International Hydrographic Review, Monaco, LXII (2), July 1985

NAVIGATION AND POSITIONING REQUIREMENTS FOR MARINE SURVEY OPERATIONS

by Dr A.R. HEDGE (*)

This paper was originally presented at the NAV 84 Conference on Global Civil Satellite Navigation Systems held in London in May 1984 and is reproduced with the kind permission of the organizers, The Royal Institute of Navigation, U.K.

The commercial Marine Survey industry, particularly in the North Sea and UK continental shelf areas, does not make as extensive use of satellite navigation systems as its investment in such might seem to show. This paper attempts to set out what are the requirements of the Marine Survey user, how these requirements are currently fulfilled, and what future satellite-based systems must provide in order to become competitive. Examples of typical survey operations are provided. The viewpoint is inevitably biased somewhat towards the requirements of the commercial survey contractor operating for the oil and gas industries, but as this is by far the largest sector of expenditure on navigation and positioning services in the UK Marine Survey sphere, the author feels that such bias is justified.

This paper, then, examines not so much what the user's expectations are from satellite navigation, but what his navigation requirements are in general, and what facilities satellite navigation must offer, and at what price, to provide a real service.

In order to illustrate the requirements, let us first examine the systems currently in extensive use, with regard to cost, coverage and accuracy.

A REVIEW OF CURRENTLY AVAILABLE RADIO POSITIONING SERVICES

A multitude of competitive radio positioning systems are in daily use. All have particular advantages and disadvantages, and the system must be chosen to suit the application.

In general, such systems do not provide a direct measure of position, but rather provide some pattern value, sometimes a direct range, from which a position

(*) Gardline Surveys, Admiralty Road, Great Yarmouth, Norfolk NR30 3NG, U.K.

may be computed given knowledge of beacon co-ordinates, velocity of propagation, and lane width on baseline, etc. A variety of survey calculator/computer systems are available for this task, discussion of which is outside the scope of this paper.

The figures quoted for range and accuracy of all the systems that follow are representative of the typical capabilities of such equipment. They are not manufacturers' quoted figures, nor are they endorsement or criticism of particular systems. In general, accuracy here and elsewhere in this paper is taken to mean repeatable accuracy. Absolute or predictable accuracy is a function not only of the equipment, but also of the calibration techniques used and the co-ordination of the beacons. Usable range is very much dependent upon chain configuration, weather and atmospheric conditions.

The cost of such equipment as a service rather than as capital purchase of hardware is difficult to put a precise figure on. Site access and chain maintenance problems vary enormously. Furthermore, chain hire rates are frequently dictated by competition rather than cost. The figures provided are representative of short term (less than 30 days) rates for a typical chain with one mobile plus a spare on the vessel.

Typical systems follow, beginning with those of highest accuracy, and are grouped by frequency and measurement technique.

Microwave Phase Comparison Systems

Commercial example :
 Tellurometer MRD1.

Frequency of propagation :
 3 GHz.

Measurement method :
 Phase comparison of modulation signals.

Range :
 Line of sight, up to approx. 50 km.

No. of independent patterns :
 3.

Accuracy :
 1 m or better.

Update period :
 0.5 sec.

Information format :
 Ranges to beacons (metres).

Physical description :
 Small portable shore or platform-based units running off battery supplies.
 Rack mounted mobile on vessel.

Restrictions and limitations :

Line of sight restriction. Subject to obstruction by vessels, etc.

Limited number of users.

Cost :

£ 150 - £ 250 per day.

Microwave Direct Ranging Systems

Commercial examples :

Trisponder, Miniranger.

Frequency of propagation :

5 GHz or 10 GHz.

Measurement method :

Time delay measurement between transmitted pulse and return pulse from transponder.

Range :

Line of sight up to 80 km.

Number of independent patterns :

4.

Accuracy :

1 - 3 m.

Update period :

0.2 - 1 sec.

Information format :

Range to beacons (metres).

Physical description :

Small portable battery shore- or platform-based beacons, rack mounted mobile on vessel (battery powered).

Restrictions and limitations :

Line of sight. Subject to obstruction and reflection by vessels, etc.

Cost :

£ 100 — £ 200 per day.

UHF Systems

Commercial examples :

Syledis, Maxiran, Trisponder 435.

Frequency of propagation :

~ 435 MHz.

Measurement method :

Time delay measured by pulse correlation techniques.

Range :

Line of sight (possibly up to 2.5 × line of sight given favourable propagation conditions).

Number of independent patterns :

3 or 4.

Accuracy :

2 - 10 m within line of sight range.

