Sample of Level 3 Editing

~~To~~ Obtaining Geo-Acoustic Parameters ~~by~~ using the Acoustic Inversion Technique ~~Using the~~with Sub-Bottom Profiler

Key words: geo-acoustic parameter, spectral ratio technique, ~~chirp sonar~~Chirp Sonar system, attenuation coefficients

Abstract

Refraction on the sea surface around Taiwan is strong because the speed of sound is high at sea level.~~The fast sound speed at sea surface in the water surrounding Taiwan causes strong refraction.~~ ~~If the water depth is lessis shallower than five thousand meters deep~~In shallow water, the sound rays will be reflected at the bottom, which ~~would~~ causes~~causing~~ severe bottom losses. Therefore, ~~the~~ geo-acoustic parameters are~~is~~ important for the ~~the~~ acoustic study of~~in~~ the water surrounding Taiwan. In the past, researchers have used single pulse sonar of 3.5 kHz to obtain geo-acoustic parameters ~~by~~ using the spectral ratio method, which is ~~(~~one of the acoustic inversion techniques~~)~~. Now, s~~Now the s~~ediment exploration has ~~already~~ advanced and ~~t and he~~used ~~Chirp Sonar~~Chirp Sonar system is used on~~on~~ Taiwanese Research Vessels such as the Ocean Researcher I (OR I) and the Ta-Kuan;~~,~~ which uses the~~'s~~ TOPAS system. This paper presents the results of the study of attenuation coefficients at their~~in~~ ocean bottom~~s~~ The attenuation coefficients were found by applying~~using~~ the spectral ratio method on the ~~chirp sonar~~Chirp Sonar data collected by the OR I. The results were~~are~~ compared with the core data, and the relative error was found to be~~is~~ within fifteen percent. The actual core sites can only provide attenuation coefficients for up to a~~of~~ few meters below~~of~~ the surface. This~~, which the~~ information is insufficient for acoustic research. The spectral ratio method depends on the depth of exploration of the ~~Chirp Sonar~~Chirp Sonar, which is able to get attenuation coefficients of the depth of all layers.

Introduction

Refraction on the sea surface around Taiwan is strong because the speed of sound is high at sea level~~The fast sound speed at the sea surface in the water surrounding Taiwan causes strong refraction~~. If the water ~~depth~~ is less~~shallower~~ than five thousand meters deep, the sound rays will be reflected at the bottom, which would caus~~e~~ing severe bottom losses. As a result, ~~the~~ geo-acoustic parameters are important for acoustic study of~~in~~ the water surrounding Taiwan. The ~~southwest~~ water to the south west of~~s of~~ Taiwan is~~are~~ 2000-3000 meters deep and to the~~the~~ east, it is~~ern waters are~~ 4000-5000 meters deep. ~~TThe~~Hence, sediment exploration method cannot be easily ~~used easily thus not be easily used because of complications due tocaused by the water~~

Comment [O1]: **CHECK**: Add 'can' if this is not always the case.

Comment [O3]: **CHECK**: This sentence suggest this is only true of Taiwan. Is this the case?

Comment [a2]: **CHECK**: Is this the correct interpretation of the phrase 'results of attenuation coefficients', which is grammatically incorrect?

~~depth~~ and ~~the difficulty of manipulating~~ because the selection of the core site location is difficult. Nowadays, s~~S~~cientists ~~nowadays~~ use the ~~Chirp Sonar~~Chirp Sonar, which uses the spectral ratio method to obtain geo-acoustic parameters. ~~Which~~ These parameters help further~~s~~ acoustic research.

