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Electromagnetic field in electric and hybrid cars

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Abstract. In recent years rapid development of electromobility has been observed and hybrid and electric cars are becoming more and more popular. Their attractiveness is influenced by the reduction of exhaust gas emissions thanks to the use of electric drives. However, the use of this type of drive also raises some concerns, because people using this type of transport are in close proximity to the vehicle's electrical installation, which generates an electromagnetic field. High current values, up to several hundred amperes, can be the source of significant values of the fields affecting the organisms of passengers. In this paper, the authors discuss the results of several recent studies of the levels of electromagnetic interactions encountered in electrically powered cars and present the results of their own measurements made on two types of vehicles.

1. Introduction

In recent years, there has been a rapid development of electromobility. Both hybrid and electric cars are becoming more and more popular. Their attractiveness is influenced by the reduction of exhaust gas emissions, which is possible thanks to the use of electric drives. However, the use of this type of car raises some concerns. People using this type of transport are in close proximity to the electrical installation that generates the electromagnetic field. High current values, up to several hundred amperes, can be the source of significant values of magnetic fields [1]. The low-frequency magnetic field that occurs in electric and hybrid cars was classified in 2002 by the International Agency for Research on Cancer as a potentially carcinogenic agent [2]. There are also several reports of the supposed negative effects of magnetic fields on humans in contributing to the development of neurodegenerative diseases such as Alzheimer's and Parkinson's. However, these reports have not yet been unequivocally proven [3]. Therefore, research is conducted on materials that may limit the effects of such fields on the human body [4,5]. An important element in considering safety in cars of this type is also taking into account people who have implanted electronic devices to stimulate the heart rate. These devices are sensitive to electromagnetic disturbances that may cause them to operate incorrectly. Research has been carried out to determine whether electric and hybrid cars are safe in this regard. In one of them, the aim was to determine whether the electromagnetic fields generated by electric cars could cause the dysfunction of electronic pacemakers [6] 108 people who had heart devices implanted participated in the study. The tests were divided into three stages. In the first, the participants of the study were seated in the front seat and the vehicles were driven on a roller test bench. This made it possible to generate the maximum intensity of electromagnetic fields. In the second stage, the participants were inside the car while it was charging. The third stage consisted in the use of the car by the participants under normal conditions of everyday use - driving on the roads. The electromagnetic field was measured inside and outside the vehicles and at the charging cables. The study found that passengers were exposed to the highest field values when loading their cars. The highest measured value was 116.5 μT and occurred in the Tesla 85S model along the charging cable, in which a current of 32 A flowed during charging. Inside the vehicle, the intensity of the magnetic induction was in the range of 2.0 - 3.6 µT. During this study, there were no episodes of implantable device malfunction, and no spontaneous device reprogramming due to electromagnetic interference. Another study was focused only on hybrid cars [7]. The study involved 30 patients with implanted devices for heart stimulation. The hybrid car used in the study was the Toyota Prius 2012.

Measurements were made on the front and outer rear seats as well as outside the car. The highest average value of the magnetic field strength occurred on the right rear seat while driving at a speed of approx. 50 km / h and amounted to 2.09 A / m. The study showed that the tested hybrid car model does not generate the value of electromagnetic fields that could interfere with the operation of devices implanted in the heart. Another study was focused only on static electromagnetic fields [8]. The authors analyzed the literature, numerical and experimental studies to identify the mechanism and interference thresholds when exposed to static fields. The tests did not reveal any interference in the CIED devices resulting from exposure to a static electric field. In the static magnetic field, unintentional triggers of devices implanted in the heart occurred at magnetic field strengths above 0.8 mT. Reset or reprogramming of CIEDs has rarely occurred.

