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## **LABORATORY STAND FOR THE ANALYSIS OF DISTURBANCES IN THE CAR ELECTRICAL CIRCUITS**

The laboratory stand for analysis the electromagnetic interferences in the electric power circuits of typical car with a gasoline engine is presented in the paper. The electrical infrastructure with voltage 12 VDC is a typically for older cars. The measurement problems of conducted disturbances in selected electrical circuits were analyzed. The radiated disturbances e.g. generated by a classic electromechanical ignition module were measured.

**Keywords:** automotive EMC testing, measurements of conducted and radiated disturbances

### **STANOWISKO LABORATORYJNE DO ANALIZY ZABURZEŃ W ELEKTRYCZNEJ INSTALACJI SAMOCHODOWEJ**

W artykule zaprezentowano stanowisko laboratoryjne, odwzorowujące podstawową infrastrukturę elektryczną o napięciu znamionowym 12 VDC, typowego pojazdu samochodowego z silnikiem benzynowym. Część badawcza dotyczy aspektów technicznych, związanych z pomiarami zaburzeń przewodzonych w wybranych obwodach elektrycznych, jak również obejmuje analizę zaburzeń promieniowanych, generowanych m.in. przez klasyczny, elektromechaniczny moduł zapłonowy.

**Słowa kluczowe:** badania kompatybilności elektromagnetycznej w motoryzacji, pomiary zaburzeń przewodzonych i promieniowanych

## **1. INTRODUCTION**

The EMC (eng. *electromagnetic compatibility*) testing of vehicles comprises different special measurements of levels of the conducted and radiated emission. The EMC analysis also requires carrying out immunity tests of typical basic electronic components of car and the independently entire car against selected conducted and radiated disturbances. Issues of immunity testing in the automotive area are already discussed in papers [1] and [2]. The analysis of conducted disturbances propagated in car electrical circuits is one of the most important stages of EMC testing of vehicles [3], [4]. These research are carried out for both new vehicles entering the world market as well as under modifying existing installations in older cars. Many dysfunctions of prototype electronic equipments are caused by disturbances in the supply lines both during normal vehicle work and a during temporary particular operating conditions. The power supply lines of the selected electrical and electronic loads of vehicle are most frequently analyzed. Analysis of the levels of disturbances in the electrical wires are done usually in the field of time and frequency. Knowledge of the parameters of real conducted disturbances is necessary because a case of immunity testing against real disturbances is required the execution in the EMC research of a new product dedicated to a specific vehicle model. The new electronic module must be resistant to disturbances. This is very important in the case of changing the older type of electronic modules to modern solutions when upgrading vehicles. The electronic modules of modern cars are much more sensitive to conducted disturbances in their power and signal circuits.

The prepared laboratory stand allows to estimate the parameters of conducted disturbances from the typical on-board electrical devices of car vehicles. Knowledge of the amplitude, shape and time duration of disturbances in the electrical installation allows us to undertake research into the development of modern filtering solutions dedicated to specific types of car loads. The disturbances in

the automotive power supply lines are generated mainly by electrical loads. The modern electrical onboard loads these are usually nonlinear electronic power devices which inject to the power supply wires the disturbances with high amplitude. In this case the topology of the wires is much less important in the EMC analysis. An very important issue is the problem of disruption analysis generated by the ignition system (gasoline engines). The ignition system always generates the conducted disturbances and the radiated disturbances with high frequency. The radiated interference are very easy introduced into the other electrical circuits. The most vulnerable for these effects are signal and control lines.

The block diagram of laboratory stand and a view of main part of this stand are shown in the Fig. 1.

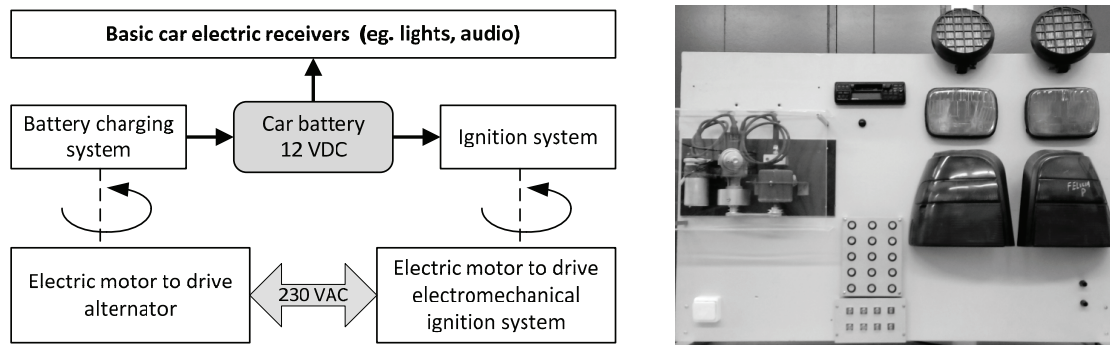


Fig. 1. Block diagram of laboratory stand for the car electrical installation analysis and a view of main part of actual stand

