*Research Article*

# Design and Analysis of Electromagnetic Insulators for Toyota Tactical Vehicle ECU

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## Abstract
This study introduces the nature of electromagnetic bombs, how they work, the dangers, and how to deal with them. An electromagnetic bomb is a weapon that takes advantage of man's deep dependence on electricity and is designed accordingly. The purpose of this article is to design and fabricate Toyota 4.5F Tactical Vehicle ECU Electromagnetic Insulators. The design and construction of this device is also considered as vital and crucial equipment during electronic warfare and EMP attacks, so that it can be used as a reinforcement and vice versa, a weakening element or divider of the power of the enemy forces. The present study was performed as a numerical simulation in Comsol software environment. The results showed that the use of insulation is very effective in protecting the target systems against the damaging effects of electromagnetic waves. Additionally, the maximum amount of radiation to the ECU is at an angle of 0.25 radians and the minimum amount of radiation to ECU is recorded at an angle of 3.14 radians.

**Keywords:** Computational Fluid Dynamics, Comsol Software, Electronic Warfare, Electromagnetic Bombs, Electromagnetic Bombshell, Toyota Car ECU.

## 1. Introduction
The effectiveness and efficiency of e-warfare has convincingly shown in recent years that the evolution of e-warfare has always undergone sudden leaps during periods of conflict or shortly thereafter. This is the result of being taken by surprise by the unknown weapons of the enemy and consequently the urgent need for a rapid response by electronic warfare. The anti-electronic actuators thus completed often consisted of systems that were hastily assembled and suitable only to deal with an immediate threat. During peacetime, the importance of electronic warfare as a powerful combat tool has been forgotten due to the desire to complete new deadly weapons. The importance of e-warfare becomes apparent only when we consider the increasing reliance of modern warfare on high-tech software, which uses part of the electromagnetic spectrum to control and direct the use of weapons. Trying to take advantage of this environment to its advantage and prevent the enemy from making full use of it has added a new dimension to the arena of modern warfare (McCusker et al., 2001).

Electromagnetic bombs can be called electrical weapons of mass destruction, covering a wide range of electrical and electronic purposes. Their destructiveness leaves irreparable consequences on the opponent's information systems and communication facilities. Therefore, this type of ammunition plays a decisive role in the information warfare process. Benefit from the knowledge of electromagnetic bombs, especially the non-nuclear type based on FCG technology, which is also more accessible. In addition to creating a practical familiarity with this system and its effects, it also provides the possibility of using and strategies to deal with their effects, solutions that should be considered as soon as possible. The failure of radar and missile systems, communications and aviation facilities, practically disrupts any appropriate defensive reaction against the adversary (Ning et al., 2017; Kesse et al., 2019; Benford et al., 2007).

More advanced military forces are more vulnerable to electromagnetic bombs due to the presence of more electrical and electronic equipment. Certainly, in any possible conflict with a military force based on modern and advanced electronic equipment, the use of an electromagnetic bomb will have more deadly effects for them, which can be considered as a strength for the weaker opponent than the military dimension. On the other hand, due to the availability of advanced civilian technologies that allow military use, the possibility of making electromagnetic bombs in terrorist applications increases. Since this type of bomb does not cause any casualties, it does not provoke public opinion and the target countries are in a difficult situation. In the end, the most important side effect of an electromagnetic bomb can be a psychological factor, a complete and high-level electromagnetic attack in a developed country in a short time can turn modern life into an annoying interruption. Everyone is alive, but they find themselves in a completely different world. A world without electricity and the like. Because this type of bomb does not cause any casualties, it does not provoke public opinion and the target countries are in a difficult situation. Therefore, rapid movement is vital for the acquisition of this technology (Grinter & Schneider, 1998).

## 2. Electromagnetic Waves

Electromagnetic waves are the emission of a wave-shaped electric and magnetic field that radiates at a velocity of 108*3 m/s and with different frequencies from a frequency source such as radioactive particles, antennas, cosmic rays, and magnetic bombs scattered around (Zhang et al., 2014).

These applications may be aimed at disrupting or even destroying electronic systems of offensive weapons such as missiles, air defence systems, aircraft self-defence and neutralizing the effect of air defence, attacking aircraft, targets with inaccurate or strategic locations, and satellites (Radasky, 2010).

