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AUTOMATIC VEHICLE LOCATION SYSTEMS

DEFINITIONS

AUTOMATIC - Generally accepted as being a system with a capability of determining position without any action by the occupants of the vehicle and its presentation to operators at a central control point.

VEHICLE - Can be Land, Sea or Air mobile.

LOCATION - Usually by Grid Reference, Latitude/Longtitude, Special Map Grid or an arbitary map square as is used by some manual input (touch map) systems.

TYPES OF LOCATION METHODS

Categories include;

-non cooperative vehicle methods - e.g. radar and DF of radio communications signals

-cooperative vehicle methods - e.g. special transmissions to and or from purpose fitted equipment on the vehicle

Systems include;

-those entirely provided for navigation, e.g. DECCA, LORAN, OMEGA and fixed route beacon systems

-those which derive location information from existing or modified radio communications systems

-those which are purpose fitted for location determination and also provide status information and a limited amount of communications e.g. pre determined messages like 10 code.

USERS OF LOCATION SYSTEMS

Existing common user navigation aids are mostly used by ships and aircraft. The systems were designed for such use and their adaption for use by land mobiles is not so simple as might appear at first sight. Two major problems are those of scale and the radio propagation aspects which are peculiar to land mobile use.

Our main concern is, of course, for use by land mobiles as in the Police and, possibly, Fire services. It is therefore of advantage to survey all methods and to try to assess their relative suitability or otherwise for this purpose.

METHODS OF DETERMINING POSITION

DEAD RECKONING i.e. given that a start location is known and fed into the mobile system, heading and distance travelled will enable present position to be determined. This calculation can be done on board the vehicle or at a central point. In either case a radio link is required to transfer the raw or processed position information. The sophistication of this type of system is dependent on the accuracy of the determination of position required, it varies from the Boeing FLAIR at one end of the scale to the London Transport bus system at the other which only needs to measure the distance travelled along a pre-determined route with frequent checks by reference to roadside beacons. An interesting system is at present on trial by British Rail on the London-Birmingham route which uses power-less beacons on the track, power being provided by the train as it passes over the beacon and digital information is passed to the on board equipment.

MEASUREMENT OF BEARING - Radio Direction Finding (DF). This can be done by DF equipment in the mobile taking bearings of two or more fixed transmitters and plotting the position on board - NOT of practical use by Police mobiles. Alternatively, bearings of the mobile transmission can be taken by two or more fixed receiving stations. Plotting/calculation can then be done automatically at the central point. The technique is commonly called TRIANGULATION but position can be determined by means of bearings from two stations. Accuracy depends on the siting of the fixed stations and the position of the mobile relative to them as well as instrument and propagation effects.

MEASUREMENT OF DIST, .E - in practice a measurement of Time which is the Difference bet ,en the times taken by radio signals to travel to or from the mobile and two or more fixed stations. These time differences are then converted to distance differences from which can be derived the vehicle position. The basic time measurement can be made

-at the mobile, by the mobile, of signals from fixed transmitters

-at a central point, of signals radiated by the mobile, received by fixed receivers and relayed to the central point

-at a central point, of signals radiated by fixed transmitters, received by the mobile and reradiated by the mobile to the central point

-at any of the above points by the phase comparison of CW or tone modulated signals or by the arrival time of pulses. The measurement of time difference must be done twice for every position determination as one will only indicate a locus of positions all having the same distance difference from the two fixed stations. At least three fixed stations are required to determine position which is done by the use of a hyperbolic grid. Accuracy is dependent on the siting of the fixed stations and the position of the mobile relative to them in addition to instrument and propagation effects. The maximum accuracy is obtained where the loci of constant difference of distance from pairs of stations intersect at right or near right angles.

Having considered the main methods, now consider several specific systems, proven and or proposed.

RADIO DF SYSTEMS

Systems in use for the location of aircraft use V/UHF commutated aerial DF stations which take bearings of the aircraft communications transmissions, these bearings are relayed to a central point where automatic triangulation equipment presents the plot to the control operator. Accuracy is largely determined by the quality of the site chosen for the DF stations as instrument and near site errors can be calibrated out. The use of this system for land mobiles is doubtful. Accuracy would be about one mile at best which might be sufficient in the wide open spaces of rural areas but would be of little use in urban areas where the accuracy would be lower anyway. Tests of a three station system in Essex, using elevated VHF Adcock aerials, were carried out by Marconis in conjunction with Essex Police circa 1966 and the results support this surmise. As far as is known, there is no system of this type is in use or on offer for Police land mobile use.