There is little research into determining the levels of magnetic fields in electric and hybrid cars. In one of them, the aim was to determine whether the use of vehicles has an influence on the change in the intensity of magnetic fields in cars [9]. The measurements were made over a period of three years each year on three different electric cars. The cars were measured while accelerating to 40 km / h and driving at a constant speed of 40 km / h. The study showed that the time lapse did not affect the levels of magnetic fields while repairs of accident cars in which parts were replaced have a significant influence. In the first year, the maximum values of magnetic induction reached 0.80 µT during acceleration, in the front and rear seats. When driving at a constant speed, the magnetic induction reached 0.18 µT. The maximum magnetic induction measured in the crash car reached 1.57 µT. In the case of a non-accidental vehicle, the intensity of magnetic induction did not change significantly. In another study, the intensity of the electromagnetic field was measured during dynamic city driving in an electric Nissan Leaf car [10]. The cockpit of the car was measured. The maximum measured value of the magnetic field was 64 µT. None of the measured values in this study exceeded the limit values.

In the study [11], an electric car was measured and compared with a hybrid car. The vehicles were measured over a period of 30 minutes in the driver's seat and in the passenger behind the driver's seat during dynamic city driving. Higher values of magnetic induction were recorded in the electric car. However, they did not exceed 3 µT. In the hybrid car, the magnetic induction values did not exceed 1.5 µT. In the next study, electromagnetic fields were measured in three electric and one hybrid vehicles [12]. The highest values of magnetic induction in an electric car were recorded in the Kia e-Soul. This value was measured while driving in reverse at the height of the driver's feet and was 1.27 µT. In the hybrid Toyota CH-R, the maximum magnetic induction was 2 µT. The average of the highest readings did not exceed 1 µT in any of the cars measured.

2. Materials and methods

Table 1. Parameters of the tested vehicles

Car	Drive type	Electric motor	Maximum power of electric drive	Battery type
LEXUS NX 300H 2015r	Hybrid 4x4	Two permanent magnet synchronous motors	Front axle: 105 kW Rear axle: 50 kW	Lithium - ion
NISSAN LEAF 2021	Electric drive on front axle	Permanent magnet synchronous motor	110 kW	Lithium - ion

3. Test description and its results

The tests were carried out on two cars. One was the hybrid Lexus NX 300H with 4x4drive, the other was the electric Nissan Leaf with front drive. The measurements were divided into three stages. First, measurements were taken in car cabins. Measurements were made on all vehicle seats, at three different heights - feet, abdomen and head. The next step was to measure the car cockpit at the points indicated in Figure 3. In the first and second stage, the cars were put into various dynamic states, such as: idling, acceleration 0-50 km / h, driving at a constant speed of 50 km / h, acceleration 50 - 90 km / h, driving at a constant speed of 90 km / h and braking 90 - 0 km / h. The third step was to determine the graph of the change in magnetic induction versus time while accelerating the car to 90 km / h and then braking the vehicle to a complete stop. Figure 1 shows the results of the measurements from the first stage of the research. On the left side there is a graph showing the average values of the magnetic field measured in a given place. The maximum mean value was 3.24 µT and occurred in the electric car, in the rear seat of the middle passenger at head height.

The values that appeared at the level of the feet of the passenger behind the driver in both hybrid and electric cars were also close to the maximum value. On the right side of Figure 1 there is a graph showing the maximum measured values of the magnetic induction. The highest maximum value of magnetic induction was 4.5 µT and occurred in the electric car at the level of the feet of the middle passenger in the rear. Similar, slightly smaller maximum values were recorded for the entire middle rear seat. In a hybrid car, the highest measured maximum value was 4.23 µT and occurred at the height of the feet of the rear passenger behind the front passenger. The rear passenger behind the driver at foot level was slightly lower, but close to the aforementioned maximum value of magnetic induction.

