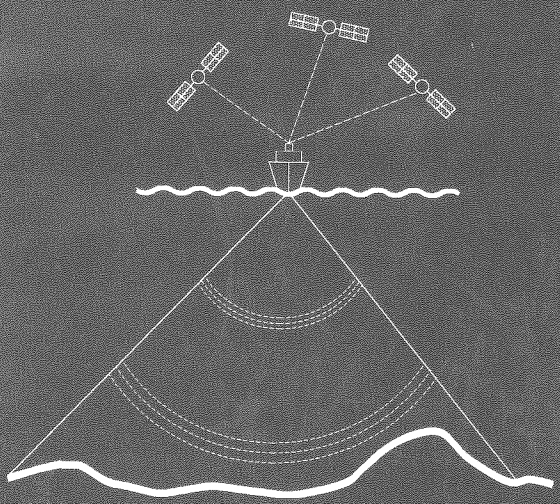
Hydrography

C.D. de Jong, G. Lachapelle,
S. Skone, I.A. Elema



Series on Mathematical Geodesy and Positioning

Hydrography

This book is based on the lecture notes for the graduate and undergraduate courses in hydrography as offered at the Department of Geomatics Engineering of the Universitiy of Calgary and the Department of Mathematical Geodesy and Positioning of Delft University of Technology. The purpose of the book is to present an introduction to and an overview of the broad field of hydrography.

Since there is only a weak interdependence between the eleven chapters, each of them can be studied separately. When used for a course, it is therefore also possible to consider only a selected number of chapters. The eleven chapters cover the following topics:

- Properties of water, waves, ocean currents and general circulation.
- Tide-generating forces, tidal analysis and prediction.
- Batch and recursive least squares estimation and quality control.
- Coordinate systems, horizontal and vertical datums, ellipsoidal computations.
- Radio frequency definitions, propagation of electromagnetic waves, time keeping systems.
- Underwater acoustics, propagation of underwater sound, sonar parameters and sonar equations.
- Law of the Sea, baselines, maritime zones and boundaries, third party settlement.
- Geometry of positioning, concepts, classification and requirements of positioning systems, standards for hydrographic surveys.
- Terrestrial and satellite positioning systems, speed determination.
- Underwater acoustic positioning systems, calibration of systems.
- Acoustic (single- and multibeam) and airborne sounding methods, sidescan and oblique sonars.

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10 Underwater acoustic positioning

10.1 Introduction

Radio waves do not penetrate waters to any significant depth and cannot be used underwater for positioning. The use of underwater acoustic waves constitutes one alternative. Underwater positioning includes the positioning of a surface platform from the seabed and the positioning of underwater vehicles required for detailed soundings, inspection of pipelines and structures, etc. The first category consists largely in the dynamic positioning (DP) of floating platforms used for ocean exploration, and exploitation such as drilling rigs. Nowadays, these platforms operate in waters with depth in excess of 2500 m for months to years at the time. Several independent positioning systems are used simultaneously for this purpose, including DGPS and underwater acoustics, in order to achieve a high level of redundancy and reliability.

Numerous underwater position fixing techniques with various degrees of accuracy, have been developed for the offshore industry. They can be classified into two categories, dead reckoning positioning systems and acoustic positioning systems.

Examples of the first category are:

- Distance line
- Trailing wheel
- Current meter/gyrocompass
- Doppler log/gyrocompass
- Inertial Navigation System (INS)

Acoustic positioning systems comprise:

- Short baseline (SBL) systems
- Super-short baseline (SSBL), also known as ultra-short baseline (USBL) systems
- Long baseline (LBL) systems
- Combinations of the above

Integration of one or several of the above with other measurement devices (e.g., gyrocompasses, attitude motion sensors) or systems (e.g., DGPS for acoustic system calibration).
ractice, systems used are integrated systems of the latter category.

