ideal reverse current gain
C_{JC}	0 F/m²	Base-collector zero-bias depletion capacitance
C_{JE}	0 F/m²	Base-emitter zero-bias depletion capacitance
F_C	0.5	Breakdown current
I_{KF}	Inf (A/m²)	Corner for forward high-current roll-off
I_{KR}	Inf (A/m²)	Corner for reverse high-current roll-off
I_s	1e-15 A/m²	Saturation current
I_{sc}	0 A/m²	Base-collector leakage saturation current
I_{se}	0 A/m²	Base-emitter leakage saturation current
M_{JC}	1/3	Base-collector grading coefficient
M_{JE}	1/3	Base-emitter grading coefficient
N_C	2	Base-collector ideality factor
N_E	1.4	Base-emitter ideality factor
N_F	1	Forward ideality factor
N_R	1	Reverse ideality factor
R_B	0 Ωm²	Base resistance
R_{BM}	0 Ωm²	Minimum base resistance
R_C	0 Ωm²	Collector resistance
R_E	0 Ωm²	Emitter resistance
T_{NOM}	298.15 K	Device temperature
V_{AF}	Inf (V)	Forward Early voltage
V_{AR}	Inf (V)	Reverse Early voltage
V_{JC}	0.71 V	Base-collector built-in potential
V_{JE}	0.71 V	Base-emitter built-in potential

Fig. 10 - BJT model description in COMSOL

6.4 OTHER PHYSICS INTERACTIONS

In addition to the interactions described and which have a predefined solver, COMSOL allows couplings with Physical equations described by the user. In this way, COMSOL can define other equations using the mathematical block, being able to define partial differential equations of motion, or classical equations, and couple them with the results of the predefined solvers.

The possible interactions generated by electric fields and mechanical deformations can be added to the study, knowing the equations that relate both interactions. These interactions are shown below.

6.4.1 ELECTROMAGNETIC PRESSURE

Electromagnetic pressure is known through the action of the solar wind. When our star emits electromagnetic radiation, it can propel any object through pressure on a surface. Therefore, the electromagnetic radiation generated by any device can, by equivalence, generate pressure and so, propulsion.

Electromagnetic pressure can be defined by the following expression

$$p_m = (1+\Gamma)\frac{B^2}{2\mu_0} + 2\pi\frac{\hbar}{\lambda S} + \frac{4}{3}\frac{\sigma T^4}{c} \quad \textbf{6-10}$$

The first term is due to the pressure of the electromagnetic wave on a surface, generated by the magnetic field ***B*** and depending on the reflection coefficient Γ of the surface. It is a purely electromagnetic pressure, derived from the Lorenz force.

The second term is due to the photons associated with the electromagnetic field. As the frequency of electromagnetic radiation rises, the wavelength λ decreases and the photon pressure on a surface ***S*** increases, being $\hbar$ the Planck's constant.

The last term has to do with the radiation of the bodies as a function of their temperature, through the Stefan-Boltzmann Law. As the temperature of one body increases, electromagnetic radiation is produced that is proportional to the fourth power of the temperature, and this causes pressure on any surface.

For example, one of the engines currently being studied, the EMDrive, is based precisely on the pressure exerted by microwaves. Recent tests have shown a possible push that could be a milestone in space travel.

