Ground-Based Localization of Means of Municipal Transport with Use of Long-Range RFID

Marek Sumiła
Warsaw University of Technology, Poland

The article presents the usability of RFID technology in the process of localization of means of municipal transport. The following sections describe division of localization systems, opportunities of RFID systems today, investigation of accessible tags and readers to the main aim of localization. The long range readers and the method of RFID localization were introduced in section 3. Finally, the paper presents existing long range readers and their parameters.
Keywords: vehicles localization, RFID, long range passive readers

The localization of means of transport is used to improve transportation process by an automatic aim navigation, the optimization of drive route, the geographical positioning of meaning of transport and many other. From the point of view a passenger localization is useful during a trip planning.

Telematics systems providing such information have existed since '80 20th century and now we can see a rapid introduction of such systems in many Polish cities. Their main feature is providing passengers with real information about the time of arrival of means of transport. For example in the centre of Warsaw there were implemented optical panels on several tramway stops to inform about the time of approaching trams to the stop.

On the other hand, accurate place and time is important for a transport company. Such information is fundamental for documentations of their work and giving account to the Public Transport Authority. Moreover, comparing time-table with real time of arrival of a vehicle at stops can be used as a part of driver assessment or as a whole transport company. Detailed analysis of collected data can also provide a knowledge about the delay because of traffic jams, queue of arriving vehicles, etc.

1. GENERAL METHODS OF LOCALIZATION OF MEANS OF TRANSPORT

All existing localization systems can be divided into two principal groups:

- Satellite systems enabling the qualification of the position of an object in relation to satellites.
- Ground-based systems which enable the qualification of the position of the object in relation to the grounds broadcasting station.

The localization systems have various adaptations. Depending on the covered area, precision of localization, continuity or specific points of measure, there can be used one of the systems of first or second group. Furthermore, it should distinguish systems in which the location is made by the object or by the network.

There are three main groups of localization systems. They depend on the size of the area on which the location of objects is made and on the source of localization's signal.

- Global range use of satellite systems like GPS, INMARSAT-C, EUTELSAT.
- Ground – based systems possessing regional range (one city or country).

- Hybrid systems using potentialities of both of the earlier solutions.

Satellite systems are more often used for the localization of vehicles of municipal transport. Unfortunately, such systems still have low precision of positioning and they are not effective in tunnels, under bridges, in the compact settlement, near skyscrapers and trees. Such environmental constrains influence the effectiveness of work but it gives almost global range of operations. The ground-based systems are much more effective than satellite systems, which is thanks to their higher precision but unfortunately they are limited geographically and they need the network of radio beacons. The most popular solution is based on GSM network and its BTS stations. The system can work in the compact settlement. The disadvantage of this solution is among other things the of adaptation of the network to the aim of the localization of vehicles and limitations of network capacity, etc.

The RFID technology can be classified as a ground-based system. Using RFID to localize vehicles of municipal transport is a new approach to this problem. As main premises there can be enumerated:

- Well-known technology,
- Simple parts,
- Inexpensive cost of tags,
- Small, easy to hide parts
- Possibility of two ways transmission of information between tags and readers.

2. OVERVIEW OF RFID TECHNOLOGY

An RFID is a wireless communication technology that is used to unique identification of tagged objects or people. In the beginning it was provided for identification pallets and cases by Wal-Mart and the Department of Defense USA and their suppliers. Now, RFID is one of the most popular technology for [3]:

- Logistics and warehouse management: goods flow, warehouse management, and the flowing management of mail, parcel, and luggage.
- Intelligent parking management: parking management and automatic charge.
- Productive lines management: production process fixed identification.

- Product counterfeit-proof inspection: using memorizer's write-protect functions inside tags to identify true-false of products.
- Other fields: widely used in club management, library, student' school, consumption management, time management, dinner management and pool management.
- etc.

RFID technology includes three basic components:

- Tag (Transponder), which is composed of a semiconductor chip, an antenna, and in special case a battery,
- Interrogator (Reader), which is composed of an antenna, an RF electronics and control parts,
- Controller (Host), which is a workstation running database and control software.

The general principle of the work of the RFID systems consists of the modulation of amplitude, frequency, phase or PWM (Pulse Width Modulation) transmitted from the reader to the tag. It means that the tag and the interrogator communicate information between one another via radio waves provided that the tag enters the red zone of the interrogator [2].

