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# POSSIBILITIES OF USING A WIRELESS TELEMETRY SYSTEM OF A RECREATIONAL VEHICLE (OFF-ROAD)

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***Abstract***

*The development of electronic systems has significantly contributed to the rapid increase in the number of controllers working in vehicles, and thus the amount of data transferred between them. The large amount of information sent prevents the driver from directly mastering or understanding them, hence it was necessary to limit the displayed parameters on the instrument cluster to the most important ones, so that the driver can focus on driving. However, in motor sports and in various types of road tests or research, where the driver is supported by an additional team of engineers, information sent between vehicle controllers can prove extremely valuable. Most often, the whole staff of people responsible for conducted traction tests does not occupy the vehicle, so as not to disturb the conditions. Their analysis usually takes place in a designated service spot, in which case the parameters from the on-board data transmission network are usually transmitted by radio from the vehicle to the archiving system. Therefore, research into the development of wireless data transmission systems from vehicle controllers is also carried out at the Opole University of Technology. This article describes the possibilities of using a system built at the Opole University of Technology for wireless conduction of diagnostics and analysis of current operating parameters of a recreational All-Terrain Vehicle (ATV). In addition, in the designed system, it is also possible to connect external sensors to analyse parameters normally not registered during the course on normal vehicle operation.*

***Keywords:*** *telemetry, wireless data acquisition, all-terrain vehicle, CAN bus*

## 1. Introduction

Current advances in the field of mechatronics (understood as a combination of mechanical engineering, electronics, control, and informatics in a situation where all those fields are integrated into a single process, i.e. for vehicle on-board systems management) are focused on miniaturization. Particular potential can be seen in telecommunications, where the computational power of smartphone mobile devices is growing. These devices are nowadays equipped with multi-core processors, which allow introducing new functionalities, including utilization in the automotive field. They not only offer access to multimedia, providing entertainment, but also serve as instant messaging devices, navigation systems and are a potential source of additional information useful to the driver. Moreover, the wireless communication, which is abundant nowadays, allows for two-way communication with the device. This makes conducting basic vehicle diagnostics with the use of a smartphone possible. In the aspect of e-mobility, maintenance of electrical vehicles with the use of dedicated apps is widespread. In respect to day-to-day maintenance, there are an increasing number of applications allowing to diagnose the vehicle and monitor its drivetrain operation parameters [5, 6].

In this work, an On-line Visualization System for monitoring drivetrain operating parameters of an off-road vehicle (OVS Off-Road) developed and the Department of Vehicles of Opole

University of Technology is shown. The system is comprised of a wireless transmitter, a CAN BUS on-board network communication maintenance system, an acceleration sensor and software for PC computer and Android mobile operating system for smartphone devices.

## 2. The telemetry system

Modern cars are equipped with a plethora of sensors monitoring vehicle performance and operating parameters. These sensors range from the ones responsible for vehicle occupant safety to the ones ensuring proper engine operation and travelling comfort of the driver and passengers. Such a large, ever-increasing amount of data has forced the vehicle manufacturers to utilize rapid data exchange buses. In the 1980s, leading car manufacturers, in cooperation with Robert Bosch GmbH, have begun working on a digital bus for correct transmission of such a large amount of data. The effect of this cooperation was the creation of a CAN (Controller Area Network) bus, initially used only to transmit a certain portion of data in the vehicle. Nowadays, the CAN bus has become a main means of data exchange in motor vehicles. The introduced standard has proven to be very reliable and elastic. Despite a great increase in electronic and mechatronic systems introduced in motor vehicles, the CAN bus provides proper communication between separate vehicle control and management units. A twisted pair cable is most commonly used to connect separate units of the CAN system. Due to the use of this medium for communication, there is a reduction in electromagnetic noise and cross-interference. Maximum data transmission speed is up to 1 Mb/s over the distance of 40 m, dropping with an increase in distance, for example to 250 kb/s over the distance of 250 m. In many instances, there is no separate control unit for monitoring the operation of the whole network. Those are called multi-master type buses. The communication is of broadcast types, as the communicates sent to the bus are received by all of the devices connected to it. Information sent between the controllers in the CAN bus is exchanged with the use of a maximum of two wires, marked CAN_L and CAN_H appropriately, which significantly reduces the amount of wiring in the vehicle. The same information is transmitted in both CAN_L and CAN_H wires; however, the signals are mutually inverted. If there is a logical 0 on one of the bus wires, there is a logical 1 on the other one, and inversely. An actual signal registered on the CAN bus is shown in Fig. 1.