When sound waves are sent~~d~~ through ~~out from~~ the ocean into the sea bed, the energy of the sound waves is transmitted to~~will go through~~ the sea bed from the water column. The resulting compressional ~~waves~~ and shear waves will penetrate to different sedimentary layers in the~~the~~ sea bed ~~into different sedimentary layers~~. ~~As the layers each have~~The distinct acoustic characteristics ~~these characteristics~~of those layers will affect the waves in different ways. In current acoustic research, Steven G. Schock and his team of researchers have used ~~the~~ information obtained from the ~~Chirp Sonar~~Chirp Sonar, ~~and used~~ the methods of waveform matching, and the inversion technique based on the Biot model to do sedimentary research [1][2].

Researchers from Taiwan have used acoustic digital information obtained from the single pulse sonar of 3.5 kHz on the Ocean Researcher I (OR I) to obtain geo-acoustic parameters ~~by~~ using the spectral ratio technique [3]. ~~Taiwanese researchers~~ They are, however, ~~have~~ yet to use the spectral ratio technique on information obtained from the ~~Chirp Sonar~~Chirp Sonar.

This research will first collect digital information from the ~~Chirp Sonar~~Chirp Sonar operations. T~~and~~hen, ~~use~~ the spectral ratio method will be used to analyze the sound waves in the sediment to obtain attenuation coefficients. These coefficients will then be compared to the experimental core data in order to determine the accuracy of the spectral ratio method. The calculated ~~se calculations (~~attenuation coefficients~~)~~ will be used ~~again be used~~ to study~~for~~ sound propagation ~~study~~. ~~—~~The ~~Chirp Sonar~~Chirp Sonar is a broadband, high signal to noise ratio device. In theory, it can produce more accurate attenuation coefficients of the sedimentary layer of the ocean [4].

Methodology

The three main reasons~~s~~ for the diffusion of~~why~~ the energy of sound waves ~~diffuses~~ are~~is due to~~ attenuation in the sedimentary layers of the sea bed, the geometric spreading effect~~,~~ and reflectivity. (the total energy of the sound wave before reflection is equal to the sum of~~=~~ the energy used to reflect the sound wave and~~+~~ the penetrating energy of the sound wave). The main goal of analyzing the digital signals from the ~~Chirp sonar~~Chirp Sonar is to find the k value of the attenuation coefficient. As it is impossible for the amplitude of signals recorded by the ~~recorded signals from the Chirp Sonar~~Chirp Sonar to be the same as the amplitude of the original signals;~~,~~ the reflected signal is ~~undergoes great~~ amplified by a large amount~~eation~~. This value is the square of the amplitude of the signal that is~~which~~ returned to the ~~Chirp Sonar~~Chirp Sonar. Therefore, ~~it is useful to use~~ the spectral ratio technique put forth by

Comment [a4]: CHECK: Is this the correct interpretation of the sentence?

Comment [O5]: IDEA: Is this discussed later in the paper? If so, mention this. If not, perhaps suggest a few areas of such research.

Comment [a7]: CHECK: Please clarify what the equation in the bracket refers to. Is it the definition of reflectivity?

Comment [O6]: CHECK: Do you mean researchers in Taiwan? ‘From’ Taiwan suggests they are not in Taiwan now. Or do you mean ‘Taiwanese’ researchers which suggests the research is for Taiwan.

Comment [a8]: CHECK: Which value do you refer to here? Please clarify.

Jacobsen et al. (1981) [5] is used to calculate the attenuation coefficient of the sedimentary layers of the sea bed. This technique disregards the influence of the geometric spreading effect and reflectivity. In the spectral ratio technique, ~~Through the use of the top and bottom signal reflection interface~~ the relationship between the energy density and the attenuation coefficients can ~~thus~~ be obtained by using the top and bottom signal reflection interface ~~through the spectral ratio technique~~.