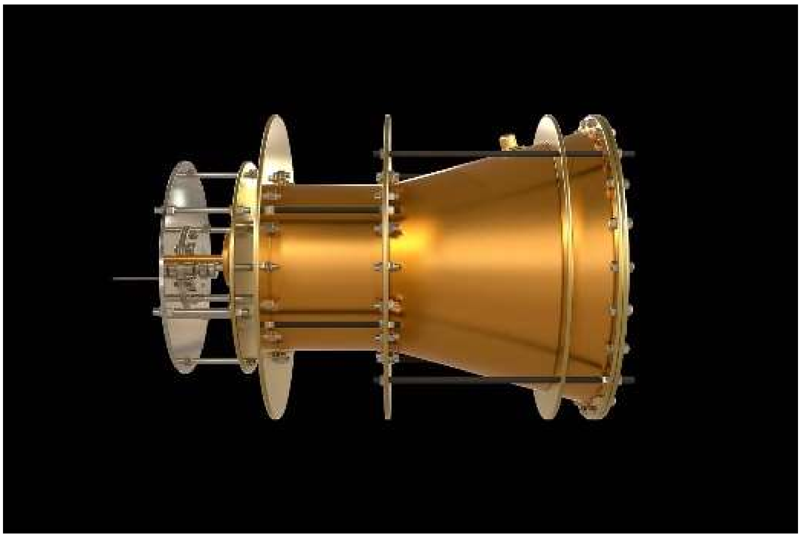

Fig. 11 - EMDrive Prototype

Therefore, the pressure exerted by the electromagnetic fields generated by the Graviflyer can generate thrusts that counteract gravity, when exerted on particles, and it is convenient to study this.

6.4.2 ELECTROMECHANICS PRESSURE

The ultrasound section converts the electric field into a sound wave, and a sound wave is, by definition, a pressure wave. In this case, the pressure is mechanical and can be directly related to a thrust. Electromagnetic pressure is present across the strain gradient described in 6-7.

In addition, the gravity model can be included within the model, studying what happens with the deformation when the body is subjected to gravitational action.

One of the most important studies that should be done on this section is of frequency behavior, since, although eigenmodes appear at various frequencies, not all eigenmodes are going to be effective, so with the study of eigenfrequencies it will be possible to establish which are the most effective modes to achieve momentum.

7 SIMULATION RESULTS

7.1 MAGNET SECTION

The simulation of magnets is done using an infinite element domain that simulates the effect of the far field, with the disc with the magnets within that domain, which is air.

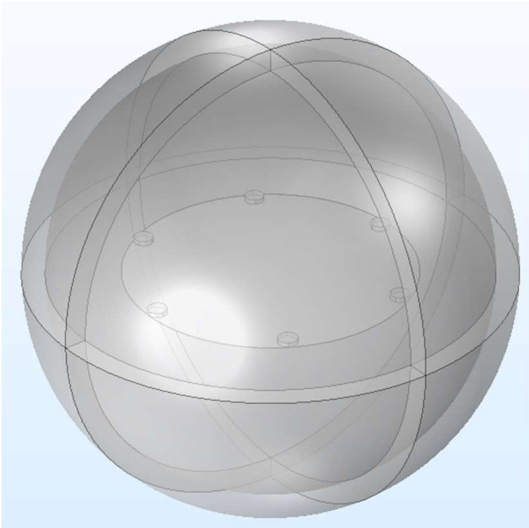

Fig. 12 - Domains of the magnets

And it is solved the equation 6-3, being the results the next

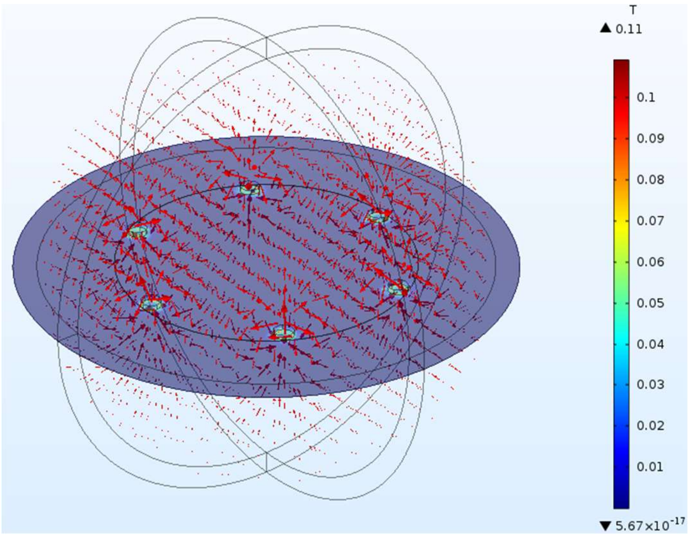

Fig. 13 - Results of magnets simulation

From the Graviflyer's point of view, magnets only represent a uniform magnetic field. The rotation of the magnets on the axis does not seem to contribute anything, since the central flux remains constant, and the highest flux density occurs precisely in magnets.