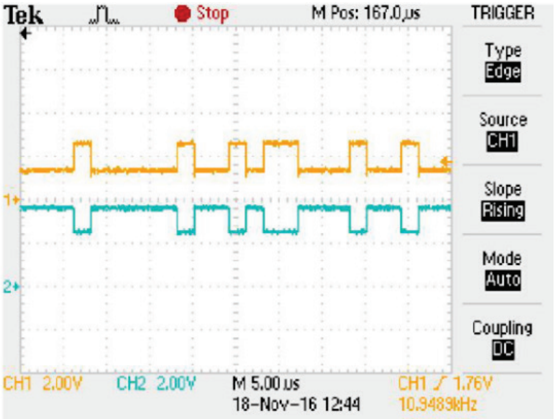

*Fig. 1. Signal on CAN_L and CAN_H lines*

The CAN bus is normalized throughout the world, however labels for transmitted data may vary. The CAN bus has also seen widespread use in off-road vehicles, industrial automatics and many other daily-use devices.

Many manufacturers of sports, recreational and utility vehicles are also eager to employ the CAN bus in their vehicles. The examples of this can be the Polaris Sportsman (Fig. 2) and Polaris RZR All-Terrain Vehicles (ATVs).

*Fig. 2. Polaris Sportsman All-Terrain Vehicle*

Data from sensors sent within the CAN bus is not directly visible to the end user of the vehicle. Only after being received and processed by appropriate controllers, it can be shown in the form of prompts or control lights. The number of information available to the end user in an off-road vehicle is relatively small, as the user can choose a single currently displayed parameter with the push of a button. In reality, the number of data available within the CAN bus is much greater.

Usually, the amount of data displayed on the vehicle's instrument cluster is sufficient for an average user. However, it proves to be insufficient in the course of conducting various road tests. Therefore, a universal measurement system allowing for wireless data transmission into a PC computer and its writing on the computer's hard disk was developed at the Department of Vehicles at Opole University of Technology.

The developed data transmission system does not require any alterations to the CAN bus. However, it does require connecting the transmitting device to the diagnostic connector located under the vehicle's bonnet. After being connected, the device draws power from the connector and collects information sent by the CAN bus. A built-in microprocessor reads, interprets, and recalculates the data, after which it sends it to the Bluetooth transmitter and a wireless UART radio transmitter working at the frequency of 433 MHz with a range of up to 1 km [1-3]. A flow chart of the system is shown in Fig. 3.

*Fig. 3. A flow chart of designed data visualization system*

In the case of road tests, or as is common with All-Terrain Vehicles, off-road tests, an important information to the researcher is vehicle performance while in motion. Information about current position of the vehicle or its accelerations can be harvested with the use of a three-axis acceleration sensor or the gyroscope [7]. There is a wide selection of sensors that could be used to build the system described in this article. However, the authors have decided to use a 3DM-GX3-25 type sensor that was already proven capable in previous research. It has a sealed enclosure, which ensures proper operation in difficult conditions, which are common in case of an ATV. This sensor sends the measured data to the device built by the authors with the use of an UART protocol with a transmission speed of 115200 bps. Basic parameters of the sensor are given below:

- attitude heading range: 360° about all 3 axes,
- accelerometer range: ±5g standard,
- gyroscope range: ±300°/sec standard,
- static accuracy: ±0.5° pitch, roll, heading typical for static test conditions.

Placement of the sensor during tests is shown in Fig. 4.

