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Vehicle Detection based on Magneto-Resistive Magnetic Field Sensor

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Introduction

Nowadays we can't imagine our life without a car. Number of cars on roads, streets and parking places is constantly increasing. It leads to increased traffic load and accidents. There are few ways to solve problem: increase permeability of the road, increase quantity of lanes, improve public transport infrastructure. Alternative method is to create and deploy an Intelligent Transportation System (ITS) which enables optimal use of existing road infrastructure by interactive management of all traffic. Intelligent Transportation Systems varies in technologies applied. Basic management systems are: car navigation, traffic signal control systems, variable message signs, automatic number plate recognition or speed cameras for monitoring applications. More advanced applications integrate live data and feedback from different sources, such as parking guidance and information systems, weather information. Most of Intelligent Transportation Systems are based on vehicle detection, classification and speed estimation.

Intelligent Traffic Systems can be divided into three main groups:

1) Information systems;
2) Data acquisition and processing systems;
3) Traffic management systems;

In order to have a single ITS with full functionality all these systems must be combined and connected with logical connections. Many of the above mentioned systems require vehicles detection, classification and movement speed estimation. Vehicle detection using indirect measurement methods could be implemented in different ways.

Advanced Intelligent Traffic System are receiving and processing information about traffic flow and flow intensity in real time reflecting live situation. Vehicle detection methods and equipment are integral part of the traffic management system [1–3].

Scientific literature describes different methods for the vehicle detection. Because of huge vehicles variety there are no completely universal methods for detection. Vehicle detection problems arising because of vehicle movement speed variations which can be up to 130 km/h in the highways but in intersections and parking places are needed to identify standing cars. For this reason vehicle detection methods used to detect moving vehicles are not suitable to detect standing vehicles. Methods used for vehicle detection can be divided into two groups – intrusive and non-intrusive (Fig. 1).

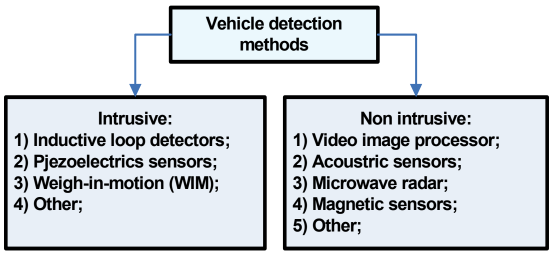

Fig. 1. Types of vehicle detection methods

Intrusive sensors include inductive loops, magnetometers, micro-loop probes, pneumatic road tubes, piezoelectric cables and other weigh-in-motion sensors. These devices are installed directly on the pavement surface, in saw-cuts, in road surface holes by tunneling under the surface or by anchoring directly to the pavement surface as is the case with pneumatic road tubes. The operation of most of these sensors is well understood as they generally represent applications of mature technologies to traffic tracking. The drawbacks to their use include disruption of traffic for installation and repair and failures associated with installations in poor road surfaces and use of substandard installation procedures. Resurfacing of roadways and utility repair can also create the need to reinstall these types of sensors [2].

Non-intrusive technologies do not require the hard installation sensors directly onto or into the road surface. Sensors for non-intrusive technologies are mounted overhead or on the side of the roadway. Video image processor, microwave radar, active and passive infrared sensors, ultrasonic sensors, passive acoustic array sensors, and magnetic field sensors belongs to this group [2].

Intrusive and non-intrusive methods collect following information: traffic speed, vehicle classification, traffic intensity.

This paper proposes an alternative, efficient, accurate and simple vehicle detection method based on anisotropic magneto-resistive (AMR) sensor.

Vehicle detection based on magnetic field sensor

Vehicles mostly are made of metal parts. When car is moving it distorts earth's magnetic field. Magnetic field distortions made by moving car can be easily detected and measured on the road. Up to now has been used an integrated inductive loop in asphalt for vehicle identification but it requires quite large interventions in the road surface.

Magnetic field sensors can be used for auto detection. As known, the earth has a quite strong natural magnetic field which strength may vary from 3.1 × 10-5 up to 6.2 × 10-5 T It is like a huge magnet. Despite magnetic anomalies earth's magnetic field is quite continuous.