HYPERBOLIC SYSTEMS

Transmitters for DECCA, OMEGA and LORAN exist and are are available now. To make use of them, the vehicle requires to

to be fitted with the appropriate VLF/IF receiving equipment.

DECCA uses continuouswave IF transmissions and measures phase differences between signals received from two pairs of transmitters. Presentation is by Zone and Lane numbers which have to be plotted on a prepared Decca chart. The design aim of the system is to tell the operator in the vehicle where he is, the venicle aimed at is a ship or aircraft at ranges of up to 100 miles from the transmitters. The effects of sky wave interference affect the accuracy beyond this range. A "lane" width varies in distance on the ground from about 400 yds on the base line upwards so that the possible accuracy varies very much with th position of the vehicle relative to the transmitters. Recent tests carried out by Decca in Central London using a marine type receiver fitted in a Land Rover resulted in 95% of readings being within 250 yards of the observed position and with a standard deviation of 88 yards. This represents the "raw" data and accuracy of the presented plot after processing for credibility etc at a central point could reduce the size of the error. To completely define a location requires 3 x 6 i.e. 18 alphanumerics, so to use this type of location system as a Police AVIS would entail the transmission to the central point of 18 alphanumeric characters plus vehicle identification symbols for processing each time every vehicle's position is updated.

OMEGA is a long range VLF phase comparison system. The transmissions are contiuous wave with a duty cycle of 1 second ON 10 seconds OFF. Propagation is by ducted wave, guided by the ionosphere, so that the phase stability and therefore the accuracy of the system varies with its height. Omega is unlikely to be used for land mobile position finding. Accuracy varies between 300 yards and 2 miles depending on time of day, position and sophistication of the receiving equipment.

IORAN C measures the difference of arrival times of pulsed transmissions on a shared frequency of 100 kHz. Each "chain" consists of three transmitters. The Master transmits 9 phase encoded pulses, each 300 microseconds long spaced 1000 microseconds apart. The pulses are received by the mobile and the other two transmitter sites, the first slave transmits 8 phase encoded pulses after a preset delay and the second slave does likewise after a longer preset delay. This whole sequence is repeated after a time which is set for each chain of between 0.0£ and 0.1 seconds, this is to enable the mobile receiver to discriminate between chains in areas where coverage overlap occurs as adjacent chains then have differing repetition intervals. A matter of academic interest is that although the system is referred to as a pulsed system, the actual time measurement is made with reference to the zero crossing point of the end of the third RF cycle in each pulse. The main advantage of the use of bursts of RF being the conservation of spectrum by enabling all transmissions to share one frequency allocation and a secondary advantage is the effective increase in the useful range of the ground wave by elimination of skywave interference. Accuracy within ground wave range is 95% within 200 yards. Note that Southern England is not within ground wave range of the local chain.

TRILATERATION SYSTEMS

Trilateration systems are the same in principle as hyperbolic systems, they use measurements of time differences between radio signals travelling different distances as the basis of calculation of position. The term trilateration is really to

to distinguish them from triangulation systems in that distances are measured rather than angles. Systems which utilise more than three stations are sometimes referred to as Multilateration systems. The main differences from systems already discussed are that the mobile is usually, not always, the transmitting member and it is always involved in an active interchange with the fixed stations, these systems having been usually designed for land mobile use. The other difference being that the transmissions are in the VHF or the UHF bands. The location of the fixed stations for these is more difficult than for a normal radiocommunications system, for the latter, areas of overlap are usually small by comparison with the main area coverage. For a location system of this type, all the area covered has to be within range of at least three stations. It may only require two to make a quarrel but it needs three to make two differential pairs. The method of measurement is by phase comparison or pulse arrival time as before but with the difference that the modulation is used for measurement rather than the carrier frequency. As a time of 1 microsecond corresponds to a distance of about 300 yards, a measurement accuracy of at least 0.1 microseconds is required. For pulse measurement, this means a bandwidth of 10 MHz. Pulse systems are thus confined to the higher frequency bands and this is probably the reason why the majority of systems proposed and on offer are phase measurement systems. It has been suggested that the LORAN C principle could be translated to the higher frequencies with a consequent increase in accuracy - unfortunately this is a load of cabbages and shows a complete misunderstanding of the principles of LORAN C and of time differential systems in general on the part of the author of the suggestion.

The main points relevant to systems which have been proposed or are on offer can now be considered.

PHASING SYSTEMS

SIEMENS system proposes using transmissions from the mobile as called for by a common transmitter and received at fixed receiving stations for onward relay to a central point for processing and presentation. Transmissions would be High Band VHF. The area covered by six receiving sites would be about 64 square miles and the accuracy claimed would be 90% within 300 yards.