High power microwave is an inaccurate term for studying the production of coherent electromagnetic radiation in the range of 4 to 400 GHz (Chou, 1984). Gamma rays also pass-through walls and rocks. Every 9 mm of lead or every 25 m of air halves its radiation intensity. Due to its very high frequency, this beam also has a lot of energy that if it hits the human body, it will cross its cellular structure and cause DNA damage in its path, and finally provide the basis for various cancers, syndromes, and other serious defects. And even these defects will be passed on to future generations. About 10 cm of lead wall is needed to prevent the penetration of gamma radiation (Garrido et al., 2020; Slowing et al., 2010).

First, we must note that the maximum amount of magnetic bomb radiation in the gamma ray region is between $5\times10^{19}$ Hz to $3\times10^{22}$ Hz (Figure 1). Therefore, we must choose a material to protect the ECU that has a high power to absorb gamma in this area and using a relatively small cover thickness on the ECU can control a large volume of flux of this beam. Since lead metal (Pb) is a good choice in terms of very high adsorption capacity in the gamma region, lead-based simulation is promoted. (Tian et al., 2018; Nithya et al., 2020)

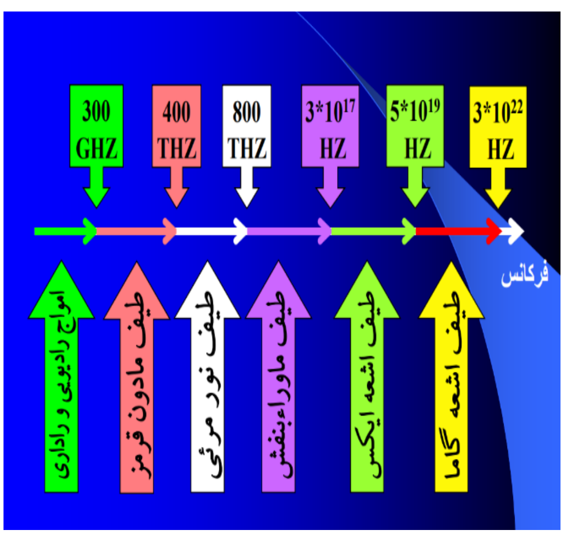


Figure 1. Frequency based electromagnetic spectrum segmentation (Kesse et al., 2019)

Figure 2. Inside cabin-Toyota Tactical 4.5F.

Figure 3. Installation location of Toyota Tactical Vehicle ECU 4.5F.

Toyota 4.5F tactical vehicle has a 4447 cc engine, 205 hp, 3200/360 torque and is equipped with a 24-valve injector fuel system with a cylinder diameter of 100 mm. The tank capacity is 70 L, and its four wheels are movable. It has a 5-speed manual gearbox, and the average fuel consumption of this model is 12.7 L per 100 km. Also, the acceleration from 0 to 100 km of this car is 11.5 seconds. In this plan, according to the data and information obtained, we can design and analyse the electromagnetic insulators of the Toyota Tactical Vehicle ECU 4.5F in such a way that it fully protects the vehicle ECU during an electronic warfare. Therefore, in this project, an attempt has been made to equip the ECU of armoured vehicles with electromagnetic insulation. Figure (2) shows a view from inside the cabin of this car. Also, the ECU installation location of this car is shown in Figure (3 and 4) also shows images of the ECU under consideration.


Figure 4. ECU of Toyota Tactical 4.5F.

## 3. Design of Electromagnetic Shielding ECU Toyota Tactical Vehicle 4.5F

The design for electromagnetic waveguide design is in the form of an almost spherical cover, different views of which are shown in Figure (5 to 11). The size of the ECU is shown in Figure (11). The lead material is 10 cm thick and is considered as a cover on the ECU. In the following, the effects of gamma ray transmission (electromagnetic bombs) at a frequency of 1022*3 Hz are investigated.

Figure 5. Shielding ECU design overview.

Figure 6. Open view of shielding ECU design.