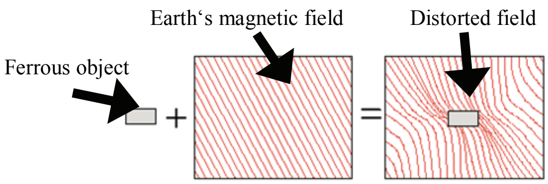

Fig. 2. Ferrous object impact to earth‘s magnetic field [6]

Ferrous object placed on the earth's magnetic field distorts it. In some places around the object field is stronger and in some places it decreases. Earth's magnetic field variation made by metallic object is presented in Figure 2. Most parts of a car are made of metals (iron, steel, nickel cobalt, etc.). Metallic parts of the car are located not evenly. In the engine compartment and on the axis metal concentration is bigger. As a result the earth's magnetic field along car is different. At the axis the magnetic field is more stronger, this can be seen in Figure 3. Lines show the earth's magnetic field changes with car's impact.

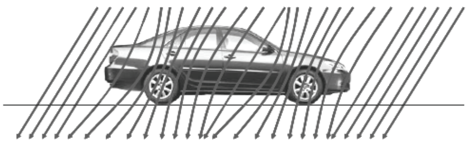

Fig. 3. Earth’s magnetic field along vehicle [4]

There are many ways to measure the earth's magnetic field. Most of them are based on the relationship between the magnetic and electric fields. Magnetic field sensing technique is widely used in physics and chemistry.

There are many other factors, especially characteristics of frequency, size and speed of which is determined by the use of sensors in certain areas. Magnetic sensors are classified according to the measured magnetic field range. In this way, sensors are divided into three main groups: the low magnetic field, medium, and high magnetic field. Sensors that can help measure the fields smaller than the 1 micro gauss will be classed low field sensors. Sensors that can measure from 1 micro gauss to 10 gauss are the medium magnetic field sensors or otherwise known as the earth's magnetic field sensors. Sensors that can measure more than 10 gauss of magnetic field are classified as strong magnetic field sensors. Magnetic sensors continue to fall under the principle of operation. The magnetic field is composed of a magnetic field strength and direction of the vector. Magnetic sensors can measure the magnetic field in several ways. Magnetic sensors which measure total magnetic field strength no matter the direction, also known as scalar sensors. Other sensors measure the magnetic field components related individual axes (X, Y, Z).

Anisotropic magneto-resistive (AMR) sensors measured magnetic field range fully covers the earth's magnetic field range. Magnetic field sensor consists of Anisotropic magnetic resistive (AMR) materials, nickel-iron alloy known as the permaloy. Permaloy have high magnetic permeability. Sensitive part of magnetic sensor is formed by depositing resistive permaloy strips on a silicon wafer. These strips are connected to the Winston Bridge as shown in Fig. 4.

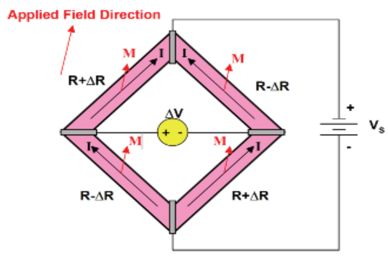

Fig. 4. AMR bridge [5]

Sensitive elements are combined into the measurement bridge to increase sensitivity. Such sensor has a relatively high linearity. Sensor’s working frequency ranges up to 5MHz. Sensor reacts instantly to changes in magnetic field. The magnetic sensor measures magnetic field direction and strength.

For the research of vehicle detection using the earth's magnetic field changes has been selected LSM303DLH ST Microelectronics 3-axis magnetic sensor which measures magnetic field in range of ± 8.1 G. This sensor contains a signal processing module and a digital I ² C interface.

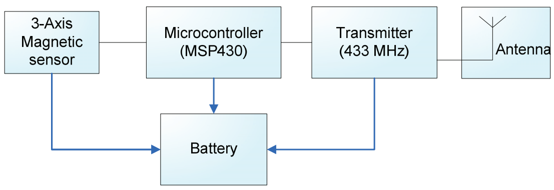

Fig. 5 Wireless magnetic sensor block diagram

For vehicle detection research of has been designed a sensor prototype. Sensor has been connected via I²C interface to the MSP430F5438 microcontroller. Data has been transmitted wirelessly into computer and recorded into a file for further processing. This data acquisition system is shown in Fig. 5 and Fig. 6.

