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SOME APPLICATION POSSIBILITIES OF LAND AND SATELLITE COMMUNICATION SYSTEMS IN ROAD TRAFFIC

1. INTRODUCTION

The rapid development of science and technology has provided new possibilities for traffic improvement. Apart from automation of many traffic elements, the introduction of communication systems into traffic has proved very useful. First of all, radio telegraphy had been introduced in ships, and today radio communication has become indispensable in specific services such as taxi, police, etc. Over the time some new applications of these links, especially in road traffic, have been found. Weather reports, reports on traffic conditions can be sent to vehicles. Vehicles can be directed over radio to destinations, and even information on parking possibilities can be given.

By launching communication satellites, the problem of creating a dense land network of receivers has been solved. The ultra high radio frequency, spreading only linearly, can now travel directly from any point on Earth where the satellite is visible, towards the satellite and back. The dimensions of the equipment needed for satellite communication is such that it can be fitted on any road vehicle without any complicated procedures, the prices are acceptable, and even the required source of energy need not be strong.

Communication via satellite provides a wide range of possibilities, some of which are identical to the possibilities offered by the land network (telephone, telex, data package network, conferences, selection of the best travelling route), whereas some are specific and refer only to satellites (determining height above sea-level and position co-ordinates of a vehicle). The package network for data transfer makes it possible to introduce also some additional communication services in the future.

At present, Croatia has not got the installations for these applications, but there is a need to introduce the satellite telecommunication systems in our country as well. The price of land installations are becoming all the more acceptable, and the channels at the already existing satellites can always be leased.

2. LAND NAVIGATION INFORMATION SYSTEM

Land systems can offer services of navigation, positioning and information transfer without the aid of a satellite. Only a dense network of receivers need to be built in the area offering these services, since their range cannot be far-reaching.

Examples of networks offering these services are GEC Autoguide and DECCA Navigation System.

2.1. GEC Autoguide System

GEC Autoguide is a system which provides the information regarding selection of the best traffic route and directing the vehicles to their destinations, to drivers with the suitable accessories in cars. The system was developed and installed in order to eliminate the effects of the increasing traffic congestion, mostly reflected in financial losses in industry, due to the delays caused by traffic problems, apart from the fuel cost saving, better care about the environment, and the drivers' jobs made easier.

The system consists of a network of the so-called "beacons" - receivers located along the roads, and linked to the central computer system over a package network with X.25 standard. The receivers allow a two-way communication with vehicles equipped with the appropriate IVU navigation units (In-Vehicle Unit) which consist of several different function units (Figure 1). The communication is done by infrared waves. The transmitter and the receiver of infrared waves are fitted into the cabin of the vehicle, in front of the rear-view mirror, and in order to make the communication possible it is necessary to place the transmitter within the viewing range of the receiver. Each IVU is fitted with a microprocessor unit for communication with the driver and locating sensors

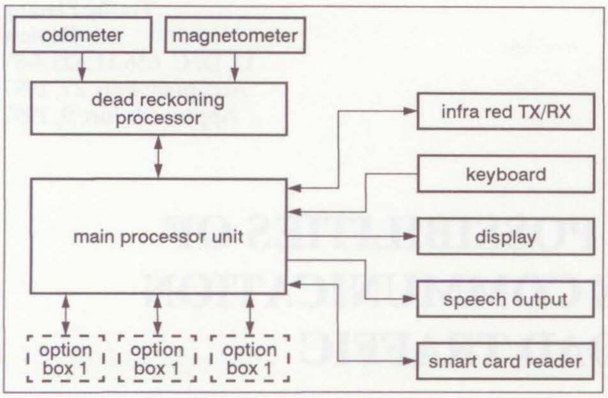

Figure 1

for autonomous navigation in areas that are out of the receiver's range. The unit for the communication with the driver is a module to be fixed on the vehicle dashboard (Figure 2). The front part of the unit consists of a liquid crystal display showing the driving route and various other information, as well as of the alphanumeric keyboard for inputting the destination. The module is attached also to the infrared receiver, speech synthetiser, magnetometer and odometer. Magnetometer is used for space orientation and its function is equivalent to a compass. Odometer is connected to the non-driving wheels and is used to measure the travelled distance taking into consideration the number of wheel revolutions and the turning angle measured by the magnetometer. Odometer is constantly calibrated, based on the data about the actual route length, so that temperature and tyre condition have no influence. The latter two devices provide a very accurate assessment of the vehicle position and autonomous navigation through areas where the communication with the receivers network is not possible.