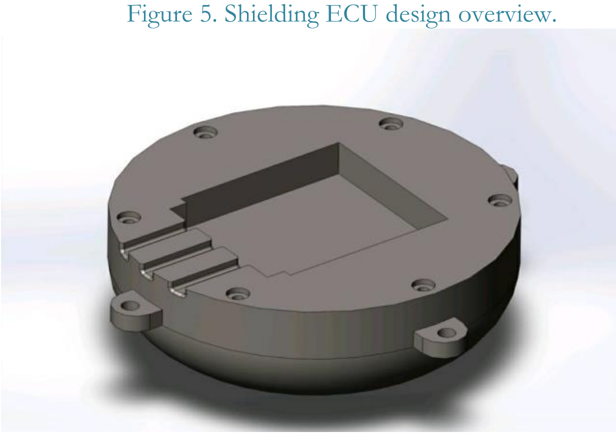

Figure 7. Bottom view of the shielding ECU design.

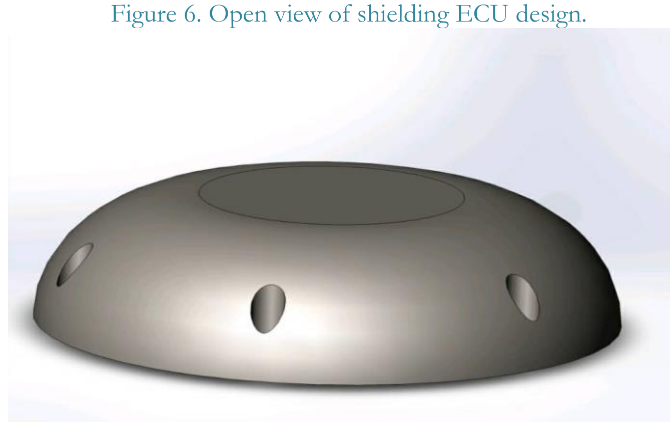

Figure 8. Top view of the shielding ECU design (ECU solid cover).

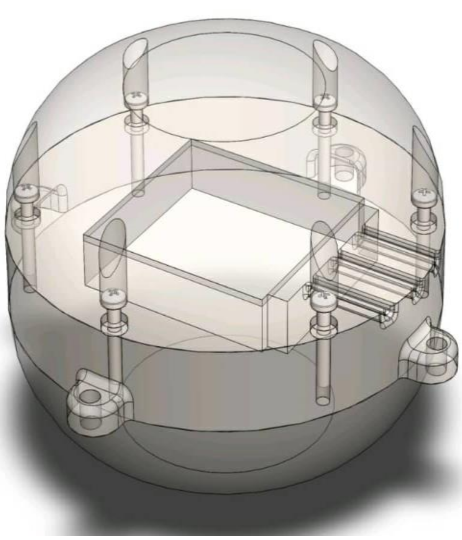

Figure 9. Glass view of the shielding ECU.

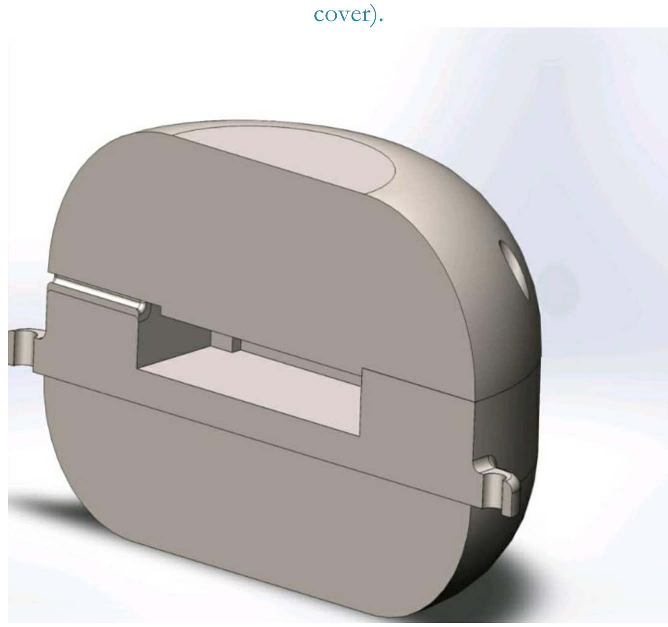

Figure 10. Side view of the shielding ECU.

