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INTERNAL DOCUMENT

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I.O.S.

AN EVALUATION OF PRECISION SURFACE POSITIONING SYSTEMS

INTERNAL DOCUMENT NO 13

NATURAL ENVIRONMENT RESEARCH COUNCIL

INSTITUTE OF OCEANOGRAPHIC SCIENCES

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1. INTRODUCTION

IOS (Taunton) has a requirement for a surface positioning system with an accuracy of a few metres, and a maximum range in the order of 50 Km. One project is dependent upon this degree of accuracy, and four others could benefit from it, or have a future requirement for it.

Such a system should be portable and easily deployed in order to accommodate all the IOS areas of interest. Systems in use at the present give no or inadequate coverage in some of these areas. Some HiFix chains are to be replaced with HiFix 6 using the same chain location and similar frequencies. However, as the HiFix 6 system is not compatible with HiFix, new receivers would have to be purchased or hired to operate in these areas.

The automatic logging of position data, and a track plotting facility is required. Transferability between vessels used by IOS is essential.

Electromagnetic position fixing systems extend from low to visible frequencies. The limitations of optical instruments such as sextants and theodolites, are well known. Systems that determine a range or bearing by means of a beam or pulse of light, can have very high accuracy. They are however essentially land surveying instruments, which require a static uninterrupted visual path for up to one minute, in order to resolve a single range or bearing. Therefore they are not suitable for marine use.

There are several alternative position fixing techniques using microwave, UHF and low and medium frequency electromagnetic waves. This report considers the relative merits and disadvantages of those systems which might be applied in the research at IOS (Taunton).

2. MICROWAVE POSITIONING SYSTEMS

2.1 Introduction

There are a number of microwave position fixing systems, designed or adapted for marine use. In general they are of the Range/Range type, although at least one system uses Range/Bearing.

The frequencies used are in the marine radar bands 'S', 'C', and 'X' (3GHz, 5GHz, and 9GHz) respectively. Ranging can be achieved by either phase comparison of the modulation on a continuous wave, or the flight time of a pulse: both have advantages and disadvantages.

Microwave systems are light and portable, and installation and operation may be performed by relatively unskilled personnel. The modern trend towards modular construction reduces down time and trouble shooting to a minimum. The power requirements are quite modest, and whole systems can be run on car batteries for several days.

In addition to the basic requirements a whole host of optional extras may be obtained for the various systems: multi-user, high-gain antennae, diversity reception, and operation with more than two reference stations, are but a few.

Update rate of one per second are usual, and in most systems the update is an average of a number of measurements. The output is usually displayed on two 5 or 6 figure readouts in metres.

All systems have digital outputs which can readily be interfaced to a computing calculator or minicomputer, together with a plotter and recording logger. Such a system could perform all necessary calculations, plot the course, print out co-ordinates and record the data.

2.1 Modes of Operation

2.2.1 Phase Comparison system

The usual arrangement for a phase comparison system is to have a mobile master station, and two remote stations, all transmitting continuous waves. The ranges are obtained by comparing the phase of modulation frequencies on the master and reference station waves. The ambiguities are resolved by means of multiple modulating frequencies. Some systems are fully automatic in this respect, while others are only partially automatic, and must be periodically checked for lane ambiguities and updated accordingly. The phase comparison systems tend to use the 'S' band. Although the peak power is low, the average power is higher than for a pulse system, and components of high power rating are more readily available at the lower frequencies.

Another advantage with continuous wave systems is the very useful bonus of having the possibility of a built-in two way voice, or even data link, between the mobile and reference stations. This facility may only be used when not ranging.

The phase comparison systems are more complex than pulse systems, and inevitably more expensive. They are however, inherently more accurate: ± 1m is quoted for some systems. Once calibrated the calibration should hold good for all ranges, and remain accurate provided the system frequencies are periodically checked for drift.

