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Physics Procedia 3 (2010) 209–215

Physics Procedia

www.elsevier.com/locate/procedia

International Congress on Ultrasonics, Universidad de Santiago de Chile, January 2009

Estimation of the variation in target strength of objects in the air

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Abstract

Target strength is one of the key values for sonar systems. The parameter is very useful in activities related to detection and estimation of marine organisms, object identification and sonar calibration. The essential difference between detection and ranging performed in water and air results from characteristics of those media. A common feature for both water and air is the fact that only longitudinal wave propagates in them. Ultrasonic wave propagation velocity in air changes when the medium's physical conditions alter (e.g. temperature, humidity, pressure, presence of other gases or pollution and gas medium heterogeneity). In water environment not all solid state objects can be assumed to be rigid and motionless – this approximation works better in case of air. This aspect is especially vital when analyzing waves penetrating objects reflecting ultrasonic wave. This paper presents calculation and measurement results of target strength of objects, shaped as spheres and cylinders of infinite and finite length, placed in air medium. The difference between the calculated and measured target strength was analyzed and escalation of difference in case of heterogeneous objects was pointed out.

Keywords: air; objects; target strength

1. Introduction

Target strength is a very helpful parameter when working on detection and identifying objects in water using sonar systems. Various objects, characterised by various consistence can be studied in water environment. Target strength can also be very important in relation to objects in air, especially when it is necessary to calibrate ranging equipment. A common feature for both water and air media is predominantly the fact that only longitudinal wave propagates in them. Differences are numerous: not all objects can be assumed to be rigid in water environment; in air environment an object causing reflection is in most cases characterised by significant rigidity, which means that ultrasonic wave hardly penetrates it. Intensity of sound reflected from an obstacle depends on many factors: intensity of sound incident on the reflecting object, distance between the object and an echo reception point, object dimensions, shape and attitude. It often proves to be advisable to separate those factors and examine object dimensions, shape and attitude aside from other factors. Such separation is only possible when wavefront radiuses

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doi:10.1016/j.phpro.2010.01.029

of curvature of the incident wave and the reflected wave are large enough in comparison to the reflecting object, i.e. when the incident wave can be treated as a plane wave.

2. Target strength

2.1. Calculation of target strength using geometric acoustics

Target strength is defined as:

$$TS = 10\log\left(\frac{I_r}{I_i}\right) = 20\log\left(\frac{p_r}{p_i}\right) \quad [\text{dB}] \tag{1}$$

where: I_i is the incident wave intensity, I_r is the reflected wave intensity, p_i is the incident wave pressure, p_r is the reflected wave pressure. Transmission loss occurs during wave propagation in a medium. In order to be able to work independently of this phenomenon it is assumed that the pressure p_r (intensity I_r) of the reflected wave is applies to the distance of $r = 1$ m.

Another definition of target strength, which gives consideration to the dimensions and reflecting capabilities of a given object is realised as [1]:

$$TS = 10\log\left(\frac{\sigma_s}{4\pi r_1^2}\right) \quad [\text{dB}] \tag{2}$$

where: σ is a scattering section, r_1 the distance of 1 m. A surface with σ stray scattering field allows graphical determination of the diffusive power of a given object; this surface can be larger than the object's section area. This surface should have a field that corresponds to such an intensity of the wave scattered identically in all directions, that is equal to the intensity of the wave reflected by a real object localised at a distance of r from the source [2]:

$$\sigma = \frac{Q}{I_i} \tag{3}$$

where Q is a total energy flux of the waves scattered in all directions which is given by the following formula:

$$Q_r = \int_{4\pi} I_r(\theta_r) r^2 \, d\Omega \tag{4}$$

The object's target strength and its scattering section can alter in line with changes in location of the observed object in relation to the incident wave.

If the object causing scattering is placed at a large r distance from the observation point, it can be treated as a point source generating a spherical wave. Scattering functions can in such case be formulated as:

$$\xi(\theta_r) = \frac{I_r(\theta_r) \cdot r^2}{I_i} \tag{5}$$

where θ_r is the scatter angle. The $\xi(r)$ value can be treated as a characteristic of the scattering object. If the incident wave's intensity is expressed as:

$$I_i = \frac{P}{r^2} \tag{6}$$