Electromagnetic interference in electrical systems of motor vehicles

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Abstract. Electronic ignition system affects the electronic equipment of the vehicle by electric and magnetic fields. The measurement of radio electromagnetic interference originating from the ignition system affecting the audiovisual test bench was carried out with a variable speed of the ignition system. The paper presents measurements of radio electromagnetic interference in automobiles. In order to determine the level of electromagnetic interference, the audiovisual test bench was equipped with a set of meters for power consumption and assessment of the level of electromagnetic interference. Measurements of the electromagnetic interference level within the audiovisual system were performed on an experimental test bench consisting of the ignition system, starting system and charging system with an alternator and regulator.

1. Introduction

The source of electromagnetic interference in vehicles is the electrical system, which has a range of devices whose natural operate (spark plugs, sparking contacts) is associated with the generation of radio electromagnetic interference. The source of electromagnetic interference in automotive vehicles is the ignition system, which can affect the operate of radio communication equipment, even within a few hundred meters from the vehicle [8,9,11]. Devices that generate electromagnetic interference inside vehicles include: elements of injection systems, vibrating voltage regulators, blower motors, wipers, fans, washers, as well as bimetal sensors and relays.

Electromagnetic interference can travel through galvanic isolation in the form of voltage drops on metallic pieces and lead resistance and trough inductive way via system capacity [1,7,12]. The existence of inductive coupling between parallel wires results in rapid changes of current, which interfere with the operate of electronic devices, and as a result may even damage the input transistor. Power surge occurs during a power failure.

By interrupting the flow of electric current by means of a mechanical switch, the spark that occurs between the contacts causes a reduction in the height and steepness of the induced pulse. There are many sources of power surge in the vehicle electrical system. It should be noted that the battery that operates with the electrical system effectively suppresses power surge which originates from the alternator, ignition system and induced in other circuits with inductance. Disconnection of the battery results in deprivation of the natural power surge protection. That is why additional electronic equipment is used more frequently to protect the system of a vehicle.

The power surge generated by the ignition system arises upon the delivery of power supply through the ignition switch. An unfavourable situation may occur if the circuit of the battery gets interrupted during charging, when the other receivers are disconnected. This results in an increased power supply to the ignition system, which was created in the winding of the alternator at the

moment of burden reduction. Dangerous power surges can occur during normal operation of the whole system, it disables the ignition switch, which in effect disconnects the battery from the receivers. Power surges can also arise in the case of welding of vehicle subassemblies using an electric arc. For this reason, manufacturers of alternators and electronic voltage regulators recommend to detach them during any electric arc welding.
An electromagnetic interference meter is used to measure radio electromagnetic interference. This is a special measurement receiver that allows, using accepted methods of measurement, to clearly assess the distortive effect in the radio or television reception, regardless of the nature and waveform of electromagnetic interference.

Electromagnetic interference measurements, with sinusoidal waveform, can be made with conventional measurement receivers, such as field strength meter or selective voltmeter. For electromagnetic interference, whose waveform is sinusoidal, there is a relationship between the amplitude of the electromagnetic interference and the effect of electromagnetic interference for a given measurement frequency.

Considering the electromagnetic interference of pulse type, which is generated by the majority of interfering devices in a vehicle, the knowledge of the pulse shape and its peak value is not enough to predict the effect of electromagnetic interference. The parameter to be considered is the repetition frequency of pulses per unit of time. It was found that the effect that interferes with radio or television reception depends largely on: the shape and the absolute value of the pulse and the pulse repetition frequency. For this reason, to measure a series of pulsed electromagnetic interference one uses an electromagnetic interference meter, instead of using a selective micro-voltmeter.

2. The analysis of anti-electromagnetic interference protection systems

We can distinguish three types of protection systems due to the different effectiveness:

- normal protection systems: reducing radio electromagnetic interference to the N level,
- tightened protection systems: reducing radio electromagnetic interference to the O level,
- special protection systems: reducing radio electromagnetic interference to the S level,
- the W level (high) is used on separated areas [2-4].

In order to reduce the level of electromagnetic interference intensity of a continuous nature, arising in the vehicle electrical system, one uses measures that suppress the radiation of electromagnetic interference along the wires. The radiation of electromagnetic interference can be reduced by shielding. The condition for this protection to be effective is a good electrical connection between the metal shield enclosing the source of electromagnetic interference and the mass of a vehicle.