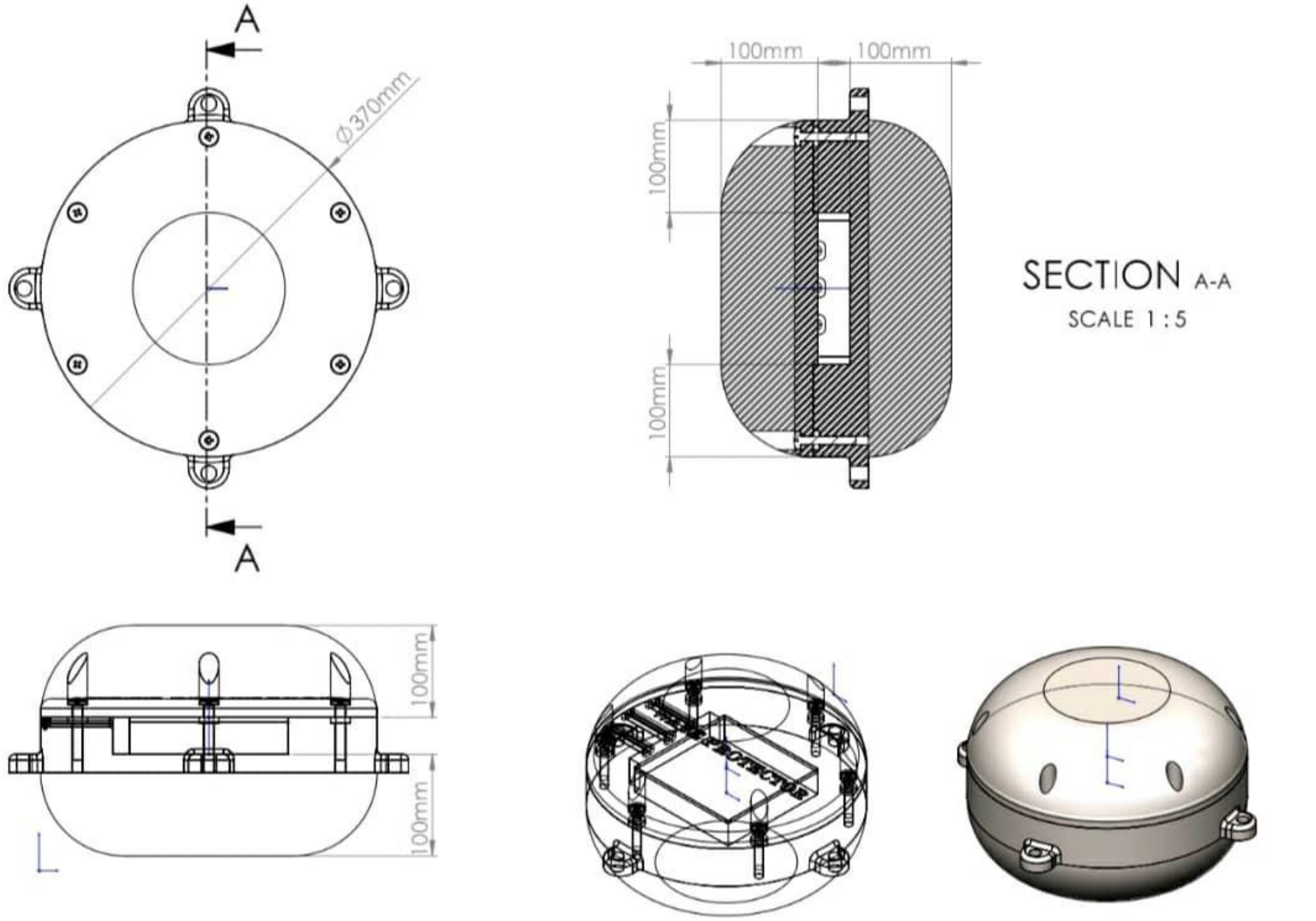


Figure 11. Overall size of the shielding ECU in different views.

## 4. Meshing

The meshing step is to divide the shape into differential components. In this work, automatic (non-organized) mesh and Extra Fine mode have been used to increase the accuracy of calculations. Therefore, the final comparison is as shown in Figure (12).

