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Systems for collecting and acquiring the dynamic parameters of special vehicles for displacement in special conditions

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Abstract. The data acquisition systems, depending on their complexity can provide a clear and real image of the dynamic movements of vehicles. The performance offered by these systems are closely related to the number of monitored parameters, data transfer speed, the sensitivity of detection factors and the accuracy of the data. Displacements of the special vehicles is generally, is conditioned by a number of specific factors that influence each other in time and space. They create different links, interdependent and complex at the same time, for the importance of action taken. When vehicles is travel under special circumstances (terrain, climate), these are substantially influenced by the dynamic factor, due to the great resistance encounter in advancing. The research highlights through the combined by used of modern equipment, a new concept of dynamic data acquisition, in such conditions. Development of acquisition system in a new complex shape, highlights the large number of data collected about the actual characteristics of the land in which the displacement is made of. By further valorisation of the data will be properly identified correlations between peculiarities of land in relation to their GPS position, and to determination accurate terrain roughness factor and its influence on vehicle dynamics.

1. Introduction

Systems for collecting and acquiring data on dynamic vehicle parameters are based on highly sensitive, high-resolution components whit linear characteristics of the measurement and signal adaptation circuits introduced into the system.

In order to obtain conclusive data on some parameters during the movement of vehicles in different terrain areas, may be used special equipment in accordance with the intended purpose, but also

equipment that is independently made for certain data acquisitions. The complexity of the equipment generates a clearer picture of the observed phenomena, the number of monitored parameters and /or the accuracy of the data obtained. The objectives set forth in the present paper are defined by the establishing of equipment capable of accurately recording and reproducing the values of dynamic parameters while driving in special conditions.
The identification of optimal solutions for data collection systems is later associated with determinations on the characteristics of the terrain in which the travels are performed, the identification of the roughness of the road and the vibrations generated on different sections of the road, or the determination of the level of comfort perceived by the vehicle's staff while driving under special conditions.

2. The special conditions of travel

The special conditions in which the travel is made can be viewed under terrain structure aspects, from the point of view the season or the atmospheric conditions of the moment.
These conditions, in any time substantially alter the dynamics of the vehicle and driving behavior of the driver. Rugged terrain and hardly accessible is in generally devoid of practicable treadmills, which puts vehicles at very high demands, creates problems for drivers and sometimes generates the impossibility of continuing the journey. The obstacles that appearing will be tackled at a certain angle, as it is known that the direct approach causes shocks that can break the suspension springs. The travel speed varies depending on the incline of the slope, the angle of attack of the wheels, and the current weather conditions. Climate conditions have a major influence on the movements of special vehicles due to their permanent interaction with soil, atmospheric pressure, air humidity and temperature, factors that have a direct influence on engine start-up and operation. In the following pictures (Figure 1 and 2) two frequent situations in which special vehicles move under special conditions can be observed.

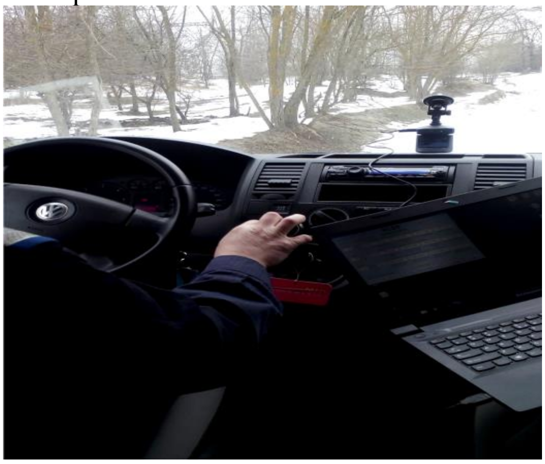

Figure 1. Traveling on a forest road in winter

Figure 2. Traveling on the very rough road

Also, on lands that in good weather the vehicles can move, after snow or rain they become hardly accessible or impassable. In such situations, there are issues related to the adhesion of the wheels, the maneuverability and stability of the vehicles having suffered. Manipulation and stability are primary requirements for safe travel on roads with very high inclination. The movement of special vehicles is generally conditioned by a number of specific factors (environment, vehicle, driver) that influence each other in time and space. They create different interdependent and complex relationships for the importance of the action taken. Driving a vehicle under special conditions is based on a permanent system of optimization of actions (figure 3), in accordance with the influence factors.
Dynamic displacement parameters of travels are the values that provide us with the information about the vehicle's operation, the exit information from the system so.