PYE system, similar to Siemens, uses High Band VHF. Tests carried out in London using three receiving stations and one transmitter for call up of transmission by the mobile resulted in 90% of measurements being within 1100 yards

COSSOR proposed system uses transmission in the UHF (c 470 MHz) band and the mobile retransmits the signal received from the master fixed transmitter for reception by three fixed receiver stations. Accuracy claimed is that 95% of measurements will be within 400 yards. This claim is backed by the results of tests carried out in the US of A. No information on receiver station spacing is given but it can be deduced to be similar to or less than Siemens.

PULSE RANGING SYSTEMS

The proponents of pulse systems argue that in conditions of multipath propagation, more accurate measurement can be made of pulse arrival time difference than by phase comparison. This is because the leading edge of the pulse must be made up of the signal which has travelled the shortest distance. In the case of LORAN C this is demonstrable since the difference in time of arrival of

arrival of ground and skywave exceeds 30 microseconds due to the distances involved. In the case of U/VHF transmissions there will be more than two paths involved with very small time differences and the shortest path may not necessarily be dominant. To take the maximum advantage of this property of pulses it is necessary that the pulse have a very steep front edge, this means BANDWIDTH, at least 10 MHz of it.

Theoretically a LORAN C type of system could be used, transmitting in the 900 to 1000 MHz band. The number of sites required to cover a city would be large and the economics would be questionable as the vehicle borne equipment would be complex.

The HAZELTINE CORPORATION pulse system is a complete location, status and routine message transmission system. Transmission is completely digital and in the 900 MHz band. Two 2 microsecond pulses transmitted by the mobile are received by fixed receiving stations and relayed to a central processor for analysis and presentation. The remainder of each mobile transmission is status and routine message bits. The accuracy claimed is 95% of measurements within 100 yards. The control and synchronising transmitter for an area of radius about 14 to 15 miles requires an exclusive channel bandwidth of 0.5 MHz. The bandwidth of the mobile transmission channel is 10 MHz. To cover this area, about 70 receiving stations will be required and each will require a 10 Mhz channel to relay to the centre. This relay channel is shared between the mobile transmissions and all the relay links by the use of spread spectrum modulation, directional aerials at the relay sites and an omnidirectional aerial at the centre. It would appear that problems of siting would loom large.

SUMMARIZING trilateration methods and systems, phasing systems can be contained in bandwidths similar to those at present required for voice communications and can provide location accuracies of the order of 300 to 500 yards. Pulse ranging requires about 10 MHz bandwidth and is claimed to be more accurate. Both types require means of synchronisation of transmissions from the mobiles by time slot or polling. Vehicle identification is required by code or timing and the number of vehicles that can be handled by any one system depends on the frequency of update and how much other information is passed to and from each vehicle.

All systems require a larger number of fixed stations than are required to give voice communications over the same area because the mobile must always be within range of at least three stations.

Relay of information to the central site is required, in the case of phasing systems it can be passed by landline or radio link, for pulse systems microwave links will be necessary. The relaying of raw signals for central analysis entails highly stable transmission paths and equipment. Partial analysis or measurement at the fixed sites and translation into digital form for onward transmission could reduce this need.

DEAD RECKONING SYSTEMS

Dead Reckoning systems depend on knowledge of the start or initial position and then the integration of heading and distance information. Similar argument might appear relevant to systems such as Decca, which require an initial position to be known, however, the reason for this in hyperbolic systems of the Decca type is to eliminate ambiguities. Similar to the case of a clock with a missing hour hand, the minutes may be to any accuracy

accuracy desired but relative to which hour?

Systems designed for land mobile use divide into two main categories, roadside beacon systems and the rest. Beacon systems are only of benefit to mobiles following predetermined routes, such as buses and trains. Of the rest, Boeing FLAIR and Marconi are for consideration. The use of roadside beacons in conjunction with either of these systems would be possible for checks and re-initialisation. This could only be on a random or bonus basis unless all road junctions in the covered area were so equipped. Their use can only be supplementary and such DR systems must, in "worst case" conditions, stand alone.

Of the MARCONI system, little is known. It is in the early experimental stage and in this form all processing and computation is done on board.

