RECOMMENDATION ITU-R M.1307

AUTOMATIC DETERMINATION OF LOCATION AND GUIDANCE IN THE LAND MOBILE SERVICES

(Question ITU-R 51/8)

(1997)

Summary

The ability to automatically determine location and to provide guidance has become increasingly important over at least the last decade and a half. This trend is likely to continue, if not accelerate, in the land mobile services. Further, various automatic determination of location and guidance (ADLG) techniques promise to play a major role in the Transport Information and Control System (TICS). This Recommendation presents a general overview of ADLG as well as technical information and examples of existing systems.

The ITU Radiocommunication Assembly,

considering

a) that automatic determination of location (ADL) will become an important part of many types of land mobile systems, particularly, but not limited to, dispatch systems and public safety systems; and other types of systems such as tracking of objects or wildlife, and search and rescue;

b) that the introduction of ADL into dispatch type systems can potentially improve spectrum utilization efficiency of communications channels due to reduction in voice traffic related to location and routine information;

c) that one of the most critical elements in dispatch service is the knowledge of current accurate location of every unit in the operational fleet;

d) that costs of running land mobile dispatch operations are increasing;

e) that a considerable part of the voice communications on a radio dispatch channel is location and other routine messages;

f) that ADL integrated with a land mobile radio dispatch system can potentially reduce the cost of dispatch operations;

g) that accurate information on the location of units in a public safety operation can increase the potential of saving lives and protecting property;

h) that ADL techniques may be of great value for non-dispatch type systems which involve tracking the location of an object;

j) that ADL may be used to locate people or vehicles travelling off-road routes or in wilderness, particularly in distress situations;

k) that within the land mobile service there is growing demand for guidance systems;

l) that both ADL and guidance systems may use the same basic techniques for location;

m) that guidance systems can potentially reduce journey costs and improve road safety;

n) that both ADL and guidance techniques may be key elements of Transport Information and Control System (TICS),

recommends

1 that ADL include the determination of location of all animate and inanimate objects, and messaging associated with the location or monitoring of the given object. Such messaging may consist of voice or non-voice communications necessary to provide accurate, timely and complete status and instructional information relating to the object (or vehicle) being located or its occupants;

2 that interconnection with the public switched telephone network (PSTN) be limited to store and forward type operations;

3 that the following broad operational requirements be considered when implementing ADL in the land mobile service.

3.1 Positional accuracy

For many services, accuracy to be provided is of the order of 100 m. In the public safety service, such as police, accuracy of the order of 10 m may be required. For other users (e.g. large area trucking and similar dispatch), an accuracy of about 1 km could be adequate. When systems such as tag readers are employed, as in bus and train routes, accuracy of 1 m may be achieved.

3.2 Updating position

The frequency of position update transmissions will depend on the specific application. For vehicles requiring quick deployment in limited areas (e.g. police, fire tenders, ambulances), a frequency of updating of approximately once per minute may be necessary. For dispatch operations over larger areas or defined routes (e.g. trucking, omnibuses, taxi, trains, or wildlife tracking), much less frequent updating is required.

3.3 Coverage area

For many systems (e.g. police, fire, ambulance, passenger omnibus, taxi) operational areas up to 100 km $\times$ 100 km are common. Some operations are confined to much smaller areas of up to 10 km^2; others may require national or regional coverage;

4 that ADL systems should be used to achieve the following benefits:

4.1 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 vehicles and personnel;

– improved on-time service;

– improved efficiency of response during emergency and dispatching a replacement vehicle;

– increased passenger loads due to more convenient and up-to-date location information being available to the public;

– economic benefits accruing from improved fuel efficiency and all of the improvements listed above;

4.2 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;

– economic benefits accruing from the above;

– possible improved chances of success in search and rescue operations at remote locations;

4.3 In other types of operations:

– scientific uses such as wildlife tracking;

– location of stolen vehicles;

– increased efficiency of certain manufacturing processes, such as assembly line quality control;

5 that ADL systems should be used to improve spectrum utilization efficiency by reducing or eliminating the need for voice communication to provide location information;