2.2.2. Microwave Pulse System

The pulse systems have a mobile master station which transmits a pulse or a coded sequence of pulses to two reference stations. The reference stations have a transponder which when interrogated by the pulse from the master re-transmits a coded reply. The purpose for the coding is twofold, it itentifies the reference stations to the master, and gives a high immunity from spurious signals in the same frequency band. As in pulse radar high peak power is used but average power is low, therefore component ratings are of less significance. This gives a wider choice to the manufacturer. The higher frequency 'X' band is usually favoured, but at least one system uses the 'C' band which is the least used of the marine radar bands and would be freer from interference. The probable accuracy of a pulse system is quoted as ± 3m.

Pulse systems, unlike phase comparison systems, have no inherent ambiguity and are thus inherently easier to use.

2.3 Problems with Microwave Systems

2.3.1. Attenuation

All microwave systems are limited to line of sight range, and suffer attenuation from meteorological conditions, for example at 'S' band frequencies, heavy rain or snow can reduce the signal by up to 7% and at 'X' band the same conditions could cause a 30% reduction.

2.3.2. Reflections

A common problem with microwave transmission is reflection of signal. Reflections from large vessels or shore installations at close range can, in some circumstances, cause gross errors. These are fairly obvious if a track plot is being recorded, and careful observation on the part of the operator can minimise this effect. A more serious problem when used over reflecting surfaces, such as water, is the interference between the direct and reflected ray. An extreme case of this causes complete cancellation by the 180° phase shift produced by the reflection process. Some factors influencing this effect are state of the sea, the range and relative heights of the mobile and reference stations. If cancellation effects occur in a survey area the effects can vary between an increase in errors, and a loss of signal along one or both paths. With care this effect can be minimised, as the areas where the effect is likely can be calculated for a particular layout (tidal variations may also have to be taken into account as they cause changes in the relative heights of the mobile and reference units).

In general the antennae should have as narrow a vertical aperture as is consistent with ship motion (15° is usually a fair compromise). Ideally the line of sight path between the mobile and reference stations should clear the sea surface by about 3 to 10m. Diversity receiving could be used where two mobile receiver units are used at different heights and only the strongest signal is used.

2.3.3. Signal Strength

One error found in pulse systems is caused by the degradation of the pulses with signal strength. The effect is that the ranges will vary slightly with signal strength. As the main cause of signal strength reduction is range, a system calibrated at one range will be in error at other ranges. If calibrated at mid range then the measured short ranges will be too short, and the measured long ranges will be too long, but the mid ranges will be correct, for example.

To minimise this error, calibration over several ranges may be performed, or a correction curve may be used to apply an offset for the range at which it is intended to be next used. However, range is not the only factor affecting signal strength. Antenna alignment due to poor setting up or excessive ship motion, cancellation, or partial obstruction, weather conditions, and mistuning of transmitters or receivers can all cause variations. A direct measurement and recording of signal strength at the master can be used to apply a correction.

2.3.4. Drift

With all microwave components there is a tendency to age, especially in the first year of operation, so a wise precaution is to periodically check frequencies and calibrations until the age and drift characteristics of the equipment have been established.

For maximum accuracy calibrations may need to be performed weekly when in regular use.

2.3.5. Simultaneous Range Measurement

If both ranges are not measured simultaneously, and the vessel is moving for example at 10 knots, a difference between measurements of 0.1 sec would give at least a 0.5m error.

2.3.6. Licensing for use of the radio frequencies

Licensing in the UK depends on type of system and options employed, the area where the equipment is to be used, the particular application of the equipment, and the amount of use. All manufacturers are confident that their equipment would be granted a Home Office radio licence.

As a condition of licensing the Home Office would require four weeks notice in writing of each usage of the equipment, stating area, reason for use, and period of use. In the event of a clash with a prior application for the same frequencies in that area, permission may not be granted.

2.4 Available Microwave Systems

2.4.1. Introduction

The five systems described have UK or European Agents with service facilities. At least one Japanese system, the 'S' band Audister is manufacturered but is not included as no Agent in Europe could be found. There are also microwave land survey instruments available but these are not generally suitable for mains use.