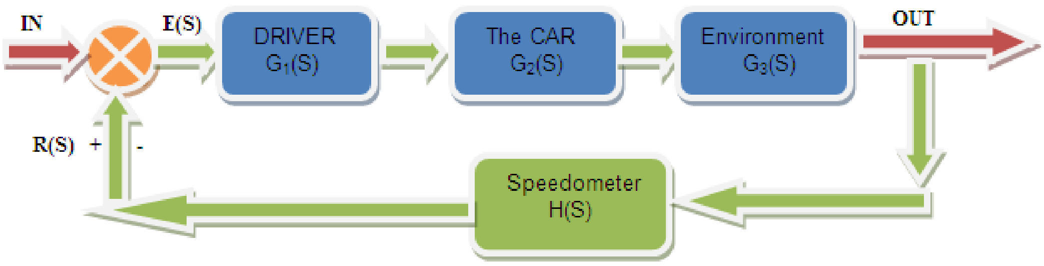

Figure 3. The block diagram of the control system during the driving of special vehicles

The change over time of a system variable (ex. land) is consistent with the initial system conditions and input data. Thus, we can describe the existing transfer function in the inverse feedback system by a mathematical expression:

$$T = \frac{EXIT}{ENTRANCE} = \frac{E_{(S)} \times G_{(S)}}{R_{(S)}} \quad (1)$$

In the case of displacements in areas with rough terrain or sandy / marshland terrain, the dynamic factor of the vehicles is greatly reduced due to the high resistance they encounter when advancing, the large slopes, but also the areas with curves that require small cornering rays. The following table (Table 1) shows the accessibility angle of different categories of military vehicles on unmanaged and rugged roads.

Table 1. Accessibility of vehicles on unmanaged roads

Category of motor vehicles	**The tiltings slope the angle of accessibility**
Cars, trucks	10^0 - 15^0
Special automobiles with capacity increased passage	20^0 - 30^0
Armored amphibious conveyors, traked	30^0 - 35^0

Understanding the traveling conditions creates the premises for the permanent optimization of the psycho-somatic factors of the vehicle driver in response to the multitude of external factors that affect his / her normality during the journey.

3. Equipment used in data acquisition

Nowadays, due to the need to approach a growing number of sizes, with increasing complexity, it is necessary to adopt equipments that allows the use of data in a varied conception, associated with their mathematical processing, which leads to accelerating the entire research program.
The Structure of the Data Acquisition System (SAD) in the process of research or monitoring of the functional parameters differs according to the intended purpose. Data acquisition systems, depending on their complexity, can provide a clear and realistic picture of the monitored processes. In general, the system components consist of: sensors / transducers, signal adaptation circuits, structures for data acquisition, processing and transmission. Their performance is closely related to the number of monitored parameters, the data transfer rate, the sensitivity of the detection factors, and the accuracy of the data provided.
The research is highlighted by the combination of modern equipment, a new concept for the acquisition of dynamic data resulting from the movement of vehicles under special conditions.
Designed SDA has a complex structure that highlights a large number of data on the characteristics of the land in which the travel is made, as well as about the dynamic factors recorded during the movement. In order to obtaining realistic data on the terrain in which the study was conducted, a series of high performance equipment was required to be permanently correlated with GPS systems.

The following image (Figure 4) shows the block diagram of the integrated data acquisition system, in accordance with the purpose proposed by the author.