The above block diagram also includes two electric motors used to drive the alternator and the electromechanical ignition system.

## 2. LABORATORY STAND

The developed laboratory stand is made in a compact form. Additional parts of laboratory stand are the battery charging system with the independent electrical drive (230 VAC) and the car battery (Fig. 2).

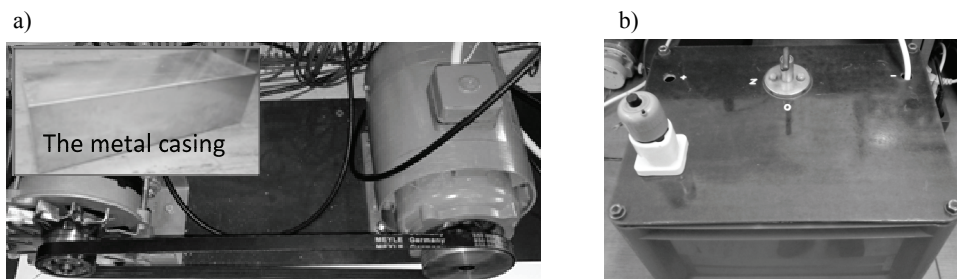


Fig. 2. View of charging system for car battery (a) and view of portable car battery 12 VDC (b)

The car battery is placed in a casing with a mechanical circuit breaker and a matched over current protection. The battery parameters are: nominal voltage 12 V, electrical capacity 72 Ah and starting current 660 A.

A classic electromechanical ignition system is installed in the prototype laboratory stand. This is a deliberate choice because this type of ignition module generates the most values of conducted and radiated disturbances. The circuit diagram and a photo of the ignition system are shown in the Fig. 3.

The circuit diagram consists of a typical ignition coil (1), a capacitor (2) a mechanical breaker (3), a mechanical high voltage splitter (HV commutator) (4) and a spark plug (5).

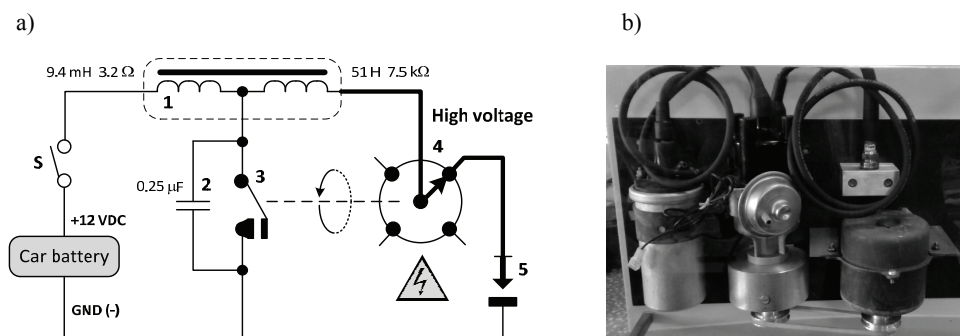


Fig. 3. The circuit diagram of the electromechanical ignition system (a) and a view of the real ignition system (b)

For the simplicity only one circuit of spark plug is used in the ignition system. The author's experience shows that the types and models of circuit components do not effect significant on the EMC research results, so these data are not presented in this paper. In this case, the structure of the ignition system and its hardware solution (mechanical or semiconductor type) are the most important. For drive of system the low power electric motor (230 VAC) is used. In a project it is also possible to change of rotational speed of ignition system by second gear ratio of the V-belt (about 2000 rpm or 3500 rpm). The default value of rotational speed in the stand is equal 2000 rpm. This is a typical value for a slow ride of car with a gasoline engine.

The basic car electrical installation is implemented in the new designed laboratory stand. The view of the connections structure of the electrical circuits, switches and measuring BNC sockets are presented in the Fig. 4.

