REPORT 904-2

AUTOMATIC DETERMINATION OF LOCATION AND GUIDANCE IN THE LAND MOBILE SERVICE

(Question 51/8)

(1982-1986)-1990)

1. Summary

In an automatic vehicle location (AVL) system the location of a mobile in a fleet is determined automatically as it moves around, within a given geographic area.

An AVL system comprises the location subsystem, data transmission subsystem and control and data manipulation subsystem. In dispatch operations including police, fire, public transportation, taxi, etc., a large percentage of the voice communications transmitted on land mobile radio channels is composed of routine information, the greater part of which is related to vehicle location status.

AVL techniques that can meet operational requirements of land mobile users can be classified into five major categories: proximity, dead reckoning, hyperbolic, satellite and combinations of two or more of these techniques, each of which has its advantages and disadvantages. The selection of the most effective technique is dependent on the type of user and operations involved [Hansen, 1977].

In the past few years, dedicated land mobile AVL systems have been introduced in many countries. These systems together with the radiodetermination satellites which are due to be fully deployed in 1990's and the already established area navigation systems would certainly provide a wide range of choices to the users. An AVL and position reporting system has recently become operational in the U.K. and test results from this system are reported in Annex I of this Report.

Operational AVL systems in Japan and Australia are described in Annex II and Annex III respectively.

Along with the development of AVL systems, numerous research and development projects have also been carried out in the field of vehicle navigation and guidance. The operation of these systems is based on the same techniques as used in AVL systems, but the significant difference is that in navigation and guidance systems, users are given advice on how to proceed to the chosen destination. Vehicle navigation and guidance systems have received attention from many countries. European collaborative projects such as Drive and Prometheus have been initiated. A description of these systems is given in Annex IV.

2. Introduction

Increasingly over the past few years, police and public transportation operators around the world have realized the potential benefits associated with the knowledge of vehicle locations. Some operators in Europe, Japan and North America have already installed AVL systems.

With the continuing increase in the costs of land mobile dispatch services resulting from an overall increase in operating and maintenance costs and the rising demand by the public for improved services, it is becoming more important to find a means of reducing costs.

One of the most critical elements in dispatch services is the knowledge of current precise location of every vehicle in the operational fleet.

An AVL system with its data reduction facility can provide the information necessary to control and adjust the operation of a dispatch fleet on a real time basis, thus resulting in a more efficient and productive utilization of personnel and equipment.

3. Operational considerations

There is no authoritative body which can define the operational requirement for the many different kinds of AVL use. The following broad requirements have been stated by potential users.

3.1 *Positional accuracy*

From 100 to 200 metres for many services. Some require accuracies of 10 m; others (e.g. large area trucking dispatch systems) would be satisfied by accuracies of about 1 km.

3.2 *Frequency of up-dating*

Ideally once per minute or so for vehicles which are required to be quickly deployed in limited areas (e.g. police, fire tenders, ambulances) but less frequently for dispatch operations over larger areas or defined routes.

In practice, attainable updating intervals may be governed by the rate at which choices of route are presented to each vehicle. These rates are proportional to the occurrence of road junctions in the area of travel and to vehicle speeds.

3.3 *Coverage area*

For many systems (e.g. police, fire, ambulance, passenger omnibus, taxi services) operational areas up to 100 km × 100 km are common. Some operations are confined to much smaller areas up to 10 km^2. Others may require continental coverage.

4. Cost/benefit considerations

Potential benefits [Wilson, 1977] that can be achieved for the two different types of operation namely: fixed route, as in public transportation, and random route, such as in police and taxi operations, are summarized in the following sections.

4.1 *Potential benefits in fixed route operations*

- Reduction in checking and control personnel.
- More even distribution of passengers between vehicles.
- Reduction in (lay-over) time resulting in reduction in number of buses and personnel.
- Increased on-time service.
- Improved efficiency of response during emergencies and for dispatching a replacement vehicle.
- Increased passenger loads due to more convenient and up-to-date location information available to the public.

The AVL requirements of many fixed route systems can be satisfied by non-radio means.

4.2 *Potential benefits in random route operations*

- Reduction in response time to emergency and service calls.
- Reduction in the number of vehicles while maintaining the same coverage area.
- Reduction of unnecessary travel.

4.3 *AVL benefits-to-cost ratio*

Results based on a computer model for AVL benefit-to-cost [Symes, 1979] have indicated benefit-to-cost ratios of up to 7 to 1 are possible for the public transportation operation and as much as 13 to 1 are possible for police operations.

Although all the benefits stated above can potentially reduce the cost of running dispatch services, to date AVL systems that have been installed in Europe and North America have the objective of improving service reliability in general and reducing response time to emergency and service calls in police services in particular.

In some public transportation systems in Europe as a result of the installation of AVL systems, a reduction in the required number of buses was experienced; however these were retained to accommodate service expansion [Herrman and Zimmerman, 1974].

