

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 km². 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 2 σ (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.