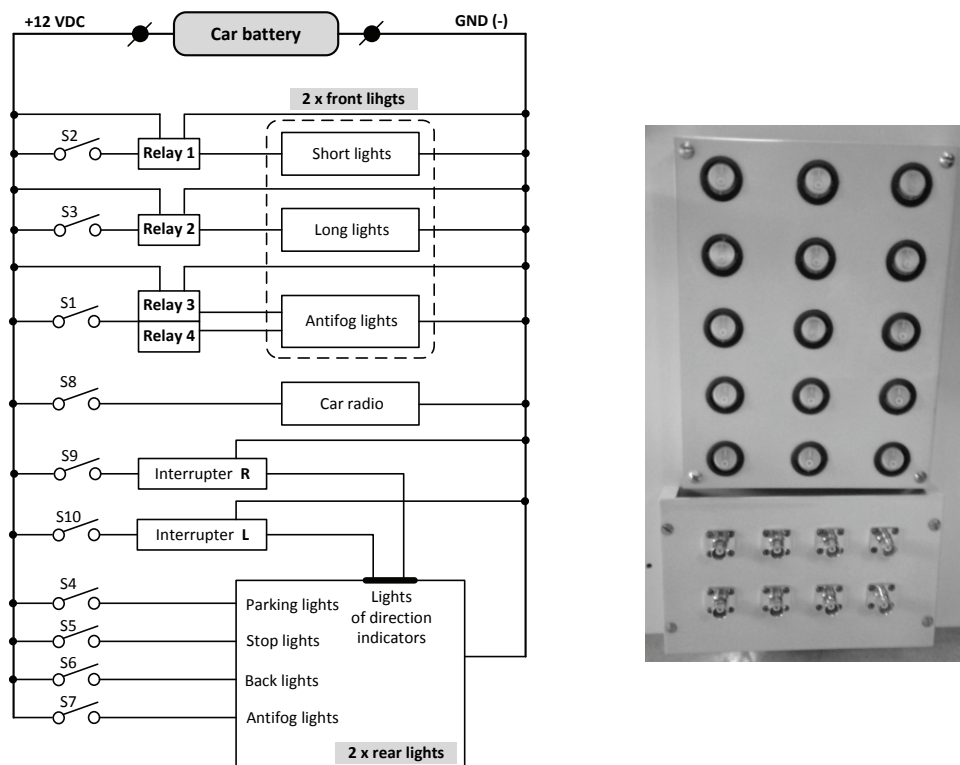


Fig. 4. The topology of circuits for car electric loads in the stand and view of switches and measuring BNC sockets

The classic halogen (H4) with power 55/60 W and typical car tungsten lighting are used in the laboratory stand. The relays and the interrupters are used in the typical electromechanical versions because the laboratory stand represents a basic electrical installation of classic cars. BNC connectors are used to connect the power supply analyzer to selected circuits. In order to perform a timing analysis of disturbances in the electrical circuits, the AutoWave recorder/generator is implemented in the laboratory stand [1], [2].

### 3. SOME TEST RESULTS OF THE LABORATORY STAND

The ignition module was tested. This module is the important source of conducted distortions injected into other wires (mainly by common ground potential) and it is a source of substantial radiated electromagnetic disturbances too. The simulation model (Fig. 5) of the ignition system according to Fig. 3a was created [5]. The LTSpice software was used for the computer simulations.

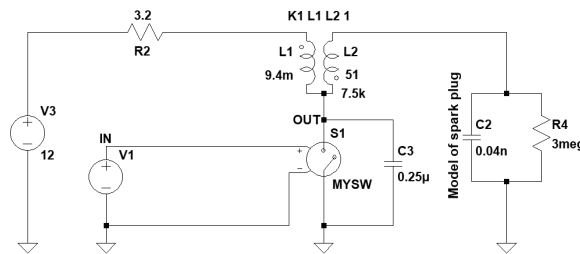


Fig. 5. Part view of simulation model of the ignition system

The resistor R2 limits the DC component of current of the primary circuit ( $12\text{ V} / 3.2\ \Omega$ ). In the real case it is the internal resistance in the ignition coil. Model of the ignition coil has electrical parameters identical to real coil used in the stand. For example, the voltage waveform of the secondary winding of the coil is shown in the Fig. 6a. The observed voltage waveform by oscilloscope of secondary winding of the coil is shown in the Fig. 6b.