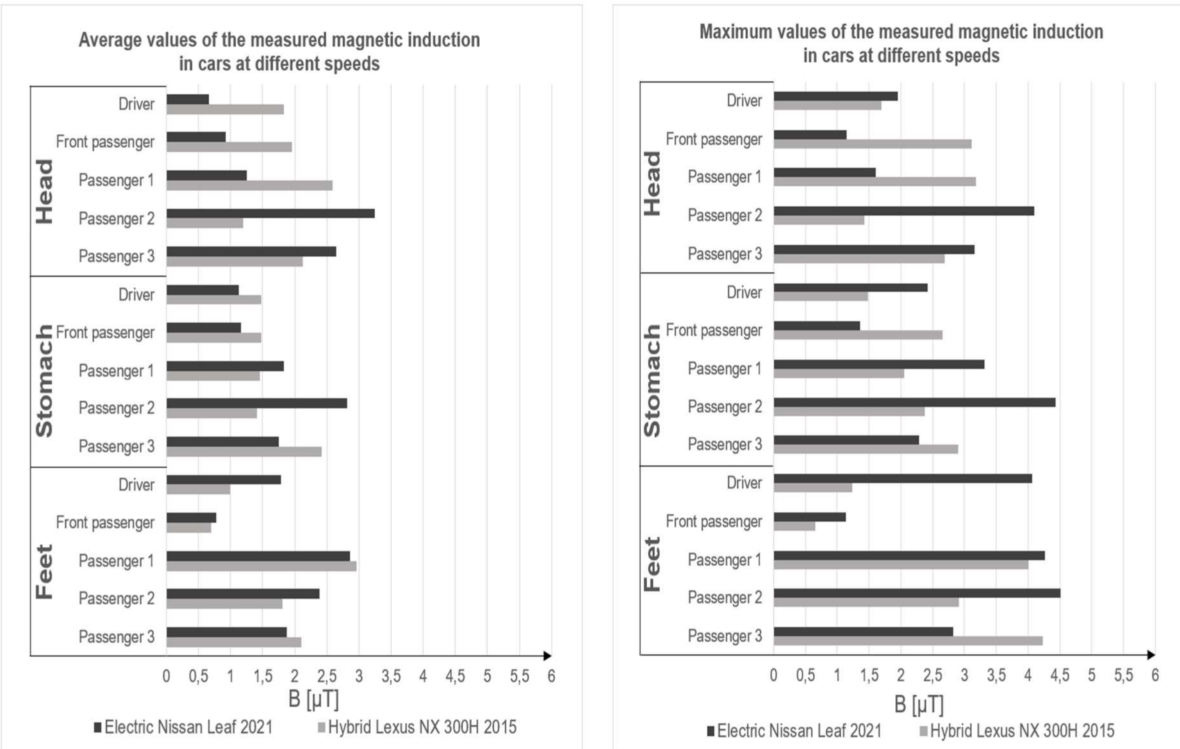

Figure 1. Graphs of average and maximum values of magnetic induction from measurements made in the vehicle cabin on the passenger and driver seats

Figure 3 shows the measurement results from the second stage of the research. The car cockpit was measured at the measurement points shown in Figure 2. On the left side there is a graph showing the average values of the magnetic field measured in a given place. The highest mean value of the magnetic induction was 3.9 µT and occurred at point 9, i.e. between the front seats in a hybrid car. The next mean values of the magnetic induction that appeared in the hybrid vehicle were slightly higher than 2 μT and occurred at points 2, 7 and 11. In the electric car, the highest mean value of the magnetic induction occurred at point 1, i.e. at the left vent. This value was 2.15 μT. On the right side of Figure 3 there is a graph showing the maximum measured values of magnetic induction at a given point. The highest maximum value of magnetic induction occurred in the hybrid car in point 9 and amounted to 5.62 μT. Another, quite high, maximum value in the hybrid car occurred at point 11, i.e. at the right-hand air supply, and amounted to 4.5 μT. The maximum measured value of the magnetic induction in the electric car occurred in point 1 and amounted to 2.90 μT. A slightly lower maximum value occurred in step 8 and amounted to 2.40 μT.