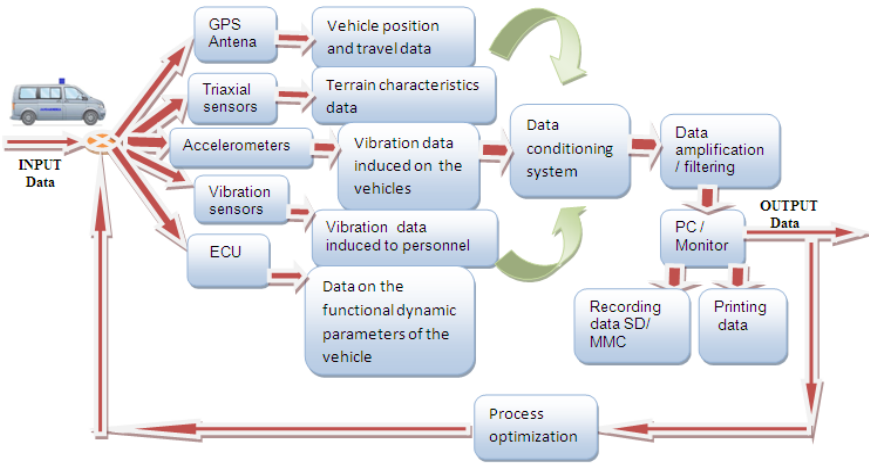

Figure 4. The block diagram of data acquisition developed for the research process

Thus, the equipment selected for the research sought to record the following data:

- Land features: length, altitude correlated with accelerations and travel speeds.
- Vibrations: at the car, seat, and driver structure of the car.
- Functional dynamic parameters of the vehicle while driving.

During the research process we used: transducers (displacement, speed, triaxial accelerometers), signal filters (Kalman, RCL), signal amplifiers and data acquisition equipment (Vbox, SpeedBox, DL-10 system). For these devices, data storage was possible both directly and after data processing at different time intervals. Also for data transmission there were options like: on shorter or longer distances. The processing of information acquired by equipment consists of various simple operations (comparisons), to complex mathematical processing (integration, differentiation, mediation). Before the data acquisition process, the equipments were subjected to the calibration process in order to obtain the most realistic values.

3.1. SpeedBox System [1]

The device is a equipment used in vehicle industry for the acquisition of data related to the movement of an automobile that moves at an increased speed. The equipment shown in the following figure (figure 5) is produced by Race Technology Ltd. and has the ability to perform real-time measurements with very high precision. The main features of the equipment are: Data read speed = 200Hz; GPS positioning speed = 20Hz; Data latency = 2-3ms.

Figure 5. SpeedBox central unit and accelerometers integrated to the position antenna [2]

In the following are presented how to position the GPS antenna on the vehicle structure (Figure 6), but also the degrees monitored by system on travel in varied terrain (Figure 7).

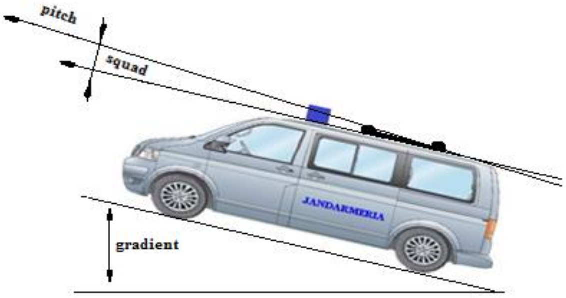

Figure 6. Mounting RF - GPS antenna on vehicle [2] **Figure 7**. Tracking system during travel [2]

For this system there is a recommendation to mount the perfectly aligned antennas on the vehicle's hood to maximize the number of satellites available for data collection, knowing that any acceleration of the vehicle will cause the changing correlation of the satellites to be used. SpeedBox functioning (Figure 8) is based on two accelerometer transducers (figure 9), which can measuring values + 6g. The data accuracy is 0.05km/h for steady speeds or moderate accelerations and 0.1km / h for strong accelerations.