However, the magnets section is one of the most important sections of the Graviflyer. Not only that: the first Graviflyers were created from the magnet section. Therefore, the contribution of this section is essential for the operation of the Graviflyer.

Studying the system completely and representing the magnetic field with all the discs in motion, it is got that the magnetic field is distorted due to their presence. This generates eddy currents in the intermediate disc, which are related to an electric field (Ohm's law) and a charge variation.

In Fig. 14, the magnetic field with disc motion is shown. It can be seen this magnetic field is distorted by the upper discs. In Fig. 15, the eddy currents is shown on the first upper disc. It can be seen this current is maximum in the vertical of the edges of the mobile discs.

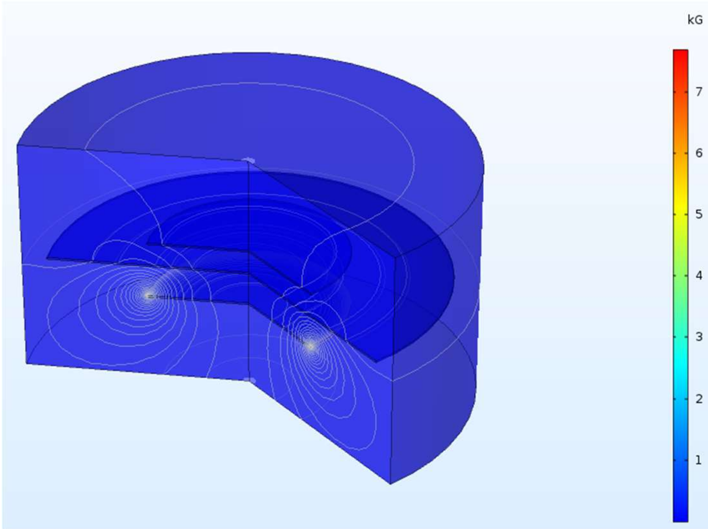

Fig. 14 - Magnetic field on the discs

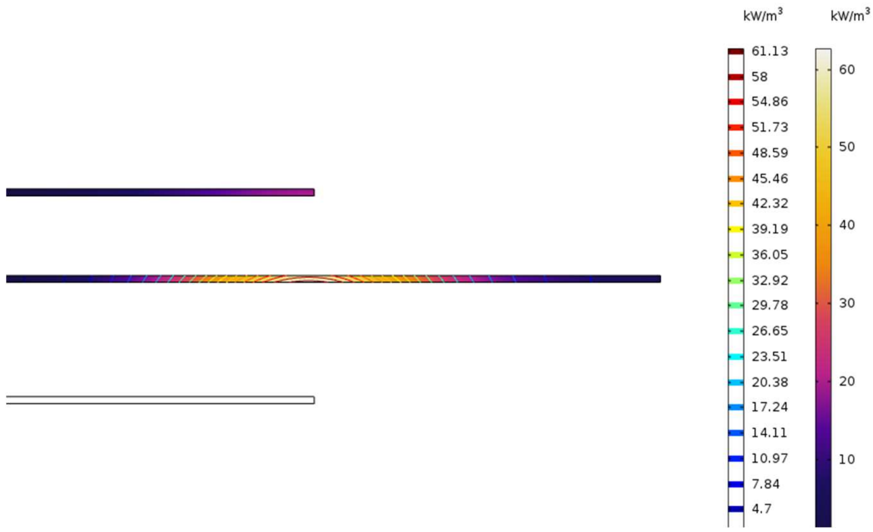

Fig. 15 - Eddy currents on the upper discs

The presence of eddy currents, which are generated by the presence of an intense magnetic field in the area, due to charge conservation, generate an electric field that influences the charges in the region. The modulation of this electric field will depend on the rotary speed of the discs. However, there is no intrinsic relationship between the electric field and gravity, although there is one between the electric field and relativistic mass. This relationship is what could make lift the Graviflyer.