Capacitors, inductors and LC filters are used on the low voltage side. In order to reduce the level of radio electromagnetic interference at a frequency of long- and medium-wave ratio one attaches capacitors in parallel to the source of electromagnetic interference (figure 1.). Feed through capacitors, conducting high currents (up to 60 A) enable good suppression of electromagnetic interference at higher frequencies of FM.

Reactors are used to improve the effectiveness of suppression in the range of UHF waves. The inclusion of a reactor in the power cord of an electrical equipment prevents electromagnetic interference from the power supply. In other cases one can use LC filters and shielding. In order to suppress electromagnetic interference from the high-voltage side, one uses special energy absorbing resistors. Such a solution may be fully effective only if suppressing resistors are embedded as closely as possible to the source of electromagnetic interference, for instance in a spark plug or high-voltage wires.

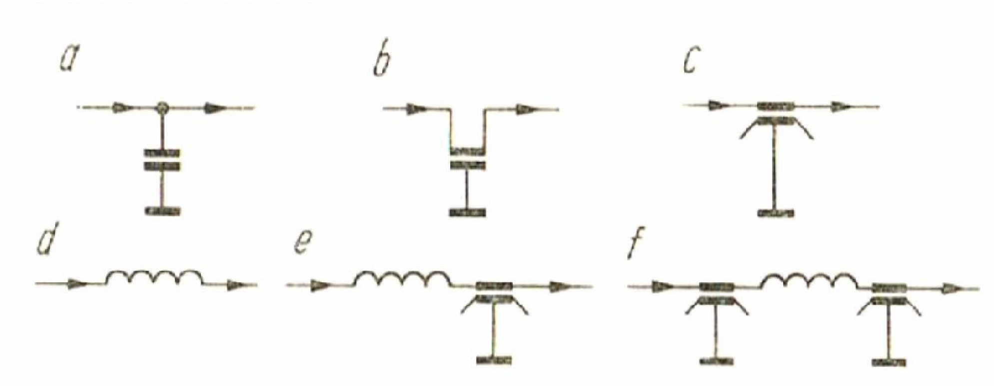

Figure. 1. Typical electromagnetic interference suppression components: *a* – a parallel capacitor, *b* – a bypass capacitor, *c* – feedtrough capacitor, *d* – inductance (reactor) *e* – a simple LC filter, *f* – LC filter with increased effectiveness.

A spark plug can be depicted as a capacitor made of metal body divided by an insulator and an inner electrode (figure 2a). After placing a resistor in place of the center electrode, the equivalent circuit is presented by figure 2b. Placement of the resistor closer to the spark plug reduces the system capacity. More than half of the energy stored in the capacity of the spark plug is forced to go through the R resistance. This causes a reduction in the amplitude of the current pulse in the capacitive phase of spark discharge. Ignition systems with a lower input impedance are more sensitive to the inclusion of suppressing resistance.