Figure 8. Installing SpeedBox and Vbox units **Figure 9**. Triaxial accelerometer RLVBIMU 03

At low speeds below 10km/h the errors increase by approximately 0.5km/h. The GPS systems used calculate the travel speed at every 50ms (20Hz), data correlated with those from the accelerometers, in order to calculate the velocity with very high accuracy. The vehicle's position can be calculated with an accuracy of 1 to 3m depending on the received GPS signal.

3.2. Vbox III System [3]

Is a high-performance device for processing and recording real-time data via GPS (Figure 8). The device's functions are related to determining the position and speed of a moving vehicle. The device operates on the basis of the attachment of some acceleration transducers and offers the possibility to connect to the CAN bus of the vehicle. The data accuracy is 40cm CEP 95% using the local DGPS differential signal and 95% CEP 2cm based on its own antenna communication system. Associated with the Vbox, the RACELOGIC manufacturer recommends RLVBIMU 03 (figure 9) to acquire data on speed, acceleration, tilt angles (pitch, roll, tilt).

The main features are: data sampling rate = 100Hz; Reading speed = 100Hz; Transmission latency = 12.5ms. Signal parameters can be imported from a CAN database or manually entered by the operator. Generated data files are saved in text format, allowing the user to easily import them into different applications. The device works with a Windows application that provides data processing and post-processing facilities, such as generating the graphing and reports. The app also includes a Kalman filter-based filtering feature.

3.3. DL-10 System [2]

It is an equipment made by the author and is intended for determine the vehicle's dynamic values during travel. The equipment was developed using an ARDUINO Leonardo platform and is based on an ATMega 32U4 microcontroller. It provides real-time data about: position, speed, time, altitude. Two DL-10 devices (Figure 10) were used during the research process, centrally mounted in the dashboard area and behind the first row of seats.

Figure 10. DL-10 system and on-board positioning

The fastening of the data acquisition equipment behind the first row of seats was done centrally on the structure of the vehicle (Figure 11).

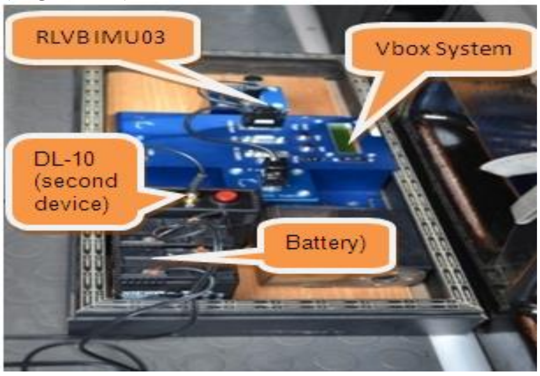

Figure 11. Fixing the equipment on the vehicle structure

The high speed of operations performed by data acquisition and processing systems also shows an increase in accuracy of the devices used. Thus, for the research activity, result a much improved ratio of some essential factors results: the quality and quantity of the resulting information, as well as a low cost.

4. Procedures and programs for data acquisition and processing

The development of the experimental program aimed to achieve some essential steps:

1). The steps of test preparation:
- preparation of the vehicle and personnel for the activities to be carried out;
- installing transducers and calibrating the equipment in accordance with the intended purpose;
- determining the measurements to be tracked;
- performing data acquisition.

2). Post-test steps:
- processing of purchased information;
- virtual analysis and verification of data;
- formulating the conclusions;
- establishing subsequent directions.

According to the purpose of the research, the author has set up his own positioning of the equipment (figure 12), so that the data provided by these keeps high accuracy.