A benefit-to-cost analysis was conducted in Canada, which shows that there is a definite benefit ranging up to a 2 to 1 ratio [Fujaros, 1976].

5. Spectrum efficiency considerations

With the installation of an AVL system, location information, which constitutes a large percentage of the voice communications [Fujaros, 1976], is automatically transmitted from vehicles to control centres in data form. This on-board capability facilitates transmission of other routine status messages as well, resulting potentially in an increase in spectrum utilization efficiency in the land mobile services. It has been estimated [Cortland, 1986] that 20 to 25% reduction in voice communications between vehicles and control posts can be achieved.

Some systems do not generate demand for any additional spectrum allocation. These systems use the existing transmissions of radionavigation aids, which are designed for ships and aircraft, to determine their positions. Examples include Loran-C and Decca systems. However some of these systems only provide limited coverage particularly on land.

Satellite systems like GPS, described below, together with the two systems mentioned above are basically broadcast systems which can accommodate an unlimited number of users.

AVL systems can be applied to improve the spectrum efficiency of other mobile services as in the following examples.

5.1 Application to cellular systems

It has been shown that AVL can be a very useful measuring tool [Meek, 1988] which can provide accurate coverage data for optimising cellular telephone networks. Furthermore, accurate mobile station location information could provide enhanced system control in terms of originating calls on the appropriate base station and effecting handover control. This may need to be considered against increase in system complexity.

5.2 Microcellular system control

Many narrowband and wideband techniques are being developed to improve spectrum utilisation. One approach is to use a microcellular system. The area covered by a microcell is small and frequent handovers may therefore be required. With the implementation of an AVL system, the channel carrier frequency can be switched as a mobile unit moves across a known microcell boundary [Towaij, 1983]. In order to operate the microcellular system, the location of every mobile unit must be known to the network controller. A proximity technique is used to determine the location of every mobile as it passes the base stations. Each base station is designated with a unique ID code. Short low power transmissions are emitted from each base station once every two seconds. Each burst contains a flag, base ID and control signals.

6. AVL techniques

AVL techniques that might be capable of meeting operational requirements of land mobile radio users can be classified into five categories: proximity, dead reckoning, hyperbolic, satellite and combinations of two or more of these techniques.

6.1 Proximity techniques

The location of the vehicle is determined as it passes roadside signposts, sometimes referred to as roadside beacons whose locations are precisely known. A wide range of techniques has been employed for the communication of information between roadside signposts and passing vehicles including inductive loops, UHF radio transmission, microwave transmission and infra-red transmission. There are two different types of signposts depending on the direction of information flow:

- active signpost: location signals are transmitted from signpost to vehicles;

- passive signpost: signals are transmitted from vehicle unit to signpost.

There are two methods of assessing proximity characterised by one of the following procedures:

- direct proximity: the active signpost transmits its location to the vehicle, which then transmits its data by radio link to the central computer;

- inverse proximity: the vehicle transmits its data to the passive signpost which then relays the data to the central computer by wire or radio link.

The precision of proximity techniques is directly related to the spacing between signposts.

6.2 *Dead reckoning techniques*

These techniques employ heading and distance travelled (e.g. odometers) sensors for calculating the location of vehicles relative to fixed known location references. The computation may be made on board the vehicle or in the centre computer. Location determination accuracies depend on the sensing devices, frequency of reference updates and the severity of external factors such as magnetic field variations, wheel slippage and road camber, etc.

6.3 Hyperbolic *techniques*

The locations of vehicles are determined from distance differences of vehicles from three or more fixed sites. These differences can either be expressed by phase differences between received signals (phase multilateration) or differences in the time of arrival of leading edges of synchronized pulse signals (pulse multilateration) producing hyperbolic lines of constant phase or time differences. The location of vehicles can be determined from the intersection of these lines. The positioning techniques can employ dedicated systems for land mobile application or utilize existing navigation systems such as Loran-C or Decca.

6.4 Techniques using satellites

The position of a mobile is established by the precise measurement of the distances between the receiver and the satellites at an instant in time. Four satellites are required to establish a three dimensional fix. Their positions must be known precisely and be available at the instant of measurement if overall system accuracy is to be maintained. It may be noted that the positions of satellites may not be as predicted by recent orbital information due to drag by abnormal solar winds at times of solar eruptions. Corrections may not be applied for some hours after such deviations.

In general, there are two types of systems with different characteristics of mobile user equipment:

- active equipment: two-way communication between the mobile and its ground control station is provided by satellites. The position calculations are performed in the ground station and the resulting location data is transmitted back to the mobile.

- passive equipment: navigation signals are broadcast to the mobile. Vehicle location is determined in the mobile equipment.

6.5 Combination of techniques

Two or more techniques may be combined to improve upon the performance available using an individual technique and to form an integrated system.

7. Applicable AVL systems

7.1 LF hyperbolic system

Within the coverage of existing transmitters, position data can be provided for many mobile users. The test results in Annex I were obtained using this system in London.