Travelling with the use of GEC Autoguide system can be considered in three separate phases:

1. *Departure / Start*

The driver inputs the data about the required destination in the unit in the vehicle, obtaining in turn information in which direction to start, and what is the straight-line distance to the destination. By using the stored data, the device instructs the driver until reaching the range of the first receiver along the road.

2. *Dynamic guiding phase*

Based on the information from the receiver, the route to the destination is selected (based on the calculation of the main computer, which has full knowledge of the current road situation). At the next receiver, new data about the further route are received.

3. *Final guiding phase*

This phase begins when the vehicle is close to the destination. Based on the detailed area map, received from the network, the device in the vehicle informs on its own the driver about the rest of the journey.

The route selection strategy provides the selection of the currently best route on the basis of the current road conditions.

2.2. DECCA Navigation System

Decca Navigation is a localisation system which has been used on ships for a long time proving very suitable for navigation. It consists of a series of transmitters arranged all over Great Britain, Scandinavia and a part of Europe. The signals are received by inexpensive electronic receivers.

The land application of this system suffers often from connection breakdowns and signal deformations due to the ground configuration, tall buildings, transmission lines etc.

Since the signals deformations are constant for the majority of locations, there is a possibility to input

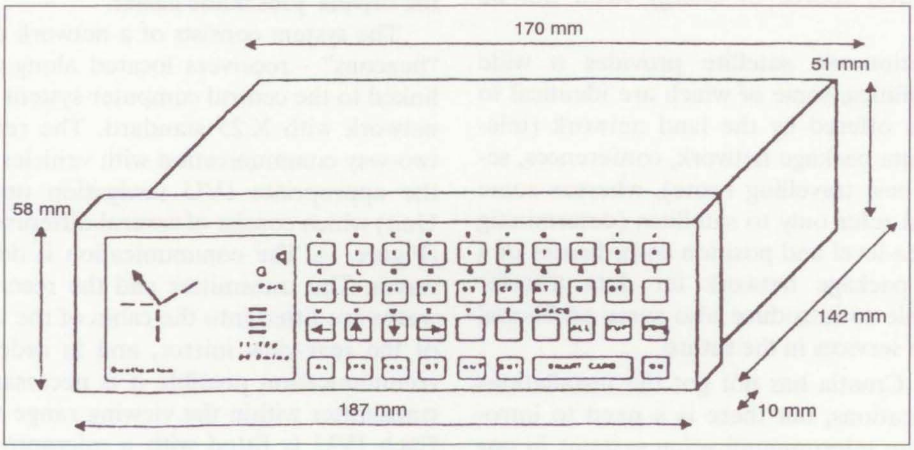

Figure 2

the expected errors into the receiver as default parameters, thus taking them into consideration when calculating the position.

By the end of the century, Decca system will be gradually replaced by the new Pan-European Loran system.

3. SATELLITE NAVIGATION ELEMENTS AND APPLICATION

In activities regarding localising and electronic guidance of vehicles, the possibilities for further development are huge. A system providing the driver with data on the fastest and best routes towards destination, taking into consideration the current congestion at certain sections, possible traffic accidents, and being able to provide information on the times that other vehicles need to travel these sections, would be a very useful one. This is why the localisation and guidance systems are needed. There are two basic methods for localisation and navigation: autonomous navigation method and co-operative navigation method. The autonomous navigation method means that the vehicle calculates its position on the basis of its starting position, direction of moving and the speed. This method is not reliable enough because there is the possibility of error, and there is no feedback to correct it. The co-operative method includes the localisation network. The vehicle receives the data about its position from the network which can be either land or satellite one. There is also a possibility to combine the applications of the two methods, so that the vehicle uses the autonomous navigation in case the connection with the localisation network breaks down, until the connection is restored.

Some of the existing systems for this application are "Early Mobile Data Service" (EMDS) introduced in Canada and "Global Positioning System" (GPS), which should be available everywhere on Earth.