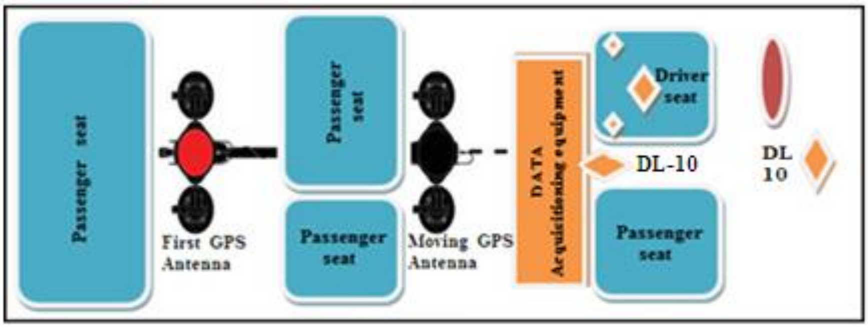

Figure 12. Scheme of positioning of monitoring and recording equipment

The programs developed by the specialized equipment manufacturers (ex. Race Technology) are related to the facilities offered by the equipment, but they can also perform some additional functions in the acquisition and processing process (Kalman filtration). The programs are adapted to other basic equipment developed in this respect. Also, purchased data can be rendered or analyzed using utility programs (Excel). Data acquisition procedures in the research aimed at receiving data reflecting the accuracy of the dynamic characteristics of the movement as well as the specifications of the field where the tests were performed. This fact has created the possibility to correctly understand the phenomena observed by establishing some directions:

* The correct identification of all the characteristics of the terrain in which the vehicle has travel, the time which has going on different portions of the road, the speeds and accelerations of the vehicle;

* Identification of all vibrations transmitted by the rugged route, suspended and unsuspended masses of the vehicle in the three directions: z, x, y. The following figure (Figure 13) shows the route exactly where the research was carried out, through the program of the SpeedBox System module and its GPS antenna.

Figure 13. The area in which the research was conducted

5. Parameters recorded during data acquisition

5.1. Data on land characteristics

The route followed during the research have presented various constructive features.

The SpeedBox GPS antenna was placed on the body, outside the vehicle, centrally positioned between the seats. The location mode giving good accuracy of vehicle positioning data in relation to the route followed, as well as accurate data on land characteristics. With the help of the analysis program, in the following picture (figure 14) we can observe the variations of the altitude of the recorded terrain during the movement, as well as the speed associated of the travel distance, through the GPS system.

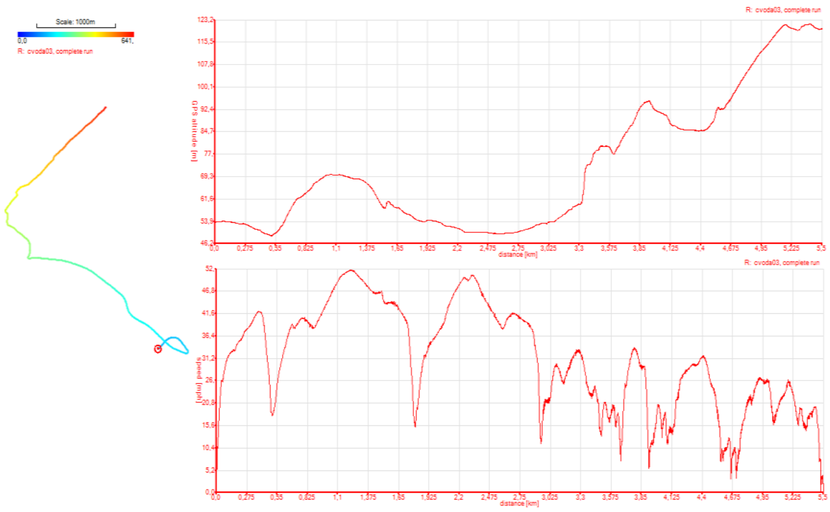

Figure 14. Graph with variations of terrain altitude and the travel speed

The rugged terrain imposed different travel speeds depending on the incline of the slope, the angle of attack of the wheels, the weather conditions at that time.

From the above we understand that, due to the multiple variations generated by the terrain, the car's dynamics characteristic (velocity) constantly presented fluctuations. These aspects represents negative influences on the travels of special vehicles.