The simplest tags transmit only their unique ID, more advanced contain batteries and chips that allow to store data. An example of such tag was put on fig. 1.
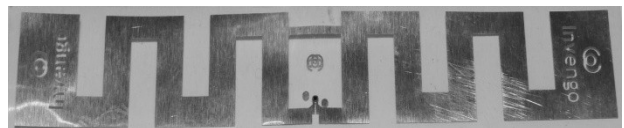

Fig. 1. An example of tag consist microchip.

RFID tags are present as passive tags, active tags and semi-passive tags. In contrast to passive tags, active tags are installed an on-board. The passive tags derive power to transmit data from the signal sent by the interrogator and contain energy in a small condenser. The semi-passive tags contain a power source but these sources are used only in special cases, for example to power on-board electronics.

Communication between tags and readers proceeds in low and high frequency bands. Low

frequency RFID bands are LF (125 – 143 kHz) and HF (13.56 MHz). High frequency bands are UHF (860 – 960 MHz) and MW (2.5 GHz) [1]. The choice of frequency affects the range of reading zone, cost of readers, speed of transmission and the resistance on electromagnetic interference.

3. VEHICLES'S LOCALIZATION WITH THE USE OF RFID

3.1. CONCEPTION OF THE SOLUTION

Technical possibilities of using RFID technology as a part of localization system appeared long before the introduction of the GPS. The use of RFID was limited by the power supply active tags. Using active tags was natural because of a longer range interaction than passive tags has. Till now passive tags have a range of influence which is about 30 cm. Maximum distance of such units works out usually less than 0.5 m. The range is possible to reach only when the tag and the reader are put together properly and they stay in this relation for a defined time. Such limitation is not easy to fulfill in the moving vehicles where the time of drive near the tag and the angle of tag's position can be different. The situation is different in the case of active tags. Their internal power supply allows to do the transmission on decidedly longer distance, coming to ten meters. Unfortunately, the source itself is unreliable because of the unforeseen factor – a weather condition.

At present there are known solutions of semi-passive tags. They have the same internal power as active tags, however it is activated only when the reader is close. The source of power is switching in to the idle state as the distance to the reader increases. It allows to save energy in the internal power supply but it is still unforeseen.

In such circumstances there was made an assumption that only the admissible solution is based on the passive unit under the condition that the range of interaction will be enlarged [5].

3.2. PRECISION OF LOCALIZATION

The most important in localization of municipal transport vehicles is a correlation between vehicle's position and the time of approaching to the point of localization. It is especially important for bus/tramp stops. The introduced RFID technology is easy to perform the task.

RFID technology allows to obtain very high precision in the localization process, which is less than a meter. Such a result comes from a predictable route of a transportation vehicle and suitably small distance between a tag and a reader in the place of detection. The condition of small distance is fulfilled especially in tram vehicles where the route of moving vehicles is defined. In a bus line the range of RFID signal may be longer and less precise can be narrowed to bus stops or bus lanes.

The precision of localization can be increased by increasing the number of RFID elements on the road. It is useful to localize important places of route, as stops, switches, traffic signaling, crossroads, underground stations, etc. An example of installation of RFID parts is presented on the figure 2.
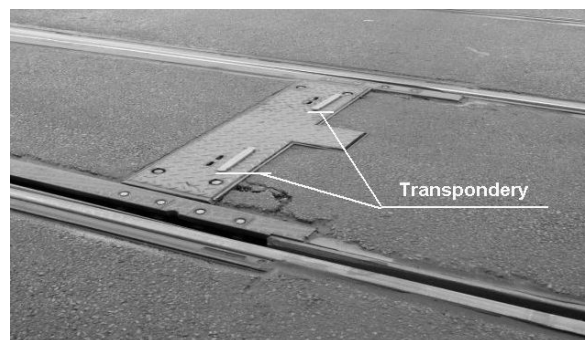

Fig. 2. Tags identifying a switch (a place of control).

3.3. TAGS AND READERS IN LOCALIZATION PROCESS

In this place it is worth to consider a general rule of location of two main parts of the RFID system (tags and readers). In most of localization systems design engineers decided to put readers in points of detection, for example doors, gates, passages, etc. Tags are connected to objects of recognition. Examples of such solutions can be found in highway telematics systems, car-parks, etc [4]. Such approach is substantiate for each case where the number of vehicles exceeds the number of places of recognitions. Using RFID to localization process leads to the situation where the number of vehicles is known and there are less of recognition points.