The total number of network elements is 450691. That is, for this number of networks, the partial differential equations governing the problem must be solved. Also, the Free Triangular option divides the structure into components with a triangular cross section, which is one of the most optimal networks in creating mesh and can be applied by the software.

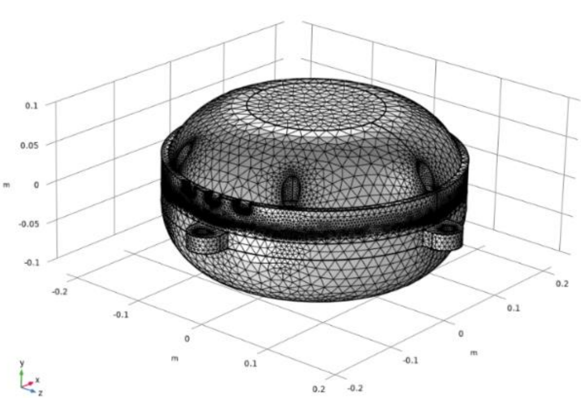

Figure 12. Meshing of the electromagnetic shielding in the present study.

One of the important parameters in this project is the air absorption coefficient equal to zero because the absorption of gamma ray by the air environment is very small and can be neglected for the dimensions of the system we have. (Its unit is 1/m.) The second parameter is power. Since the hypothetical radio source must have two basic factors: frequency and power, for this purpose we define the amount of power as 1 $w/m^2$. The third parameter is the lead absorption coefficient, which is considered to be 100.1/m according to the size of the gamma ray energy. The fourth parameter is alpha, which is defined as the angle of gamma ray radiation on the surface of the cover and its initial value as $\pi/2$, which will be considered in the continuation of calculations of all values between 0 and $\pi$.

After creating the headset and introducing it to the software, we must define the type of material for the structure. The schematic consists of two main parts: the cover and the ECU. The cover components are made of lead, and the ECU is made of air. It should be noted that it does not matter if the ECU is made of electrical circuits or not.

The last part in the simulation is the type of study. We can have all kinds of studies on structures according to their physics, in this case, which is not time dependent, we must use constant study. This type of study calculates the structure in infinite time mode and allows changes such as complete absorption to occur and then extracts the final and complete value.

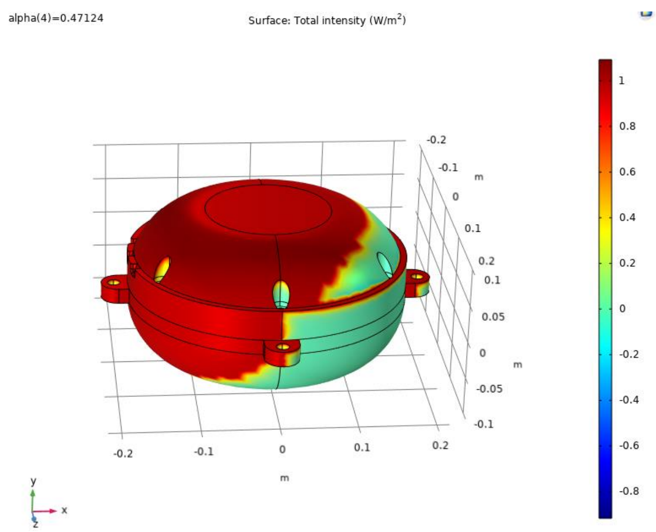


Figure 13. Total absorbed radiation (power) contour at a radius angle of 0.47 radians.

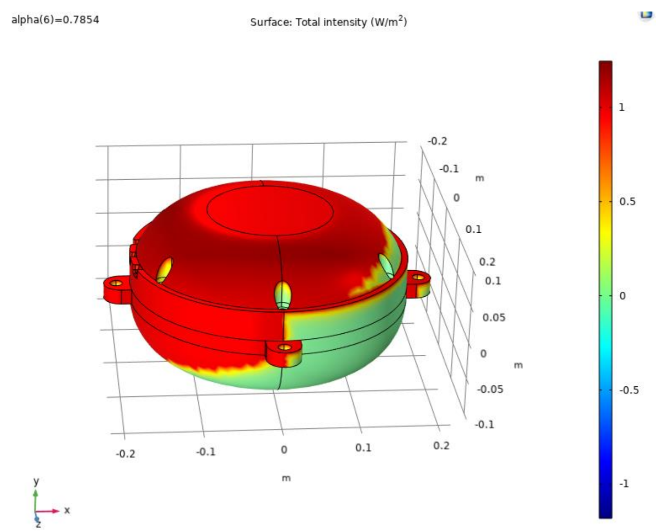


Figure 14. Total absorbed radiation (power) contour at a radius angle of 0.78 radians.