BOEING have at least two systems installed in the US of A at Wichita and St Louis for Police use. The system called FLAIR is an integrated system providing location, status and routine message transmission by telemetry to a central control point via a VHF radiocommunications system. The accuracy claimed by Boeing is 95% within 17 yards (50ft). Whether this is for the raw plots or after credibility assessment by the central processor is not clear but the latter is thought more probable since the heading is claimed to be within plus/minus 6 degree and the odometer within 0.5%. Wheelspin on rough ground, wet a. icebound roads can cause greater errors than this. The system has been demonstrated to work well in American towns with roads disposed mainly on right grids but requires "re-initialisation" after traversing open ground and off metalled roads. This resetting has to be done by the control staff, and it is for discussion how feasible it would be for centre staff to monitor the accuracy of a large number of mobiles. All tests and demonstrations of which information is to hand did not involve more than a few cars. Trial runs using Met Police mobiles in London and Boeing's computer in Wichita gave results in conformance with Boeing's claims.

The radiocommunications network has to be of sufficient quality to bear information in digital form. To be able to take advantage of the high accuracy of the basic position determining method, the polling or update cycle is 2 seconds and this limits the number of vehicles which it is possible to handle on each radio channel to about 200.

THE REQUIREMENT

Is there a requirement for an AUTOMATIC VEHICLE LOCATION SYSTEM for Police and or Fire Service use?

It has been argued that such a system is only needed if the occupants of the vehicle are not to be trusted to report their position accurately. This is demonstably another load of cabbages. The time at which up to date position information is required for action descisions is when an emergency arises requiring a fast response. The voice communications system and the operators for that matter just could not cope with the continuous flow of position information required from all vehicles on the move. Without an AVLS the present method must be perpetuated i.e. "Any mobiles in the vicinity of ..... proceed to assist .....". Depending on the nature of the incident, the response will vary, for example, a car chase will probably attract the entire divisional mobile strength

strength and depriving the area of balanced cover.

Thus AVLS appears to be a highly desireable system to have available for Police use. Whether it can be justified as an essential is not so clear. The case will largely succeed or fail on costs which in turn depend on the accuracy required. It has been calculated that even a rudimentary system could be cost effective as a result of savings in mileage travelled by mobiles responding to incident calls, neglecting such things as reduced response times which are unquantifiable.

It is difficult to see AVLS being justified for Fire Service use unless all appliances in a Brigade are to be used for fire prevention and inspection duties while still remaining available for first attendance mobilisation.

It seems that two standards of accuracy could be relevant, one for rural areas and the other, of a higher order, for urban areas. Unfortunately, this would probably mean two different systems rather than a Coarse and a Fine version of one. Another possibility would be a high accuracy system in towns and none in the country or a manual system at the most as the levels of activity of the Police and their quarry are much lower there.

The choice of a particular location system could have a major influence on the choice of data transmission system for use by the mobiles for purely communications purposes, it could also affect the communications area coverage, maybe for the better, as more fixed stations may be required and the whole area be in an overlap situation in one direction of transmission at least.

CONCLUSION

Of the systems discussed, and although all generic types have been covered by no means all existing or proposed systems have, all require additional expense for mobile equipment and for fixed stations.

The highest order of accuracy would appear to be obtainable with some form of Dead Reckoning and this would seem to be most suitable for use in towns where there are ample opportunities for check and correction by road junction positions etc. Its requirements for radiocommunications would be the minimum in that a few digits would have to be sent to the centre at regular intervals and these digits could easily be combined with status and other "user aid" binary data. No additional fixed stations would be required if good communications cover already exists, as indeed it should.

Similar arguments for the data transfer requirements of DECCA can be applied, but the on board radio navigation equipment would be more bulky, costly and so require a separate aerial, for a less accurate system.

Trilateration systems will give medium accuracy results with additional mobile and fixed equipment costs. The effect on the radiocommunications system will be variable depending on the actual system chosen.

The coarsest results will most likely be possible with DF or triangulation equipment. A polled or time slot transmission from the mobile will be required as for the higher accuracy systems and the presentation and processing equipment is likely to be of the same order of cost. Taken together with the cost of additional fixed receiving sites with a more stringent siting criterion, this makes it unlikely to be a serious contender for our purpose.

The final accuracy of all systems can be improved if credibility checks are performed by the central processor programme against such factors as distance from last known position, the position of rivers, roads, railways, bridges and other topographical features, speed of car and so on, before presentation to the control staff.

THE AVLS PROJECT SITUATION

The Directorate has invited a number of firms to demonstrate the capabilities of the various systems they are sponsoring in part of West Mercia.

No trials have as yet been mounted, it is anticipated that the first system to be used will be by DECCA.

It seems that although Police interest is apparently high, the level reduces rapidly when cost is mentioned and the object of the West Mercia trials must be to define what sort of system is feasible at what cost in a County area so that a proper Requirement can be stated which has some chance of being operationally valid and reasonably cost effective.

The use of the Boeing type of high accuracy system may be justifiable in densely populated areas such as London, though it is arguable whether Boeing have the right mixture for our purposes.

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