Has been performed an experiment to test sensor’s suitability to detect the car at parking lot. Experiment has been made in such order: first stage – car entering parking place; second stage – car standing in parking place and third stage – car leaving parking space. First car was parked in front. Thereafter experiment was repeated parking car backward. Research results are shown in Fig. 7 and Fig. 8.

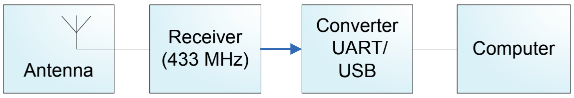

Fig. 6. Receiver block diagram

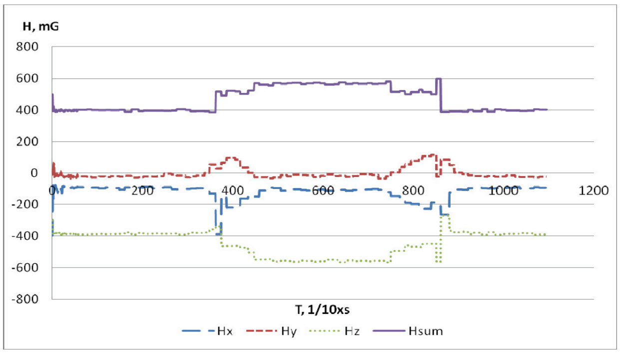

Fig. 7. Vehicle parked forward into parking place

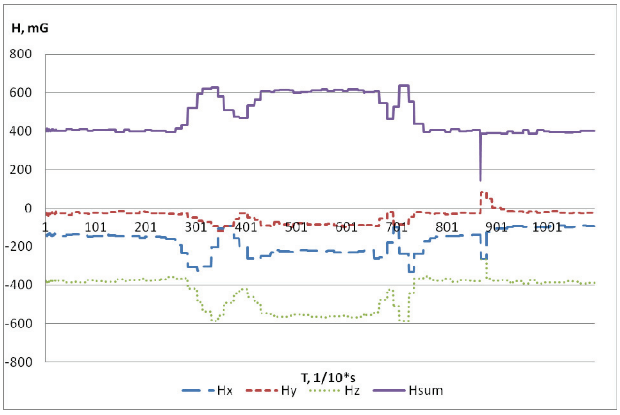

Fig. 8. Vehicle parked backward into parking place

Research results shows that sensor can be used for detecting car above the sensor. At the moment of the entrance of the parking place magnetic field components varies differently. At certain moment increased total magnetic field strength starts to weaken. When car stops in parking place field stabilizes and components are stabilized. Although the total magnetic field strength and increase in the minimum impact on the car has magnetic field component Y-axis (curve Hy). The results show that there is a difference in how the car is parked: forward or backward. Moving forward Hy component has changed only slightly, when parking backward Hy and Hz values remained the same.

The following research was carried out how the earth's magnetic field is distributed across parking lot. The magnetic field has been measured according to the diagram in Fig. 8, magnetic field measurement points are marked in red.

After measurement magnetic field of all the parking lots from the graph Hsum in Fig. 8, can be seen that total magnetic field varies slightly. Components Hx, Hy, Hz of the magnetic field in Fig. 10 – Fig. 12 varies slightly higher. This can be explained by the fact that parking lot is a relatively large. Magnetic anomaly occurs when other metallic objects impacts magnetic field. This is perfecty illustrated by the peak in the left corner in all graphs (it means in 1st parking place) in Fig. 9. This is because in this parking lot is placed manhole of city engineering services with huge metal cover.

