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HYDROGRAPHIE ACOUSTIC SYSTEMS - MEASUREMENT PRINCIPLES

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ABSTRACT: *Hydrography is an applied science that deals with the study of the bottom and shores of the world ocean (all oceans and seas), lakes, rivers and dams, i.e. all natural and artificial water bodies. Hydrographic research is the study of individual areas of the hydrosphere, including the design, implementation of hydrographic works, processing and analysis of the collected data.*

KEYWORDS: *Hydrographic measurements, Transponder, Sound speed*

1. Introduction

Accurate depth information is required for the safety of navigation. Where subkeel distance is a major limiting factor, vertical accuracy must be strictly controlled. It is necessary to conduct a survey of the water bottom and indicate the likely dangerous objects from a navigational point of view. Such can be both natural formations (rocks) and objects that arose as a result of human intervention (remains of sunken objects) [2].

The acoustic systems used in hydrographic positioning measurements measure the range and direction of beacons located at the bottom of the water basin mounted on a remotely operated underwater vehicle (ROV) or a ship. Depending on the technique and range used, we will also have different accuracy [1, 4].

In acoustic systems, there are three main techniques:

- Long Baseline Method (LBL);
- Short Baseline Method (SBL);
- Ultra or Super Short Baseline Method (USBL or SSBL);
- Combined systems - combine the benefits of the three above methods.

2. Principles of measurement

Range measurement

- If the oblique range (R) is determined by transponder information and the angle θ is known, then (Fig. 1):

$$R = \frac{c.t}{2},$$

the horizontal distance (S) can be determined by: $S = R.\sin\theta.$

- If the transponder is replaced by an ordinary headlamp, the direct slope cannot be obtained and the depth (D) must be known to calculate the horizontal distance: $S = D.\tan\theta.$

- The known sound velocity (c) allows to determine the angle θ by measuring the signal arrival time differences between hydrophones 1 and 2 (Figs. 1 and 2). The angular measurement between a transducer/hydrophone and a beacon can therefore be determined [1, 4].

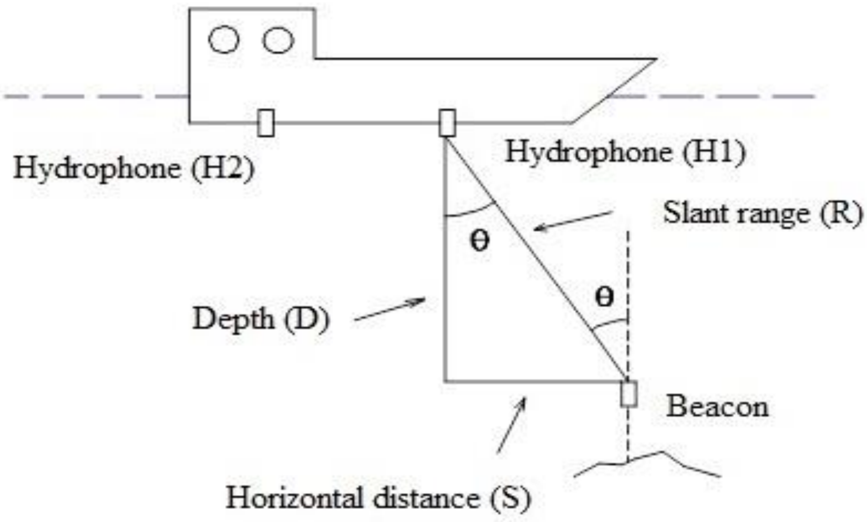

Fig. 1. Scoping

Angular measurement

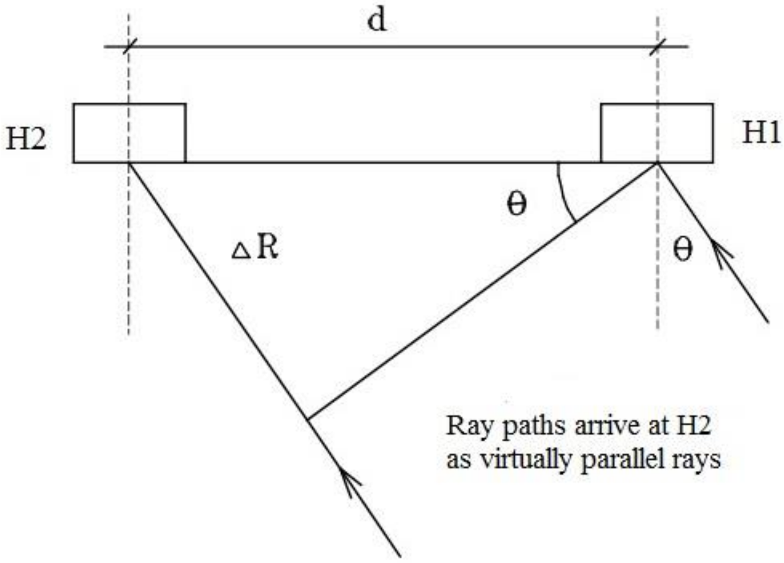

Fig. 2. Angular measurement

- Where the intended speed of sound is known: $\Delta R = c.\Delta t$ and $\sin\theta = \frac{c.\Delta t}{d}$,

where: c – speed of sound; Δt – signal arrival time difference at H1 and H2; D – distance between transducers / transducer elements / hydrophones.