$$\begin{gathered}\vec{\nabla}\cdot\vec{E}=\frac{\rho}{\varepsilon}\\ \vec{\nabla}\cdot\vec{B}=0\\ \vec{\nabla}\times\vec{E}=-\frac{\partial\vec{B}}{\partial t}-\frac{m_\gamma c^2}{\hbar}\\ \vec{\nabla}\times\vec{B}=\frac{m_\gamma}{\hbar}\vec{E}+\frac{1}{c^2}\frac{\partial\vec{E}}{\partial t}\end{gathered} \quad 7\text{-}1$$

With m_γ the relativistic photon mass. It should be remembered that, although the photon has no resting mass (in reality, there is no photon at rest), it has relativistic mass due to its movement and for this reason, light is affected by gravity. Maxwell's quantum equations are not integrated into COMSOL, so in future lines of research a model would have to be composed using these equations, instead of the classical equations.

7.2 TESLA'S COIL SECTION

The section of the Tesla coil is analyzed in steady state and frequency. The oscillator generates a current that is coupled to the Tesla coil, and with the resonant circuit, there is a voltage peak on the disc that orients the charge around it.

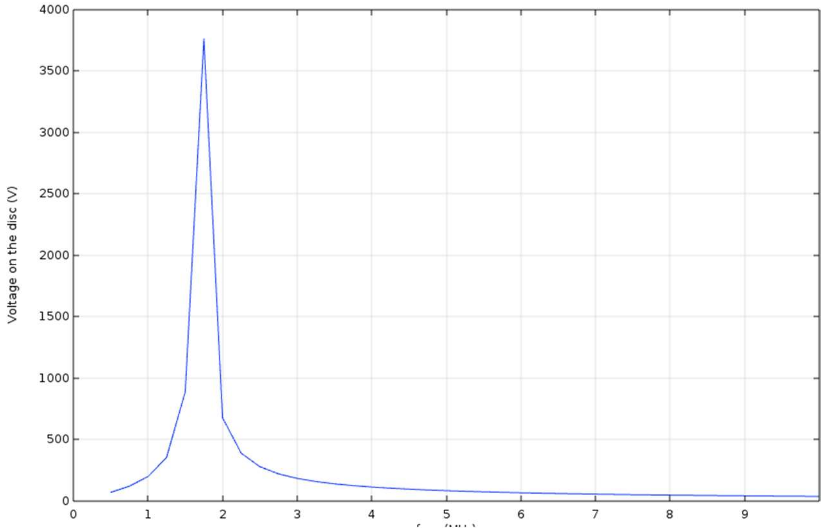

Fig. 16 - Voltage on the disc

The magnetic field inside the Tesla coil, at the frequency at which the maximum pulse is produced

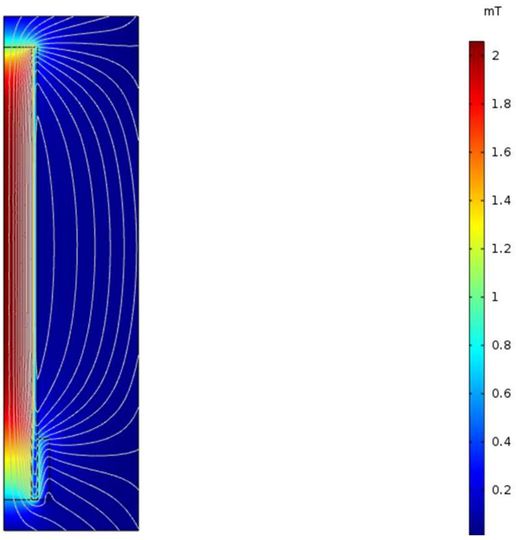

Fig. 17 - Magnetic field inside the Tesla's coil

The magnetic field is charged and discharged through the capacitor formed by the Graviflyer disc with the air, generating a high-voltage pulse that orders the charges in the environment.

7.3 ULTRASOUND SECTION

The ultrasonic section consists of a supply circuit and a ceramic piezoelectric, installed on top of the Graviflyer. The simulation is carried out in two processes: an eigenmode simulation and a stationary simulation.

The first simulation shows us the eigenfrequencies the piezoelectric operates, in its current setup. The second simulation shows us how the circuit works in stationary mode.

