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Acoustic Signal Processing Technique to Classify Reservoir sediments

Aditi Awasthi[1], Dr. (Mrs.) S.S. Lokhande[2], M. Selva Balan[3]

[1]*M.E Student, E&TC Dept. Sinhgad College of Engineering. Maharashtra, India*
[2]*Associate Professor, E&TC Dept. Sinhgad College of Engineering, Maharashtra, India*
[3] *Scientist D, Central Water and Power Research Station, Maharashtra, India*

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Abstract - *Acoustic reflected signals are the most acceptable technology which carries the information of the underwater objects based on frequency, amplitude. To estimate the capacity of the reservoir and plan the reservoir operations it is required to find the underwater objects in an acceptable accuracy. The reflected echo carries information about the material characteristics based on absorption, reflection and refraction. It is initially proposed to develop the model of reservoir. The model of the reservoir is created using Finite volume method. Then the model for underwater layer classification is created using the material characteristics. Then different sediment types are identified based on the features extracted from received signal.*

Key Words: Underwater Acoustics, Finite Volume method, material characteristics, backscatter signals, sedimentation.

1. INTRODUCTION

The applications of Acoustic signal processing techniques are increasing in a wide variety of underwater investigations. An area which was primarily for military and deep sea research applications has been developed into rich fields such as oil exploration, commercial fishing and sediment classification. The main reason of using acoustic signals in underwater is that acoustic signals can travel over long distances as compared to electromagnetic waves[1]. In these systems the acoustic reflected signals are used to carry the information of the underwater objects. Then based on reflected signals surface plot is made for analyzing the sediment composition. For centuries, since the European started exploring the oceans, hydrographers used manual measurement systems like chronometers, sextant fixes and lead lines, to produce nautical maps, which were key in determining safe shipping routes. In the beginning of the 20th century the acoustic systems were developed for measuring ocean depths and for obstacle detection. These were active systems, emitting and recording sound, and were called SONAR (Sound Navigation and Ranging)[2]. These devices consist of one source and one recording unit i.e. a hydrophone. Such systems are now known as single beam eco-sounders. In the second half of the 20th century eco-sounders became more accurate and other types became available, such as the side-scan sonar and the multi-beam eco-sounder.

For classification of reservoir characteristics it is required to determine the depth as well as sediment composition of the reservoir. Classification of reservoir characteristics can be performed using two approaches, the empirical and the model based methods. Instead of classifying the reservoir characteristics on the actual reservoir using empirical method, the model based approach is used where the model of the reservoir is created using Finite volume method and simulated using Matlab. Then the underwater objects are classified based on the acoustic reflected signals. sediment parameters, such as mean grain size, to the acoustic classes.

On the contrary, in the model based methods, we determine the sediment type with the comparison between modeled and measured signals or signal features. Where the sediment type or parameters are input to the model and the resulting signals in correspondence to each sediment are output of the model. Therefore in model based approach no independent information is required, since they provide the sediment type or properties for sediment type instead of acoustic signals. In this project the acoustic input signal is modeled and then different sediment types are classified based on the resulting output signals and measured material characteristics.

2. MATHEMATICAL MODEL OF RESERVOIR

The very first block of the proposed work is creating mathematical model of reservoir. Shallow water equations are used to create the model of reservoir [3]. These are generally hyperbolic equations. The Finite volume method is established method for solving hyperbolic equations. Therefore FVM is found to be a good option where shallow water equation is solved.

$$\frac{\partial}{\partial t}\int_{\Omega} U\, d\Omega + \int_{\Omega} (Fdx - Gdy) = \int_{\Omega} S d\Omega \qquad (1)$$

Where U is the vector of flow variables, F and G are fluxes and S is the source term induces because of bed slope, frictional slope The FVM falls into the family of Godunov-type algorithms and is a technique for solving system of hyperbolic equations[3]. This method is considered very accurate as it conserves mass at every time step. It operates by updating the solution with some control volume and includes all the mass and momentum fluxes. Here FVM is used as the variation of the Godunov algorithm instead of breaking the model into discrete volumes. The main advantages of this method are that it can handle Non-Cartesian geometries which are required for most natural circumstances. It does not to generate and remove cells around wetting and drying boundaries. It can handle supercritical and subcritical boundaries with only minor adjustments.