The 'S' band systems are:

Tellurometer MRB 201

Cubic Autotape DM40A

The 'C' band system is the Motorola Mini-Ranger III.

The 'X' band systems are:

Del Norte Trisponder

Artemis II

Table 1 summarises the properties of the respective systems.

2.4.2. Tellurometer MRB 201

The MRB 201 is an 'S' band (3 GHz) continuous wave system that determines a range by phase comparison of modulation frequencies. A separate Master unit is required to operate in conjunction with each remote station, and it is customary to employ two independent Master/reference pairs to provide position data, the two ranges being measured within 1m sec of each other. An advantage of the MRB 201 is that a reference station can be used as a Master. The two reference stations can therefore be used to double check their base line to a quoted static accuracy of $\pm \frac{1}{2}$m.

Ambiguities are resolved by means of several modulation frequencies. The master station modulation frequencies are selected manually, and the reference station modulation frequencies are automatically selected. The checking of ambiguities must be carried out periodically.

A maximum range of 50 km (line of sight) with an accuracy of $\pm$ 1.5m is claimed with a speed limitation of 30 knots. The readout of a 6 figure display for each range in metres, with an update rate of 1 per m sec.

A digital range integrator, which is what might be termed the electrical analogue of the fly wheel, senses the rate of change of distance, and if for any reason the signal is lost for a short time the instrument will continue to integrate range at the rate it was immediately before the loss of signal. This rate sensing system has the added advantage that it provides averaging for ship motions, as it tends to follow the average rate rather than actual movements of the ship. As opposed to other methods this give very little lag, approximately 1 m sec.

The power requirement of the systems is quite modest and can be supplied from car batteries. The reference stations are portable and can be erected quickly. The controls and setting up are somewhat complex, and at the shipborne installation the operator would be required to give his full attention to monitoring the lane identification facility, and to maintaining maximum signal strength by adjustment of the steerable antenna array (unless fitted with tracking antenna). So at least some degree of training and familiarisation would be necessary to achieve optimum performance.

The shipborne antenna array consists of twin steerable parabolic dishes each independently controlled from a remote control box. The main lobe angles are 27° horizontal and 22° vertical. At close range satisfactory operation is possible at much larger angles. A tracking antenna option which automatically seeks and locks onto its reference station is available. It can also be directed by computer or digital compass. The remote reference station antennae are fixed parabolic reflectors with main lobe angles of 24° horizontal and 20° vertical. For some operations it could be necessary to realign at intervals. This could be achieved manually by means of the two-way communication link that can be used when the sys system is not ranging.

Options for the MRB 201 include a dial readout unit with no logging facility but a resolution of 0.1m and would be suitable for static measurements of say base lines between remote reference stations. A digital velocity indicator is available to indicate true speed when on a transit with a remote station. A multi-user option allows up to three pairs of master stations to operate by the time sharing of two remote instruments. A compass drive unit can direct a tracking antenna to within 2° relative to the ship's head. There is also an interface for the Hewlett Packard 9810 calculator.

2.4.2. Cubic Autotape DM40A

The DM40 is an 'S' band (3 GHz) continuous wave system that determines a range by phase comparison of modulation frequencies. Ambiguities are automatically resolved by means of a number of modulation frequencies applied sequentially.

A single master is used in conjunction with two reference stations, and displays the ranges in metres on two 5-figure arrays. A maximum range of 100 km (line of sight) is claimed, and quoted accuracy is $\pm$ ($\frac{1}{2}$ + range/100,000) m, ie 0.6m at 10km.

The system is very simple and portable. After initial setting up the system can be left unattended when used with the data logging facilities. The automatic update rate is 1 per sec and digital outputs are available for peripheral equipment.

The shipborne antenna is omnidirectional in the horizontal, and has a main lobe angle of 10° in the vertical. The reference station antennae are adjustable in the the horizontal angle from 30° to 150° and are 10° in the vertical. There is an integral two way communications link between master and the reference station.