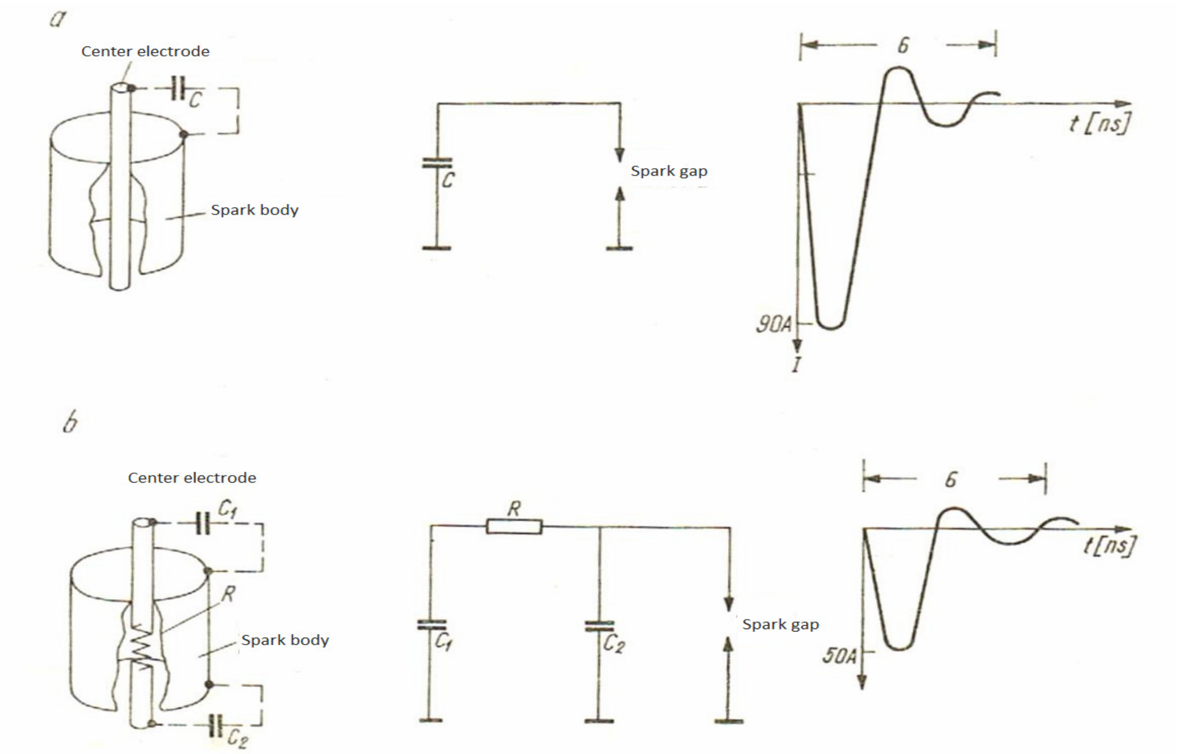

Figure 2. Anti-suppression protection systems in the form of a series resistance: *a* – scheme of a conventional spark plug, *b* – scheme of a spark plug with a built-in suppression resistor.

A very effective way of limiting the level of electromagnetic electromagnetic interference emitted from the ignition system is shielding of its individual elements. These results in increased capacity of the entire circuit of the high voltage, which in effect reduces the voltage across the electrodes of a

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spark plug, thus contributing to ignition misses. The lack of connection between the engine, the body and the weight of a vehicle can help to reduce the effectiveness of the suppression equipment. Ground connection should be as short as possible and its cross section must be at least 16 mm^2.

3. Measurements of radio electromagnetic interference in automobiles

Measurements of the intensity of any electromagnetic interference field are performed using an electromagnetic interference meter equipped with a special measurement antenna, enabling determination of the intensity of an electromagnetic interference field. The voltage at the antenna terminals is proportional to the electromotive force (SEM) induced in the antenna and to the intensity of the electromagnetic interference field, in which the antenna is located. The ratio of the intensity of the electromagnetic interference field *(E)* to the voltage measured *(Uz)* at the terminals of the antenna attached to the electromagnetic interference meter is determined by the manufacturer of a given electromagnetic interference meter, and is known as a calibration coefficient of the antenna *(kf)* in a function of frequency. The intensity of the electromagnetic interference field is determined from the following formula:

$$E = k_f + U_z \tag{1}$$

where:

E – the intensity of the electromagnetic interference field [dB], (0 dB = 1μV/m),

U_z – the voltage level measured by an electromagnetic interference meter [dB], (0 dB = 1μV/m),

k_f – calibration coefficient of the antenna [dB].

In the short-, medium- and long-wave ratio, that is from 0.15 to 30 MHz, one applies the rod antenna, whose length is 1 m. It allows to measure the electrical component of the field strength. The magnetic component is also measured in this frequency ratio using a tuned dipole antenna (requires a change in the length of dipole arms for a particular frequency), or a wide-band antenna which does not require tuning for a particular frequency. With these antennas one can measure the electric component of the electromagnetic interference field strength for the vertical and horizontal polarization.

4. Experimental tests

The experimental audiovisual test bench has full radio and monitor equipment (two-way). In order to determine the level of electromagnetic interference, the audiovisual test bench was equipped with a set of meters for power consumption and assessment of the level of electromagnetic interference. The block diagram of audiovisual test bench is presented by figure 3.

The experimental test bench consists of a two-channel stereo amplifier, two liquid crystal panels and a set of speakers. The system requires power supply from the battery or alternator. The system is protected by a serially switched fuse (15 A). The liquid crystal panels *DVD052 Dual Screen Player* are equipped with screens with a diagonal measurement of 7", built-in stereo speakers and the ability to play multimedia files from portable storage media (DVD, VCD, MP3, MPEG4, JPG). The amplifier *Voice Kraft C-238* has a nominal effective power of 2 x 20W, supplies power to two, two-way coaxial speakers *Houston Acoustic HA-402* with a maximum power of 120W.