lerwater acoustic navigation and position fixing systems use various types of erwater markers: transmitters, receivers or both. They are of the following types:
nsducer - a transmitter/receiver, frequently mounted on a ship's hull or on an erwater platform. It sends out an interrogation signal on one frequency to get a ly on a second frequency.
nsponder - most versatile type of underwater marker, mounted on the sea bottom on a submersible. It is a receiver/transmitter working in conjunction with a isducer. On receipt of an interrogation signal (command) on one frequency, the isponder sends out a reply signal on a second frequency, and then it becomes sive until the next interrogation (to save power).
icon/pinger - most simple active underwater marker, mounted on the sea bottom on a submersible. It is a transmitter that sends a pulse on a particular frequency on gular basis; no interrogation required.
lrophone - an omnidirectional or directional receiver installed on a hull, which eives signals from a transponder or a beacon/pinger.
ponder - a transmitter attached to submersible or seabed which can be activated a hard wired external control signal to transmit an interrogation signal for receipt a transducer or hydrophone.

all of the above cases, the antenna gain patterns (polar diagram) are either nidirectional or hemispherical. The sound energy being propagated underwater is enuated by various ambient and self noise. The majority of ambient or self noise ckground sea noise) in the ocean which affects an acoustic telemetry system are ow the level of 5 kHz. Therefore, to avoid spurious signals and commands, the vest frequency used for underwater acoustic positioning is 7-12 kHz. The final oice of frequency for an acoustic system is a function of application (range), curacy, size and cost. It is a result of compromises between different frequency pendent characteristics. In general, the higher the frequency, the shorter the range ie to higher absorption coefficient), and the higher the accuracy. Frequency versus ige is shown in Table 10.1. The accuracy of underwater acoustic systems depends frequency, propagation loss, ambient and machinery noise, refraction, reflection, :, see also Chapter 6).
pically, accuracies of a few metres are achievable in deep water. With the use of derwater platforms, the accuracy can be improved to a few decimetres, because the inity and temperature are more stable once a certain depth has been reached.

Table 10.1: Typical ranges of acoustic systems versus frequency.

Frequency [kHz]	Range [m]
10 - 20	10000
300	400

10.2 Short baseline systems

A *short baseline* (SBL) acoustic system is an underwater positioning system which is used to position a transponder or pinger installed on the seabed or mounted on an underwater vehicle using a hull-mounted array of co-planar hydrophones spaced typically by 5-20 m. The vessel can either be static or moving. Due to the short distances between the hydrophones relative to the water depth, the positioning geometry is weak and the distance between the hydrophone array and the underwater transponder or pinger must be kept relatively short.
Alternatively, if the transponder or pinger is located at a known position on the seabed, the position of the vessel can be determined, provided additional sensors (e.g., heading sensors) are used on the vessel, since the ship's coordinate frame, defined by the array of hydrophones, should be aligned to the reference frame in which the transponder or pinger location is given.
Due to the above geometry consideration, the method is restricted to confined environments such as dynamic positioning of a stationary platform. A short baseline acoustic system is applied to

- Positioning of a ship within a small radius (from a seabed mounted beacon or transponder) equal to the water depth.
- Positioning/tracking of a submersible or towed fish.
- Dynamic Positioning (keep the ship at rest over a specific point), e.g., drilling.

The methods of operating a short baseline acoustic system are distinguished in terms of the instruments used, i.e. the underwater acoustic markers mounted on the seabed: beacons/pingers, or transponders/responders.

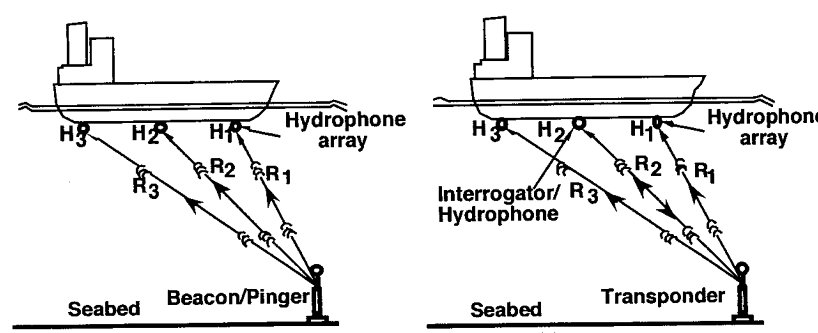

Figure 10.1: Short baseline concept, using a beacon/pinger (left) or a transponder/responder, mounted on the seabed.

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