- The third transducer, mounted at right angles to H1 and H2, allows the determination of the bearing(orientation) of the beacon.
- When the vessel is directly above a transponder, two hydrophones in the same axis will receive signals in phase. This is a useful technique used in dynamic positioning, where each station shift is intercepted by signals arriving out of phase [1, 4].

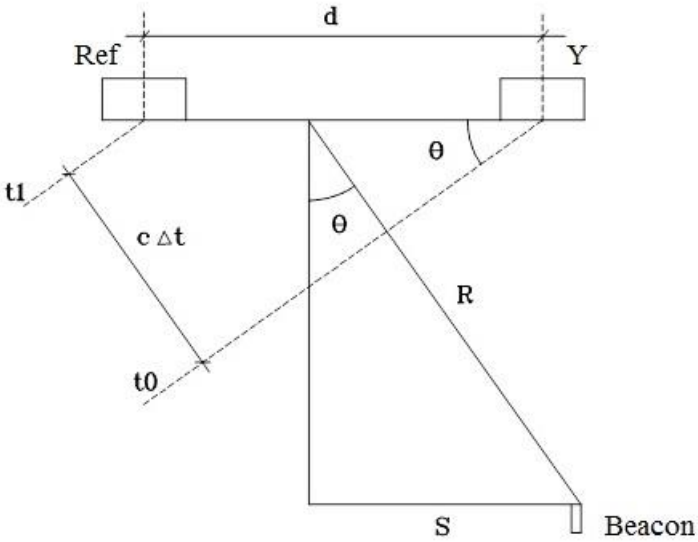

Fig. 3.

Substituting sinθ for the horizontal distance, we obtain: $S = R.\sin\theta = R\frac{c.\Delta t}{d}$.

Calculation of position in two planes

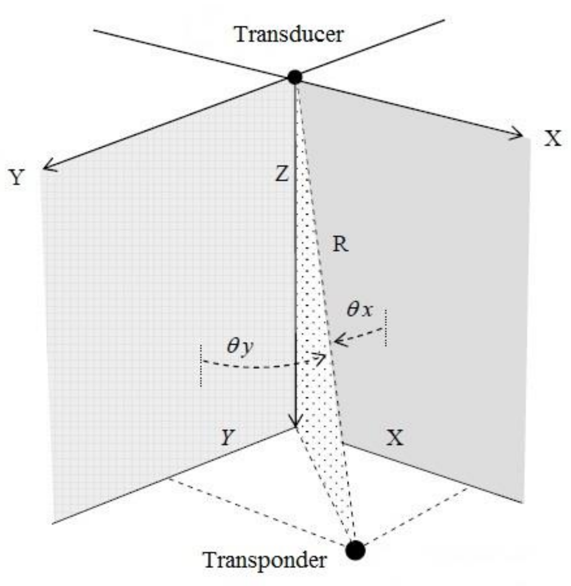

Fig. 4. [1]

$X = R.\sin\theta x$, $Y = R.\sin\theta y$ and therefore $Z = R\left(1 - \sin^2\theta y - \sin^2\theta x\right)^{1/2}$

The visible position requires correction for:

✓ angle of inclination and roll;

✓ alignment of the hydrophone (at installation);

✓ hydrophone offset (fixed size);

✓ transponder offset (fixed size).

• The Z coordinate is calculated from acoustic data, therefore depth information can be used to improve position accuracy under conditions of thermal gradients. The positioning accuracy is considered to be better than 1% of the inclined region [1, 4].

Accuracy and sources of error

The overall acoustic correction depends on [1, 4]:

- The accuracy with which the transponder grid is established against geodetic data;
- Determination and removal of multipath effects (reflections). This is particularly noticeable in regions of fixed structures such as production platforms and is worse for SSBL and SBL systems than for LBL systems;
- The accurate determination of sound speed, velocity gradients and refraction of signals;
- The frequency used. Accuracy increases with increasing frequency, but at the expense of range and power required;
- The fixed geometry and, to some extent, the topography of the water bottom, i.e. whether there is a "line of sight" between the transponders;
- Improvement of the processing and software system used;
- Errors in time measurement due to the presence of noise in the received signals. Noise can be:
  - ambient noise: waves, wind, rain;
  - self-contained noise: noise from engine, machinery, etc.;
  - echo noise (reflection): volume echo, water surface, water bottom structures.

The equipment normally used must operate at ambient temperature within certain ranges specified in the instrument prospectus. The system should also work in rainy weather [3].

3. Conclusion

Water (oceanic, marine, river, etc.) is not a uniform, isotropic medium and therefore the sound speed in water is affected by changes in temperature (dominant factor), salinity and depth. For example, the mean value of sound speed in seawater will increase approximately as follows:

- With 4½ m/s for every 1° C temperature increase;
- By 1.21 m/s for each part per thousand increase in salinity;
- By 1 m/s for every 60 meters at increasing depth.

All systems require an accurate knowledge of the average speed of sound and knowledge of the sound speed profile is preferable. This is usually obtained by using an independent TSD probe or profiling rate.

Acknowledgments

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