Update period :

0.2 — 1 sec.

Information format :

Range to beacons (metres).

Physical description :

Portable shore- or platform-based beacons, Yagi antennae mounted on short tower or structures (battery powered).

Rack mounted mobile on vessel.

Restrictions and limitations :

Limited users in range range mode. Frequency and mode of transmission can cause licensing problems.

Cost :

£ 300 - £ 600 per day.

2 MHz Phase Comparison Systems

Commercial systems :

Hydrotrac, Hyperfix, Argo, Raydist.

Frequency of propagation :

2 MHz.

Measurement technique :

Phase comparison, range range or hyperbolic.

Range :

300 - 400 km depending upon chain configuration.

Number of independent patterns :

3 or 4.

Accuracy :

5 - 25 m.

Update period :

1 - 2 sec.

Information format :

Lanes and fractions (1 lane = $\lambda/2$ in range mode and on baseline of a hyperbolic pattern).

Physical description :

Transportable base stations usually in small hut, with a typically 20 m high transmitting tower. Require generator or mains A.C. supply.

In hyperbolic mode, mobile unit is rack mounted receiver.

In range range mode, mobile additionally requires master drive and power amp units (rack mounted), plus transmitting antenna (typically 10 m rigid fibreglass whip).

Restrictions and limitations :

Lane ambiguity. Sky wave, especially at night, can lead to instability.

Limited number of users in range range modes.

Cost :

£ 350 - £ 700 per day.

Low Frequency Systems

Commercial example :

Pulse/8.

Frequency of propagation :

100 kHz.

Measurement technique :

Pulse timing.

Range :

600 - 800 km.

Accuracy :

50 - 100 m.

Update period :

0.1 sec.

Information format :

Hyperbolic patterns in terms of microseconds and hundredths. (1 μs = 150 m on baseline).

Physical description :

Semi-permanent shore installations usually in brick buildings, mains power essential. Transmitting masts 100 metres high.

Restrictions and limitations :

Some lane ambiguity. Sky wave, especially at night, can cause instability.

Cost :

£ 700 per day.

EXAMPLES OF TYPICAL MARINE SURVEY TASKS

In order to evaluate the demands of particular types of marine survey tasks, we shall examine four typical survey operations, each with different accuracy requirements. The U.S. Federal Radio Navigation Plan [1] identifies three phases of the Marine Operational Requirement, these being Ocean Phase, Coastal Phase and Harbour Approach/Harbour Phase.

Some conclusions of that publication with reference to marine survey are tabulated below :

Phase	*Accuracy*	*Fix interval*
Ocean	10 — 100 m	1 min.
Coastal	1 — 100 m	1 sec.
Harbour	1 — 5 m	1 sec.

The examples that follow are representative of each such phase and serve to illustrate how these requirements originate and how (and at what cost) they are met.

(A) Hydrographic survey of a river or harbour

Phase :

Harbour/Harbour Approach.

Purpose of survey :

Measurement of bathymetry for safe navigation charts or dredging control.

Typical vessel :

10 m launch.

Survey tools :

Survey grade echo sounder (dual channel).

Conduct of survey :

Line length :	200 metres
Line spacing :	25 metres
Scale :	1:2,500.

Accuracy required :

1 - 2 m.

Position update interval required :

1 sec.

Total package cost :

£ 1,000 per day.

Navigation :

Typically Trisponder or Miniranger microwave system. Possibly Tellurometer if higher precision required.

(B) Near offshore pipeline or debris survey

Phase :
Coastal.

Purpose of survey :
Detection and location of surface or near sub-surface objects.

Typical vessel :
50-metre survey vessel.

Survey tools :
Echo sounder, Side scan sonar, Pinger, Magnetometer.

Conduct of survey :
Line lengths : 1 - 2 km
Line spacing : 100 m
Scale : 1: 10,000.

Accuracy required :
~ 5 m.

Position update interval required :
1 - 4 sec.

Total package cost :
£ 4,000 per day.

Navigation :
Either : Trisponder/Miniranger if within range *or* permanent 2 MHz chain *or* permanent UHF chain.

(C) High resolution geophysical site survey

Phase :
Coastal/Ocean.

Purpose of survey :
Evaluation of sea-bed properties for construction or drilling work.
Detection of shallow gas pockets.

Typical vessel :
50-metre survey vessel.

Survey tools :
As for example B, *plus*
Multichannel digital recording system
Streamer (300 m)
Seismic sound source (Sparker or Minisleeve Exploder).

Conduct of survey :
Line length : 5 km

Line spacing : 250 m
Scale : 1: 10,000.

