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Calculation of Bistatic Scattering from Underwater Target with Physical Acoustic Method

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Abstract

This article presents an efficient way to calculate big bistatic angle scattering from underwater target using physical acoustic method. When using the traditional physical acoustic method to forecast bistatic echo of underwater target, the error is becoming unacceptable with the increment of bistatic angle. Aiming at this problem, the integral formula of the physical acoustic method is modified so that it can be used for arbitrary bistatic angle. Target strength of rigid sphere and cylinder with finite length is calculated to verify the proposed method. The simulation results show that the proposed method can be used to calculate big bistatic angle scattering from underwater target.

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Keyword: bistatic scattering , physical acoustic method, target strength;

1. Introduction

Comparing with monostatic sonar, there are many merits in detecting and locating underwater targets for bistatic sonar [1]. In recent years researchers pay more attentions to the bistatic sonar system [2]. However, the effectiveness of bistatic sonar is based on taking full advantage of target scattering characteristic. So it is important to study on bistatic target scattering characteristic. As an efficient method, the physical acoustic method is used widely in analyzing monostatic target scattering characteristic. However, when using the method to analyzing bistatic target, the problem is that with the increment of bistatic angle

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the error is becoming unacceptable. According to the characteristics of large bistatic angle scattering, we consider the contribution of the area which is invisible for the source and visible for the receiving point. The areas that are visible or invisible are calculated separately and the formula which is fit for any bistatic angle is given. Numerical bistatic target strength results of acoustically rigid sphere and cylinder with finite length obtained using the formulation developed in this paper is compared to analytical solutions in order to validate the revised formulation. Finally the result of bistatic Target Strength of the Generic subumarine [3] is given.

2. Theory

The standard three-dimensional Helmholtz integral formula which is valid for an acoustic medium B' exterior to a finite body B with smooth surface S takes the following form [4]:

$$\varepsilon\phi_s(P_2)=\int_s\left(\phi_s(Q)\frac{\partial G_k(P_2,Q)}{\partial n}-G_k(P_2,Q)\frac{\partial\phi_s(Q)}{\partial n}\right)dS_Q \tag{1}$$

The free-space Green's function G_k for the Helmholtz equation in three dimensions is given by

$$G_k(P_2,Q)=e^{ikr_2}/4\pi r_2 \tag{2}$$

Where r_2 is the distance between the field point P_2 and the moving point Q (depicted in Fig. 1), P_1 is the source point, and n is the outward directed normal at Q. ε has value $1/2$ for point P_2 on surface S.

As $\phi_s(Q)$ and $\partial\phi_s(Q)/\partial n_Q$ are unknown, equation (1) can be solved by means of integral equation method. Physical acoustic theory suggests that there are generally some high-frequency approximate conditions as follows, when $L ? \lambda$ (L is the size of the target, and λ is the transmitted acoustic wavelength),

Geometric shadow's contribution to the field point P_2 can be neglected. The integral area is the visible area of P_2 which is include the visible part S_1 and the invisible part S_2 to P_1.

Part impedance condition is satisfied, i.e., scattering acoustic field $\phi_s(Q)$ can be expressed by incident acoustic field $\phi_i(Q)$. For rigid boundary condition, $\partial(\phi_s+\phi_i)/\partial n=0$. When $Q\in S_1$, $\phi_s(Q)=V(\theta)\phi_i(Q)$. When $Q\in S_2$, the total sound field is zero, so $\phi=\phi_s+\phi_i=0$.

Sound energy is radiated evenly within the solid angle of 2π by the surface element.