## 5. Results and Discussion

After performing the calculations in Comsol software, the results are extracted. First, we calculate the total intensity (absorbed power) which is shown for different alpha angles in Figures (15 and 16). It should be noted that in each figure we have an index that is coloured from the minimum value of 0 to the maximum value of 1 and is assigned a number for each colour. If in the figure, the left area of the schematic is red, it means that the amount of light from the left was the highest value, and the right side of the schematic is blue, i.e., the amount of beam flux was practically zero or negligible.

As shown in Figure (13), when the beam source increases its angle relative to the horizontal surface (here angle No. 4, which is equal to 0.47 gradients), we see that the beam flux has reached the higher regions of the structure. It can be seen that the source starts moving on the left and reaches an angle of 180°.

Figure (14) shows that the beam source has increased its angle relative to the horizontal plane. Here is angle number 6, which is equal to 0.78 radians.

Figure (15) shows the total intensity (power) when the beam source has increased its angle relative to the horizontal plane. Here is angle number 16, which is equal to 2.35 radians.

As shown in Figure (16), the beam source has increased its angle relative to the horizontal surface (here angle number 21 equals 3.14 radians). This angle is exactly opposite to the first angle, which was 0, and the direction of the ray flux is from right to left.

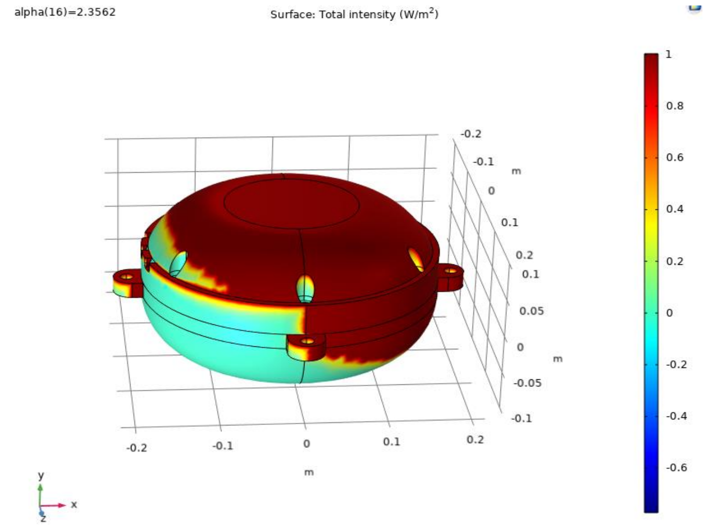


Figure 15. Total absorbed radiation (power) contour at a radius angle of 2.35 radians.

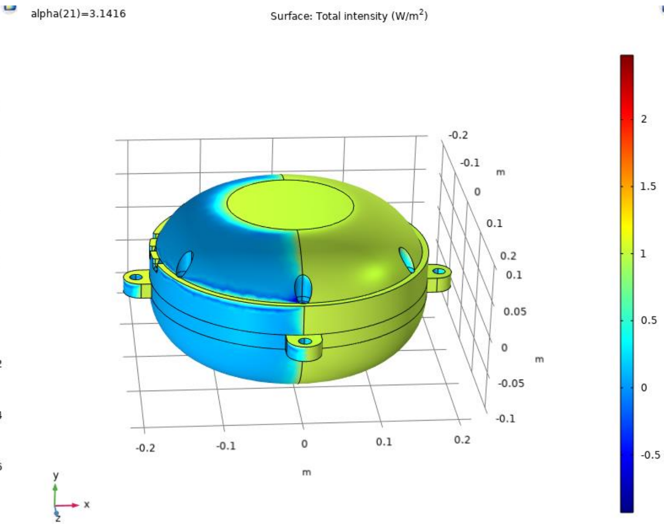


Figure 16. Total absorbed radiation (power) contour at a radius angle of 3.14 radians.