Another version called the DM43 measures three simultaneous ranges instead of two. Cubic can also modify Autotape systems for unique requirements.

Cubic offer a rapid repair and spares service in the UK with a turn round time of less than 48 hours. A growing variety of optional equipment includes printers, plotters, recorders, and complete systems for processing other parameters in addition to positioning.

2.4.4. Motorola Mini-Ranger III

The Mini-Ranger is a coded pulse system that determines a range by means of a propagation time measurement. Operation in the 'C' band (5.4 - 5.6 GHz), reduces rain and snow attenuation, and also keeps clear of the main marine radar bands. It has the option of operating in the 'X' band (9 GHz).

The system is non-ambiguous, but requires initial and periodical calibration. The basic form has a shipborne master and two reference stations, which recognise their own code and retransmit when interrogated by the master. Other options are a four code commutation, in which four reference stations can be interrogated in automatic sequence. A sixteen code interrogate option provides a selection of sixteen different reference station codes selected by a control on the mast console so that many different reference stations can be used. Another option is an arc-steering indicator which allows the master to steer in circles or arcs about a fixed reference station.

The ranges in metres are displayed on two five digit LED displays. BCD outputs are also available for recording on ancillary equipment such as a Hewlett Packard Calculator/Plotter.

The normal (line of sight) range quoted is 37 km and the probable accuracy quoted at ± 3m. This accuracy can be improved to a quoted ± 1m by use of the signal strength monitor option, which enables the user to reject weak signals. This option also has a digital output so that automatic rejection would be possible.

Update rates are 1 per sec or 1 per 10 sec. The basic system takes the average of five valid replies to create each range. A range averaging option allows the user to select groups of 10, 20, 40 or 75 replies to average, via a selector on the console.

The system is simple and modular, reference stations can be set up by unskilled personnel. The reference stations require 24 volt dc and can be powered from car batteries. A low current drain option automatically reduces the reference station to a standby condition after 30 min of no interrogation. When interrogations resume the reference station will be operational within one minute. The master station may be powered by standard mains or 24v dc.

The master antenna is omni-directional in the horizontal and 15° in the vertical with a gain of 13db. A 10 db gain reference station antenna is available which can increase the quoted (line of sight) range to 74 km.

The Mini-Ranger is basically a single user system, but a time sharing option will allow several master stations to use a common set of reference stations.

Cancellation effects can be reduced, by use of a second receiver/transmitter unit, with sense logic, to operate in a diversity mode.

Other options include a built-in test evaluation unit for field checking and trouble shooting, a 19" rack adaptor, and a watertight transit case.

2.4.5. Del Norte Trisponder

This system operates in the 'X' band (9 GHx), and utilises coded pulses to determine a range. Two frequencies are employed, one transmitted by the Master Unit and another from the Remote Units.

The shipborne equipment consists of a single Master unit, and a transmitter/receiver unit which is integral with the antenna. The standard Master unit interrogates any two out of a possible four Remote shore stations by the employment of coding techniques: the appropriate Remote station will only retransmit on recognising its own unique code.

The claimed maximum range is 80 km (line of sight). The resolution is 1m with a probable accuracy of ± 3m. The ranges are displayed on two five figure arrays. The update rate is 1 per sec, each update consisting of the average of 100 range values. An average of 10 values can be taken but the resolution in this mode is only 10m. If the signal is lost the display will indicate the last range received, and a fault lamp will be lit.

The control panel and the setting up procedure are simple and thus no particular skills are called for from the single operator required. The equipment can be left unattended after initial setting up. The Base Unit associated transmitter/receiver unit weighs only 7 kg so that installation should present no undue problem. The mobile station antenna is omnidirectional in the horizontal and 30° in the vertical.

The Remote stations each employ an antenna with a beam angle of 87° in the horizontal and 5° in the vertical. These angles can be greatly exceeded at close range. The Remote units have no controls whatsoever so that the setting up procedure consists merely of connecting the power supply and pointing the antenna in the right direction. The Transponders shut down to a standby mode after 40 mins without interrogation, and are reactivated in about 1 min after the first interrogation.