7.2 UHF hyperbolic system using spread-spectrum

A terrestrial-based AVL system utilizing paged spread-spectrum beacons on the vehicles to be located has been developed and installed in Australia. Specifically developed for urban environments, the system has demonstrated positional accuracies of the order of 30m on moving or stationary vehicles with 1 second measurement time. A unique frequency division multiplexing scheme endows the system with a high location throughput. (See Annex III).

7.3 Signpost/Dead reckoning systems

A pilot system which is installed in London consists of about 700 UHF roadside signposts. The on-board vehicle equipment is initialised when it first comes to the coverage area of a signpost. Between signposts, the vehicle location is established by dead reckoning based on the last initialisation. Whenever the vehicle approaches another signpost, the on-board equipment is reinitialised by the reference signals continuously transmitted from the signpost so that the accumulated errors are removed. The vehicle location is automatically stored in the on-board vehicle memory even when the engine is switched off. This system can provide useful location information within the network. The provision of the considerable number of signposts required for high locational accuracy can be costly.

7.4 Omega

The international VLF global radionavigation aid OMEGA is available without charge and continuation is assured into the next century.

An extensive programme of field trials on OMEGA, operating differentially, has demonstrated that over a wide range of environment, including mountains and city centre, the practical accuracy is 300m 2σrms (95-98% probability), or better [Stratton 1987].

The accuracy of differential OMEGA can decrease as the distance between the differential monitor and mobile increases beyond 100km; errors can also increase substantially at night. The cause has been identified as diurnal variations in the local velocity and direction of propagation from the standard values used in converting the differential phase measurements into position. By linking data from three to four monitoring stations the variations in azimuth and velocity can be continuously measured and correction applied [Stratton 1988].

An AVL system using differential OMEGA is operational in the Middle East.

7.5 Radio-determination satellite systems

From 1990 onwards, several radio-determination satellite systems will be available, a description of these systems follows.

TRANSIT, [Blanchard, 1983] a currently operational satellite radionavigation system, is of very limited use to land vehicles because of its long measuring time. By 1996, TRANSIT will be replaced by GPS.

The GPS system which is expected to be fully deployed after 1992, will provide three-dimensional position and velocity information. The technical characteristics of the NAVSTAR GPS are described in ANNEX I of Report 766.

GLONASS [IMO, 1989] is a satellite system which will provide position and velocity information to civilian users when fully deployed between 1991 and 1995. The design of this system is very similar to that of the GPS.

A proposed radiodetermination satellite system being developed for operation in the United States of America starting in 1991-1993 is expected to be capable of providing two functions : localisation and communications. Three-dimensional accuracies at the order of 30-40 m can be achieved, with a measuring time of less than 1 s. The system, which will utilize geostationary satellites in the radiodetermination satellite service, is described in Report 1050. A similar radiodetermination satellite system which has been proposed to provide coverage in Region 1 is now under development [Hernandez, 1987].

8. Guidance systems

Guidance systems employ the same basic techniques for location as used by AVL systems with additional information being provided to the moving vehicle (see Annex IV).

9. Conclusions

AVL should be viewed as a technology that could have significant influence on the effectiveness and productivity of dispatch operations as well as on spectrum utilization efficiency.

Satellite systems can provide global coverage which will benefit all the land, maritime and aeronautical users and hence may have significant implications on spectrum saving. However, in urban areas, the performance can be degraded due to signal blocking. To overcome this problem the mobile equipment may have to include a dead reckoning system so that continuous tracking can be maintained. In the near future, several autonomous satellite systems will become available; the potential for mutual interference between these systems and for interference with other services needs further study.

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ANNEX I

TRIALS CONDUCTED WITH DATATRAK AVL SYSTEMS IN THE UNITED KINGDOM

1. Datatrak, a low frequency (LF) hyperbolic system, has been in operation since April 1988. The present system provides coverage of the south east of England and the Midlands, and coverage of the whole United Kingdom is expected to be available in early 1991.

2. The network consists of a large number of UHF base stations (for mobiles reporting to base stations) , a vehicle control centre and 16-20 time-multiplexed LF transmitters which are approximately 160 km apart. Each LF transmitter comprises a 50 metre monopole aerial with radial earth mat, the radiated power is approximately 50-100 watts e.r.p.

2.1 The transmitters all operate at the same pair of frequencies and time sharing is achieved with Time Division Multiplexing technique. Navigation frequencies are 135kHz (f1) and 145kHz (f2) both of which are class of emission ——————— **1k00 PON. The navigation timing diagram is illustrated in Fig. 1. The pattern of the time slots 1-8 is repeated every 1.68s, whereas time slots 9-24 are effectively at half rate and are repeated every 3.36s. The faster time slots are assigned for urban areas while the slower time slots** are for **rural areas.**

3. The vehicle equipment comprises a locator unit, a status keypad and an antenna.

3.1 The navigation processor is the central processing unit of the vehicle locator. After the lines of position are established from the phase data derived from the navigation transmissions, the position of a vehicle is converted into Ordnance Survey National Grid coordinates and the status data are collected via the bidirectional data bus connected to the keypad. The position and status data are formatted by another processor before being transmitted over the UHF channel (460MHz) to the base stations at a data rate of 3600 bit/s.