6 that the following ADL techniques could be used in the land mobile services:

6.1 Multilateration systems:

– hyperbolic,

– Global Navigation Satellite System (GNSS),

– differential-GNSS;

6.2 Non-multilateration systems:

– proximity,

– dead reckoning,

– satellite,

– homing beacons,

– combinations of the above;

6.3 Combinations of multilateration and non-multilateration systems;

6.4 Links:

– a forward link is any signal transmitted to a mobile unit to be located by a multilateration system,

– a reverse link is a multilateration signal transmitted to the fixed or base station,

– a communication link is used for two-way messaging in multilateration systems.

A brief description of each ADL technique is given at Annex 1;

7 that the following navigation systems could be used within land mobile service application:

– GNSS (Global positioning system (GPS), GLONASS, etc.);

– Loran-C;

8 that examples of parameters which may be useful for international standardization, can be found in the examples of three such systems given in Appendices 1, 2 and 3;

9 that guidance systems can provide savings of journey costs by reducing travel time;

10 that the following guidance systems could be used in the land mobile services:

– autonomous systems,

– infrastructure supported systems,

– dual mode systems,

– a brief description of each is given at Annex 2;

11 that frequency bands which could be used in automatic determination of location and guidance (ADLG) in the land mobile services would be found within the bands allocated to radiolocation and mobile as necessary for specific uses described in Annexes 1 and 2.

ANNEX 1

ADL techniques

The following ADL techniques can be used individually or in combination to meet the operational requirements of land mobile users:

1 Multilateration

1.1 Hyperbolic

Location is determined using distance differences from three or more fixed transmitting 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. Location is then determined from the intersection of these lines.

2 Non-multilateration

2.1 Proximity

A number of techniques may be employed which use proximity detection:

2.1.1 Tag readers

Location is determined by proximity to signposts of precisely known location. A wide range of techniques has been employed to this end (generally for location of vehicles), including inductive loops, UHF radio transmission, microwave transmission and infrared transmissions. Generally, signposts at known locations along a predetermined route are equipped with small low power transmitters. The vehicles travelling the route are equipped with “tags” affixed to their sides which, at close range, passively reflect or retransmit the signal from the signpost – modulating the signal to provide specific information about the vehicle – which the signpost receives in acknowledgment to its interrogation. This information is then relayed to the dispatcher. This type of system may also be useful for tracking objects in manufacturing assembly lines for quality control, and in electronic toll and traffic management systems.

2.1.2 Homing devices

Radio-frequency beacons have been successfully used for the purpose of locating stolen vehicles. A transmitter is automatically activated upon unauthorized use of the vehicle. The location of the vehicle is then determined using direction finding arrays and triangulation.

2.1.3 Radar proximity devices

Super high frequency short range radar can be used in vehicles to detect the presence of other vehicles moving into range for potential collision. These form the basis of land mobile collision avoidance systems.

2.1.4 Dead reckoning

These techniques employ heading and distance-travelled sensors for calculating the location of vehicles relative to fixed known location references. Location determination accuracies depend on the sensing devices, frequency of reference updates and the severity of external factors such as magnetic field variation, wheel slippage and road camber, etc.

2.1.5 Links

Links are used in multilateration systems, as follows.

2.1.5.1 Forward links

A forward link is any signal transmitted to a mobile unit to be located by a multilateration system.

2.1.5.2 Reverse links

A reverse link is a multilateration signal transmitted to the fixed or base station. Reverse link signals are contained within the broadband segment of the multilateration signal and are primarily location pulses originating from mobile units and used for determination of the position of mobile units. Such transmissions may also originate from other fixed or base stations for the purpose of system synchronization or testing. These transmissions are likely to occur less frequently and more randomly than forward links and are therefore less likely to cause interference.

2.1.5.3 Communication links

Communication links emanate from the fixed or base station and mobile units ancillary to the ADL function of the multilateration system, and provide status and instructional information relating to the vehicle being located or its occupants. These links may be interconnected with the PSTN to enable emergency communications.