Moreover, readers need a power supply and they are more expensive than tags. In some cases they do not need power, which is an important premise to use such parts. So the misuse of the elements leads to the increase of the cost and to the decrease of the reliability of the system. Reliability is straightly connected to endangering the electronic parts of the reader on weather conditions, acts of vandalism, disturbance of power supply or electromagnetic interference.

One can enumerate more advantages. Using a passive tags allows to obtain operational reliability because the passive tag has not got electronic parts and even when it is damaged, it is cheaper to buy a new one. Next advantage is the safety of a localization process. If we admit that each of the tags has his own unique ID in the whole of urban infrastructure, we receive random stream of data without any geographical coordination. Other advantage is the possibility of using more advanced read/write tags which can be used as a road data store. Each vehicle can get or leave information for next means of transport approaching to the same point.

To sum up, tags are installed in the places to recognize in localization process. If readers are installed in correct way in each moving vehicle, it leads to the increase of reliability and a reduction of cost of the system.

3.4. SAFETY OF INFORMATION EXCHANGE IN PASSIVE TAGS

The separate issue is the safety of exchange data between tags and the antenna.

For security reasons, the transmission process between the tag and the antenna should be kept in a safe manner. We assume that the transmission is with the use of appropriate encryption keys, the most appropriate of which are those changeable ones. Unfortunately, in the case of long range passive RFID tags available for tests, in devices such security measures are not guaranteed. The reason for this is not enough power which is crucial to tag encryption chips. Therefore, tags' ID can be copied and freely used by an unauthorized person.

In the case of vehicle location, it is of little consequence. However, a single ID without links to the geographical location is useless. Only connection with the ID location, gives the possibility of unauthorized manipulation. Also a sniffer during the transmission of the ID tags is not very useful because it represents a set of random tags selected during installation by chance.

3.5. PASSIVE RFID LOCALIZATION SYSTEM CONFIGURATION

The conception of the localization system relies on the connection of the reader, the single chip microcomputer with the GSM transmitter of data. The designed device should be installed on the vehicle board in a way enabling to read the passing tags. Collected tags' ID are stored in internal memory and they are transmitted through GSM (GPRS) channel to the Control Centre. The device can be connected to other parts via RS ports, for example: to GPS signal to give accurate time and GPS position, to a counter of passengers to statistical analyses, to the board computer to collect working parameters and control onboard equipment.

The long distance readers installed on the vehicles board should be placed in the places allowing the best conditions of detection of tags. In the case of buses it can be the right side of the vehicles, the closest to the shoulder (right driving) or its hood. For trams, the chassis is the best place of the installation of the reader. It allows to obtain regular, small and always certain distance between the reader and the tag attached to the sleeper.

Passive tags can be installed as small plates everywhere it is necessary. Places like stops, cross roads can be marked by more than one tag. There is no opposition to enlarge the number of tags because they are cheap. More tags improve the reliability of the system and the precision of localization.

According to the presented premises, tags, when used to localize vehicles, should be resistant to destruction and should also guarantee the short time of reading and stable parameters of work in the wide range of temperatures. Such requirements are fulfilled by tags made of large plates covered in thermosetting plastic. Accessible passive tags work in temperatures from -20 ° C to + 110 ° C. The range comes from the physical properties of the unit's antenna because of the thermal expansion.

It is worth noticing that the lower limit of the range of temperatures makes it impossible for these devices to work on some winter days in Poland.

4. LONG RANGE RFID PASSIVE SYSTEMS

First devices enabling detecting and reading of information written down in passive tags for a distance of 2 to 8 m appeared about five years ago. The principle of their operation is still kept in secret. There are only several manufacturers in the world which produce them.

The long range RFID passive solution can be used for goods identification and data collection, but it is especially widely used in the following areas with its specialty.

- Transportation management: road and railway transportation management and container transportation management and so on.
- Motor vehicles management: police stations and transport department supervise and manage the motor vehicles.
- Road and bridge charge: as the product is able to read the tag data quickly at a long distance, road rate and bridge can be charged without stopping vehicles.
- Customs management: the management of goods to pass and transit the customs and vehicles.
- Logistics and warehouse management: goods flow, warehouse management and the flowing management of mail, parcels, luggage.
- Parking management: in order to manage and charge automatically
- Doors control management: including vehicles and people to pass in and out management.
- Craftwork manufacture flow: supervise parts in the whole manufacture flow.