The DL-10 system with GPS receiver (Figure 10) consisting of two receiver units, was fitted in accordance with the SpeedBox GPS antenna. This system provides data on the dynamic behaviour of the vehicle being monitored while driving. The data recorded by the equipment are NMEA type "GPRMC" written in text form, in accordance with NMEA 0183 standard. This standard specifies the requirements for the electrical signal and the data transmission protocol on a serial data bus between the GPS receiver and another device. Registered system sequences contain a minimum recommended PVT data (position, speed, time) to determine the solution, in based on the received GPS signal. [4]

According to the two reception units and the NMEA protocol, the following data were recorded:

* DL-10 (on-board unit):

- start of registration: $ GPRMC, 073726.400, A, 4421.0102, N, 02801.8743, E, 10.38,18.90, 130516 ,,, A * 64

- finishing the registration process:

$ GPRMC, 074124.600, A, 4420.1779, N, 02801.8935, E, D * 69,,, 0.00,127.13,130516

* DL-10 (unit of behind the chairs):

- start of registration: $ GPRMC, 073708.000, A, 4420.9921, N, 02801.8270, E, 9.12,44.49,130516 ,,, A * 55

- registration process completion: $ GPRMC, 074127.000, A, 4420.1785, N, 02801.8929, E, 0.00,140.63,130516 ,,, D * 64

In the following (Table 2) we exemplify the system-acquired data for the DL-10 on-board unit.

Table 2: The following table presents the explanation recorded data by DL 10

Opening sequence	**Final sequence**	**Data interpretation**
$GPRMC	$GPRMC	The identifier
073726.400	074124.600	Start time / end time of registration
A	A	Active signal
4421.0102,N	4420.1779,N	The latitude of N
02801.8743,E	02801.8935,E	The longitude of E
10.38	0.00	Speed in knots
18.90	127.13	Direction of travel in degrees
130516	130516	Registration date

A*64	D*69	Checksum

5.2. Vibration data transmited by the ground to vehicle

The triaxial accelerometers coordinated by the GPS antenna mounted on the vehicle structure provided data related by the vertical accelerations existing during the movement (Figure 15).

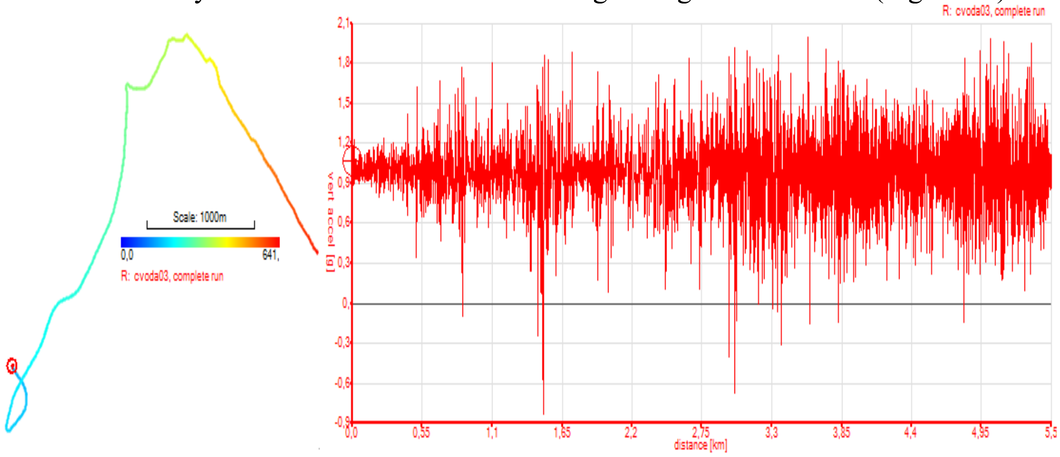

Figure 15. Vertical accelerations recorded on the road segment

Referring to the route and the orthogonal coordinate system (z, x, y) we can see in the following (Figure 16) the acceleration values transmitted on the vehicle's metallic structure on the three axes and recorded by the triaxial accelerometer RLVBIMU 03.

