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GUI Model for Comparative Study of Acoustic Wave Absorption

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ABSTRACT: A MATLAB based Graphical User Interface (GUI) [1] accesses the depth (D), salinity(S), temperature (T), pressure (p) frequency (F) and pH (ph) data and evaluates coefficient of absorption The MATLAB GUI supports to plot the total absorption of sound waves traveling through the oceanic environment w.r.t. the depth and frequency. Values of Coefficient of absorption calculated by GUI model have been compared with the observed values graphically. The results are closely matching which validates applicability of the GUI model

KEYWORDS- GUI model, depth, salinity, temperature, pressure, coefficient of absorption.

I. INTRODUCTION

Because the electro-magnetic wave is highly attenuated by seawater, research on underwater communication is done using acoustic wave [2].In recent years; the need for high-speed underwater acoustic communication to construct sensor networks on the sea floor or to communicate with underwater vehicles has become prominent. In this paper the GUI[1] model has been developed to calculate and represent graphically the absorption coefficient of sea water by using formulations of four different methods namely a) Francois[3,4] b) Fisher[5] c) Schulkin[6] and d) Thorp [7,8].The results are presented in the paper.

II. RELATED WORK

In [2] authors had presented a review of high speed underwater acoustic communication, focusing on the bandwidth, efficient phase coherent method. In [3] authors had presented for sound absorption in sea water as a function of frequency, temperature, and pressure based on laboratory data. The equation includes contributions to absorption due to boric acid, magnesium sulfate, and water. The effect of pressure on sound absorption due to magnesium sulfate and water has been treated differently than in the Schulkin and Marsh equation. At 4°C our results for absorption at frequencies from 10–400 kHz and pressures up to 500 atm are substantially lower than those calculated from the Schulkin and Marsh equation.In [4]. An experiment was conducted to provide an empirical evaluation of attenuation in sea water in the frequency range of 354–3540 cps. Recordings were made of solar shots detonated every 5 miles along a 500-mile track. The receiving elements were located near the axis of the so far channel. An analysis is outlined both in terms of received energy spectrum and transmission loss as a function of rangeIn [5] authors had presented a simple practical expression is given for determining frequency-dependent sound attenuation coefficients. The expression is an extension of Horton's equation to lower frequencies and represents a fit to experimental data covering the band below 50 kHz. In [6] authors present the design, implementation and measurement of Aqua-Lab, an acoustic communication hardware, and a set of software. In [7] Authors design of underwater acoustic networks is to provide for a self-configuring network of distributed nodes with network links that automatically adapt to the environment underwater acoustic sensor network lab test bed. Aqua-Lab consists of a water tank, a set of through selection of the optimum system parameters. This article considers several aspects in the design of shallow water acoustic networks that maximize throughput and reliability while minimizing power consumption

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III. DATABASE

The main database necessary for acoustic propagation prediction is sound absorption coefficient.

A. *Sound absorption coefficient.*

We have used the database of different oceans to calculate the coefficient of sound absorption .The practical values of depth, salinity, temperature, pH, pressure and frequency of sound wave propagation are used to calculate the coefficient of absorption (alpha) by the empirical formulae derived by the Francois method b) Fisher method c) Schulkin method and d) Thorp method are used to calculate the coefficient of absorption. The fig. 1 shows the GUI model of comparative study of sound absorption.

IV. SOUND ABSORPTION GUI MODEL

The fig. 1 shows the GUI model of sound absorption in sea water. The model consists of eleven edit boxes named as Depth, Temp, Pressure, Salinity and Sound speed. The data is read in this GUI model. These buttons invoke the programs which calculate the sound absorption coefficient (alpha).When the acoustic wave propagates in sea water, absorption loss occurs, which is caused by a part of the energy changing into the heat owing to the viscous friction of the water molecule, aside from the spreading loss. The absorption loss is represented as αr, where α is the coefficient in dB/Km and r is the transmission distance.