*Fig. 4. Placement of the 3DM-GX3-25 sensor on the vehicle during tests*

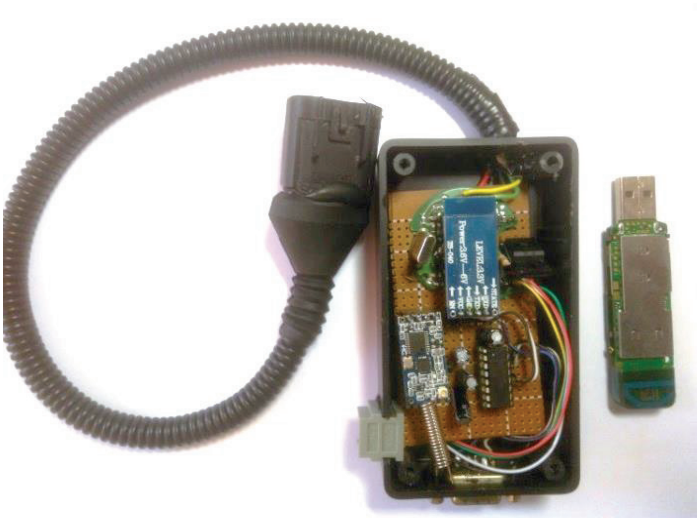

*Fig. 5. Data transmission system with a USB receiver*

A DB-9 type connector was used in the constructed telemetric system to connect the acceleration sensor. After the processor detects the connected accelerometer, an initialization of determination of type and amount of transmitted data commences. After this, the microprocessor switches to the receiving state. Received data is transmitted to the PC computer along with the data from the CAN bus using radio transmission [4]. The device is based on an efficient PIC18 family processor. Besides receiving data and sending it to the radio modules, the processor is also equipped with functions related to filtering received raw data. An additional advantage of the used processor is the ability to connect up to eight external analogue signals, for example from additional pressure, temperature, or strain sensors. The constructed telemetric system is shown in Fig. 5.

A part of designed system is the author-developed software-allowing preview of current vehicle operating parameters and saving the data to the computer's hard disk.

## 3. Off-road tests

The off-road tests were conducted at the Commons of Opole University of Technology. It is a grassy terrain with flat parts of land and terrain elevation of about 5% in certain parts. During the tests, a range of manoeuvres was performed, including abrupt acceleration, braking or drifting. The ATV was equipped with a telemetric system connected to the three-axis accelerometer and the gyroscope.

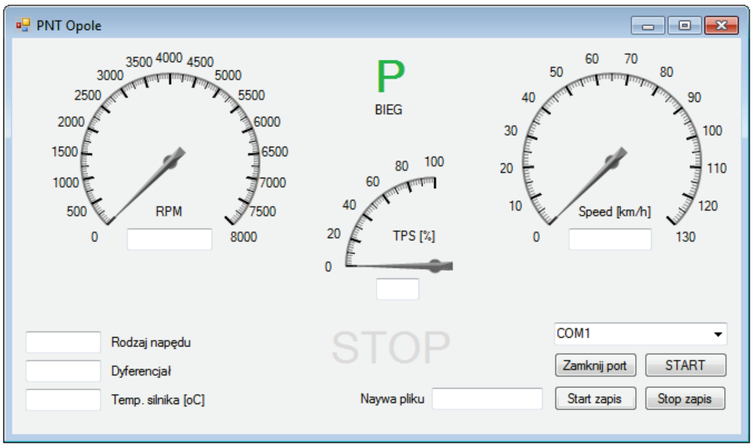

*Fig. 6. Received data visualization panel working with Windows operating system*

Data registered by the device can be used to reconstruct vehicle performance and its operating parameters during the tests. Changes in throttle position and engine speed during test-driving are shown in Fig. 7a. Vehicle speed during the test drive can also be recovered on the basis of registered data, as can be seen in Fig. 7b.

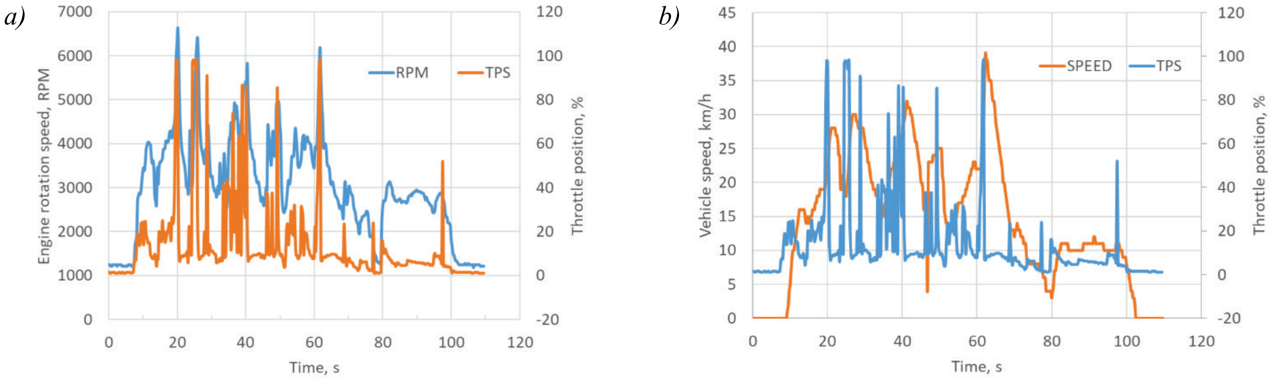

*Fig. 7. Off-road test registered data: a) throttle position and engine speed during off-road tests b) throttle position and vehicle speed during off-road tests*