3.2 Each locator unit is assigned one or more 30ms time slots within a 30 minute timing cycle and there are approximately 54000 slots available. The locator units and base stations are synchronisied to the same timing cycle so individual vehicles can be identified at the base stations by its slot position. The 30ms vehicle slot data format as shown in Fig. 2 begins with a 1ms guard band. Synchronisation is achieved by the following 10 bits preamble and the 16 bits Gold code. The status data and the vehicle's latest position are also transmitted within this timing cycle.

3.3 The locator unit has a power consumption of 14W and requires 12V or 24V d.c. supply. The unit can be powered by the vehicle battery via the ignition switch, so it is switched on automatically when the engine starts. The locator unit has a built in time delay device, so the vehicle's position continues to be monitored for 20 minutes after the engine is switched off.

3.4 The status unit indicates the coordinates of the current vehicle position. Communication from vehicle to the central control is established by the status keypad which activates the locator unit to transmit up to 250 user defined status codes. It is not possible to send data in the reverse direction.

3.5 The vehicle antenna for LF reception is an active monopole. With a diplexing facility, reception of the LF navigation signal and data transmission at UHF is accomplished with a single antenna.

3.6 With this vehicle location technique the vehicle does not need to transmit in order to obtain its position. This implies that an unlimited number of vehicles may be used to obtain their positions using the system. However, for fleet management and control purposes data transmission to the control centre is needed as described in Sections 4 and 5 below and this imposes an upper limit to the numbers using a given system. A block diagram of the system is shown in Fig. 3.

4. Equipment at the vehicle control centre comprises a computer, VDU and keyboard and a microprocessor controlled modem to couple the computer to the data gathering and distribution centre.

4.1 At the radio base stations, vehicle data are re-formatted and tagged with the slot identity at the base station. Then these data are transmitted onto the control centre via the data gathering and distribution centre. Transmission between the base station and the control centre is conducted by the means of leased telephone lines.

4.2 The data transmissions over the UHF channel are received by more than one base station, this redundancy technique is employed to ensure that vehicles' data will still be received even if one station fails to receive the signal correctly. At the control centre, data information is sorted and logged by the data centre computer and any redundant data is removed.

4.3 Vehicle positions, identities and directions of travel are overlaid on digitized map stored within the high-resolution display. Areas of special interest can be displayed in greater detail with Zoom facilities.

4.4 In addition to the graphic display, each vehicle's data information are displayed in tabular form on a VDU. These data include vehicle identity, current coordinates, direction of travel, speed and its last reporting time.

4.5 Unallocated alarm slots are reserved for emergency signalling. In this event, the vehicle's identification together with its status and current position are transmitted. The alarm facility can be initiated either automatically (e.g. in the case of a vehicle collision) or by the action of the driver. The alarm slot data format is illustrated in Fig. 4.

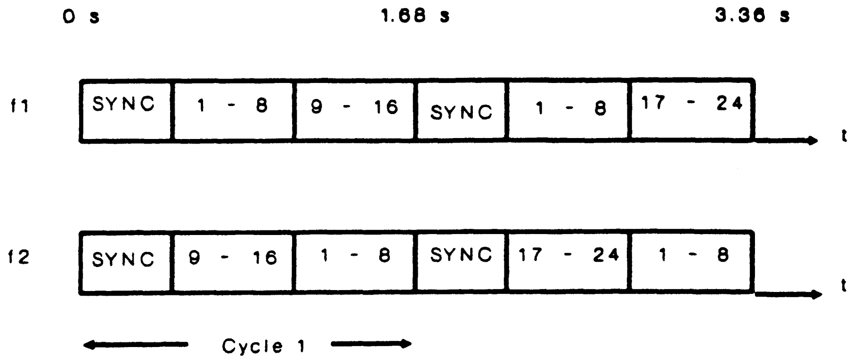
5. Tests

5.1 Both dynamic and static tests have been conducted. The dynamic testing was conducted by driving the vehicle in a normal manner along public roads and observing its progress against a digitized map background at the control centre. For the static tests the vehicle was parked at a known location and its position data were continuously being monitored over a period of time.

5.2 A specimen computer printout of recorded data from the dynamic tests is shown in Fig. 5.

5.3 Static tests were made by recording data from a stationary vehicle. The "observed position" was estimated using Ordnance Survey maps. The "computed position" was derived from the recorded hyperbolic coordinates converted to Ordnance Survey National Grid reference. The "position error" is the distance between "observed position" and "computed position" in Eastings and Northings.

5.4 Static tests have been conducted at Richmond, a residential area between Central London and Heathrow Airport. The test location was approximately 70 km away from the nearest LF transmitter. The results of the tests showed that a typical standard deviation for a 24 hour period was 9 metres. So the 95% circle of position was of radius 18 metres.