The theory behind the spectral ratio technique states that when sound waves are being transmitted~~transmitting~~ through a medium, their~~its~~ amplitude will mainly be affected by the geometric spreading effect, reflectivity, and attenuation. This can be expressed ~~in the~~ as shown in equations~~formulas~~ (1) and (2):

$$A(x,f)=A_0(f)\cdot G(x)\cdot R\cdot 10^{-\alpha(f)\cdot(x/20)} \qquad (1)$$

$$\alpha(f)=k\cdot f^{n} \qquad (2)$$

A: amplitude of reflection

A_0: amplitude of original wave

G: geometric spreading loss

R: reflectivity

α: attenuation value (dB/m)

x: distance traveled by the sound wave (m)

k: attenuation coefficient (dB/m/kHz)

f: frequency (kHz)

n: frequency index [If the layers are isotropic, uniform, and elastic~~ity~~, then n = 1 (Hamilton，1972)][6]

After calculating~~on of~~ the energy spectral density, the ~~formula~~ above equation can be rewritten as ~~formula (3)~~:

$$S(f)=S_0(f)\cdot G(x)\cdot R\cdot 10^{-\alpha(f)\cdot(x/10)} \qquad (3)$$

S: the spectral energy density of the reflected sound wave

S_0: the spectral density of the original sound wave

Assume there are two depths labeled X_1 (the top layer) and X_2 (the bottom layer). Then, the spectral energy density can be expressed by the following equations~~through formulas (4) and (5)~~ (Jannsen 1984) [7].

$$S_1(f)=S_0(f)\cdot G(x_1)\cdot R_1\cdot 10^{-\alpha(f)\cdot(x_1/10)} \qquad (4)$$

$$S_2(f)=S_0(f)\cdot G(x_2)\cdot(1-R_1^2)\cdot R_2\cdot 10^{-\alpha(f)\cdot(x_1/10)}10^{-\alpha(f)\cdot(x_2-x_1/10)} \qquad (5)$$

The Spectral Ratio can be expressed as ~~formula (6)~~ ~~:~~ :

$$SR(f)=\left|S_2(f)\right|/\left|S_1(f)\right| = \left|\left[G(x_1)/G(x_2)\right]\left[\left(1-R^2\right)R_2/R_1\right]\right|10^{-\alpha(f)\cdot(x_2-x_1/10)} \qquad (6)$$

~~Take the logarithm of both sides and times ten~~On taking logarithms and multiplying by ten on both sides, ~~-~~ t~~T~~wo divisions can ~~thus~~ be seen: an~~An~~ equation ~~formula~~ that is dependent on~~which is influenced by~~ frequency factors (7), and ~~a formula~~an equation that is ~~which is not influenced by~~independent of frequency factors (8):

$$10\log SR(f)=10\left\{\log\left|G(x_1)/G(x_2)\right|+\log\left|\left(1-R^2\right)R_2/R_1\right|\right\}-\alpha(f)\cdot(x_2-x_1) \qquad (7)$$

$$10\left\{\log\left|G(x_1)/G(x_2)\right|+\log\left|\left(1-R^2\right)R_2/R_1\right|\right\} \qquad (8)$$

Equation ~~Formula~~ (8) is not affected by frequency factors.~~,~~ T~~t~~he geometric spreading effect varies over depth, and the reflectivity depends on the speed and density of different layers. We can make a group with two reflective surfaces X_1 and

Comment [a9]: CHECK: Did you mean to say 'elastic' here, or something else?

Comment [O10]: CHECK: Perhaps remove this sentence as you already stated it is independent.

Comment [a11]: CHECK: Which speed do you refer to here?

X_2, which are constants; and R1 and R2, also constants. ~~which are constants too.~~ This group can be seen as one constant. The two different frequencies of the spectral ratio, f1 and f2 ~~of the spectral ratio~~ can be expressed ~~as formulas~~by equations (9) and (10):

$$10\log SR(f_1) = \text{constant} - \alpha(f_1)\cdot(x_2 - x_1) \qquad (9)$$

$$10\log SR(f_2) = \text{constant} - \alpha(f_2)\cdot(x_2 - x_1) \qquad (10)$$

Substituting equation~~e~~ (2) in equations (9) and (10) and setting n=1 gives~~to get~~ equations~~formulas~~ (11) and (12).