Registered data from the CAN bus allows to observe the driver's operation of the brake pedal and vehicle speed during the tests (Fig. 8).

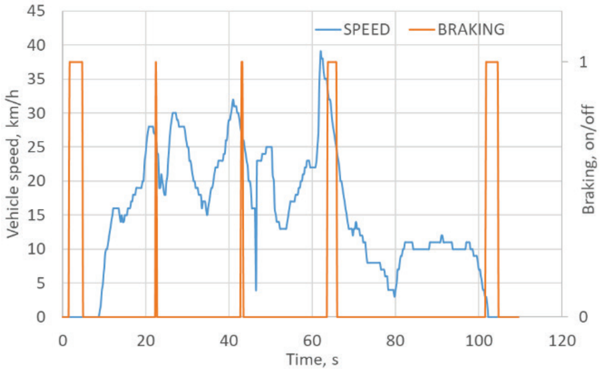

*Fig. 8. Vehicle speed and information on brake pedal use during off-road tests*

As was previously mentioned, the constructed device allows connecting an external acceleration sensor through an RS232 serial port. Data obtained from the sensor is also sent to the PC computer by a radio transmission. Accelerations noted in all three axes of the sensor are shown in Fig. 9. Forces acting on the vehicle and the driver can be determined on the basis of this data.

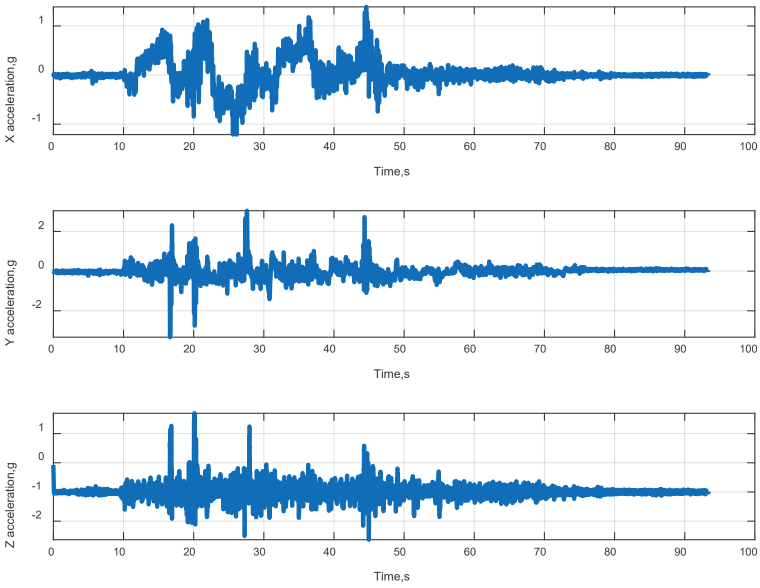

*Fig. 9. Accelerations acting on the vehicle during off-road tests in three axles*

As can be seen in Fig. 9, the greatest acceleration were noted in the X axis, which is in accordance with the way the sensor was mounted on the vehicle (Fig. 4) – this is the transverse axis of the vehicle. The Y-axis corresponds to the vehicle's axis of symmetry, whereas the Z-axis is oriented vertically in relation to the vehicle. During the tests drive, drifting (intentional oversteer) was performed while turning the vehicle left and right. As can be seen in Fig. 9, greatest values of side accelerations (and forces) acting on the vehicle and driver were noted during these manoeuvres. Accelerations related to the driver's use of acceleration and brake pedals (and therefore accelerating and braking the vehicle) can be seen in the Y-axis. In the Z-axis, the greatest influence on the acceleration comes from the inclination of the terrain through which the vehicle moves.