Figure (17) shows the amount of gamma ray absorption in the ECU. The red areas mean that they have experienced the most radiation. At an angle of 0, however, the ECU chamber was safe and experienced the lowest amount of radiation around 0 to 0.01.

As the angle increases, the amount of radiation on the inputs to the ECU decreases, which is explicit in Figure (18), and the red areas decrease.

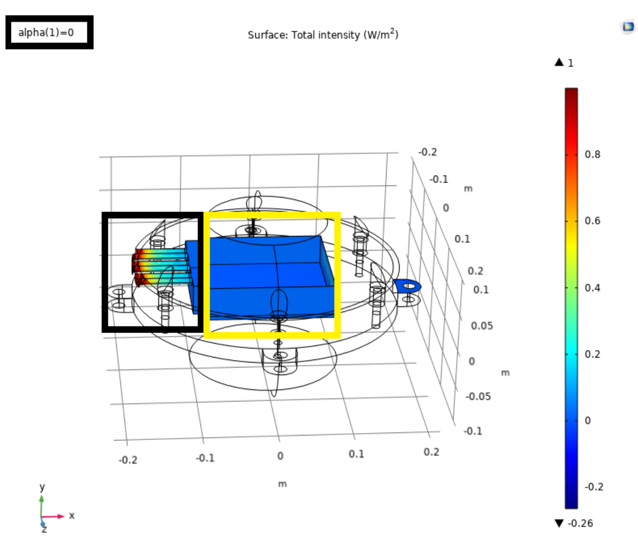


Figure 17. Contour of gamma ray absorption in the ECU at a zero degree radiation angle.

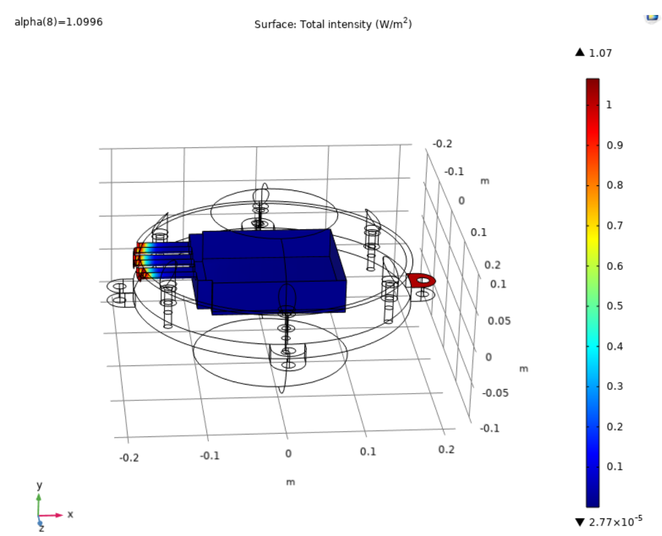


Figure 18. Contour of gamma ray absorption in the ECU at a 1.09 radiation angle.

At the last angle, which is 180 degrees, we see that practically the whole ECU system is safe, and the amount of beam absorption has reached the lowest possible value (Figure 19).

In Figure (20), the amount of power absorption by the cover and ECU can be seen. Pin, which is the same absorption by the cover on the Y axis is drawn in terms of angle on the X axis. The ECU absorption diagram is also displayed with Pout, which has a value of zero in all angles.

Finally, Figure (21) shows the ECU-to-cover ratio factor (Pout/Pin), which examines from an angle of 0 to 180. The maximum amount of radiation reaching the ECU is at an angle of 0.25 radians and the minimum amount of radiation reaching the ECU is recorded at an angle of 3.14 radians.