7.3.1 EIGENMODE SIMULATIONS

In piezoelectric materials, the Helmholtz wave equation for mechanical displacement, shown below, must be solved

$$\nabla^2 \overrightarrow{\delta u} + \gamma_{\delta u}^2 \overrightarrow{\delta u} = \alpha_E \vec{E} \qquad \textbf{7-2}$$

being $\overrightarrow{\delta u}$ the mechanical displacement of piezoelectric material, $\gamma_{\delta u}$ the propagation constant of the displacement, $\vec{E}$ the applied electric field and α_E A constant obtained from the constitutive relationships between the electric fields and the mechanical pressures of the material.

One of the fundamental simulations, before performing the real simulation, is the calculation of the piezoelectric modes. These eigenmodes are the result of solving the equation 7-2 in its homogeneous form.

$$\nabla^2 \overrightarrow{\delta u} + \gamma_{\delta u}^2 \overrightarrow{\delta u} = 0 \qquad \textbf{7-3}$$

and represent the resonances that occur in the material, depending on its cutting.

A well-known piezoelectric material is quartz crystal. This material, which is used to make oscillator circuits and high-precision clocks, usually has a simple electrical equivalent in the Butterworth-Van model

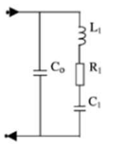

Fig. 18 - Butterworth-Van Dyke piezoelectric model

This model is most used when it comes to simulating quartz crystals in electrical circuits. However, there is a more complex model that relates the applied electric fields to the mechanical characteristics of the material. This model is named the Mason model

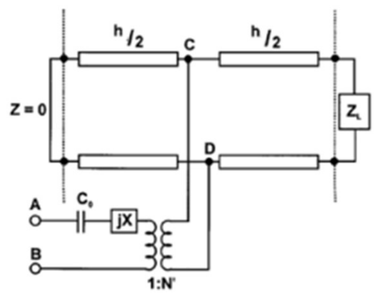

Fig. 19 - Mason piezoelectric model

In the Mason's model, the voltage applied between terminals A and B is converted, through a 1:N transformer, into a mechanical voltage that is applied to a transmission line whose impedance is related to the acoustic impedance of the material. This acoustic impedance is related to the density of the material and the speed of sound propagation in the material.

$$Z^D = \rho v^D \qquad \textbf{7-4}$$

Being ρ the material density and v^D the speed of sound propagation.

Since the model is a transmission line, it is periodic as a function of the wavelength, so the piezoelectric will present multiple modes, rather than a single resonance, as shown in the Fig. 18.

In the case of the piezoelectric used in the Graviflyer, it is a buzzer like those used in telephones and alarms, and according to the manufacturer's datasheet (Murata), it is a piezoelectric buzzer whose fundamental frequency is 4.6 kHz. It should be noted that, even if a piezoelectric material has a resonance at a fundamental frequency, it will get vibration over the entire frequency range, although the maximum energy will happen precisely at the resonant frequencies. And since the piezoelectric is, in fact, a mechanical transmission line, it will have multiple solutions to the equation 7-3.

On the other hand, the equation 7-3 It can present complex results, since the electric field is a complex phasor and there can be frequencies that present complex conjugate results. These types of modes are called degenerate modes since they lack a single solution for the same propagation constant $\gamma_{\delta u}$.

In the case of the used piezoelectric, the main eigenmode is at 5.08 kHz, as shown the Fig. 20. This resonance depends, fundamentally, on the Physical characteristics of the material (diameter, thickness, ceramics, etc.). The element where the material is held also plays a role.

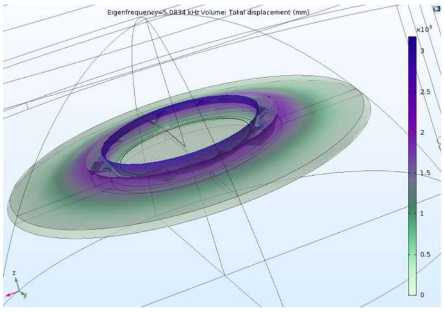

Fig. 20 - Main eigenfrequency, total displacement

A uniform displacement of the material can be observed in the material because this displacement has a wave-like character (it is a solution of a wave equation). And like the electromagnetic modes that appear in waveguides, modes will appear at higher frequencies. Therefore, a piezoelectric material is a multimode device, with several resonances in the frequency domain.

