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Good Practice Guide for calibrating a hydrophone "in situ"

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Abstract- The aim of this paper is to provide the basis for the calibration of a hydrophone "in situ", thus assigning a value of uncertainty, which may be high, but according to requirements may be sufficient.

I. Introduction

Nowadays a multitude of tests are performed in the marine environment such as the measurement of pH, CO2, etc. Some of the tests performed are the measurement of noise pollution as well as the study of cetaceans in the marine environment. To perform this type of test, hydrophones are used. These devices are microphones for the marine environment. The calibration of this equipment is detailed in various standards such as [1] as a function of frequency. In our case we propose an in situ calibration of the hydrophone in the marine environment. This method of calibration involves a considerable increase in the uncertainty, but in many cases this increment of the uncertainty compensates little investment in performing calibration.

II. Development

A. Equipments

To carry out the calibration, the following equipment's are used:

-Sound Source.
The sound source shown in Figure 1 has to be known and we have to know its calibration uncertainty, TVR (Transmit Voltage Response), that it is function of SPL (sound pressure level) and the emission frequency.

Figure 1. The sound pressure generator, Lubell model LL9642T, used as acoustic source.

-Hydrophone
The hydrophone, Figure 2, device under test (DUT) must be characterized with their sensitivity in function of frequency.

Figure 2. Hydrophone (Bjørge Naxyx Ethernet Hydrophone 02345 used as acoustic receiver.

-GNSS Receiver
The GNSS receiver has to be able to get the data from satellite reception in raw data and be compatible with RTKlib applications.

B. Development-(Design)

-Sound level pressure source, SL
The sound pressure level generated is calculating through TVR that is a manufacturer specification. The TVR convert the tension that out of the amplifier to sound level pressure. The transformation equation is (1).

$$SL = TVR + 20 \cdot \log(V) \text{ dB/1}\mu\text{Pa @ 1 m} \qquad (1)$$

The origin signal is generate by the function waveform HP33120A. This signal is a sinusoidal signal with 1 cycle and the amplitude of 1 V_{pp} with a frequency in function of the calibration range.

Before start the calibration process is more important to analyze the different components that can to affect in the process, such as spreading, the absorption of the environment, and the echo contribution by the reflection in the sea surface and the seabed. All this factors are the transmission loss, TL.

-Echo by reflections in the sea surface and the seabed
The sound velocity in seawater is function of the salinity, the temperature and the depth, but in this case the test are make in offshore, and for this reason the velocity of sound will be constant. This approach is good to calculate the distance because the main signal travels by a different way that the first echo. The Figure 3 shows a schematic with the main parameters.

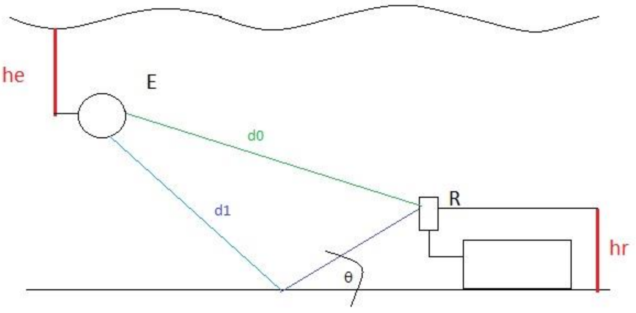

Figure 3. Schematic test with the main parameters

The result is the time interval between the main signal and the first echo (2) and the minimum distance for the device acquires the main signal without echo (3).

$$\Delta t = \frac{1}{c \cdot \sin\theta} \cdot \left[(hr - d_0 \cdot \sin\theta) \pm \sqrt{{d_0}^2 \cdot \sin^2\theta - {h_r}^2} \right] \qquad (2)$$

$$d0 = \frac{1}{2 \cdot \sin\theta} \cdot \left[\frac{(c \cdot \sin\theta \cdot \Delta t - h_r)^2 - 3 \cdot {h_r}^2}{c \cdot \Delta t \cdot \sin\theta - h_r} \right] \qquad (3)$$

Figure 4 details the calculation of the distance between receipt and source. But the GNSS get the coordinates (longitude, latitude) on the WHG84. For this reason the Vicenty [2] is used by the D determination.

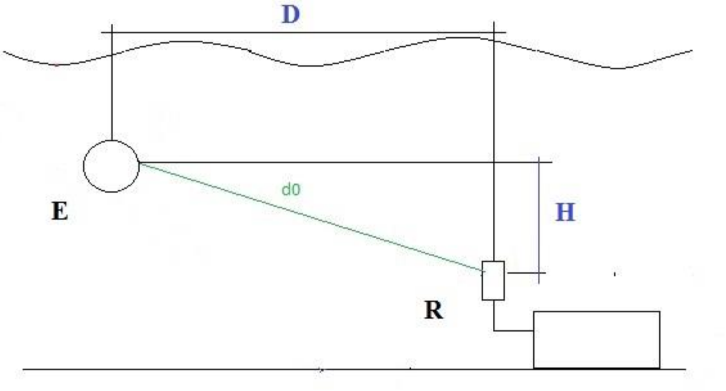

Figure 4. Schematic by D and d_0 determination

-Spreading loss
When a sound wave is generates inside environment, in our case seawater, the wave loses power because the energy is spread over a greater surface. In (4) is shown the spreading loss equation, where r is la distance between source and receipt measured in meters and C is the constant that is function of the generator and the environment test.

$$C \cdot \log(r) \tag{4}$$

In the ideal cases the constant C have two possible values. The C constant is 20 for spherical spreading and 10 for cylindrical spreading. The C value is very important because it is a major component of loss, in fact always the C value should be calculated, but the details of the C calculations are provided in the Martech 2013 congress. However here in comments the main principle. The C process consists in generating sound peaks at 10 kHz and saved the distances between source and receiver with a hydrophone has been calibrated. The next step is to fit the parameter C thought graph.