3.1. The Canadian "Early Mobile Data Service"

The system provides the possibility for installing more than 4,000 mobile terminals using several satellite channels of 5 KHz bandwidth. One of them is used by the ground station (hub) for sending control information to the network, signalling, and traffic information provided for all mobile terminals. Three channels send messages, two are for position reporting and one is for text transfer. The data are transferred per packages (Figure 3).

EMDS system offers three basic types of services:

1. Two-way transfer of messages

The messages of approximate length of 32 characters, the maximum length being 128 characters are transferred. The transfer capacity is 330 messages of approximate length per hour, for each channel.

2. Vehicle position report

The position is determined by Loran-C receiver, which is a component of the mobile terminal. The data are sent at specific intervals, usually 15 minutes, and one channel can transfer 4,000 position reports per hour.

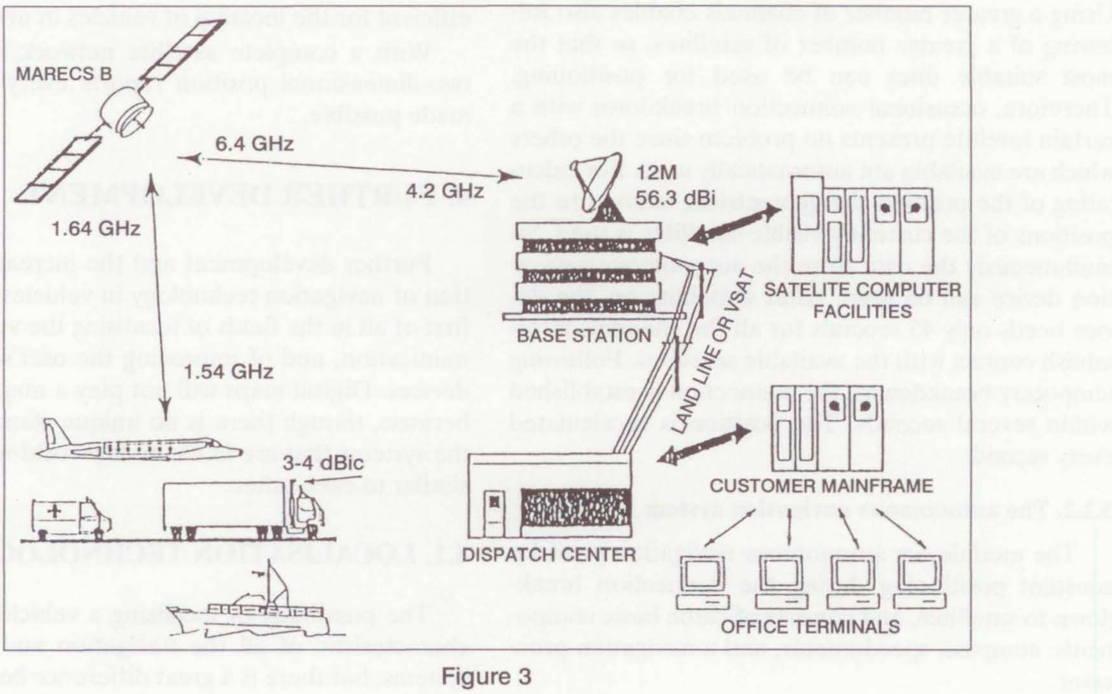

Figure 3

3. *Text transfer*

Messages of about 4,000 characters are transferred. The transfer capacity is 32.9 characters per second.

3.2. GPS Navigation Subsystem for Automatic Vehicle Locating Systems

The automatic vehicle locating system consists of several subsystems: navigation, communication and digital maps. When the Global Positioning System (GPS), the navigation subsystem, reaches its full operation condition, it will be able, by using the satellite network, to determine geographical latitude and longitude as well as the height of the terminal above sea level at any point on the Earth, with a possible error of not more than 50 metres. The subsystem has six main components:

- GPS receiver
- autonomous navigation system
- communication processor
- modem
- radio interface
- mobile display terminal

3.2.1. The function of the GPS receiver

The problems in sending signals from the satellite caused by interference of tall buildings, vegetation and hilly ground, have been solved in GPS system by a six-channel receiver version. Even a signal weaker by 5 dB than for the other versions is sufficient for this system, with a localisation accuracy of 10 metres. Using a greater number of channels enables also following of a greater number of satellites, so that the most suitable ones can be used for positioning. Therefore, occasional connection breakdown with a certain satellite presents no problem since the others which are available are automatically used. For calculating of the position the geometrical relation to the positions of the currently visible satellites is used. Simultaneously the data from the autonomous navigation device can be used. After switching on, the device needs only 45 seconds for all the channels to establish contact with the available satellites. Following temporary breakdowns, the connection is established within several seconds. The position is recalculated every second.