Accuracy required :

~ 25 m.

Update interval required :

1 - 5 sec.

Total package cost :

£ 6,000 per day.

Navigation :

2 MHz or UHF system by preference.
100 kHz system if ranges dictate.

(D) Offshore deep seismic

Phase :

Coastal/Ocean.

Purpose of survey :

Determination of geological structure for oil or gas prospecting.

Survey tools :

Multichannel digital recording system
High penetration seismic sound source, e.g. airgun array
Streamer (3 km)
Echo sounder
Magnetometer
Gravimeter.

Conduct of survey :

Line length : 25 km
Line spacing : 1 km
Scale : 1: 25,000.

Accuracy required :

~ 50 m.

Update interval required :

1 - 5 sec.

Total package cost :

£ 15,000 per day.

Navigation :

2 MHz or UHF by preference
100 kHz if ranges dictate
or
Transit integrated system with Doppler Sonar, Gyro, Loran C, etc., *if* outside coverage of *all* other systems.

THE APPLICATION OF THE TRANSIT SYSTEM IN THE MARINE SURVEY FIELD

From previous paragraphs it would seem that the commercial marine survey contractor has little use or application for the Transit system. This is not so, as is borne out by the sales figures for dual channel Doppler equipment. There are in excess of 2,250 such receivers in use world-wide [2]. Of these I would guess maybe 1,000 were in military or government vessels. Some of the others are certainly redundant, but most survey companies of any size have some holding of dual channel equipment. What, then, is it used for ?

Virtually all deep seismic vessels are equipped permanently with an Integrated Transit System, including Doppler Sonar and Loran C. The very nature of deep seismic work dictates that they must operate in areas where as yet there are no proven viable oil reserves, and, therefore, no justification for the establishment of radio positioning chains. However, once the seismic vessel begins to work in areas such as the North Sea, the SatNav becomes secondary to a higher precision system. In comparison, few shallow geophysical or general purpose survey vessels are permanently equipped with Transit equipment and would install such only on an "as needed" basis.

Transit equipment is used widely by marine survey contractors for static positioning (3D). It is a useful tool for establishing survey control for locating beacon sites for all radio positioning systems. Also it is invaluable, and usually contractually required, for independently verifying the position of offshore structures such as drilling rigs which have been positioned by radio positioning systems.

Attempts were made in the mid to late seventies to use Transit to establish correct lane counts for 2 MHz systems [3]. The result was, in general, a system which could give a fair estimate most of the time, but did not give sufficient confidence for regular use except where there were no local structures or second radio navigation systems whatever. Such techniques are now rarely used, although dynamic translocation may make them viable.

In areas where precise positioning (accuracies of a few metres) is required in the absence of shore-based radio positioning, Acoustic/SatNav integrations have been developed whereby the Transit system is used to calibrate a network of sea-bed transponders. All subsequent positioning is relative to the transponders. Such systems are useful but expensive, partly due to the (sometimes unintentional) "disposable" nature of the sea-bed transponders.

THE FUTURE ?

The future of SatNav positioning as a major contributor to marine survey requirements depends very much on what can be achieved with GPS and at what cost. 100 m repeatable accuracy would be of similar usability to integrated Transit systems (i.e. acceptable where there is no alternative). Differential techniques may well provide acceptable accuracies and sensible competition to 2 MHz and 100 MHz systems *if* there is some "confidence indicator" available in real time (such as is provided by the standard error of a multiple pattern radio navigation fix).

CONCLUSIONS

The marine survey operator requires accuracies in excess of what is currently available with Transit systems and (in the commercial sector) is willing to pay for the service needed. Transit does have a number of vital uses within the marine survey field however.

The usefulness of GPS depends on what accuracy and confidence can be achieved through enhancement techniques such as differential correction.

ACKNOWLEDGEMENTS

The author would like to thank : Mr. J.H. BEATTIE for his help and advice; Mr. T.G. DARLING, Managing Director of Gardline Surveys, for permission to contribute this paper; Mr. I. BONE, Technical Manager of Gardline Surveys, for his assistance in compiling the paper and Mrs. Monica GOFF for the typing and preparation of the paper.

REFERENCES

[1] U.S. Federal Radionavigation Plan, Issue 2, March 1982, Volume II.

[2] Satellite Surveying, Dr Gregory J. HOAR, Magnavox, 1982.

[3] The Gardline Surveys Hydrotrac Satellite Integration, Paul H. GAYLEON, Magnavox, Hydrographic Society Workshop, Gardline Surveys, 16th January 1980.