Let the incident acoustic potential function be $\phi_i=(A/r_1)\exp(ikr_1)$ .According to the approximation conditions above, we get

$$\phi_s(P_2)=\frac{ikA}{4\pi}\left[\iint\limits_{S_2}\frac{e^{ik(r_1+r_2)}}{r_1r_2}(\cos\alpha_2-\cos\alpha_1)ds-\iint\limits_{S_1}\frac{e^{ik(r_1+r_2)}}{r_1r_2}(\cos\alpha_1+\cos\alpha_2)ds\right] \tag{3}$$

In the traditional document, the contribution of area S_2 on scattering field is ignored; only the area S_1 is calculated [5]. Actually when the bistatic scattering is considered, the influence of area S_2 to the result

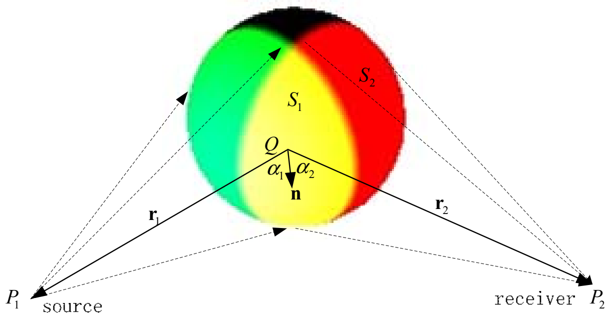

Fig. 1. Underwater target and bistatic coordinate system

is bigger and bigger with the increase of bistatic angle, and the error will be remarkable if the influence of area S_2 is ignored.

3. Validation

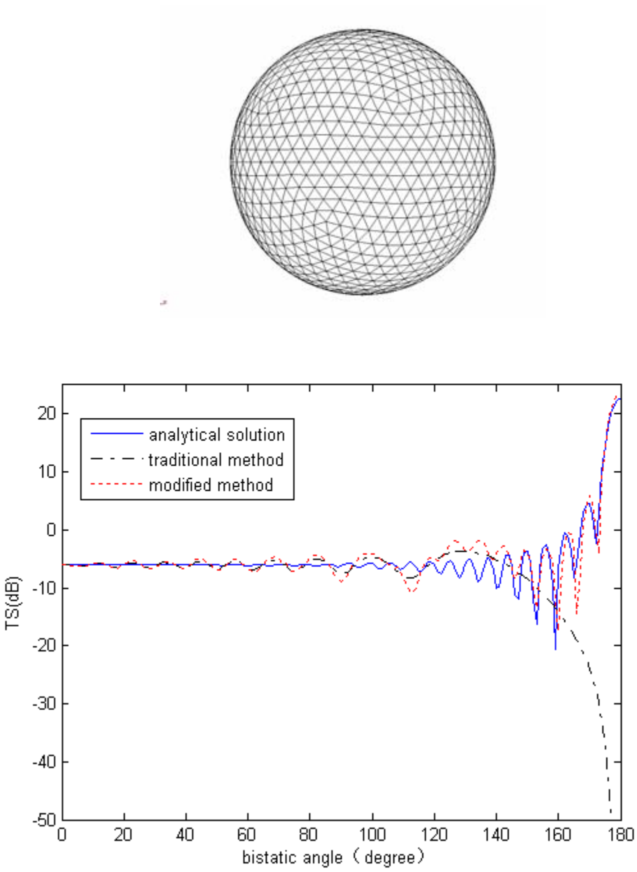

Fig. 2. (a)Model of sphere; (b) Target Strength for rigid sphere (ka=30)