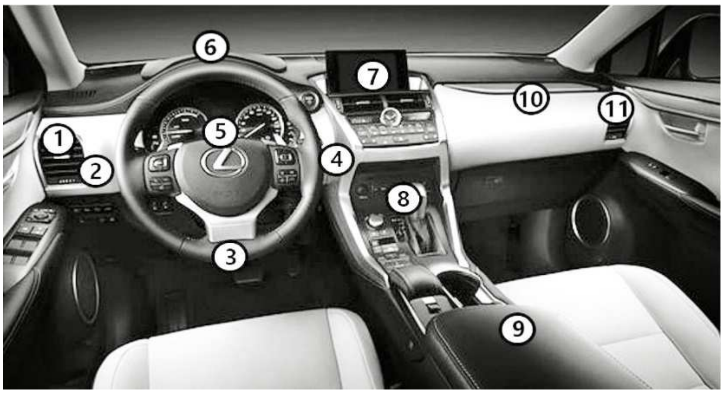

Figure 2. The car cockpit with marked measurement points

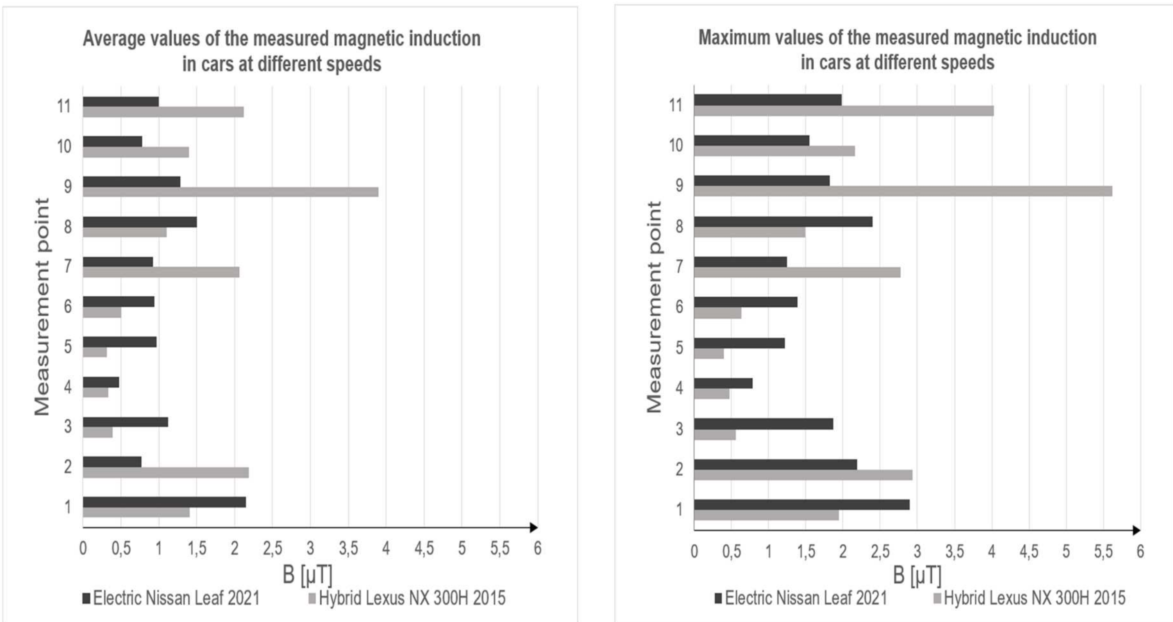

Figure 3. Graphs of average and maximum values of magnetic induction from measurements made at the cockpit of vehicles

Figure 4 shows the value of the magnetic induction depending on the speed, measured in the driver's seat, at the level of the abdomen. The highest value of magnetic induction occurred in an electric car idling and was 2.42 μT. Another significant value in an electric car is the value of the magnetic induction that occurred during acceleration of the vehicle from a speed of 50 km / h to a speed of 90 km / h, it was 1.92 μT. In a hybrid car, at the driver's belly, the highest value was recorded when braking the car from a speed of 90 km / h to a complete stop. None of the magnetic induction values exceeded 2.5 μT.

Figure 5 shows the value of the magnetic induction depending on the speed, measured in the seat of the middle passenger in the rear, at the level of the abdomen. The highest values of magnetic induction occurred in the electric car during acceleration. When the car accelerated to 50 km / h, the magnetic induction reached 4.43 μT. In the hybrid car, the values did not exceed 2.5 μT in any of the tested vehicle dynamic states. Additionally, it can be seen from the graph that the magnetic induction values in the seat of the middle passenger in the rear in an electric car are higher than in a hybrid car.
Analyzing both graphs in Figures 4 and 5, it can be seen that in the seat of the middle passenger in the rear, the magnetic induction values were higher than in the driver's seat.