1. Numbers shown are the slot numbers of transmitters
2. Slot numbers 1-8 repeat every 1.68s on each frequency
3. Slot numbers 9-24 repeat every 3.36s on each frequency

Fig. 1 Timing diagram - navigation chain

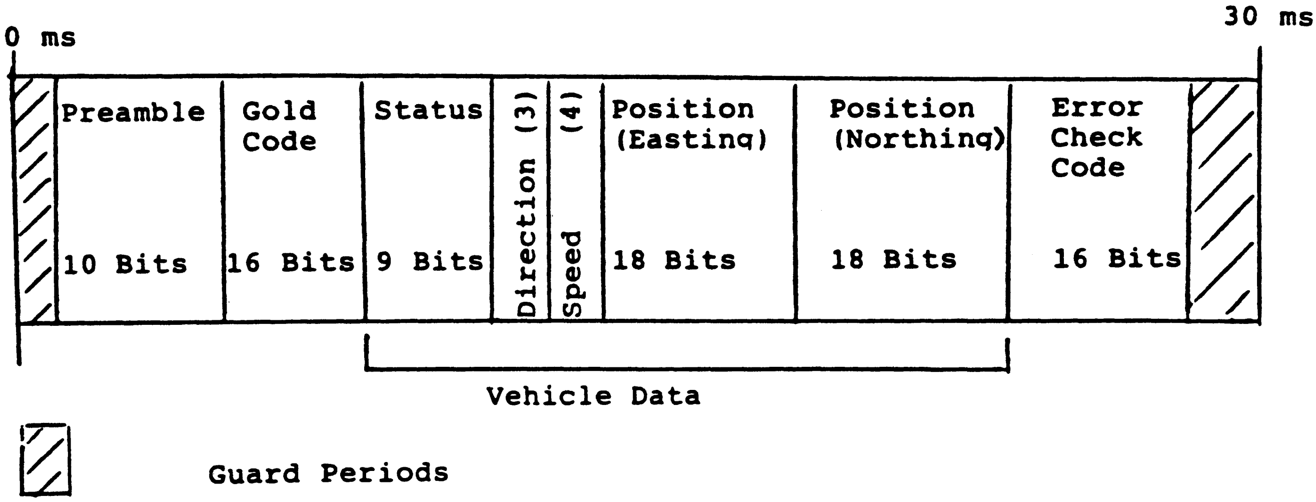


Fig. 2 Vehicle Slot Data Format

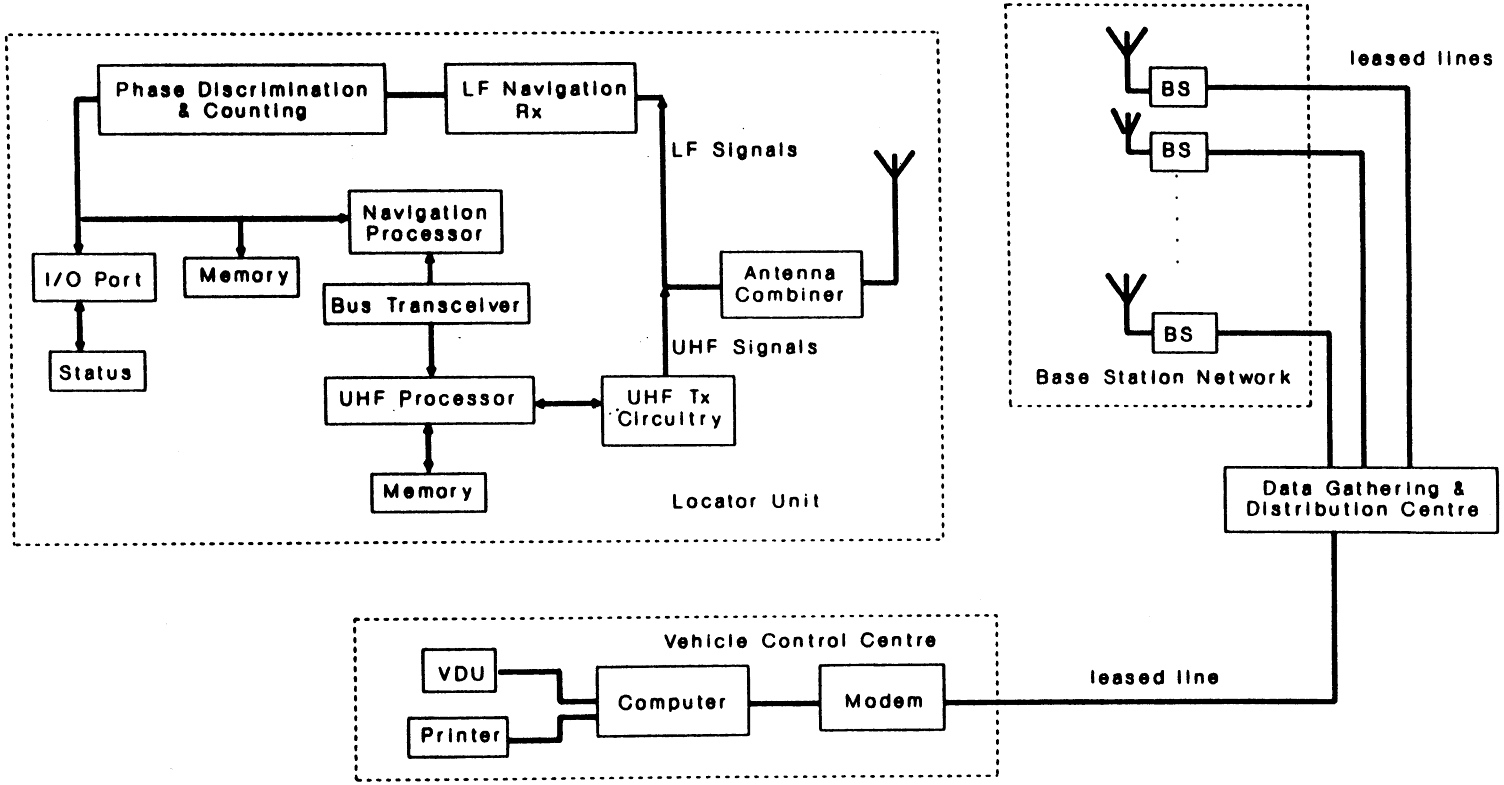


Fig. 3 Vehicle location system

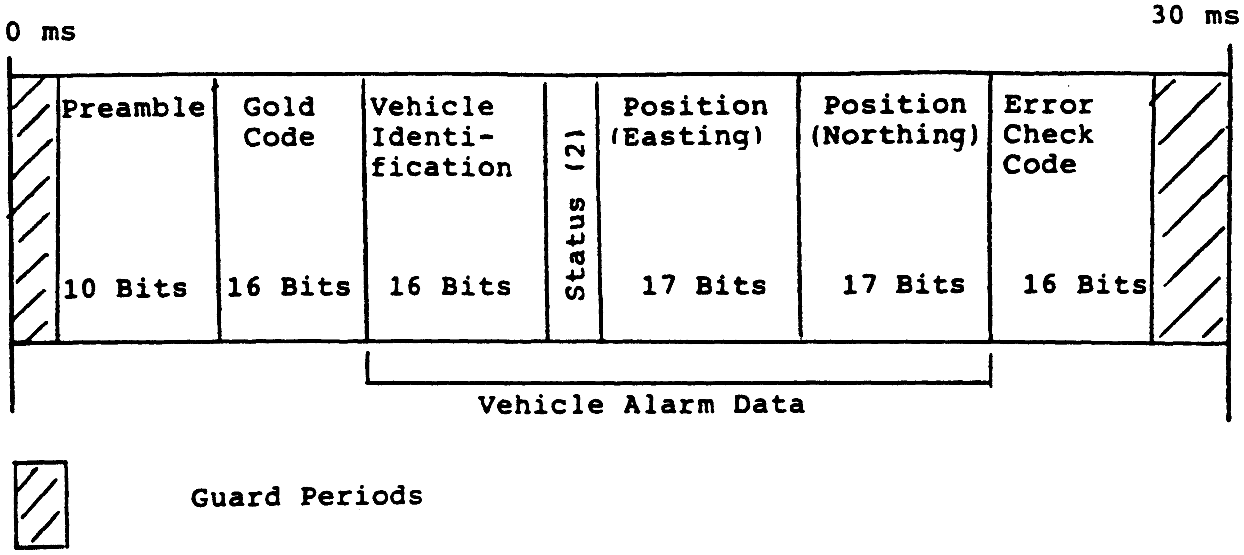


Fig. 4 Alarm Slot Data Format

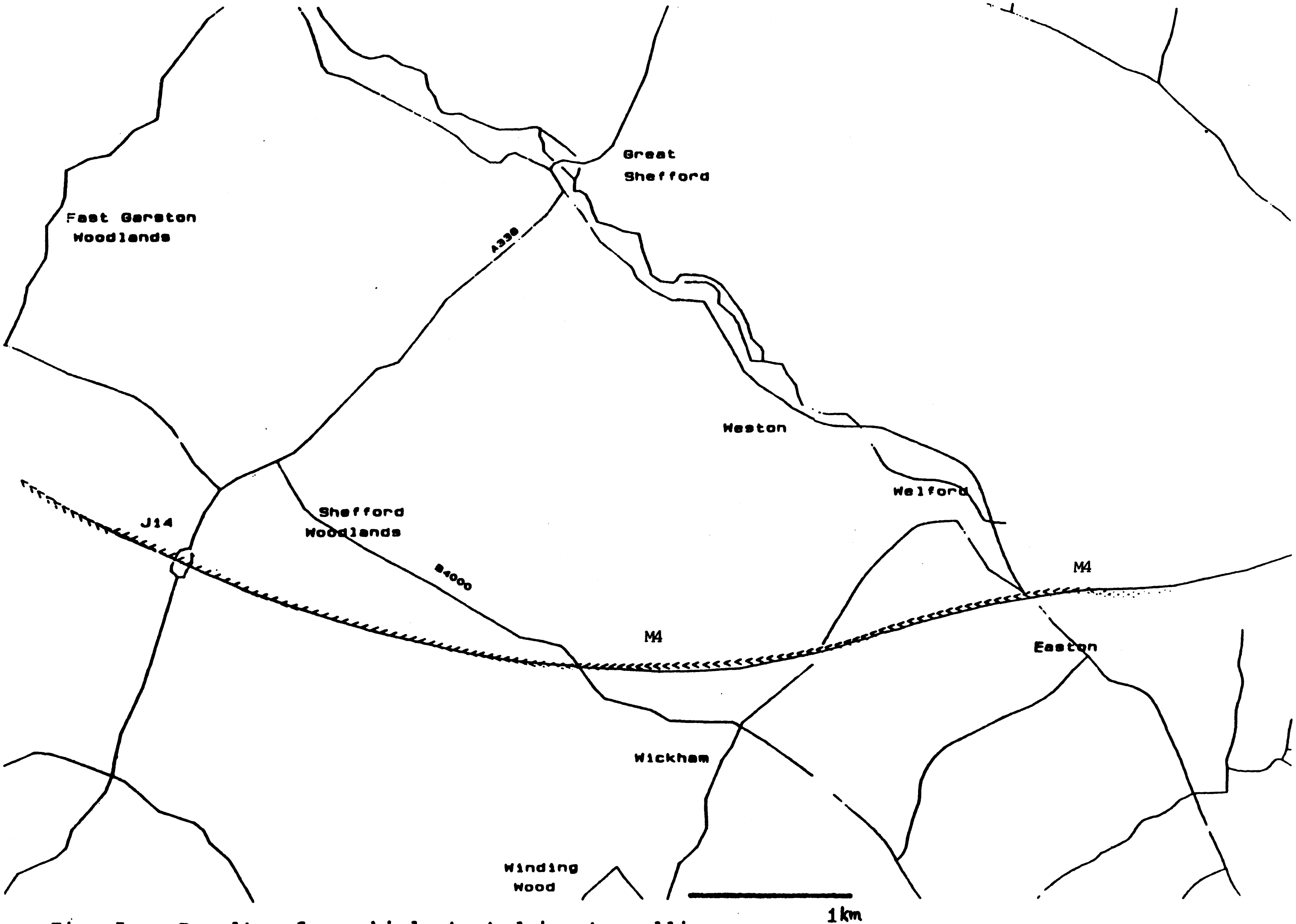


Fig. 5 Results of a vehicle test drive travelling West along motorway M4 in West Berkshire.

ANNEX II

AVL SYSTEMS IN JAPAN

Since 1980 Japan has introduced direct proximity AVL systems in 7 cities and inverse proximity systems in 16 cities.