Thanks to the ability to connect an external accelerometer to the system, it was possible to recreate the vehicle trajectory along the test course. Data obtained from the gyroscope built into the accelerometer is shown in Fig. 10. This data also depicts the same test drive, during which the vehicle was put into a series of controlled slides (drifting). As was previously mentioned, the Z-axis is oriented vertically in relation to the vehicle. Therefore, greatest angular rotation velocity values were registered in Z-axis during drifting.

## 4. Summary and conclusions

Thanks to development of the On-line Visualization System for monitoring drivetrain-operating parameters of an off-road vehicle (OVS Off-Road), a starting platform for further development of the system were prepared. First of all, operating parameters from the on-board vehicle data transmission system were made available. Critical values that could result in vehicle failure were determined. Software for data visualization for two different operating systems was developed. The designed transmitting device is reconfigurable and can be further expanded and improved. Performed tests have shown good reliability and no occurrence of communication errors. The following is included in the scope of further development of the device:

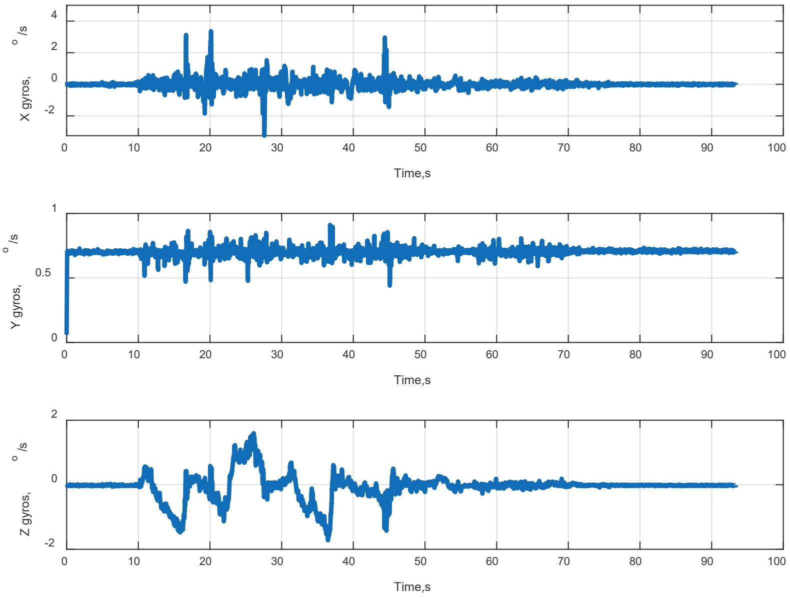

*Fig. 10. Angular rotation velocity for corresponding vehicle axes*

- an increase in the number of read parameters,
- utilization of the communication channel to control vehicle components, including control of the damping system,
- utilization of mobile device sensors to conduct measurements of acceleration, vehicle leaning or registering the travelled distance and track,
- connection of additional sensor to the analogue ports of the microprocessor.

The implementation of this project shows that mobile devices can be used not only as multimedia entertainment centres, but also as control, measurement, diagnostic or research tools. Data registered during road tests is incredibly valuable information, on the basis of which new diagnostic algorithms for off-road vehicles can be researched and designed [7].

## References

[1] Chaładyniak, D., *Wybrane technologie bezprzewodowej transmisji danych*, Zeszyty Naukowe Warszawskiej Wyższej Szkoły Informatyki, T. 5, 2011.
[2] Grzywiak, A., Rostyński, M., Pikiewicz, P., *Sieci bezprzewodowe*, WSB, 2009.
[3] Kurytnik, I. P., Karpiński, M., *Bezprzewodowa transmisja informacji*, WPAK, Warszawa 2008.
[4] Makowski, D., *Technologie komunikacji bezprzewodowej*, Wprowadzenie do przedmiotu, prezentacja w ramach EFS, 2015.
[5] Merkisz, J., Mazurek, S., *Pokładowe systemy diagnostyczne pojazdów samochodowych*, WKŁ, 2006.
[6] Merkisz, J., Mazurek, S., Pielecha, J., *Pokładowe urządzenia rejestrujące w samochodach*, Wydawnictwo Politechniki Poznańskiej, 2007.
[7] Prażnowski, K., Brol, S., Augustynowicz, A., *Identification of static unbalance wheel of passenger car carried out on a Road*, Solid State Phenomena, Trans Tech Publications, Vol. 214, pp. 48-57, Switzerland 2014.

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