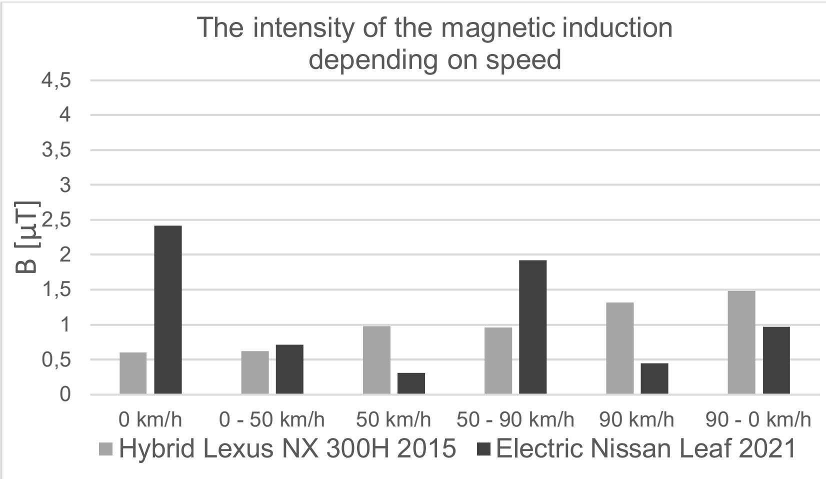

Figure 4. Magnetic induction intensity against speed measured in the driver's seat at abdominal level

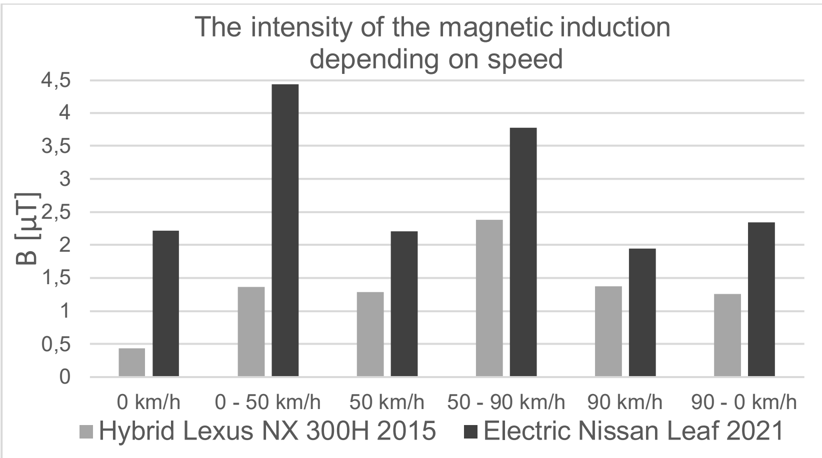

Figure 5. Magnetic induction intensity against speed measured in the middle rear seat at abdominal level

Figures 6 and 7 show the results of the measurements made in the third stage. Figure 6 shows a diagram of the magnetic induction depending on the time during acceleration and braking of the vehicle. The measurement was made at the height of the driver's belly. It can be seen from the graph that during acceleration, the induction values in both cars were similar. During braking, the hybrid car achieved higher magnetic induction values than the electric car. Additionally, it can be noticed that the magnetic induction in the electric car increased in the last seconds of braking, before stopping completely, while in the electric car it decreased.
Figure 7 shows a diagram of the magnetic induction depending on the time during acceleration and braking of the vehicle. The measurement was made at the abdomen of the middle rear passenger.

The induction in the electric car reached higher values only during the final phase of acceleration and the initial phase of braking. In the remaining periods of time, the hybrid car showed higher values.