The piezoelectric used in the Graviflyer has been tuned to higher frequencies: at 40 kHz and 90 kHz orders. Then, near of 40 kHz and using the eigenmode solver, it can be seen the next displacement mode

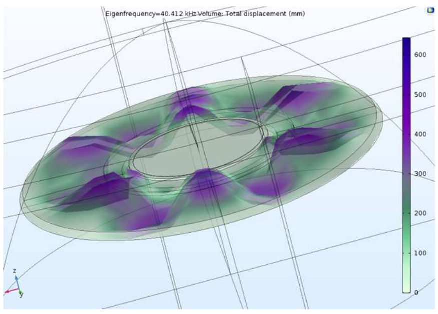

Fig. 21 – 40.412 kHz eigenfrequency, total displacement

The same happens at 90 KHz, where the displacement mode is now

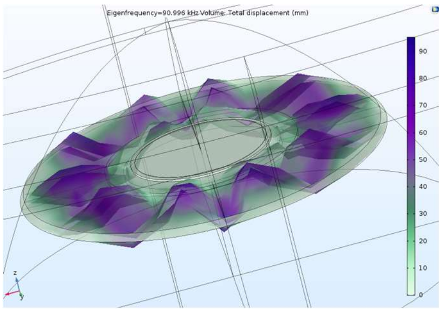

Fig. 22 - 90.996 kHz eigenfrequency, total displacement

Then, the displacement produced by ultrasound in the piezoelectric is displaced to the support, being a regular displacement.

But not in all cases there is a regular displacement. This is the case of degenerate modes, when the result is a complex conjugated frequency, producing two different displacements. In the case of Fig. 22, there are another displacement, due to the conjugate frequency.

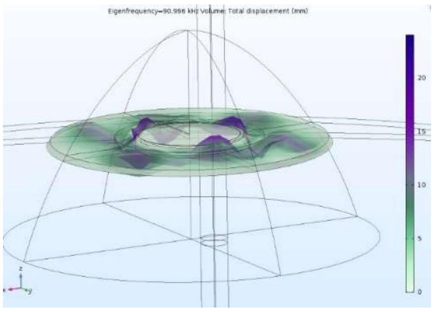

Fig. 23 - 90.996 kHz conjugate eigenfrequency, total displacement

This can happen over the entire frequency range used, which could result in abnormal behavior at those frequencies. The following tables show the degenerate modes got in the 40÷50 kHz and 90÷94 kHz ranges.

Eigenmode	Freq. (Hz)
1	39710
2-A	40141–I*2.84E-3
2-B	40141+i*2.84E-3
3-A	40282–I*4.21E-3
3-B	40282+i*4.21E-3
4-A	40412–I*6.75E-3
4-B	40412+i*6.75E-3
5	48232
6	48810
7	51027
8	51206

Table 3 - Degenerate Modes at 40÷50 kHz range

Eigenmode	Freq. (Hz)
1	90047
2-A	90996–I*1.35E-3
2-B	90996+i*1.35e-3
3-A	91900–I*3.23E-3
3-B	91900+i*3.23E-3
4	92423
5-A	92995–I*8E-4
5-B	9.2995+i*8e-4
6-A	93839–4.4E-3
6-B	93839+4.4E-3

Table 4 - Degenerate Modes at 90÷94 kHz range

The main consequence of these degenerate modes is the absorption of part of the energy supplied at that frequency, without producing a specific displacement (one or the other, or both may happen alternately). In an electromagnetic guided-propagation, degenerate modes work as energy-absorbing modes.

7.3.2 STATIONARY SIMULATION

The stationary simulation is performed by modeling in COMSOL the following excitation circuit, which will be connected to the piezoelectric, physically modeled, by means of External I vs. U connections.