Solid-state circuitry is employed wherever practical with the result that power requirements are quite modest. A BCD output is provided and a Decca 'Maglog' interface is available.

A track-plotter facility is also available and consists of a processor drive unit and a track plotter, or a calculator and x, y plotter combination.

The Trisponder system has an optional multi-user capability whereby up to four mobile stations can operate simultaneously by employing time-sharing techniques.

2.4.6 Artemis II

This is a range-bearing system operating in the 'X' band. Two stations only are employed, one on shore at which the bearing observations are made, and the other on the vessel where ranges are measured. Both stations employ radar-type scanners which do not however rotate continually as in conventional marine radar applications, but, after initial setting up, lock onto each other's signal and thereafter each tracks the other.

2.4.7.

TABLE 1

	MRB 201	AUTOTAPE DM40A	TRISPONDER	MOTOROLA MRIII	ARTEMIS
TYPE OF SYSTEM	Phase Comparison Range/Range	Phase Comparison Range/Range	Microwave Pulse Range/Range	Microwave Pulse Range/Range	Microwave Pulse Range/ Bearing
FREQUENCY	2.8-3.2GHZ	2.9-3.1GHZ	9.325-9.480GHZ	5.45-5.60GHZ	9.2-9.27GHZ
PROBABLE ACCURACY	±1.5m Dynamic conditions	±0.5m or 1:105 x Range	±3m	±3m Probable	2' of arc ±1.5m
RESOLUTION	0.1m	0.1m or 1m	1m	1m	30" of arc 0.1m or 1m
MAXIMUM RANGE LINE OF SIGHT	50km	100km or 200km	80km	37km,74km or 185km	10km or 30km
FREQUENCY OF UPDATE	1 per millisec	1 per ⅔ sec	1 per 1 sec	1 per 1 sec or 1 per 10 sec	1 per 0.2 sec or 1 per 2 sec
NO OF READINGS AVERAGED	1	1000	100	5 or 10,20,40, 75	
ARE RANGES SAMPLED SIMULTANEOUSLY	Independent update 1 msec	Yes	Yes	12 msec between ranges	NA
IS A FULL TIME OPERATOR REQUIRED	Yes	No	No	No	No

Operating characteristics of Microwave position fixing systems

Initial setting up is achieved by aligning the shore station antenna with a triangulated point some distance off in order to provide a grid bearing reference. This is facilitated by a theodolite-type telescope rigidly mounted on top of the scanner which is turned manually until the cross hairs intersect the required point. In this position the bearing indicator can be set to read either the grid angle or the true angle to the remote object. Angular measurements are made by the employment of a digital shaft encoder and this information is passed to the shipborne mobile station via a wide band data channel. This channel can alternatively carry voice.

Range is derived at the mobile station by measuring the two way propagation time of a pulse and converting this to distance. Both range and bearing are displayed at the mobile station as five or six digit LED readouts. A BCD output is provided and interfacing to a Hewlett Packard programmable calculator/ X-Y plotter package is available.

System operation appears simple and power requirements are modest.

Tracking (bearing) accuracy is claimed as better than 2' of arc, corresponding to 16 metres at the quoted maximum range of 25 km. Claimed range accuracy is $\pm 1\frac{1}{2}$ metres.

3. UHF POSITIONING SYSTEM

3.1 Introduction

The UHF system falls between the medium frequency and the microwave systems. Only one system is known, this is the UHF SYLEDIS system manufactured by SERCEL in France, this system was aimed at the port and harbour type of application.

3.2 Mode of Operation

Syledis uses a single frequency in the 420 MHz to 450 MHz band. Peak output power is 20 watts, or with an optional booster amplifier 400 watts. The standard 20 watt system has a quoted range of 2.5 times line of sight. Resolution is 0.1m, with a probable accuracy of $\pm$ 1m deteriorating to a few metres at maximum range. The system is insensitive to diurnal and meteorological influences. Time discrimination techniques are employed to reduce multipath errors.