3 Satellite

Satellites in the mobile-satellite service may be used to relay information concerning the location of vehicles. Satellite systems may be similarly employed in search and rescue operations. The vehicle or person in distress activates an emergency transmitter which relays its location to a rescue centre.

ANNEX 2

Guidance systems

1 Autonomous systems

Autonomous systems do not require any external map data or route guidance calculation. There are three types of autonomous systems - directional aids, map display, and route guidance systems.

1.1 Directional aids

These systems primarily use dead reckoning techniques, although some include other methods such as GPS. An on-board processor estimates the vector connecting the initial location with the destination. The route of travel is inferred by the driver using the heading and distance information provided.

1.2 Map display systems

These systems indicate position on a map display of digitized cartographic data. The vehicle tracks its own progress along the route using gyroscopes, map matching, dead reckoning, and GPS techniques. Centrally assembled digital traffic information can be transmitted to the vehicle and displayed on the map for the driver’s information.

1.3 Route guidance systems

These systems include an on-board computer, which computes turn-by-turn driving directions. The vehicle tracks its own progress using gyroscopes, map matching, dead reckoning, and GPS techniques, and corrects the routing instructions as necessary. These systems may also accept digital traffic information for real-time route optimization.

2 Infrastructure supported systems

In infrastructure supported systems, a large number of roadside signposts are installed at strategic locations. Guidance between signposts is accomplished by dead reckoning techniques. A vehicle on-board computer measures journey time between signposts and transmits this information to a central controller via two-way communication signposts which have combined active and passive functions. Journey time, together with the traffic conditions, is taken into account by a central computer which determines the best route for each individual user. The recommended route information is then transmitted back to the user through the signpost network.

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

3 Dual mode systems

Dual mode systems combine features of infrastructure-based and autonomous route guidance systems. In city centres and other densely populated and congested areas, infrastructure-based mode is used to combine route guidance capabilities with real-time traffic management. Signalized intersections or other appropriate structures in the central area are equipped with beacons. Outside the central area, the system switches to autonomous mode, providing wide area route guidance capabilities without need for infrastructure.

APPENDIX 1

ADLG system used in the United States of America

The band 902-928 MHz is one band that will be used for ADLG in the United States. The basic technical and operational characteristics of this system are as follows:

1 Technical parameters

1.1 Bandwidth

The bandwidth used will vary depending upon the type of ADL system or utilization, as follows:

– between 2 and 8 MHz for multilateration systems,

– between 2 and 12 MHz for non-multilateration systems,

– 250 kHz for narrow-band data links.

Maximum peak effective radiated power (e.r.p.) is limited to 300 W for narrow-band datalinks and 30 W for multilateration and non-multilateration systems, in order to reduce the potential for interference between ADL systems and between ADL and other systems.

2 Operational characteristics

Communication links may be wideband or narrow-band.

2.1 Narrow-band communication links

Narrow-band communication links are used to provide voice and data communications using narrow (25 kHz) bandwidths within the multilateration band being used. Maximum power of such links should probably not exceed 30 W e.r.p. Given this power limitation and the sporadic nature of such transmissions, the probability of interference to other users of the band 902-928 MHz should be minimized.

2.2 Wideband communication links

Wideband communication links are employed as follows:

– Forward links may either be wideband, that is, operating over the entire bandwidth of the multilateration signal; or narrow-band, in which the uppermost 250 kHz portion of the multilateration bandwidth is employed. Because narrow-band forward links will generally be used in the upper portion of the band 902-928 MHz, the probability of interference to other users of this band is lower, and a greater e.r.p. may be used (up to 300 W).

– Reverse link signals are contained within the broadband segment of the multilateration signal and are primarily location pulses originating from mobile units and used for determination of the position of mobile units. Such transmission may also originate from other fixed or base stations for the purpose of system synchronization or testing. These transmissions are likely to occur less frequently and more randomly than forward links and are therefore less likely to cause interference to other users of the band 902 - 928 MHz.