The battery is connected to two terminals Z1 and Z2 of the test bench. Between the Z1 terminal and the W1 switch one can find a serially switched fuse that protects the system. The Z1 terminal supplies voltage to the power amplifier and the car lighter socket, into which the M1 monitor is connected. The audio-video signal (A/V) of the M1 monitor is supplied to the M2 monitor with a mini-jack cable. The power supply of the M2 monitor is implemented with the M1 monitor. A stereo audio signal of the M1 monitor is led out of the mini-jack headphone socket to the input of the phono amplifier. A memory stick with sample media files, that one can play using the system, is connected to the USB port of the M1 monitor. The system has two ways to adjust the volume, the first at the M1 monitor and the second at the stereo power amplifier. The view of the test bench is shown in Fig. 4.

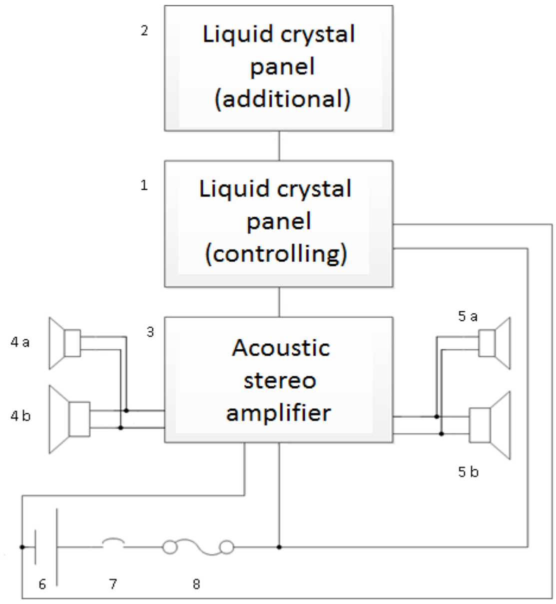

Figure 3. The block diagram of test bench: 1 – liquid crystal panel (controlling), 2 – liquid crystal panel (additional), 3 – acoustic stereo amplifier, 4 – two-way speaker, left *a* – tweeter, *b* – woofer, 5 – two-way speaker, right *a* – tweeter, *b* – woofer, 6 – battery/alternator, 7 – power switch, 8 – fuse (15 A).

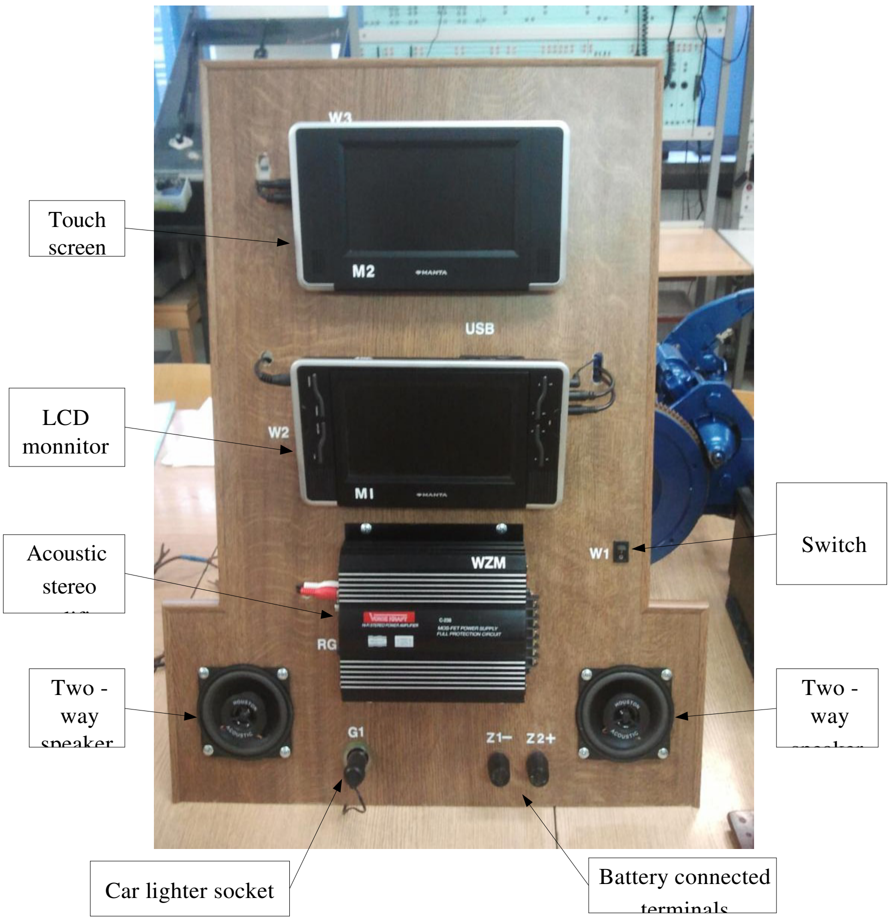

Figure 4. The view of the audiovisual test bench.