-Absorption environment loss
The absorption of the environment [3] is function of the frequency, pressure, salinity, temperature and pH. This contribution is detailed in (5), where the r is the distance between source and receipt measured in km.

$$\alpha \cdot r \tag{5}$$

The attenuation index α is calculate with the parameters measured by the CTD installed at OBSEA [4]. The Figure 5 shows the attenuation index variability in function of the temperature, depth and salinity.

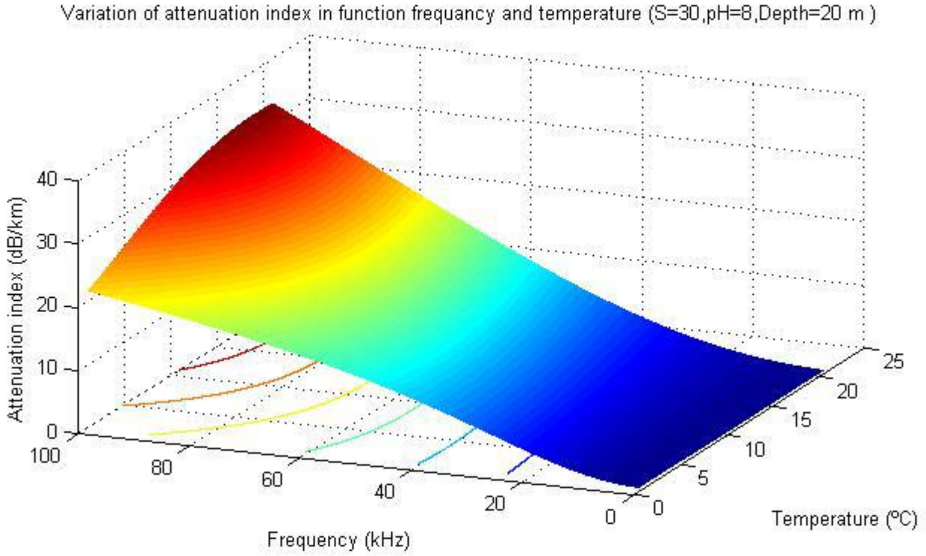

Figure 5. The attenuation index is temperature and frequency function. The Salinity, pH and depth are 30 $^{0}/_{00}$, 8 and 20 meters respectively.

The transmission loss, TL (6), includes the echo factor, spreading loss and the attenuation factor.

$$TL = C \cdot \log(r \cdot 1000) + \alpha \cdot r \mp R_{echo} \tag{6}$$

The objective is to find the receipt level. The work equation is (7), where SL is the source sound level, TL is the transmission loss and RL is the receipt level

$$RL = TL - SL \tag{7}$$

The sensitivity in function of parameter (7) is (8), where V is the receiver tension.

$$S = 20 \cdot \log(V_{RL}) - SL + C \cdot \log(1000 \cdot r) + \alpha \cdot r \mp T_{ECHO} \tag{8}$$

Where:
V_{RL} is the voltage of the Receiver
C is the spreading parameter
r is the distance between source and receiver in km
α is the attenuation index
T_{ECHO} is the contribution of the echo on seabed and under the sea surface.

C. Procedure

The systematic consists in generate sound in a known position. This position must have a minimum distance as shown in (3). Also the movement of source in seawater is very important, because in this case the source isn’t omnidirectional. The movement is blocked with the triangle made with PCV as illustrated in Figure 6.
In all this time the GNSS receivers is ON.

Figure 6. Item indicator of the emission direction

The sequence proposed must be for every frequency, and all the data are analyzed to posterior. This study is for the registration of sound as the position of the GNSS.

D. Uncertainty

The different factors of uncertainty are provided in [5]. All factors are separated in three fields:

Contribution to source (9)

$$u^2(SL) = \left(\frac{20}{\ln(10) \cdot P_S / P_0} \right)^2 \cdot \left(10^{-\frac{S}{10}} \cdot u^2(V) + \left(-\frac{V \cdot \ln(10)}{20 \cdot 10^{S/20}} \right)^2 \cdot \left(\frac{U_{SL}}{k_{SL}} \right)^2 \right) \tag{9}$$

Contribution of receiver (10)

$$u^2(RL) = \left(\frac{20}{V \cdot \ln(10)} \right)^2 \cdot \frac{{V_{\min}}^2}{6} \tag{10}$$

Contribution of environment (11)

III. Results

In 6 of June of 2013 the test has been realized. The boat stops at one point, and the duration of the test was 45 minutes. During this time the boat drifted about 500 meters, and for this reason the measures have been takenin different positions.

Table 1. Sensitivity table example.

Frequency (kHz)	Distance (km)	Position	Sensitivity (dB)	Uncertainty (dB)
10	1,335602	1	-190,17	3,00
	1,401709	2	-195,89	2,70
	1,525931	4	-190,92	2,93
	1,664731	5	-192,31	3,19
	…..	…..	…..	…..

With all values graphed, the value of S is the fit found from all these measurements. The final result is that the Sensitivity is –189,25 ±2,95 dB rel 1 V/µPa alt 10 kHz.

IV. Conclusions

The article gives the basis for considering the realization of in situ calibration of a hydrophone. The uncertainty contribution is high, and for this reason is necessary to repeat this test for better find the different contributions to uncertainty. Some improvements are the increase value of the source generator and decrease the contributions factors to uncertainty, of source pressure and receiver voltage.

In the last hydrophone calibration, about February of 2010, the sensitivity value was -192 dB rel 1 V/µPa at 10 kHz, and this value is inside our confidence interval.

References

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