APPENDIX 2

ADL system used in the United Kingdom

This ADL system, known as Datatrak, typically provides regional or national coverage. The system is well-established in the United Kingdom and systems are either in operation or under construction in Argentina, Belgium, Holland, and South Africa, and are being planned in a number of other countries.

Location is derived from phase measurements made on the signals from a network of VLF transmitters, and position reports from the mobile units are routed to control or monitoring centres through a UHF data network. Full two-way data communication links are also available.

System characteristics are as follows:

1 The system has been specifically developed as a cost-effective system for land mobile services, and most applications involve vehicles. Some specialist requirements, however, are covered by portable equipment. The system provides integrated ADL, data messaging, and dispatch control in real time.

2 Data interfaces are available, enabling links to command and control systems, PSTN, etc.

3 a) Positional accuracy under normal operating conditions is better than 50 m. In favourable conditions, or if used differentially (e.g. one vehicle tracking another) accuracies of the order of 10 m may be obtained.

b) Position is re-calculated on a continuous basis by the mobile unit, and position update transmissions are made at regular intervals to suit the requirements of the application. Standard update intervals vary in the range from 28 m to 13 s.

c) A typical network will provide accurate coverage over an area between 100 km × 100 km and 1 000 km × 1 000 km, depending on the number of stations in the network.

4 The system is used in a wide variety of applications:

– trains and buses (for passenger information and fleet management),

– emergency services (for command and control),

– security vehicles (for protection of high-value loads),

– service operations (for improved fleet efficiency),

– loan worker protection,

– police operations,

– stolen vehicle tracking and recovery.

5 The system is spectrally efficient, requiring only approx. 250 Hz bandwidth at two VLF frequencies in the 100-150 kHz band, and a single 12.5 kHz channel pair at UHF in the 450-470 MHz band to provide two-way short message data communication at up to 10 kbit/s for all units within the coverage area.

6 The system is a terrestrial system using hyperbolic multilateration techniques. It has also been integrated with other techniques, including dead reckoning and GPS, to provide special features for particular applications. Location is determined on the basis of forward links only, with a one-way or two-way communication link as required for the application.

7 The system uses terrestrial, hyperbolic techniques.

8 It is a proprietary system, for which no international standard exists. However its increasing use in different countries makes it a strong candidate for inclusion in future standardization activities.

9 The reduction of travel time, particularly in vehicle fleet management, is one of the main application areas for the system.

10 It is an autonomous system, providing wide area coverage from a relatively sparse network infrastructure rather than a dense beacon infrastructure.

APPENDIX 3

Taxi automatic vehicle monitoring system used in Japan

A system used in Japan, the taxi Automatic Vehicle Monitoring system, is used to determine the states and positions of taxicabs by radio equipment mounted on each vehicle. The vehicle positioning techniques developed and put into practical use in the past 20 years are shown below in historical order.

1 Distributed transmission system

Many radio stations transmitting the respective position signals are distributed. When a vehicle passes near each station (generally within 500 m in radius), it receives the position signal and transmits it, adding information such as vehicle number and state, etc. back to the vehicle operation centre. Since shared use of radio stations by multiple taxi companies is possible, this system is mainly used in cities where there are many users.

2 Distributed receiving system

Receiving stations are distributed in the operating area of a taxi company to receive each vehicle position number and state and send this information to the vehicle operation centre. Since each company installs the receiving stations, they can be placed for desired positioning accuracy but the communication line cost from the stations to the operating centre is expensive.

3 Semi-automatic system

This system grasps the position of each vehicle when the driver pushes the position set button according to the predetermined rule. Because the positioning depends on the drivers' operation, this system does not belong to the ADLG category. This system has been used widely, however, because of the inexpensive equipment cost and satisfaction of the needs of taxi companies and taxi drivers.

4 GPS receiving system

This system has been spreading recently along with the implementation of the GPS satellites and car navigation systems. The positioning accuracy has been improved greatly. A road map is displayed on the screen and the relative location of the vehicle is indicated for easy use by almost anyone.