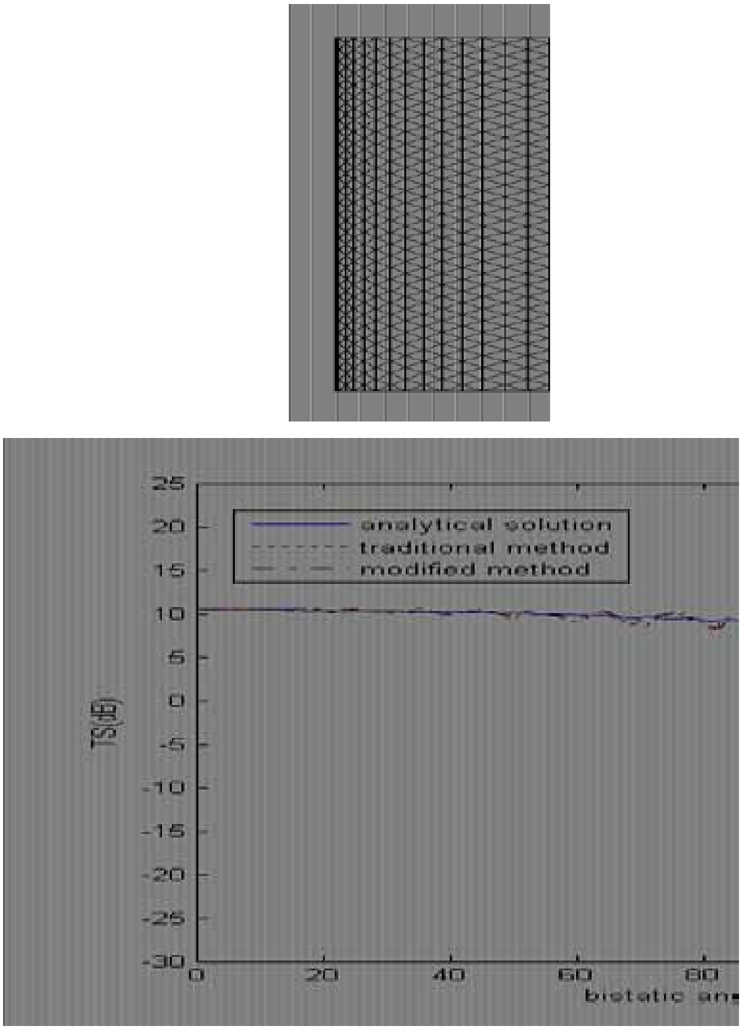

Fig. 3. (a)Model of cylinder with finite length; (b) Target Strength for rigid cylinder with finite length (ka=35)

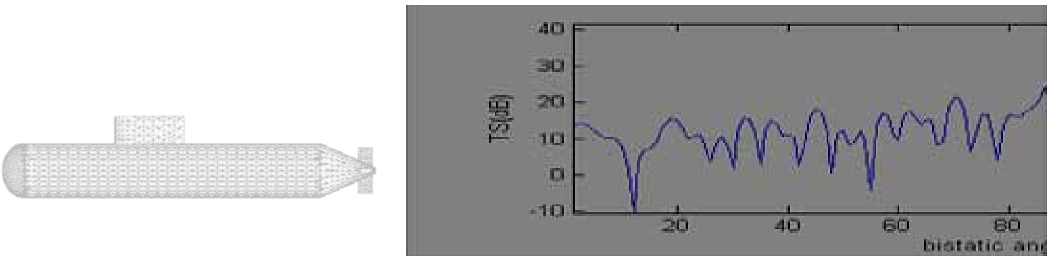

Fig. 4. (a) 3D model of the Generic submarine; (b) Target Strength for rigid Generic submarine

The model of a rigid sphere, cylinder with finite length and the Generic subumarine [3] for the numerical computations during the validation process is depicted. The radius of the sphere and the cylinder is 1 meter. The cylinder is 2 meters long. The target strength of the rigid sphere and cylinder varing with the bistatic angle using the traditional method and the modified method is given in Fig.2 and Fig 3. The analytical solution of them is also employed for validating this method. As is shown in the figures that when using the traditional method to analyzing bistatic target with the increment of bistatic angle the error is becoming unacceptable, especially when the bistatic angle is bigger then 150 degree. The problem is settled pretty well by using the modified method and excellent correlations between the simulation and analytical solutions can be observed for both sphere and cylinder model. Finally we use the modified method to calculate the Target Strength of the Generic submarine which can be used to analyze the characteristic of bistatic submarine in the future and is given in Fig.4.

4. Conclusion

An efficient way to calculate big bistatic angle scattering from underwater target is given using physical acoustic method. When using the traditional physical acoustic method to forecast bistatic echo of underwater target, the error is becoming unacceptable with the increment of bistatic angle. Aiming at this problem, the integral formula of the physical acoustic method is modified so that it can be used for arbitrary bistatic angle. Target strength of rigid sphere and cylinder with finite length is calculated to verify the proposed methods. The simulation results show that the proposed method can be used to calculate big bistatic angle scattering from underwater target.

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