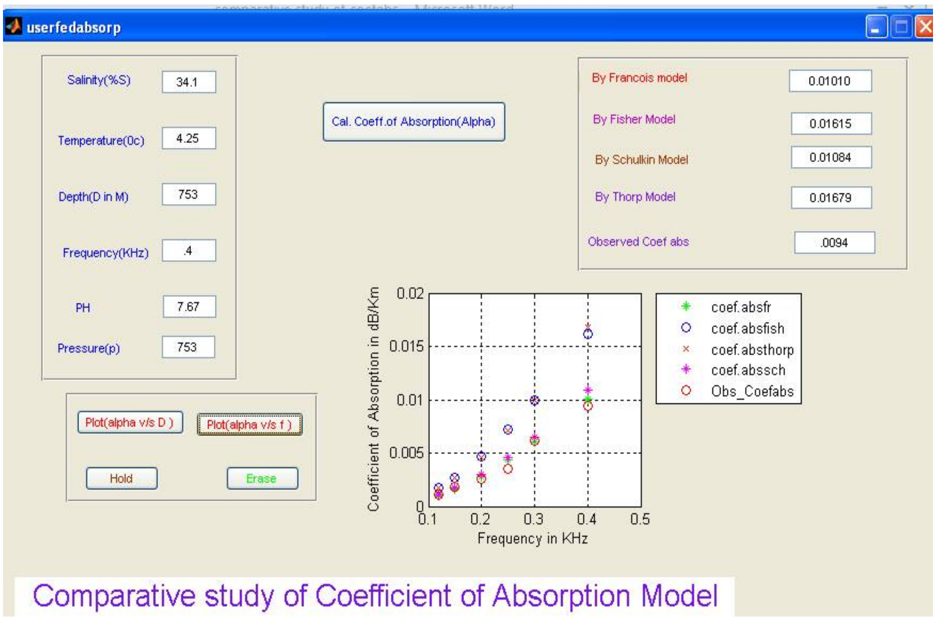

Fig.1 GUI model of Coefficient of Absorption of sea water

Expressions of absorption coefficient α have been proposed by various researchers on the basis of the laboratory and sea –based experiments. Some of these expressions are shown below.

The empirical expression of Francois-Garrison as a function of salinity, frequency, depth, pH and temperature is expressed as follows.

$$\alpha = \frac{A_1 P_1 f_1 f^2}{f_1^2 + f^2} + \frac{A_2 P_2 f_2 f^2}{f_2^2 + f^2} + A_3 P_3 f^2$$

The first term gives the sound absorption due to the Boric Acid and second term gives the sound absorption due to the magnesium sulfate. The contribution of sound absorption due to these chemical ingredients has been found to be

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small. The third term represents the sound absorption due to pure water. The pressure dependency of above equation is shown by P_1 ,P_2 and P_3 constants .Frequency dependency is given by f_1,and f_2 which are the relaxation frequencies of Boric Acid and Magnesium sulfate. f is the frequency of sound. The constants A_1, A_2 and A_3 shown are not purely constants but it has been experimentally proved that their values vary with the water properties, like temperature, salinity and pH of water.
The total coefficient of absorption of sea water is calculated by considering separately the absorption due to boric acid, magnesium sulphate and pure water. Separate contribution by the ingredients has been given below.

Following formulae have been used to calculate the coefficient of absorption of sea water. On entering the depth (d), temperature (t), pressure(p),salinity(s),pH and frequency in edit boxes and pressing the push button 'plot(Alpha v/s d)' displays the graph of coefficient of absorption v/s depth and pressing the push button 'plot(Alpha v/s f)' displays the graph of coefficient of absorption v/s frequency .

Table I. Coverage of parameters in each equation.

	T (0C)	S (ppt)	D (Km)	pH	Frequency (KHz)
Thorp	4	35	1	8	
Francois Garrison	-2 to 22	30-35	0-3.5	8	10-500
Schulkin-Marsh	-	35	-	8	-
Fisher-Simmons	-	35	-	8	-

Absorption coefficient due to Boric Acid

$$attn_1 = \frac{A_1 P_1 f_1 f^2}{f_1^2 + f^2}$$

$$A_1 = \frac{8.86}{c} \times 10^{(0.78\,pH - 5)}, \qquad \text{dB Km}^{-1}\text{KHz}^{-1}$$

$P_1 = 1$,

$$f_1 = 2.8\left(S/35\right)^{0.5} \times 10^{\left(4 - 1245/\theta\right)}, \qquad \text{KHz}$$

Where c is the sound speed (m/s), given by

c=1412+3.21T+1.19 S+0.0167 D,

T is the temperature(^{0}C),

θ=273+T,

S is the salinity(‰), and D is the depth (m).