The research program conducted on the audiovisual test bench. The test equipment used to determine the active power of the system and the level of electromagnetic interference included: two analog ammeters to measure the direct current, magnetoelectric having isolation equal to 3 kV, accuracy class 0.5 and two analog voltmeters to measure the DC voltage, magnetoelectric having isolation equal to 3 kV, accuracy class 0.5, finder of electromagnetic interference type ZSS-1 (figure 6), speed meter DT-2234C+ and the universal diagnostic tool from Bosch model MOT-150.
Measurements of the electromagnetic interference level within the audiovisual system were performed on an experimental test bench consisting of the ignition system, starting system and charging system with an alternator and regulator. The tests were conducted by registering:

- the level of radio electromagnetic interference originating from the ignition system,
- the measurement of current and voltage intensity generated by the alternator and the level of radio electromagnetic interference resulting from its operate,
- the measurement of power consumption and voltage on the audiovisual test bench,
- the measurement of current and voltage during switching of the starter.

The block diagram of the complete measurement system is presented by figure 5, and the view of the complete measurement system is presented by figure 6.

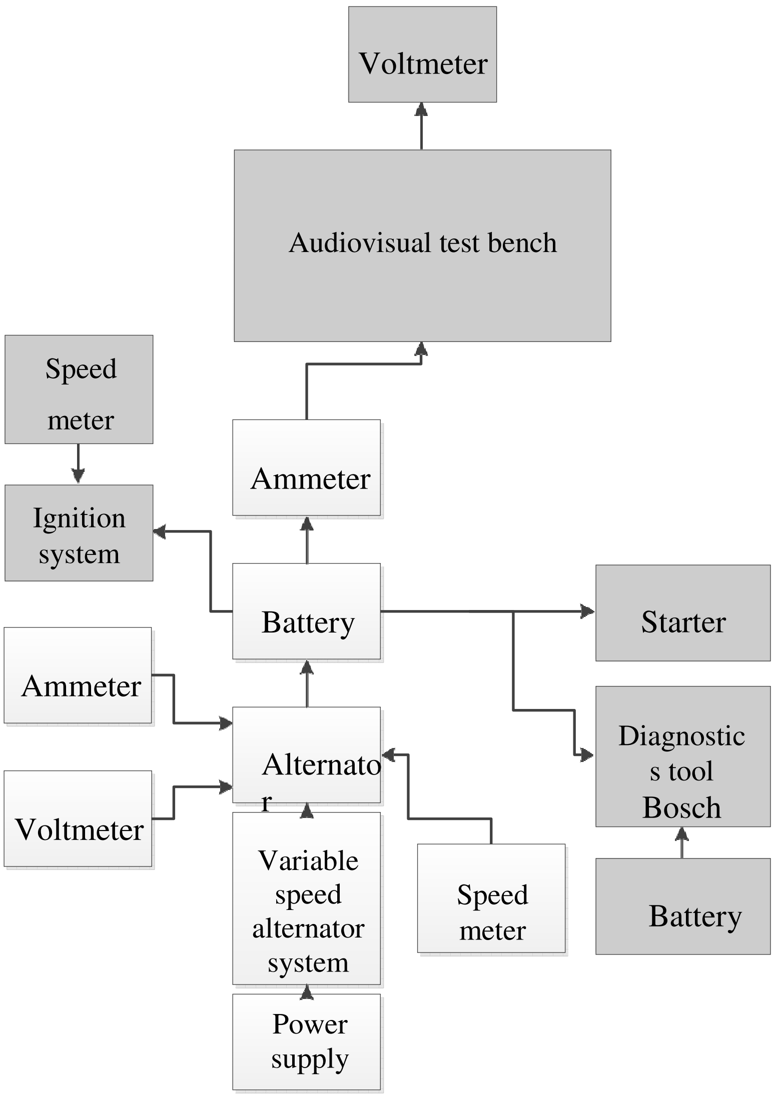

Figure 5. The block diagram of the measurement system.