3.2.2. The autonomous navigation system

The module for autonomous navigation provides constant positioning during the connection breakdown to satellites, and consists of three basic components: compass, speedometer, and a navigation processor.

3.2.3. Communication processor

This part of the system is basically a computer managing the data flow between different navigation system components.

The communication processor also informs about the position on the request from the dispatch centre, and determines the most accurate position based on the data from the GPS receiver, autonomous navigation system, or any other available source.

3.2.4. Modem

Modem enables transfer over the same radio connection which is used for speech communication, at a speed of 1,200 baud, using the differential binary phase modulation (DBPSK). When the data and the voice are transmitted through the same channel, voice gets priority. The positioning data are then transmitted whenever the microphone is put down.

3.2.5. Mobile display terminal

For those applications that need a display terminal, a compact keyboard terminal has been designed, for mounting in the vehicle cabin within the driver's view. The display is of liquid crystal accommodating 16 characters in two lines.

The keyboard has up to 16 function keys, each of which has a graphical presentation of the currently executed function, and a LED diode indicating which function has been activated. The terminal can store a series of messages from the dispatcher and then present them one by one on the display.

3.2.6. Conclusion

The combination of a six-channel GPS receiver and an autonomous navigation has proved to be very efficient for the locating of vehicles in urban areas.

With a complete satellite network, receiving of two-dimensional position reports every 24 hours is made possible.

4. FURTHER DEVELOPMENT

Further development and the increasing application of navigation technology in vehicles will happen first of all in the fields of localising the vehicles, communication, and of improving the user's handling of devices. Digital maps will not play a major role here, because, though there is no unique standard format, the systems that are in use today world-wide are very similar to each other.

4.1. LOCALISATION TECHNOLOGY

The possibility of localising a vehicle is the basic characteristic of all the navigation and localisation systems, but there is a great difference between single systems and their purpose regarding accuracy and frequency of determining the position.

Automobile navigation systems for guidance need continuous position reporting with an accuracy of 10 to 25 metres, in order to determine exactly the name of the street. In areas outside the city, for cargo vehicles, an accuracy of 500 to 1,000 meters is sufficient, because the dispatcher only needs to know what city the vehicle is close to or on which motorway.

Systems reporting on the position of commercial vehicles used in urban areas require a medium level of accuracy (100 - 300 metres).

In spite of these, very opposing characteristics regarding accuracy and operation methods of single systems and technologies, the financial advantage provided by such systems will not suffice for introduction of a greater number of various independent systems (position reporting, dynamic guidance of vehicles depending on the road network conditions, communication, etc.). Therefore, it will be necessary to cover all of these purposes by a unique system, and because of the urban areas where a higher level of accuracy in localisation is needed, a system for guiding vehicles to their destination would be welcome.

Although low-range receivers located along the road are also used in some European and Japanese projects, the autonomous navigation using maps will soon be the dominant method for achieving high precision in positioning, necessary for navigation systems and vehicle guidance systems. Apart from that, autonomous navigation is necessary to overcome the problems of interference and breakdown of radio connections, whereas the digital maps are needed for guidance systems since the position co-ordinates themselves are not enough.

However, these two methods need to be combined with the radio-location method, in order to eliminate manual adjustment, when leaving the roads shown on maps and the like. Moreover, a radio-location system will provide commercial vehicles with guidance systems, position reporting even when they are not in the area covered by maps.

Navstar's "Global Positioning System" (GPS) is the most widespread available radio-location method. Although GPS itself is not sufficient for the requirements of road traffic navigation and guidance, because of the difficulties in communication which are caused by the buildings constructed along the roads etc., this system offers great possibilities in determining the vehicle position when other autonomous methods fail.

The utilisation of Loran-C system may also be considered (or of some other land radio-location system) for the same purposes in the areas where the signals are strong, but GPS is preferred compared to other systems due to its global availability.