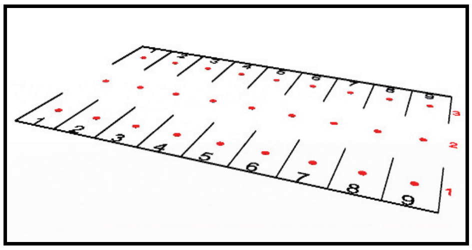

Fig. 9. Magnetic field measurement points in the parking lot

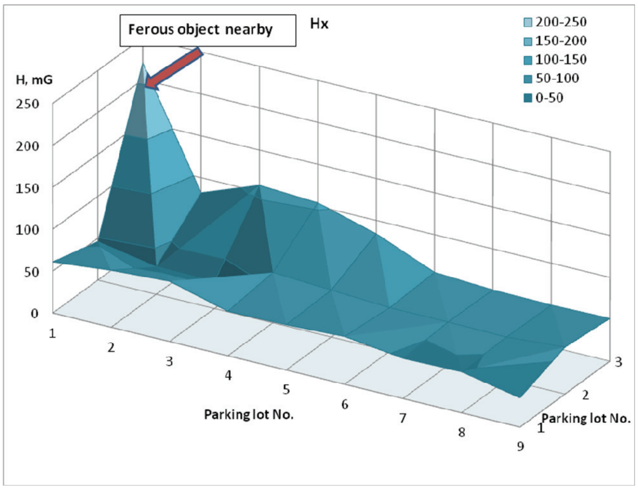

Fig. 10. Magnetic field distribution of component Hx in the parking lot

For further research has been chosen parking lot at the location without the magnetic anomalies and metal objects near it. Test results displayed in Fig. 14 – Fig. 16 when parking place is free and in Fig. 17 – Fig. 20 displayed results when can is standing in parking place.