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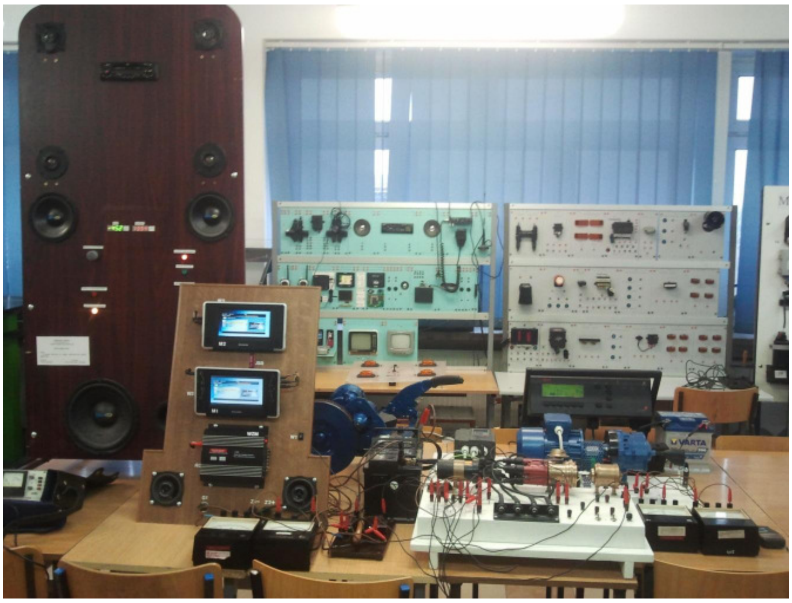

Figure 6. The view of the complete measurement system.

The finder of electromagnetic interference and the diagnostic tester from Bosch MOT 150 were used in the study (presented in Fig. 7).

Figure 7. The finder of electromagnetic interference type ZSS-1.

5. The results of experimental tests

The measurement of radio electromagnetic interference originating from the ignition system affecting the audiovisual test bench was carried out with a variable speed of the ignition system. The electromagnetic interference level in a function of rotational speed of the ignition device is presented by figure 8.

The measurement of current and voltage generated by the alternator and the measurement of electromagnetic interference resulting from its operate was carried out with variable speed alternator. The measurement results are shown in figure 9 and figure 10.

The measurement of current and voltage consumption was performed by changing the volume. The results of the measurement of intensity of the current and active power consumption are presented by figure 11 and figure 12.

The measurement of current and voltage during the operate of a starter was carried out on neutral gear and for a short circuit condition.

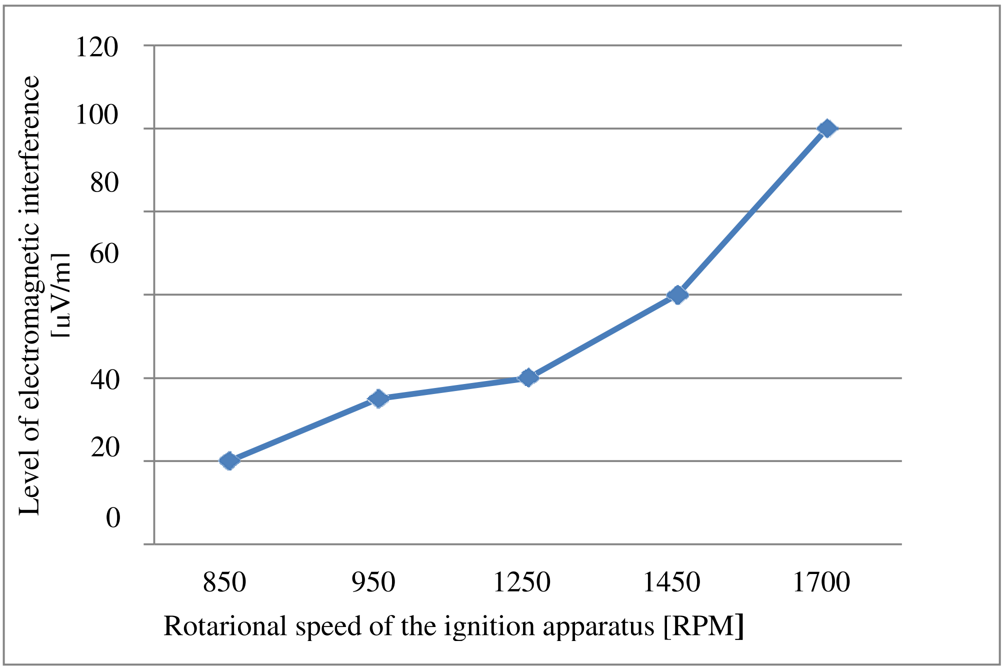

Figure 8. The level of electromagnetic interference in a rotational speed of the ignition apparatus.