$$10\log SR(f_1) = \text{constant} - k\cdot f_1\cdot(x_2 - x_1) \qquad (11)$$

$$10\log SR(f_2) = \text{constant} - k\cdot f_2\cdot(x_2 - x_1) \qquad (12)$$

Substituting equation~~Substitute~~ (12) in (11) and ~~cancel~~canceling the constants to give~~set~~ equation~~formula~~ (13):

$$\{10\log SR(f_1) - 10\log SR(f_2)\}/(f_2 - f_1) = k\cdot(x_2 - x_1) \qquad (13)$$

The left hand side of the equation is the slope of the spectral ratio value and~~to~~ the spectral value.~~,~~ T~~and t~~he right hand side of the equation is~~has~~ the attenuation coefficient multiplied by the depth of the sediment. Therefore the above equation can be solved to get the k value of the attenuation coefficient~~ can thus be solved from the formula given above~~. These steps ~~are what~~ form the basis of the spectral ratio technique (Figure 1).

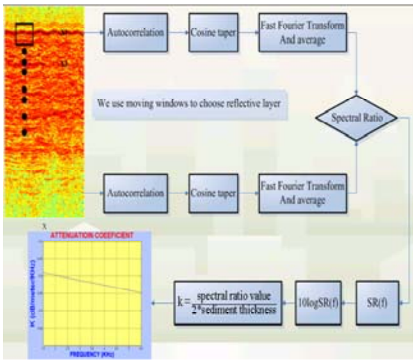

Fig 1. Spectral ratio method flow chart

Data Processing

The Chirp Sonar information used in this research project ~~from the Chirp Sonar~~ ~~i~~is from the period~~months~~ July to October~~ in~~ 2005. It was collected on the 760^{th} and 772^{nd} voyage of Ocean Researcher I during~~from~~ the Variations Around the Northern South China Sea (VANS) survey. The~~is~~ route was ~~specially~~ selected such that~~o that~~ it would~~designed to~~ bypass~~ by the~~ locations from where core site data had already been collected ~~before~~ (Chen, 1997)~~-~~ (Figure 2 [8]).~~,~~ The core sites are used to~~which~~ verify the results of the spectral ratio method. The process can be divided into three steps (Figure 3):

~~2.~~1. Preceding process: First~~ly~~, record the information files obtained from the ~~Chirp Sonar~~Chirp Sonar into the BATHY-2000P system. T~~and t~~hen, use the signal transformer to transform~~change~~ the signal into the BATHY-2000W system. Record and save the data onto a computer hard drive.

Comment [a12]: **CHECK**: Is this the correct interpretation of this sentence?

Comment [a13]: **CHECK**: Which process do you refer to here?

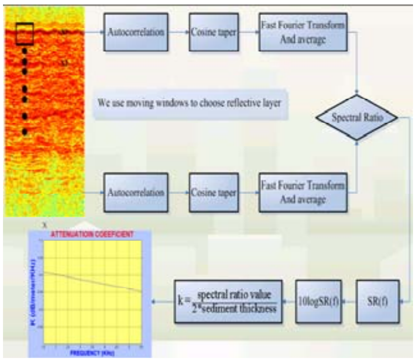

Fig 1. Spectral ratio method flow chart

2. Transformation procedure: The information is~~ will be~~ transformed from bB~~B~~inary code to the ASCII format by using~~through~~ the SIOSEIS seismic data processing software (f~~F~~rom the UNIX system).
3. Information processing procedure: O~~Firstly, o~~rganize the digital information collected by~~from~~ the ~~Chirp Sonar~~Chirp Sonar on Ocean Researcher I in the research area. Analyze the data according to the different sedimentary characteristics and locations. The analysis procedure is as follows (Figure 4):

(1) Examine the~~ illustrated~~ sections of analog and digital signals as shown in Figure 4. Choose a section with obvious reflective layers that~~which~~ is close to the horizontal level (Figure 4-A).