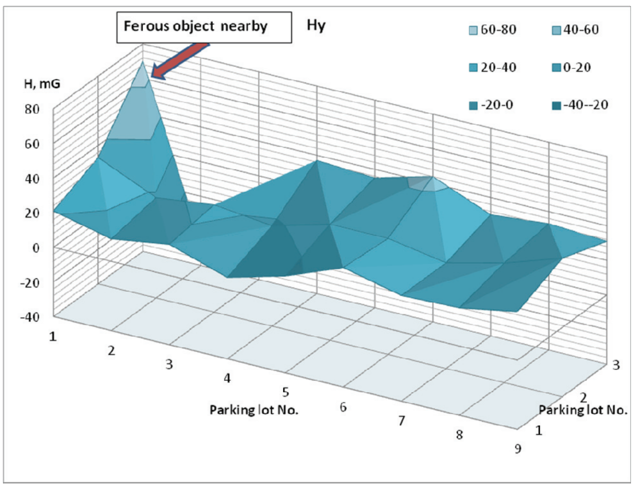

Fig. 11. Magnetic field distribution of component Hy in the parking lot

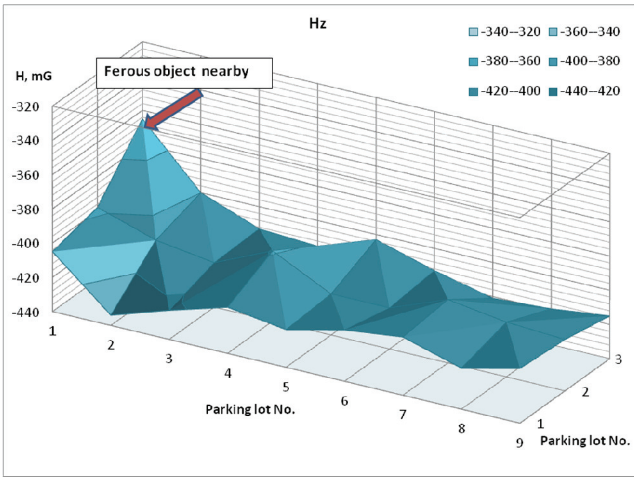

Fig. 12. Magnetic field distribution of component Hz in the parking lot

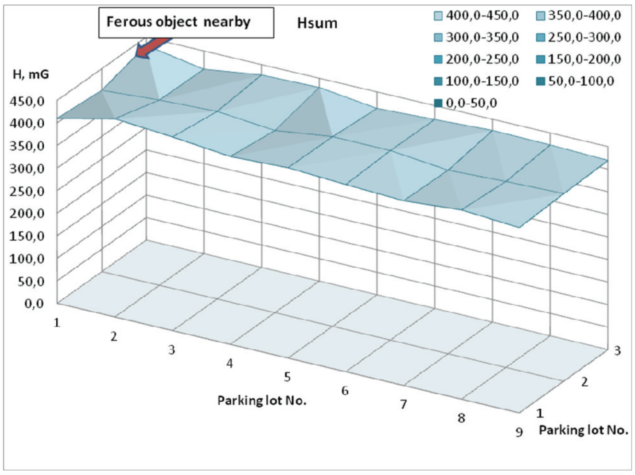

Fig. 13. Magnetic field distribution of Hsum in the parking lot

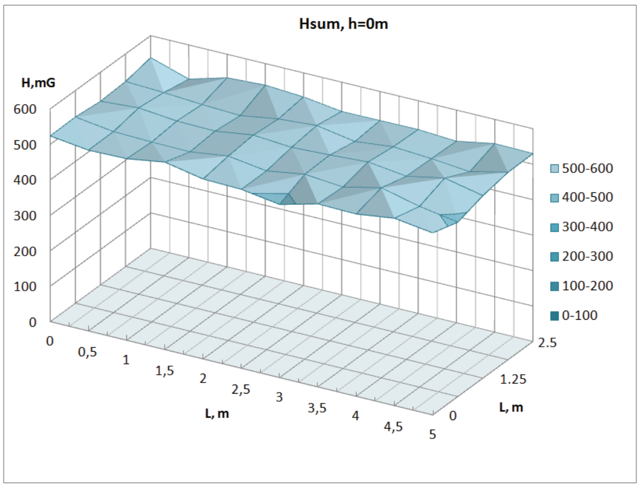

Fig. 14. Magnetic field distribution Hsum h=0 m at free parking space

This study shows earth's magnetic field is distributed fairly evenly, while standing car makes larger distortions of magnetic field in the front and the back near the car axes. Also in the front of car are located engine and gear box.

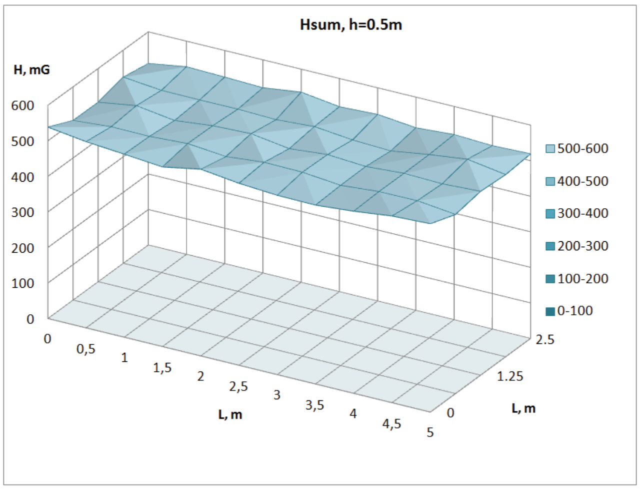

Fig. 15. Magnetic field distribution Hsum h=0,5 m at free parking space

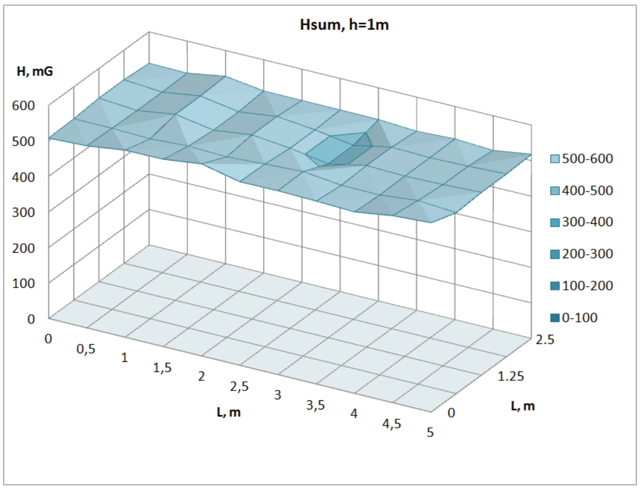

Fig. 16. Magnetic field distribution Hsum h=1 m at free parking space

During the experiment were observed that magnetic field components vary differently while a car is moving. For this reason has been made dynamic test with a car passing through the sensor.