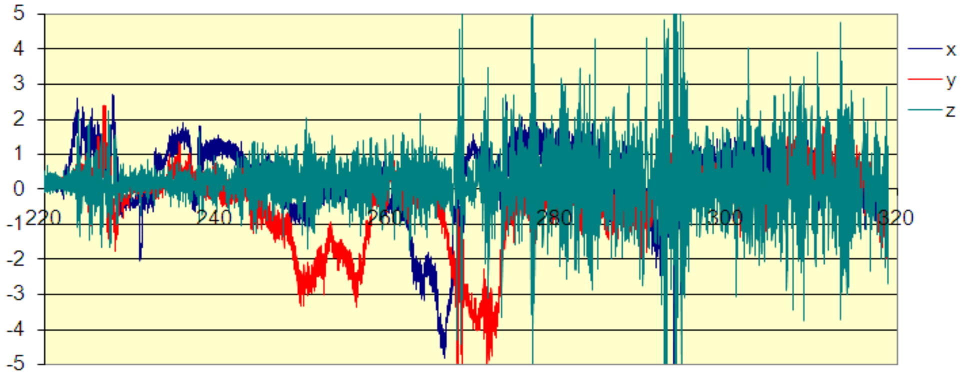

Figure 16. The unfiltered acceleration values manifested on the three axes: x, y, z.

The following image (Figure 17) represents the same values, but filtered using the program whit a CFC filter -10.

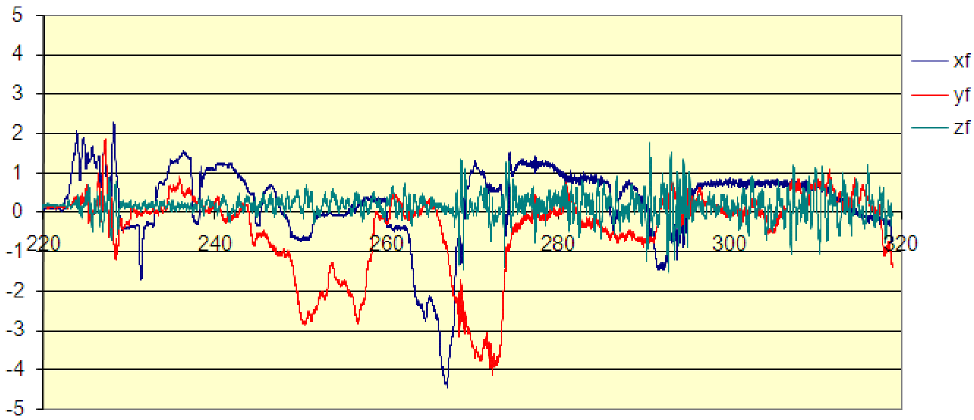

Figure 17. The accelerations on the three orthogonal axes: x, y, z after filtration

Nowadays, due to the need to approach a growing number of mathematically measured and mathematically matched quantities, with increasing complexity, it is necessary to adopt equipment that allows the use of data in a new conception, varied, associated with their rapid processing, which leads to the acceleration of the entire research program. The high speed realized of data acquisition and processing operations also results in a higher accuracy of the devices used, so the research activity results in a much improved ratio of the essential factors: the quality and quantity of the resulting information.

6. Conclusions

The research has highlighted the usefulness of using well-identified equipment for the intended purpose.

The complexity of the acquisition equipment, as well as the facilities made with the related programs, highlight the quantity and quality of the parameters recorded during the researches. Identifying and establishing methods of fitting the equipment for the intended purpose facilitates the obtaining of accurate data in any research. We can also mention that:

- obtaining precise and real data on the ground through selected equipment, highlights the possibility of knowing exactly the characteristics of the land in which the movement is taking place.
- the use of equipment whit GPS sensor is beneficial for significant correlations between the different equipment used in the ADS.
- the correlation of several equipment makes it possible to obtain as complex and precise data as possible on the phenomena pursued.

Reference:

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