(2) In order to increase the signal to noise ratio of the information, choose five neighboring trace lines and determine the quality of the information (Figure 4-B). Take an average of the five trace line values as the basic value.

(3) Use the moving window method to find the trace line that~~which~~ has a frequency between 1.5 kHz and -5.5 kHz with a frequency gap of 0.1 kHz and has~~with~~ a window gap of 2 ms (90% overlap) regarding the spectral value (Figure 4-C).

(4) Draw a spectral value chart for the moving windows (Figure 4-D).

(5) Substitute the~~ moving windows~~ spectral value of the moving windows into the automatic reflective layer identification software. Identify the time of appearance of~~s that~~ each reflective layer ~~appears~~.

~~(7)~~(6) Compare the possible emerged time of the reflective layer, as selected from the automatic reflective layer program with the profile of the location time of the reflective layer,~~ which is~~ drawn from the digital signal. Then select the reflective layer.

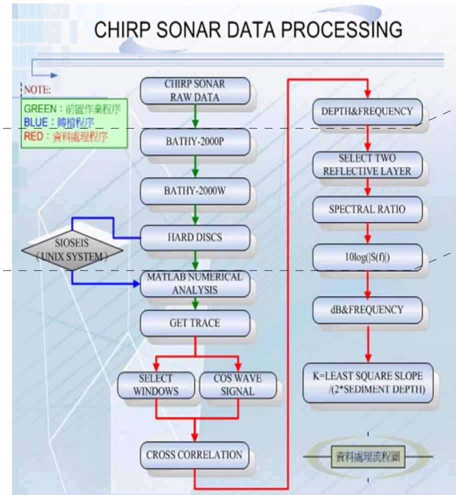

Fig 3. Flow chart of Chirp sonar data processing

(7)

Comment [a16]: CHECK: is 'regarding' the word you meant to use here? Perhaps you meant to say 'as compared to' or 'relative to'?

Comment [a17]: CHECK: What do you mean by emerged time here? Is this the same as the 'time of appearance' in the previous sentence?

Comment [a18]: CHECK: It is unclear if you mean the time or the profile here, you may want to reword it to clarify what you refer to.

Comment [O14]: CHECK: The three steps have been described. Perhaps add an introduction for these next points.

Comment [a15]: CHECK: Is this what you meant to say by 'illustrated sections?'

Use the spectral ratio technique to calculate the spectral ratio values of both reflective layers.

(8) Take the logarithm of the spectral ratio values and multiply~~times~~ by 10. Use the least squares method to find the slope of the data points. Lastly, divide the linear slope by the distance between the two reflective layers to obtain the k value of the attenuation coefficient. The above distance is the speed of sound ~~(sound speed x~~ multiplied by two times the~~2~~ travel time in a sedimentary layer;~~,~~ the speed of the sound wave is taken to be~~at~~ 1650m/s (Huang, 1996)[9].~~)~~

~~(Huang,1996)[9] to obtain the k value of the attenuation coefficient.~~

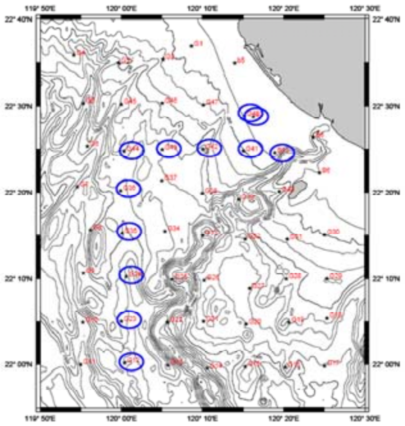

Fig 2. The Core Sites in South-west Taiwan Sea

Use this value and the frequency to draw a graph. Compare the calculated k value of the attenuation coefficient with the core data (Figure 4-F).