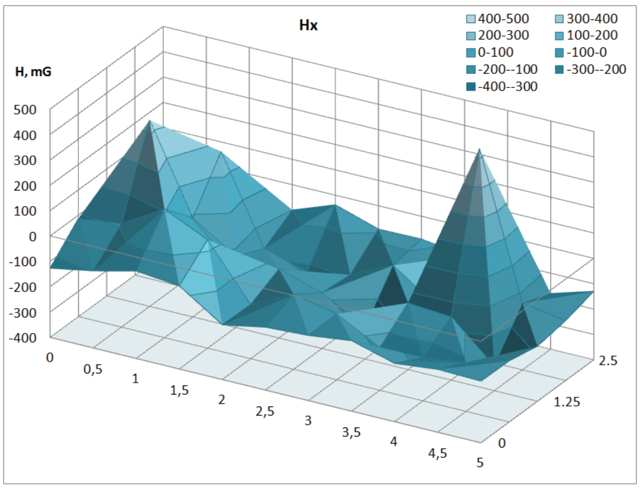

Fig. 17. Magnetic field distribution at parking space with a car

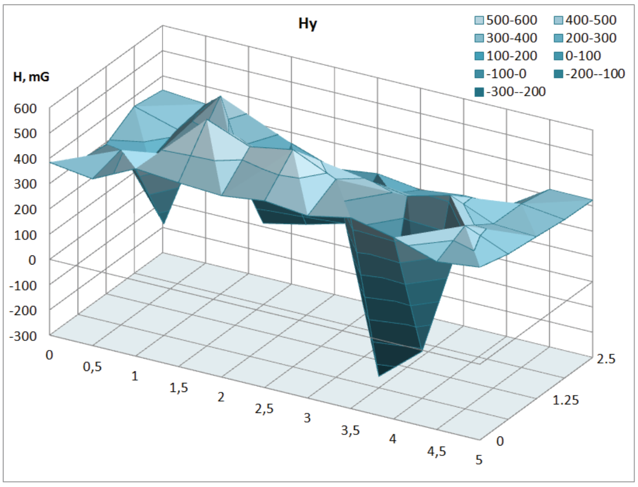

Fig. 18. Magnetic field distribution at parking space with a car

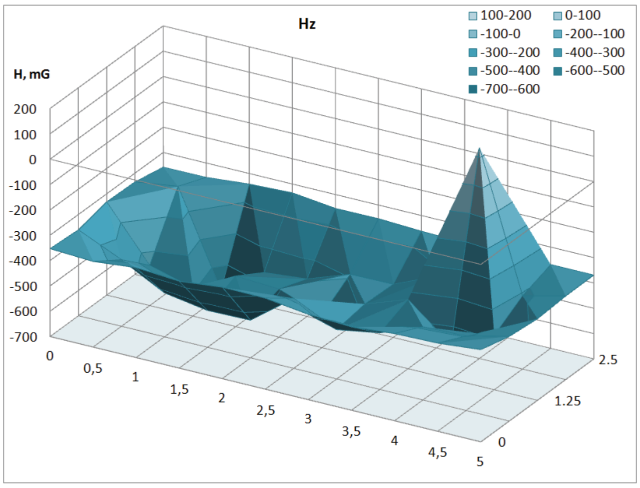

Fig. 19. Magnetic field distribution at parking space with a car

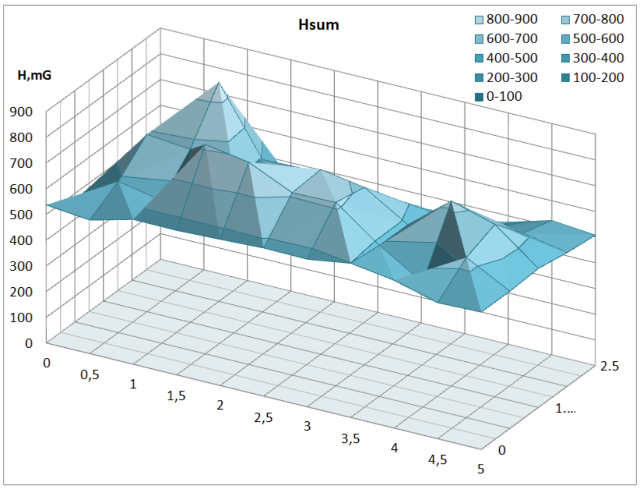

Fig. 20. Magnetic field distribution at parking space with a car

It has verified the ability of the magnetic sensor to detect moving vehicles. In this case the sensor has been placed on the pavement and the car just moved over it, the reslt are shown in Fig. 21. Survey results shows the biggest change in the z component of the total magnetic field. Meanwhile the amplitude of X and Y components first rises then falls to initial level then rises again and finally after passing the car comes back to the baseline value.

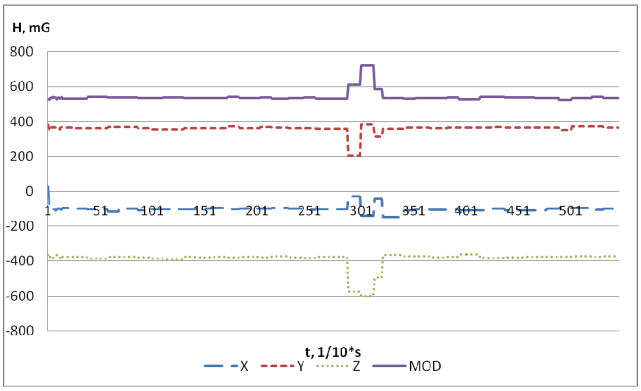

Fig. 21. Magnetic signal then vehicle passes through the sensor

Conclusions

The research shows that car detection methods using magnetoresistive magnetic field sensors which measure changes of the earth's magnetic field are fully realized.

Earth's magnetic field has been distorted not only by cars but also with adjacent huge metal objects. The detection accuracy is higher when avoiding these huge metal objects but sometimes it could be difficult or even impossible. For this reason vehicle detection using the earth's magnetic field is quite complicated.

Vehicle detection requires magnetic field signal processing. To detect not moving vehicle can be used the signal amplitude. But the choice of magnetic field measurement components must be properly made. Some of the components are not informative, such as Hy magnetic field component. Using this component vehicle could not be detected when in parking stands backward.