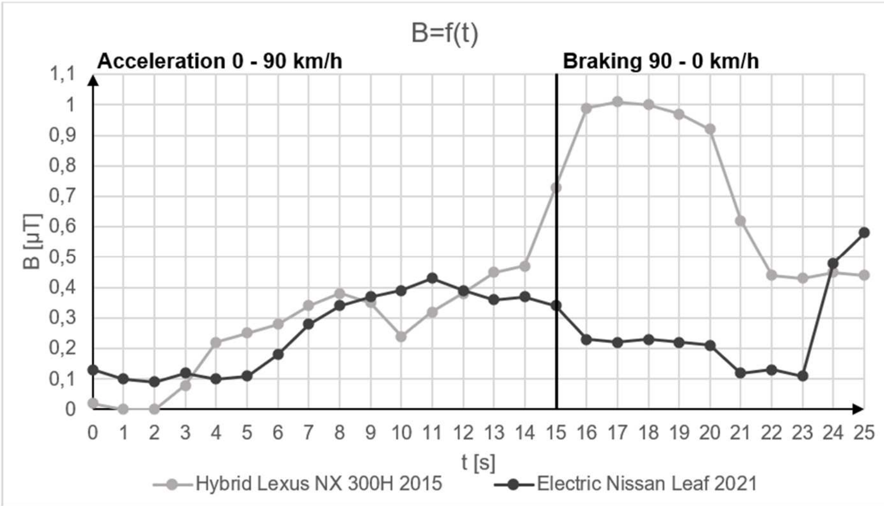

Figure 6. Graph of magnetic induction versus time during acceleration and braking of vehicles. Abdominal measurement in the driver's seat.

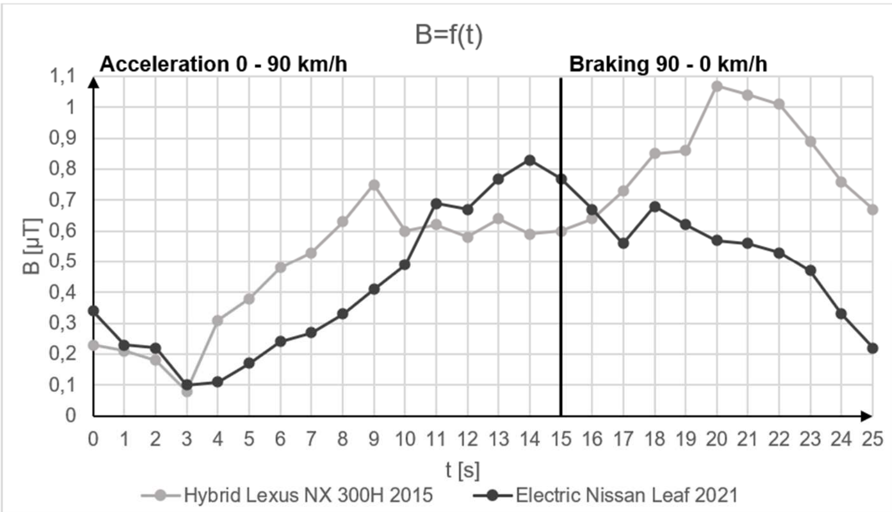

Figure 7. Graph of magnetic induction versus time during acceleration and braking of vehicles. Abdominal measurement in the middle rear passenger seat.

4. Summary

Higher values of the magnetic induction intensity appeared in the rear seats in both cars. At the level of the feet, the values were higher than at the level of the head, which is due to the distance from the electrical installation. During the first stage of measurements, the highest value of magnetic induction recorded in the electric car was 4.5 µT and occurred at the height of the feet of the middle passenger at the rear. In a hybrid car, the highest recorded value was 4.23 µT and occurred at the level of the feet of the rear row of seats behind the front passenger. In the second stage of measurements, the maximum value measured in the electric car was 2.90 µT, and it occurred at the left air supply. In the hybrid car, the maximum value in the second stage was 5.62 µT and it appeared between the passenger seats, at the armrest. Higher values of the magnetic induction intensity in a hybrid car may result from the car's four-wheel drive type, which is associated with having two electric motors, and the car's weight, which was greater than that of the electric car. The graphs presented in Figures 6 and 7 clearly show that the magnetic induction increases during acceleration and decreases during vehicle braking.

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