In the Tokyo metropolitan area, a direct proximity AVL system with 29 signposts is used by about 5400 taxis (October, 1983). For direct proximity systems, the country is divided into 50 km squares, each with an area code and a reference point in the North-West corner. Each signpost is assigned an area code (2 digits) and an *x* and *y* position code (2 times 3 digits) relative to the reference point.

The signposts transmit on 426 MHz with a power of 0.01 to 1 W using sub-carrier FM modulation (1500 Hz, 1900 Hz FSK at 200 bit/s). A 15 bit frame synchronization signal is followed by the area and position code in which each digit is BCD coded with added parity bit.

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ANNEX III

SPREAD-SPECTRUM AVL SYSTEM DEVELOPED IN AUSTRALIA

1. In the Sydney metropolitan area of Australia, an automatic vehicle location system called QUIKTRAK has been operational since late 1987 [Hurst, G., 1989]. The system has been designed to provide coverage over an area of some 2000 square kilometres with an accuracy of about 30 metres. The system has the capability to support many independent users and many thousands of vehicles with a tracking capacity of 30 000 locations per hour. Spread-spectrum, phase-multilateration techniques are used to provide accurate locations on moving vehicles in the severe multipath environment encountered in heavily built-up areas.

2. The QUIKTRAK system consists of:

- Vehicle-mounted transponders,
- Multi-channel, spread-spectrum receivers at remote sites,
- Transponder control transmitters co-located with some of the receiving sites,
- A system timing-reference transmitter,
- A central processing site,
- User terminals.