Dynamic testing has showed that signal processing methods used for moving vehicle detection are not suitable for detection not moving objects which require different signal processing methods.

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Provided currently used methods for vehicle detection in the intelligent transportation systems. Considered possibility to detect the transport using magnetic field sensors. Describes operating principles of the anisotropic magneto-resistive sensor. Examined how the vehicle affects the earth's magnetic field. Studied the earth's magnetic field strength distribution in the empty parking lot and specific parking place, results displayed graphically. Measured a moving vehicle is stationary and the magnetic field signals. Analyzing further signal processing of magnetic sensor and processing algorithms possible to use. Ill. 17, bibl. 6 (in English; abstracts in English and Lithuanian).

A. Daubaras, M. Žilys. Magnetorezistorinių jutiklių taikymas transporto priemonėms aptikti // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2012. – Nr. 2(118). – P. 27–32.

Pateikti šiuo metu taikomi metodai ir galimybės aptikti transporto priemones intelektualiose transporto valdymo sistemose. Nagrinėjama galimybė transporto priemonėms aptikti naudoti magnetinio lauko jutiklius. Aprašomas anizotropinių magnetorezistorinių jutiklių veikimo principas. Tiriama, kokią įtaką automobilis turi žemės magnetiniam laukui. Tiriamas žemės magnetinio lauko stiprio pasiskirstymas tuščioje stovėjimo aikštelėje bei konkrečioje automobilio statymo vietoje ir atvaizduojama tai grafiškai. Išmatuojami judančios ir stovinčios transporto priemonės magnetinio lauko signalai. Nagrinėjamas tolesnis magnetinio jutiklio signalų apdorojimas ir galimų apdorojimo algoritmų naudojimas. Il. 17, bibl. 6 (anglų kalba; santraukos anglų ir lietuvių k.).