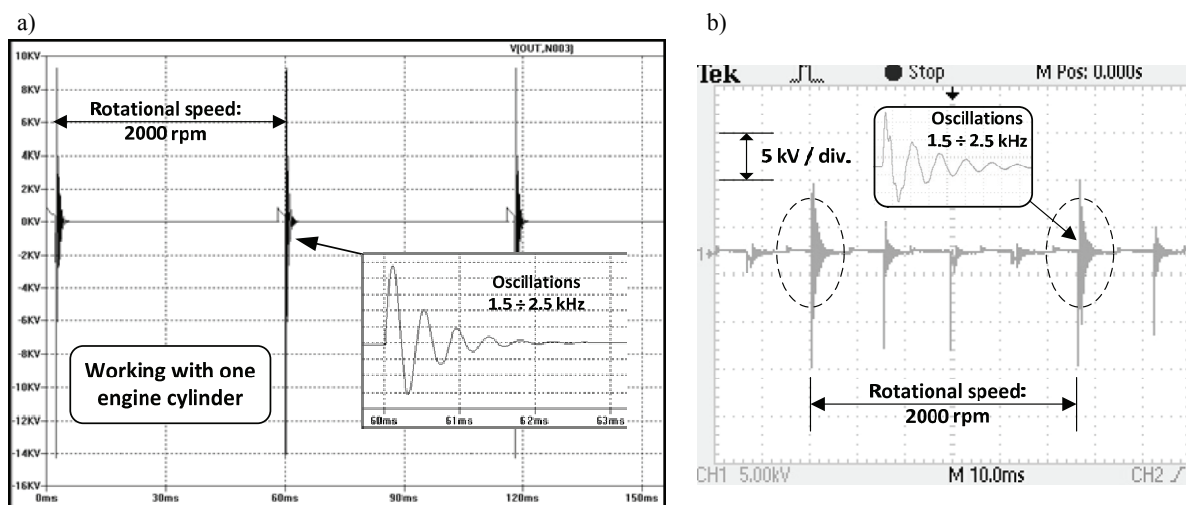


Fig. 6. Voltage waveform of the secondary winding of ignition coil – simulations (a) and measurements (b)

The waveform has oscillations with frequency about a few kHz. Similar oscillations resulting from resonances are observed in real measurements. These resonances are effect of equivalent capacity of the spark plug model (Fig. 5) and the real parasitic capacitances of the ignition coil. The slopes of

voltage waveform with a short rise times and high voltages and resonance oscillations are usually a source of radio interferences. The voltage waveforms of the primary winding of ignition coil are shown in the Fig. 7 (measurement process).

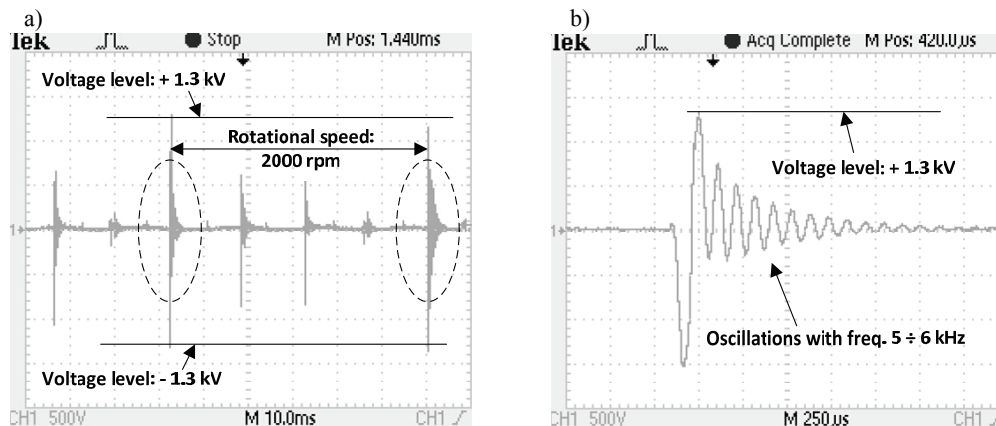


Fig. 7. Voltage waveform of the primary winding of ignition coil (a) and the oscillations in this voltage waveform (b)

The laboratory measurements were performed to determine the levels of radiated disturbances generated by the electromechanical ignition system (Fig. 8). Spectrum of radiated disorders are presented in the Fig. 8. The analysis was done in a typical frequency band from 30 MHz to 1 GHz.