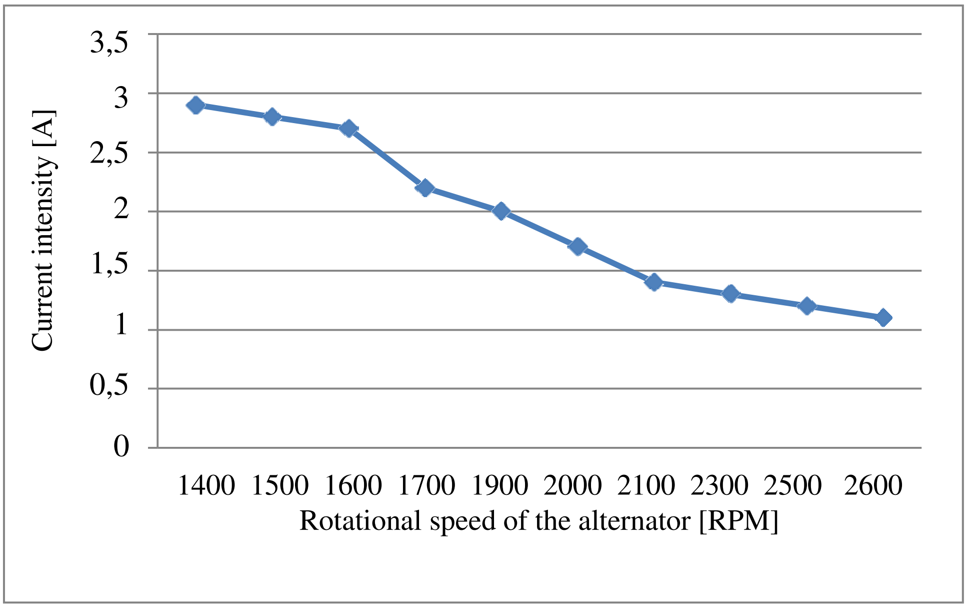

Figure 9. The current intensity in a rotational speed of the alternator.

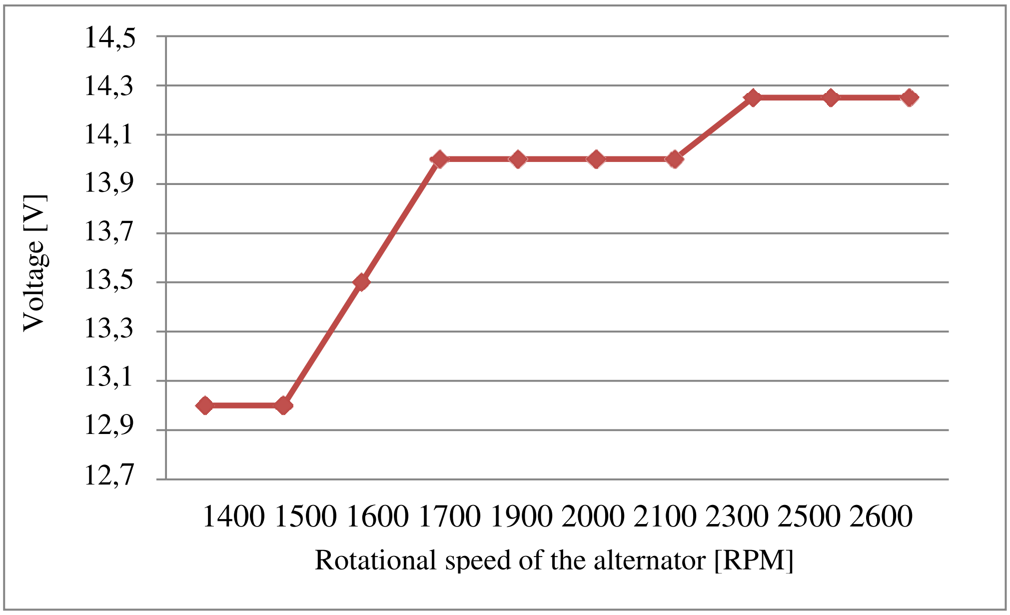

Figure 10. The voltage in a rotational speed of the alternator.