3. UNDERWATER LAYER CLASSFICATION AND SIGNAL PROPAGATION

Acoustic signals are the most suitable signals used in the underwater as they can propagate over long distances. To realize the mechanism of acoustic signal propagating through underwater layer media a computer simulation program is developed for accounting attenuation effects. A seven layer underwater structure is assumed based on the data given in Table (1). The input signal x (t) as a representative of a typical seismic source signature analytically expressed by[4]:

$$x(t) = 1360 * e^{-500t} - o.5 * e^{-15.3t} \sin(\omega t) \quad (2)$$

Here t is the time and $\omega = 2\pi f$ is the frequency of the input signal x(t). In reflection seismology a source of energy produces a signal x(t) applied close to or on the water surface in reservoir. Mathematically, if the experiment is represented by a lossless wave equation, then all the signals within the media will be the time delayed scaled replicas of the source signal, x(t).Let y(t) be the resulting output signal of the model given by :

$$y(t) = \sum_{i=0}^{N} A_i * x(t - \tau_i) \quad (3)$$

Here τ_i are the time delays and A_i are frequency dependent medium amplitude scale factors that vary with layer thickness and defined by

$$A_i = \alpha_i * e^{-\omega D_i} \quad (4)$$

Where α_i frequency independent amplitude scales factors and are the media damping factors then the Eq. (3) becomes,

$$y(t) = \sum_{i=0}^{N} \alpha_i * e^{-\omega D_i} * x(t - \tau_i) \quad (5)$$

Seven layer is simulated to find the value of y(t),using convolution model given by Eq.(3) The model parameters are listed in Table I. Using the media characteristics and defined the input signal, the synthetic observation data in the layers is obtained. These waveforms indicate that the amplitude of the output signals is affected by the attenuation parameters of each sediment type.

Table- I. Material Characteristics

Material	α_i (mV)	g_i (mm)	a_i (db/ft)	d_i (ft)	τ_i (ms)
Silty Sand	0.061	0.10	2.80	27	0.20
Fine Sand	0.063	0.18	7.00	45	0.56
Very Fine Sand	0.051	0.09	4.50	48	0.74
Sand-Silty Clayey	0.032	0.03	7.30	56	0.80
Medium Sand	0.046	0.60	3.60	62	1.40
Coarse Sand	0.041	0.30	2.90	64	2.60

4. RESULTS

The mathematical model of the reservoir is shown as below which is created using Finite Volume method.

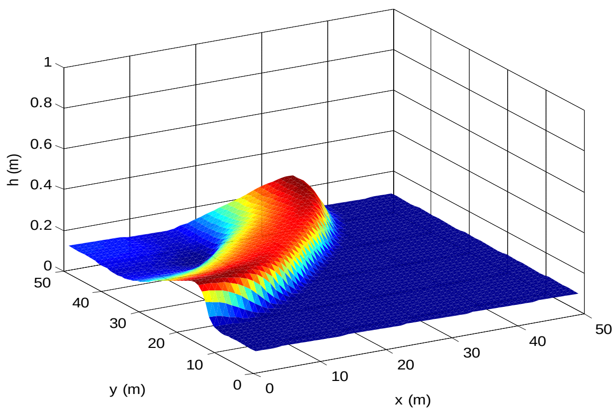

Fig-1: Plot obtained from simulation of reservoir

After creating model of reservoir the model of underwater layer media is created which shows the output of computer simulation program showing input signal and its time delayed reflected signals representing each layer.

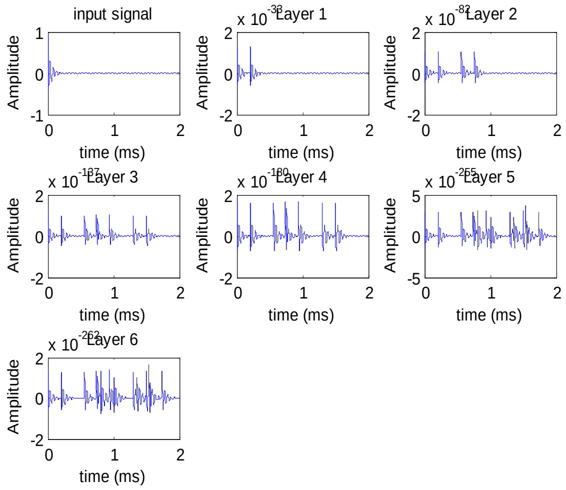

Fig- 2: Input signal and the reflected acoustic signals.

In the Fig-2 it is observed that the acoustic signal is attenuated as it traversed through each layer.

3. CONCLUSIONS

Classification of the reservoir sediments can be done using two approaches i.e. empirical and model based approach. The empirical approach is commonly used this method uses bottom samples to classify the sediments but the drawback of this method is that it is slow and expensive.

The model based approach in principle eliminates the need of bottom samples. Here a theoretical model is used to predict the signal and then depending on the material characteristics and the reflected acoustic signals the sediment is classified. The model produces the range of that can correlate to the actual received signal.

Hence the model based approach is used to classify the reservoir sediments which is done by extracting features from received signals. The features are found to vary depending on the sediment type.

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