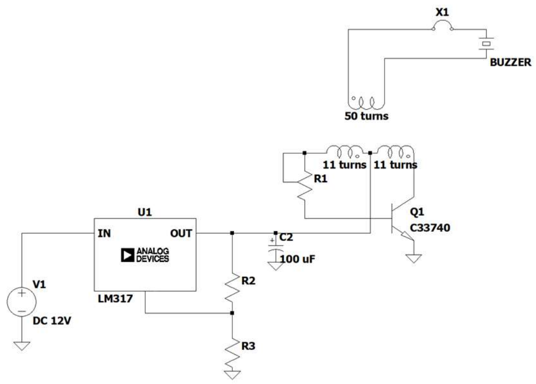

Fig. 24 - Piezoelectric feeder

The stationary simulation assumes that the piezoelectric feeder is oscillating at a certain frequency and transfers the energy to the buzzer.

The solid displacement of the piezoelectric is studied, in a frequency range between the fundamental and 100 kHz, and the results are shown in the next table

Freq (kHz)	Solid displacement (μm)	Solid displacement (norm)
5.00	1.32	1
25.00	0.67	0.51
45.00	0.54	0.41
65.00	0.88	0.67
85.00	0.46	0.35
105.00	0.49	0.37

Table 5 - Solid displacement vs. frequency

As the frequency increases, the displacement decreases, although it increases again by 65 kHz, decaying again. The vibration shape can be seen in the next figures, at 5, 65 and 105 kHz.

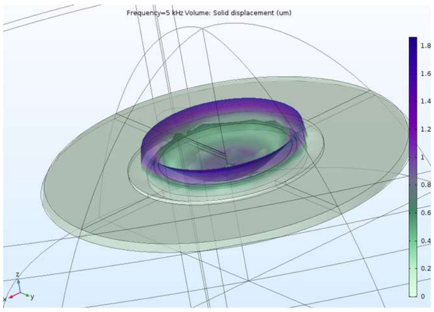

Fig. 25 - Solid displacement at 5 kHz

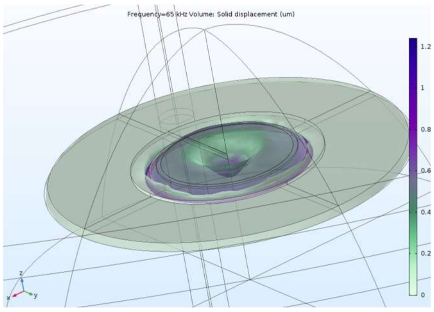

Fig. 26 - Solid displacement at 65 kHz

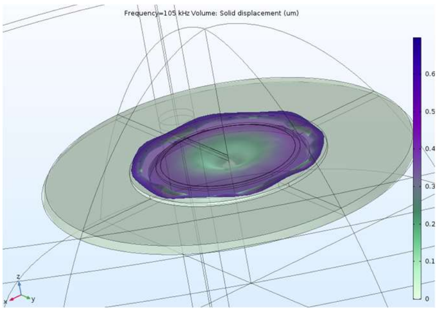

Fig. 27 - Solid displacement at 105 kHz

At 5 and 65 kHz there is a strong central shift. This could explain why the inventor finds that, when it rises in frequency, the lifting effect seems to increase.

7.4 INTERACTIONS FOR GRAVIFLYER LIFTING

In view of the simulations, in my opinion the most important interactions in the Graviflyer are, according to the weight of each, the effect of the ultrasound device, the section of the Tesla coil and finally the magnets. The magnets seem to have little influence on the device, since even if a rotational motion occurs, no motor system is produced, since the rotation is produced by an independent motor, with its internal magnets.

However, previous experiments show that the section of the magnets is fundamental for the Graviflyer, so it seems that another interaction is present and is not exactly classical but would be in the field of Quantum Mechanics.

Maxwell's equations cannot explain the effect of lifting from the classical point of view. There needs to be a relationship between the electromagnetic field created and gravity, and gravity does not exist. There could be electromagnetic pressure, but the density of the electromagnetic field decreases very quickly with square of the distance, so the second term of the expression begins to play an essential role 6-10, being this the photonic term.

The piezoelectric shows very curious functions, since, although the frequency is very low (in the order of 5 kHz), the higher the frequencies, the higher the frequency, the displacements of a similar order to the main frequency. It's the reason why a more comprehensive study has been devoted to this device.

It must be kept in mind that the electromagnetic Physics that COMSOL solves only integrates classic concepts of electromagnetism. Quantum electromagnetism should be modeled within COMSOL to obtain a more reliable result of the phenomenon. This should be done in a future research line.