2.1 Transponders. The transponder mounted in a vehicle to be located consists of a low-power, spread-spectrum transmitter and a low-current-drain receiver to pick up system commands and control the spread-spectrum transmission. The control receiver receives and decodes standard paging data to activate the transmitter and to select the spread-spectrum channel. The transmitter produces a direct-sequence spread-spectrum signal with a main-lobe bandwidth (null-to-null) of 2 MHz and a power output of 25mW. Within the QUIKTRAK system, spread-spectrum channels are defined and selected by their carrier frequencies which are offset from each other by small amounts relative to the signal bandwidth. All channels are accommodated within essentially the same 2 MHz system bandwidth located in the UHF Radiolocation band.

2.2 Receivers. Remote receiving sites are located throughout the system coverage area at approximately 15 km spacing. Each site contains a multi-channel spread-spectrum receiver and a remote site computer. The receivers acquire and track the spread-spectrum signals and measure the phase of the pseudo-random spreading code with respect to a system-wide reference signal. In addition to controlling site operation, the remote-site computer relays the signal time-of-arrival information (code phase) from all channels to the central computer via telephone line. Some remote sites also include a transponder control-signalling transmitter.

2.3 Transponder Control Transmitters. Transponder control is accomplished using conventional wide-area paging techniques. Consequently the transponder control transmitters consist of simulcasting 25W paging transmitters. QUIKTRAK transponder control signalling is located in the UHF land-mobile band.

2.4 Timing Reference Transmitter. System sychronisation is achieved by transmitting a separate spread-spectrum signal, from a centrally located site, which all remote sites receive and track. The signal is similar in structure and power output to that radiated by a transponder but is located in a separate 2 MHz band. By locking to this system-wide, low-power signal it is possible for all remote-site receivers to be synchronised to nanosecond precision and thus highly precise comparisons may be made on time-of-arrival of transponder signals at the various sites.

2.5 Central Processing Site. All sites send transponder time-of-arrival information to the central processing site by telephone line. The central computer processes all available information to calculate a best estimate of transponder location. In addition to calculating positions, the central computer schedules transponder activation in response to user requests and passes transponder locations to the relevant user terminals via telephone lines.

2.6 User Terminals. The user terminals are located on the users' premises and are connected to the central computer via telephone lines. The terminals usually take the form of a Track Display Station (TDS) which consists of QUIKTRAK software running on a personal computer. The TDS accepts operator inputs for vehicle location requests and displays vehicle locations on colour video maps stored within the TDS. A complete suite of maps for the system coverage area is stored within each TDS.

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ANNEX IV

GUIDANCE SYSTEMS

1. Introduction

Increasingly the potential benefits associated with the use of guidance systems are being recognised. Many such systems have been developed in Europe and North America.

European collaboration has been agreed for the development of electronic systems for road traffic. The European Commission has funded a planning exercise called DRIVE (Dedicated Road Safety Systems & Intelligent Vehicles in Europe). This programme [Commission of the European Communities, 1988] is aimed to assess if information and telecommunication technology could make a major contribution to the improvement of road safety. The main emphasis is being placed on making the system available as widely as possible. Two of the major studies are of vehicle guidance and communication.

Also, PROMETHEUS (PRO-graMme for European Traffic with Highest Efficiency and Unprecedented Safety), is a programme initiated by the European car industry. One of the subprogrammes, Pro Road, suggests the creation of roadside communication and information equipment to provide data to a computer on a vehicle for use in higher level management systems. One important task is the standardization of a European digital road map.

2. Benefits

Research by the British traffic researchers [Belcher, 1989] has shown that saving of about 10% of journey costs could be achieved with a route guidance system. Average journey times could also be reduced by about 10%.

3. Types of guidance systems

Guidance systems can in general be classed as Autonomous systems and Infrastructure-supported systems.

3.1 Autonomous systems

The major advantage of autonomous systems is that they do not require any external navigation information and so they are self-contained. There are two types of autonomous system - simple directional aids and map display systems.

Simple directional aids are essentially dead reckoning systems. The on-board processor computes the vector connecting the initial location and the destination. Drivers are only provided with heading and distance information but the route of travel is decided by the driver.

Map display systems show the driver his position on a map display. A data base containing digitised cartographic data is required. In some map display systems, an automatic route search facility is available in an on-board computer which presents to the driver the optimum travel route. However these driving recommendations may in fact be sub-optimum because changes in the road network or actual traffic conditions have not been taken into account for route calculation. This problem might be overcome by receiving information from an external broadcast traffic channel such as RDS (Radio Data System) [European Broadcasting Union, 1984].

3.2 Infrastructure supported system

In an infrastructure supported system, a large number of roadside signposts are installed at strategic locations. Guidance information between signposts is provided by dead reckoning techniques. The vehicle on-board computer measures journey time between signposts and this information is transmitted to a central control room via two-way communication signposts which have the combined nature of the active and passive signposts. This information together with the traffic conditions such as the effects of incidents and time-of-day variations in traffic patterns are taken into account by a central computer which then determines the best route to the destination for each individual user. This recommended route data is transmitted to drivers via the signpost network.

Guidance and up-to-the minute traffic information are available in this system, but the information is only valid within the coverage area of the infrastructure network.

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