A mobile transceiver, and a display unit are carried by the ship. On shore two or three transceiver stations are required. (Three shore stations allow some redundancy of data). One of the shore stations is designated 'master' and is connected to a computing centre supervised by an operator. In a harbour type of installation the operator enters administration information, and constants, into the computer. He also supervises the storage and distribution of the processed data.

Positional data is obtained by a sequence of propagation time measurements between the mobile and shore stations, and between shore stations. The measurement is made by means of a 2.6 m sec coded pulse. Between sequences information is transferred from the master shore station to the ship for display.

Syledis is a portable and flexible system; combinations of up to eight shore stations and seven mobiles may be used. Two mobiles may be carried by a ship to give rate of turn information. It is also possible to use the system in a Hyperbolic mode with any number of users, or a combination of hyperbolic and range/range.

4. LOW AND MEDIUM FREQUENCY POSITIONING SYSTEM

4.1 Introduction

Almost all low and medium frequency systems use hyperbolic patterns to obtain a position. The frequencies range from 5 MHz down to 120 KHz. Generally the lower the frequency the longer the range obtainable, at the expense of lower accuracy and higher power requirements. Special charts are needed. Accuracy is variable for geometrical as well as propagational reasons. The hyperbolic systems are all normally multi-user systems, but can be altered to a single user, or a very limited number of user, Range/Range type of system, by carrying a transmitter on the ship.

A major source of error is the 'skywave'. This is a reflected or refracted wave return from layers in the ionosphere.

Eight systems were considered. Although others were available they were not included as they were unsuitable for close survey work for one reason or another.

4.2 Available Systems

Decca navigator operates at about 120 KHz. It cannot exclude 'skywave' effects and at relatively short ranges an accuracy of 25 - 30 m can be achieved, but the user must be aware of the diurnal and seasonal variations in performance.

Decca HiFix operates on about 2 MHz. Errors can be as low as a few metres under very favourable conditions but about 10m is usual in daylight. For the best results the transmitter stations may need special earthing arrangements. It can also be used in a differential mode with monitor stations for greater accuracy. If the signal is lost for any reason then return to a known position is the only way to resolve lane ambiguities.

Related systems are SEAFIX which is a more compact version and can operate up to 3 MHz, and HIFIX 6 which is the successor to HiFix.

Existing HiFix chains are being replace by HiFix 6 over the next three years. Each chain could consist of up to six stations, this would be useful in awkwardly shaped areas such as estuaries, and the mobile unit would select the most suitable stations by means of a thumbwheel control on the console.

Auxiliary frequencies are to be transmitted so that by means of a calculation the lane identity may be established, however radio frequency licensing problems may result in some chains being without this facility. The system can be locked in at a known location as is HiFix, the lanes being set in by means of a slightly complicated thumbwheel arrangement. The fast response of the seven segment displays are rather more difficult to follow visually than the HiFix type of display. The power supply rails have been reversed so that HiFix 6 has -ve earth, and in the changeover period, where it is possible to have both systems on the same ship, great care must be taken not to allow any electrical contact between the two.

In general the operation and performance of the system is similar to HiFix.

Other systems mentioned in the table are similar in operation and performance to the above. More details is not given because there are no chains set up for their use in the UK.

Table II gives some of the parameters of the above systems.