The Tesla coil also has a strong influence, as it produces a very intense electrostatic field in the vicinity of the Graviflyer. In principle, it has been simulated in the presence of air, without including humidity conditions or the presence of loads in the environment. An intense electric field would act on the charged particles in moist air, and there would be noticeable differences with respect to dry air. It is, perhaps, where new studies should be directed.

8 CONCLUSIONS AND FUTURE RESEARCH LINES

The fundamental conclusion is that the relationship between Graviflyer and lifting does not belong exclusively to the classical world. Even if Maxwell's equations are solved in Graviflyer, there is no direct relationship between gravity and classical electromagnetism, so the lifting of the device cannot be governed by it.

The inventor does not give much evidence of knowing how it works, rather he only shows lifting. From the answers given to his followers, it can be deduced that there is not much applied Physics, but a lot of urban legend. For example, lifting of magnets does not occur in all magnets, only in the presence of superconductors. And the levitating ones are not the magnets, they are the superconductors. And the inventor has not used superconductors in his design

The lifting of MAGLEVs (magnetic lifting trains) requires that the electromagnets levitating the vehicle be fixed with respect to the Earth, and these magnetic fields generate magnetic forces based on the Lorenz force, which counteract their weight. It is, therefore, a clear classical interaction between gravity and magnetism.

Another example is the use of piezoelectric, justifying it with the use that the Egyptians made of sound to make pyramids. There is no applied Physics in this concept either, and it would be necessary to know if they used sound to make the stones of the monuments lighter or it was simply a way of setting the pace for the construction workers. Setting the pace in jobs that require human strength is necessary for the effort of all the workers involved to be synchronized and harmonized, and it has nothing to do with reducing the effective mass of a body. In any case, what the piezoelectric can do is generate an acoustic pressure on the particles that surround the Graviflyer.

As for the Tesla coil, it has a strong influence, it's true. But not because it is a Tesla coil. The inventor speaks of "Tesla coil" because in this way, the device has more impact among his followers, but it does not necessarily have to be a Tesla coil to have the behavior it has in the device. In fact, the author uses a conventional transformer that does the same function. The Tesla coil is something else and the wiring diagram does not exactly show a Tesla coil.

In any case, the inventor's device works, or at least it seems so, in view of the videos that the author has published. However, the studies carried out show that, at least in certain parts such as the electromagnetic section, they do not adhere to classical electromagnetism, and therefore cannot explain its operation.

It must be remembered that, under the relativistic aspect, gravity is not currently considered a force in Physics. At least, not in the same style as classical electromagnetics. Although its behavior can be modeled by Newtonian mechanics, when only a massive body and much less massive bodies are considered, it is an interaction that not only acts as a function of space, but also intervenes with time.

Unlike Maxwell's equations, which must be invariant regardless of the frame of reference used, in relativistic mechanics there is no absolute frame of reference, so gravity will depend on the observer's system. In the case of Newtonian mechanics, gravity must be invariant with respect to the reference frame, which allows validating an absolute reference frame.

If the interaction between the electromagnetic section and gravity is of a quantum type, then we must introduce the relativistic mass of the photon and under that circumstance the electromagnetic pressure appears, since the classical electromagnetic intensity is insufficient to produce a high pressure that allows the Graviflyer to lift.

This could open future research lines, if they were of interest. From the simulations carried out, the future lines mark a clear quantum, not classical, aspect. This must be framed in quantum models and simulators that encompass these computational models. In this case, COMSOL can collaborate on computational capacity, but the model must be fully developed. In my opinion, future lines of research should focus on the search for interactions at the particle level, focused, above all, on electromagnetic pressure. That should be the main premise of the system. That means that there must be resources specialized in Quantum Physics, who carry out work under quantum electrodynamics. However, it is necessary to remember that, under the aspect of Physics, Quantum Mechanics and Relativistic Mechanics are still Theories that do not fit between them, so it is not easy to find a clear link since these interactions are still ignorant of each other.

With the delivery of this report I conclude the work, closing this project, and making myself available to the client for the future lines of research that they wish to follow.