The Department of Transport at Warsaw University of Technology carried out a series of tests of these devices.

Delivered kits were prepared for transport applications. They have wide possibilities of installation places, software control, high resistance to weather conditions.

4.1. CHARACTERISTIC OF LONG RANGE READERS

The products can be compatible with multi-protocol, small volume, quickly read and multi-tag identification – polar antenna is not a limitation for direction of the tag and is water proof [5].

The main functions are:

1. Awakening the tag: only the tags that are awakened can communicate with the reader and prevent the disturbance of those tags out of the system and thereby confirm the credibility and the smooth exchange of information between the reader and the tag of the system.
2. Reading the tag data: it can not only read the ID N^O. of the tag but also the data of the appointed tag storage area; it can not only read the single tag data but also multi-tag data of the antenna wave synchronously.
3. Real-in tag data: it can read-in data to the appointed tag storage area.
4. It can connect with the control equipment with standard W26 or W34 interface without exploitation, therefore it is convenient to use.
5. It connects the controller of the PC machine through the communication interface to process and exchange the data communication, and to provide SDK exploitation bag, so that the customers can use it again.

Main technical parameters are:

- Protocol: ISO18000-6B, ISO18000-6C (EPC GEN2),
- Frequency Range: ISM 902÷928MHZ (FCC),
- Operation Mode: Fixed Frequency or FHSS Software Programmable,
- RF Power Output: 0÷30dBm,
- Reading Rate: Software Programmable, Average Reading per 64Bits: <10ms,
- Reading Mode: Auto And Touch or Software Programmable,
- Communication (Ports): RS232, RS485 (Syris485), Wiegand26/34, RJ45 Software Programmable,
- Data Input: One Team,
- Reading Range: <5 m,
- Antenna: Built-in Antenna – Gain: 7dBi,
- Power Consumed: DC +9V (max. 3A),
- Dimension: 240mm×240mm×30mm,
- Avoirdupois: 1 Kg,
- Operation Temp: -20°C ÷ +80°C,

Long-range RFID readers are typically installed on brackets in one out of the two ways: "flank 1 pattern fixing" and "L pattern fixing" as follows' figure: can choose fixing mode according to application needs and spot fact instance. Generally speaking, "flank 1 pattern fixing" has a short

distance but is easily fixed.. "L pattern fixing" has a longer distance but the fixing is complex.
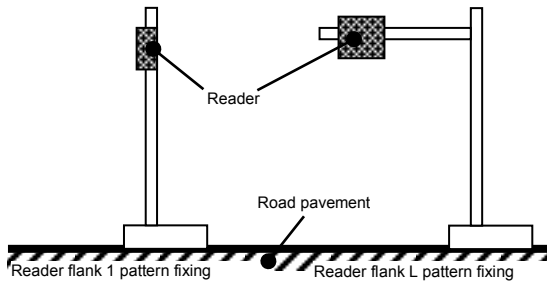

Fig. 3. Reader's fixing mode.

Antenna angular: indicates the included angle between the antenna and level when the antenna inclines to the ground. Azimuth angle of the antenna - indicates the deviation angle when antenna deflects to the direction of vehicle drive. It seems very important to the proper detection tags, and it is also connected with the speed of moving tags.
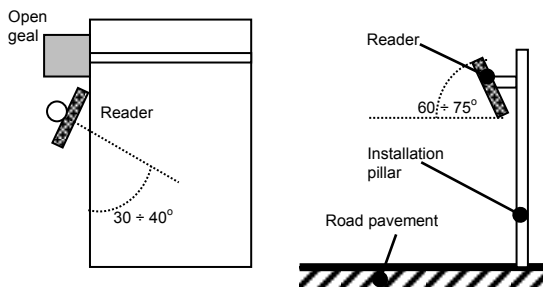

Fig. 4. Sketch map of the azimuth angle adjustment of the reader.

4.2. CONFIGURATION AND CONTROL OF READERS

All operations connected to the service and the configuration of readers can be realized through one of the ports RS. Such solution allows to connect many various co-operating devices like computer-controlled systems, hardware controllers and so on. It is important to conduct the full configuration of the device to obtain a high effectiveness of the operation.