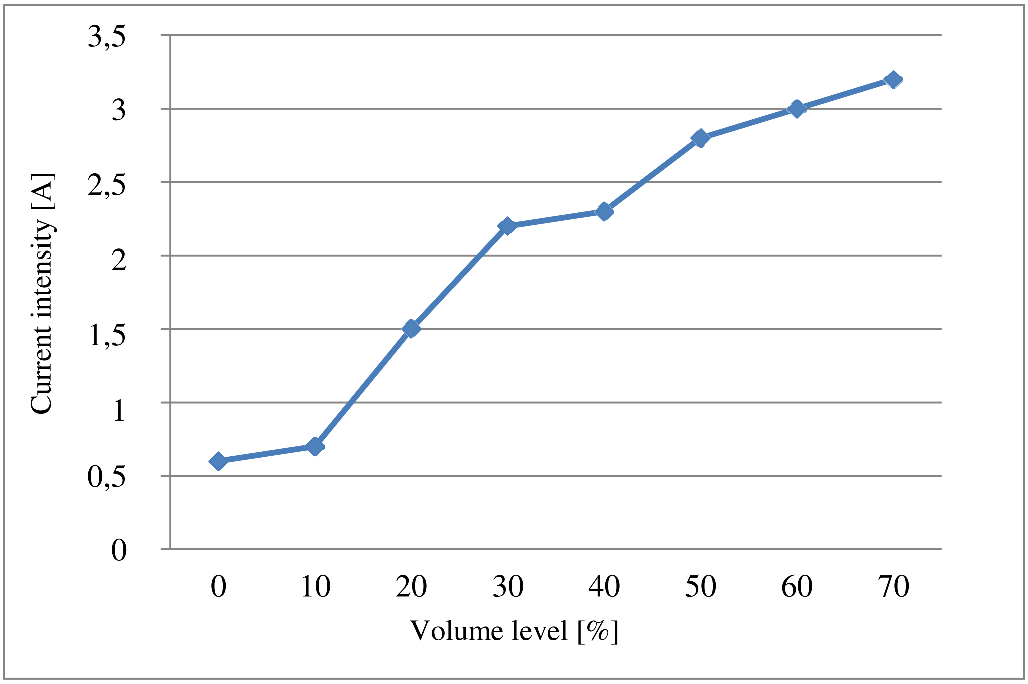

Figure 11. The current intensity in the volume level.

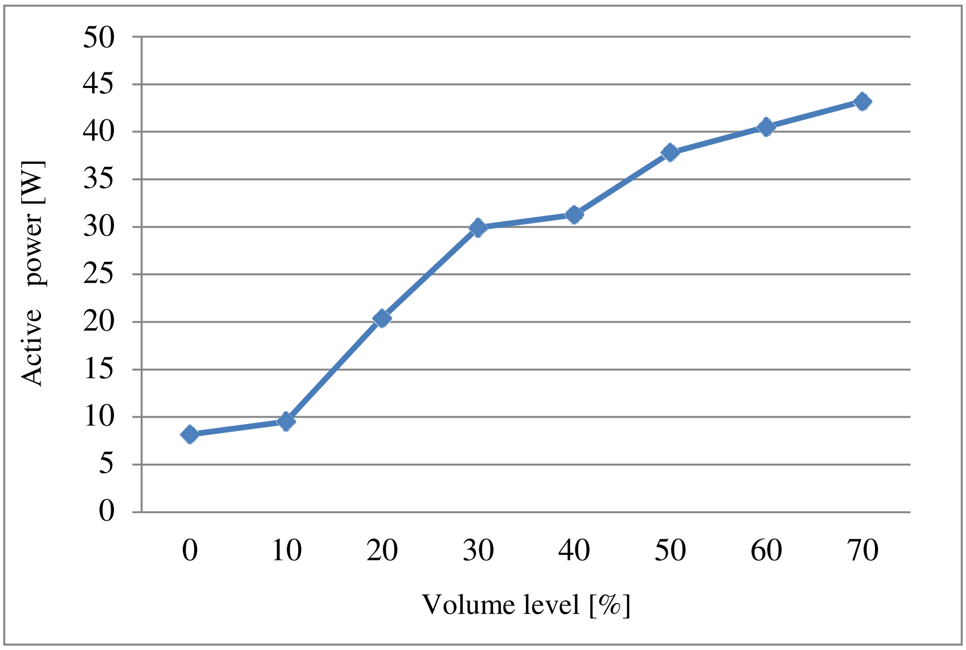

Figure 12. The active power in the volume level of the audiovisual test bench.

5. Conclusions

The analysis of tests results as well as visual and listening observations shows that despite the exceeding values of radio electromagnetic interference, the operation of the monitor and amplifier was not disturbed by the operation of the ignition system and alternator.

The current on the neutral gear 37 A was recorded when the starter was engaged, while the current 295 A was recorded during the braking torque, at which there was a momentary drop in voltage at the experimental test bench.

The measurements of current and voltage of the alternator at variable speeds up to 2600 rev/min showed an electromagnetic interference level of 30 µV/m.

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