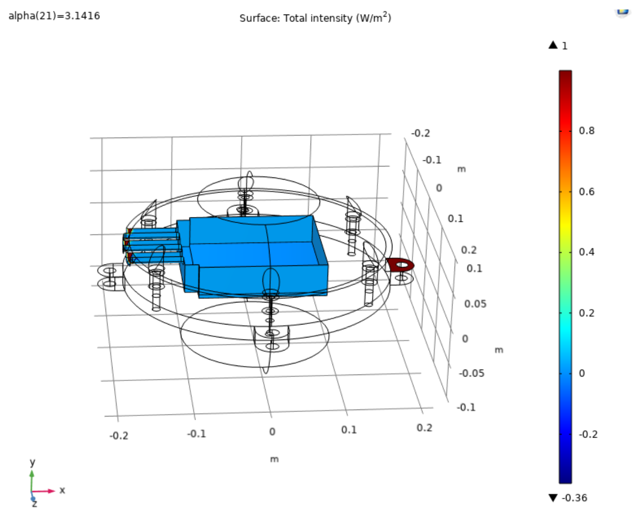


Figure 19. Contour of gamma ray absorption in the ECU at a 3.14 radiation angle.

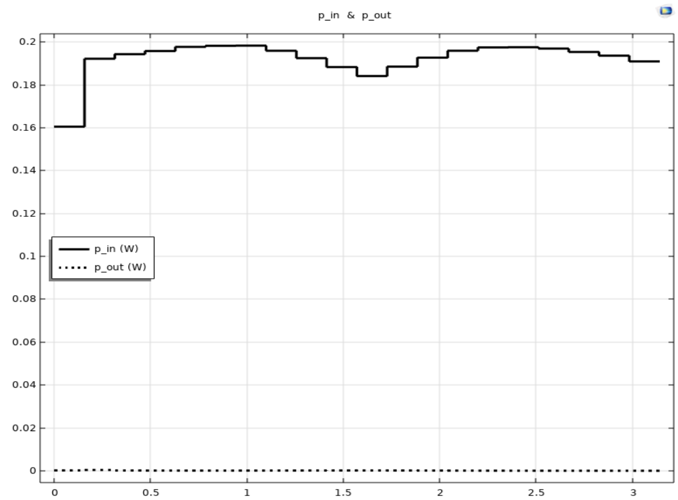


Figure 20. Power absorption by cover (solid lines) and ECU (dashed line).

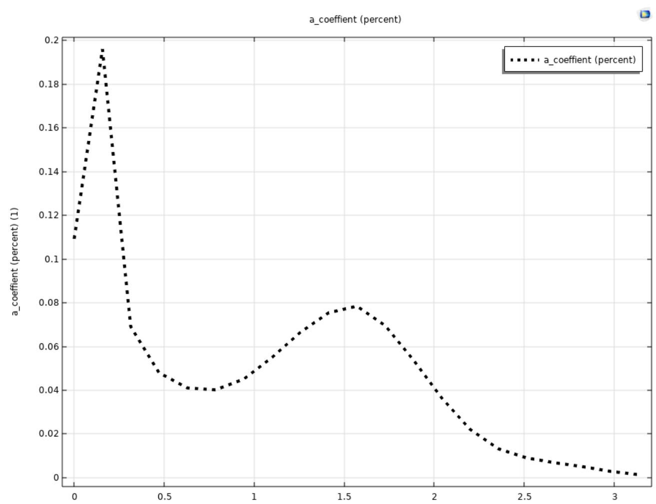


Figure 21. ECU to cover power ratio diagram (Pout/Pin).

## 6. Conclusion

The most important pillars of a military battle are the movement of military equipment, telecommunications, radar, defence, weapons, individuals, etc. Therefore, equipping the ECU of the Toyota 4.5F tactical vehicle is very important during an electronic war. This car is one of the tactical vehicles, which due to the nature of its performance on the battlefield, has special conditions and a lot of capability in the military discussion. Do not enter in order to be able to move weapons, military equipment, defence, radar, telecommunications, etc. well. In this paper, which uses Comsol software to analyse numerical models, the effect of electromagnetic wave radiation angle on the ECU of the car under study with the absorption of these waves was investigated. One of the important parameters in this project was the air absorption coefficient, which we considered equal to zero; Because the absorption of gamma rays by the air environment is very small and can be neglected for the dimensions of the system we have. The results show that the highest amount of radiation reached the ECU at an angle of 45 degrees and the lowest amount of radiation reached the ECU at an angle of 180 degrees.

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