The producer of the readers offers a software which displays many parameters. The displayed parameters can be described as follows:

- Displaying port includes port choosing, rate display and reader's address choice.

- Work mode can choose command mode, timing reading and trigger reading.
- RF settings parameters allow to set frequency power and frequency according to application needs.
- Antenna display uses a multi-port reader.
- Timing interval display includes reader tag frequency' setting (namely timing cycle) and border identification.
- Communication parameter settings allow to set all I/O ports.

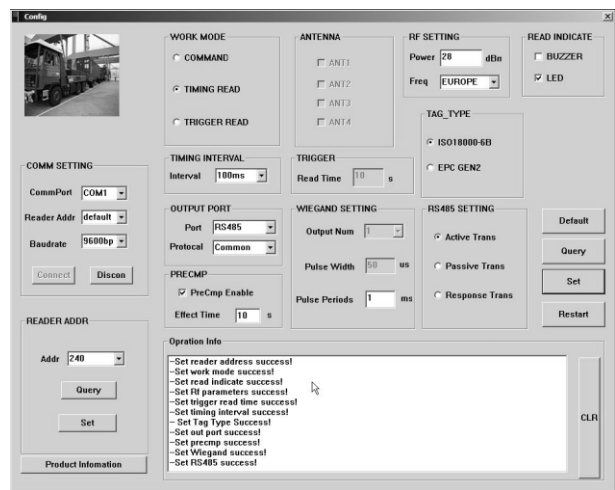figure 5 presents main configuration interface.

Fig. 5. Displaying the configuration interface.

4.3. RESULTS OF RESEARCH

The research concerning the long passive RFID devices were carried out in the Laboratories of the Institute of Telecommunication in Transport at Warsaw University of Technology. Tests were meant to prove the effectiveness of reading tags in various conditions of the propagation of the signal. There was made an assumption that effectiveness of the reading was a function of three variables: distance, speed and the angle of yaw from the axis of perpendicular to the direction of the track. Moreover it was assumed that the reader is approaching the tag face-to-ground or during the passing it by closely.

The result of the conducted research showed, that:

- Correct ID reading of the tag was made after several tests

- Acceptable angle of the yaw of the reader guaranteeing yet the correct read of the tag:
    - Horizontal between 30º ÷ 40º
    - Vertical maximum carries out approx. 20º
- Distance of reading:
    - In the axis of the aerial: 0 ÷ 8m
    - Over the yaw 1m in perpendicular plane from axis of the aerial: 0 ÷ 2m
- Speed of the approaching vehicle to the tag in the axis of the aerial: up to 300 km/h (algebraical enumeration)
- Speed of passing by the tag: depend on distance, approx. 60km/h
- Resistance on Electromagnetic interferences: large.

Testing construction tags was strongly restricted due to a limited access to the climatic chamber. The manufacturer of the supplied tags placed them in a plastic body and a shock-resistant strain of dimensions 205mm x 25mm x 5mm. Each tag can be glued to the ground with adhesive tape or with two mounting pins, for which holes have been prepared on both ends of the element. The aforementioned protection ensures that in all likelihood the tag will be attached to the ground for good.

Fig. 6. The tag used during the test.

To summarize, it has been established that the latest passive RFID devices are suitable to use in the process of localization of urban means of transport if the condition of safe distance, shifts in relation to axis and the angles of the track of the reader on the tag is kept.

The investigation was meant to qualify the error rate of readers, the influence of the vibrations of the vehicle on the reading and the influence of the temperature of the work on the reading tags but it has not been conducted so far.

5. SUMMARY

The increase in popularity of the RFID technology is a natural consequence of a rapid increase of market places, transportation of mass of products, verification and identification of people and items. Nowadays, society is waiting for access to real time information, which is especially visible in WEB 2.0 and transportation industry.

Using the RFID technology, originally developed for the identification of objects and animals, for localization of vehicles provides unprecedented high-precision measurements to the GPS system.

Testing of real devices partially confirmed the validity of the application of passive RFID in the localization process.

Currently, the biggest limitation described is a significant difference in the cost of its implementation in comparison to the most commonly used technology based on the GPS satellite system.

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Marek Sumiła
Warsaw University of Technology, Poland
sumila@it.pw.edu.pl