4.3

TABLE II

	DECCA NAVIGATOR	HIFIX	SEAFIX	HIFIX 6	RAYDIST	TORAN P10	TORAN P100	LORAC	RANA
Frequency	120 KHZ	1.6-2MHZ	1.6-3MHZ	1.6-5MHZ	1.5-5MHZ	1.6-3.8MHZ	1.6-3.8MHZ	1.6-2.5MHZ	2MHZ
Claimed Accuracy	30m	4-5m	2-4m	1-3m	2-3m	1-3m	2-4m	3-30m	10m
Approximate Range	450km	300km	37km	300km	300km	80km	500km	80km	200km
Skywave Suscept-ibility	Yes	Low	Low	Low	Low	Yes	Yes	Yes	Yes

Operating Characteristics of Low and Medium Frequency Position Fixing Systems

5. SUMMARY

Microwave position fixing systems are portable, and relatively simple to install and use. Suitable shore sites in the survey area would have to be provided. The accuracy and range (slightly more than line of sight) is generally adequate for inshore precision survey work. Power requirements are small, and can be provided by car batteries. A position is fixed by measurement of the ranges to two or more locations whose coordinates are known. This is referred to as a range/range type of system. Such a system may accommodate only a single or very limited number of ships. Microwave signals are insensitive to the 'skywave' effect, although they suffer attenuation by certain meteorological conditions, and can be reflected from large surfaces.

For 'on line' position fixing a moderately fast calculating or computing unit is required to convert ranges into an acceptable coordinate system. Data logging and track plotting would normally also be required.

Two types of system are available. One uses the propagation time of a microwave pulse. The other compares the phase of modulation frequencies applied to a continuous wave. The phase comparison types can be more accurate than pulse systems, but they are more complex (multiple ambiguities have to be resolved),and so inevitably more expensive.

The UHF system described has adequate range (2.5 times line of sight). By means of complex signal processing, and computer analysis of the data, an accuracy comparable with microwave systems is achieved. In order to utilise its full potential a sophisticated computing facility is required. This portable and versatile system can employ range/range or hyperbolic modes of operation. UHF transmissions are not susceptible to 'skywave' effects and are insensitive to meteorological conditions. It is unlikely that the Home Office would grant a radio frequency licence for coastal use in the UK for a UHF system.

The low and medium frequency systems are generally multi-user hyperbolic systems. Special charts may be used on which a position may be plotted in terms of hyperbolic 'lanes'. Track plotters are usually available for use with these systems.

The range is adequate, but there may be no or poor coverage from existing chains in some areas of interest. (Low and Medium frequency shore stations are less portable, and more expensive to install and maintain than UHF or microwave stations). The accuracy is variable for geometrial and propagational reasons.

The 'skywave' effect can cause difficulties during the hours of darkness. Even under favourable conditions the accuracy is not good enough for some IOS(T) projects. Multiple ambiguities generally have to be resolved by returning to some known location. In the future more HiFix chains may be replaced by the non-compatible HiFix 6 which could incur extra cost. With increasing installation and maintenance costs some chain operators may require a fee for use of their chains.

All systems have advantages and disadvantages. A common problem with range/range systems is: if real time display or track plotting is required, then fast on-the-spot data processing is necessary. This is not normally part of a basic system.

6. CONCLUSIONS

The breakdown of comparative costs is given in Tables III, IV and V.

Syledis, although a rather attractive system, cannot be considered at the present time, as the Home Office state that for our type of usage a radio frequency licence would definitely not be granted.

HiFix 6 is similar in operation and performance to HiFix, its range is adequate and with interfaces it would be compatible with our Maglog and track plotter. It does suffer from night effect, it may still be necessary to lock in at known locations, and there may be no or inadequate coverage in some areas that we may wish to work.

The Microwave systems have shorted ranges, but most of our work should be within reach of them. Sites for reference stations would have to be found and surveyed. The 'laned' type of chart used with HiFix would not be available and so special charts might have to be prepared. Licensing would only be a problem should there be a clash of frequencies at a certain site.

The pulse systems are cheaper by at least a factor or two, although at the expense of slightly lower accuracy.

Two such systems would seem to be adequate for our needs, the Miniranger III and the Trisponder. As a requirement the system must include a means of track plotting and data logging, the Trisponder could be more easily made compatible with our existing data logger and track plotter (see Table 4).