4.2. COMMUNICATION LINKS

The requirements on the communication equipment are different and depend on the fact whether the guidance or the localisation system is considered, as well as whether the system is used in town or for long travelling of commercial vehicles in international traffic.

For guidance system, the minimum requirement includes a one-way communication from the local infrastructure for traffic control to the equipment in vehicle, but a two-way communication would be advantageous in order to have a feedback on the travelling data of certain vehicles which could then be used for a more accurate assessment of the current road traffic conditions.

In systems for localisation of commercial vehicles a one-way communication would also be sufficient, direct or via network from the vehicle to the dispatch centre. However, since dispatch centres have the need to send messages to the vehicles, almost all localisation systems have a two-way communication.

Vehicle guidance systems often transmit a huge number of data (digital maps), as compared to the localisation systems which only send very short messages and these not continuously.

Such a variety of requirements regarding range, destination, as well as the speed of transmitting data, is difficult to fulfil by a single communication network.

Two-way communication for guidance and localisation of vehicles through a network composed of short-ranged receivers along the roads is in use in Europe and Japan and the infrared or microwave communication is used, which enables a very high data transmission rate. Using wireless telephones for these purposes has also been studied in Europe and Japan. In the USA various methods of communication and localisation have been tried, using a transmitter network of greater ranges.

Satellite communication may be the most promising method for position reporting at greater distances because of the wide area that a satellite can cover. Covering a great area is not an advantage with guidance systems, since the data are not usable outside a narrow range to which they refer. Future communication satellites will maybe have the possibility of focusing to narrow areas for the needs of the guidance system, at the same time covering a maximally wide area for localisation and data transmission. In the future, maybe every communication of the satellite and the vehicle would automatically mean simultaneous determining of the position.

4.3. USER TO DEVICE CONNECTION

The interaction between the driver and the navigation device in the vehicle has received until now very little attention. The device commands as well as the way in which the information is displayed to the user should be standardised so as to enable the drivers to use navigation and guidance systems in different vehicles in the same way.

The existing systems transmit information to the driver in various ways, such as maps on the screen, simplified graphics and synthetised voice.

With rare exceptions, the synthetised voice is used only as an addition to the visual display, rather than as the basic communication method with the driver, due to the noise that might affect the understanding.

Maybe the most problematic aspect of driver-to-device communication is inputting the required destination and the criteria for the selection of the optimal route, in the guidance system. The available methods today are the usage of a miniature alphanumeric keyboard. In the future this problem might be solved by a system which would recognise spoken instructions.

5. CONCLUSION

A universal navigation system in the future will consist of a GPS receiver with the possibility of autonomous navigation, usage of maps and it will provide, apart from position reporting, also guidance of vehicles to the destination via the best routes. The same basic system is used in the whole system, but with different receiver, so that it will be able to adjust to various local installations for data transmission. As needed, the commercial vehicles will also have an additional connection for position reporting to a remote dispatch centre.

The graphic symbol presentation should be standardised, similarly to the standardisation of traffic signs.

Mass introduction of new technologies will start in the late 90s, and only after a successful integration of the guidance and the localisation systems will the use of these devices become normal sometime in the first decade of the 21st century.

Regarding the future building of a number of roads in Croatia, especially motorways, and the reconstruction of the existing roads destroyed in the war, a need should be considered to introduce various telecommunication systems into the road traffic, and to prepare plans for integrating the necessary land installations in the roads during their construction, reducing thus the costs. At this moment all the technology has to be imported, and launching one's own satellites for these purposes is too expensive. Croatia has very poor conditions for production and development of navigation systems. Building of the first land station for communication via satellite is in the preparation phase, but it is uncertain due to financial reasons, in spite of the fact that it may be an investment which could get repaid in a very short time. It is likely that in the near future only global systems of foreign companies will be available, for the usage of which a mobile terminal is sufficient. When properly used these systems can bring huge economic advantages (reduced mileage, saved time, reduced number of accidents), and therefore they will be used more and more in the future.

SUMMARY

The land and satellite communication systems provide a more rational utilisation of road network, by guiding the vehicles to the destination using the best routes. This results in economic advantages regarding reduced mileage, shorter travelling times, etc.

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