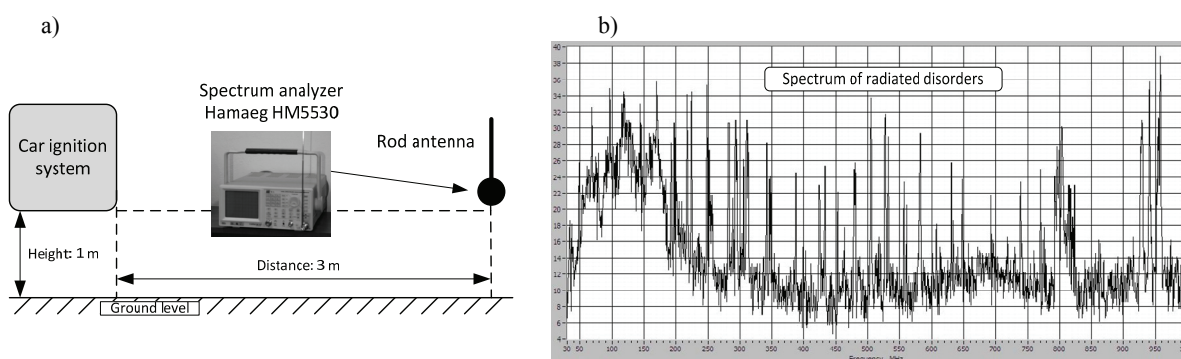


Fig. 8. Setup of the laboratory stand for measurements of radiated emission (a) and the measurement results of the radiated disturbances generated by classic electromechanical ignition system (b)

For cognitive purposes the measurements of power supply parameters in selected circuits of laboratory stand were performed. Research has determined which electrical loads are the source of the greatest electromagnetic interferences. Exemplary electrical motor of car windscreen was included to laboratory stand too. View of the disturbances of on-board power supply caused by the working of electrical motor of windscreen are shown in the Fig. 9.

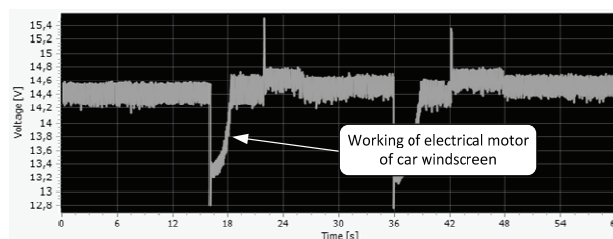


Fig. 9. Interference of power supply from the working of typical electrical motor of car windscreen

#### 4. CONCLUSIONS

The laboratory stand can serve both research purposes and didactic process too. The knowledge of time and frequency parameters of disorders in the selected car electrical circuits allows to studies the ways of minimizing these disorders. The new laboratory stand is very flexible solution. It is possible to expand of the panel with additional on-board car devices. One can implementation a modern electronic modules with a large scale of integration. For example: CB radio, GPS navigation, airbag controller, etc.

The elaborated LTspice model of the ignition system very good reproduces the parameters of the work of the real device. This allows for further work on modeling and laboratory studies on the optimization of the ignition system angled EMC requirements. It was confirmed that the main elements of the ignition system which generate radiated interferences are the high voltage wires. The unscrewed spark plug (not shielded in the combustion chamber) does not increase the level of radio interferences. The frequency range of the highest disturbance levels is very wide from 100 MHz to 800 MHz.

As part of the research a trials of filtration of the disturbances generated from some car electrical receivers were conducted. Minimization of conducted disturbances in the vehicle on-board electrical installations is a difficult process. The common mode disturbances are biggest problem. This is a problem of common reference potential for different circuits. This is usually a metal body of vehicle. The efficiency of the car EMI filter is limited due to the lack of ground potential as is the case with stationary AC or DC power supply.

The lab stand also allows you to do some immunity tests of automotive devices against electromagnetic disturbances (eg. test against electrostatic discharge – ESD). Many vehicle manufacturers create its own models of conducted disturbances for the immunity testing [1]. The newly developed car electric device must obtain positive test result for each required of test (ISO standards and models defined by car manufacturers).

The presented laboratory stand is a good training ground for scientific research and cognitive tests in the field of didactics.

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