Both the Miniranger III and the Trisponder could be used with a HP 9810 and 9862A combination which IOS already have, but the HP 9810 calculator and 9862A plotter were purchased for wave analysis and are still used for statistical work. This would inevitably lead to clashes if it were to be used with a positioning system.

The HP 9810Aand 9862A combination could be inconvenient in that it uses single sheets of paper and room would have to be found for both units on the ship's bridge. The 350Ts track plotter on the other hand has a continuous chart, and allocation of space is made for this standard type of track plotter on most bridges.

Interfaces would have to be purchased and additionally with the Miniranger III a cassette recorder would be required (this would not be compatible with the IOS(T) computing equipment).

6.1 Table III

Basic Minimum System without track plot, data logging facilities, or spares.

	Price £
MRB 201	36,000
Cubic Autotape	55,046
Motorola Miniranger Mk III	17.552
Trisponder	18,884
Artemis	48,387
Syledis	34,375
HiFix 6 Receiver	7,255

All prices used are only valid for 3 months or less from August 1976 and are used for comparison only.

6.2 Table IV

Auxiliary equipment required to enable track plotting and data logging to be performed.

HiFix 6

Digital to analogue converter	£1,000
Maglog interface card	550

Used with existing 350Ts track plotter and Maglog data logger

Motorola Miniranger Mk III

Interface 11261A to HP 9810 and 9862A	260
ROM 11203A for HP 9810	636
HP 9865A cassette recorder	1,390
ROM 11262A for 9810	499

Interfaces for existing 350Ts track plotter and Maglog data logger are not available.

Trisponder

Processor drive unit 10295 for 350Ts	4,328
Buffer junction splitter 10297 for 350Ts	140
Alternatively:	
Interface unit 90110 for HP 9810 and 9862A	1,840
Receiver splitter	220

A Trisponder/Maglog interface is already installed in the Maglog.

6.3 Table V

Spares:

HiFix 6

This is a new system, and a recommended spares kit is not yet available, but service from field engineers is rapid.

Motorola Miniranger Mk III

Range console spares kit	£2,027
Spare reference beacon	3,574

Trisponder

Spares kit	2,897
Spare reference beacon	4,723
Spare receive/transmit unit	4,898

With the Trisponder spares kit all the cards except a power supply unit are available, and so in the event of a failure the faulty card can be found by substitution, and if returned to Decca for a cost of £75 to £100 per card a replacement can be returned within 72 hours.

6.4 References

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SARGENT G E G 1969. The short range fix system and methods of use Hydrospace, 2 (4), 21-27.

6.5 List of UK or European Agents where information or service may be obtained.

TELLUROMETER MRB 201

Tellurometer (UK) Ltd, Roebuck Road, Chessington, Surrey, KT9 1RQ. Tel: 01 397 8244

CUBIC CORPORATION AUTOTAPE CM-41A

Radio-Holland NV, 20 Jan Rebelstraat, PO Box 9094, Amsterdam 1018.
Tel: 020 101972

MINI RANGER III and RPS

Motorola Military and Aerospace Electronics Ins, Taylors Road,
Stofold, Hitchin, Herts, SG5 4AY.
Tel: 0462 730661

TRISPONDER

Decca Survey Ltd., Kingston Road, Leatherhead, Surrey
Tel: 03723 76971

ARTEMIS

Osiris Survey Projects Ltd, Port Causeway, Bromborough, Wirral
Merseyside L62 4SY.
Tel: 051 645 2293

SYLEDIS

Kelvin Hughes Ltd.
Tel: 01 500 1020

DECCA NAVIGATOR, HIFIX, SEAFIX, HIFIX 6

Decca Survey Ltd, Kingston Road, Leatherhead, Surrey
Tel: 037 23 76971

TORAN P10, TORAN P100

Sercel, Radionavigation and Systems
168/190, Ave Charles de Gaulle, BP1000, 91420 Morangis, France
Tel: 909 34 20

RAYDIST

Hastings-Raydist, Div of Teledyne Inc, Teledyne Hastings Raydist Box 1275,
Hampton, Virginia.
23661 USA