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Absorption coefficient due to $MgSO_4$

$$attn_2 = \frac{A_2 P_2 f_2 f^2}{f_2^2 + f^2}$$

$$A_2 = 21.44\frac{S}{c}(1+0.025T) \qquad \text{dB Km}^{-1}\ \text{KHz}^{-1}$$

$$P_2 = 1-1.37\times10^{-4}\ D+6.2\times10^{-9}\ D^2$$

$$f_2 = \frac{8.17\times10^{\left(8-1990/\theta\right)}}{1+0.0018(S-35)} \qquad \text{KHz}$$

Absorption coefficient due to Pure Water

$$attn3 = A_3 P_3 f^2$$

For $T \le 20^0C$,

$$A_3 = 4.937\times10^{-4} - 2.59\times10^{-5}\ T + 9.11\times10^{-7}\ T^2 - 1.50\times10^{-8}\ T^3 \quad \text{dB Km}^{-1}\ \text{KHz}^{-2}$$

For $T \succ 20^0C$,

$$A_3 = 3.964\times10^{-4} - 1.146\times10^{-5}T + 1.45\times10^{-7}\ T^2 - 6.5\times10^{-10}\ T^3 \quad \text{dB Km}^{-1}\text{KHz}^{-2}$$

$$P_3 = 1 - 3.83\times10^{-5}\ D + 4.9\times10^{-10}\ D^2$$

The empirical expression of Thorp is shown as a function of the frequency by

$$\alpha = f^2\left(3.01\times10^{-4} + \frac{43.7}{4100+f^2} + \frac{0.109}{1+f^2}\right) \qquad \text{(dB/Km)}$$

Where f is the frequency in KHz

The expression of Schulkin Marsh is shown as function of the frequency, salinity, temperature, pressure, pH, and speed of sound as

$$\alpha = \left\{\left[\frac{2(\alpha\lambda)_r}{c}\right]\frac{f_r f^2}{f_r^2+f^2}x10^3 + \left(\frac{SAf_T f^2}{f_T^2+f^2} + \frac{Bf^2}{f_T}\right)\left(1-6.54x10^{-4}p\right)\right\}\times8686 \qquad \text{(dB/Km)}$$

Where

$$(\alpha\lambda)_r = 3.1\times10^{(0.69pH-6)}\times10^{-5} \qquad \text{(Np/wavelength)},$$

$$f_r = 6.1\times\left(\frac{S}{35}\right)^{0.5}\times10^{\left[3-(1051/\theta)\right]} \qquad \text{(KHz)}$$

$$\theta = 273 + {}^0C$$

$$f_T = 21.9\times10^{\left[6-(1520/\theta)\right]} \qquad \text{(KHz)}$$

The expression of Fisher-Simmons is shown as function of the frequency, temperature, and pressure as

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$$\alpha = \left(\frac{A_1 P_1 f_1 f^2}{f_1^2 + f^2} + \frac{A_2 P_2 f_2 f^2}{f_2^2 + f^2} + A_3 P_3 f^2 \right) \times 8686 \ \text{(dB/Km)},$$

Where

$$A_1 = 1.03 \times 10^{-8} + 2.36 \times 10^{-10} T - 5.22 \times 10^{-12} T^2 \ \text{(s/m)}$$

$$f_1 = 1.32 \times 10^3 (T + 273.1) \times \exp^{[-1700/(T+273.1)]} \ \text{(Hz)}$$

$$A_2 = 5.62 \times 10^{-8} + 7.52 \times 10^{-10} \times T \qquad \text{(s/m)}$$

$$f_2 = 1.55 \times 10^7 (T + 273.1) \times \exp^{[-3052/(T+273.1)]} \ \text{(Hz)}$$

$$p_2 = 1 - 10.3 \times 10^{-4} p + 3.7 \times 10^{-7} p^2,$$

$$A_3 = (55.9 - 2.37T + 4.77 \times 10^{-2} T^2 - 3.48 \times 10^{-4} T^3) \times 10^{-15} \qquad (s^2/m)$$

$$p_3 = 1 - 3.84 \times 10^{-4} p + 7.57 \times 10^{-8} p^2$$

Where f is frequency in Hz, T is temperature in ^{0}C, and p is the pressure in atm

V. RESULTS

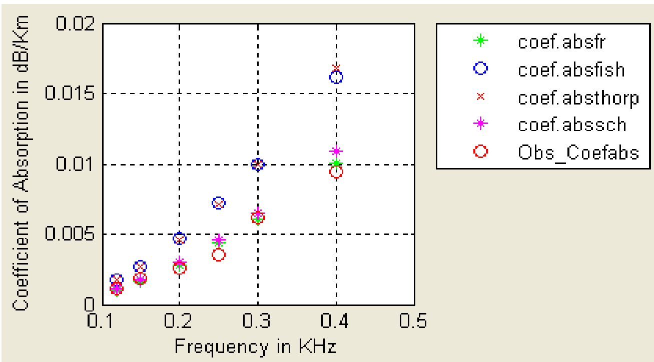

Fig.2 Comparison GUI model results with observed values of sound absorption (alpha) at NE Pacific

Comparative graphs given in fig. 2 to fig. 3 clearly indicate the validation GUI model with observed values of coefficient of absorption.

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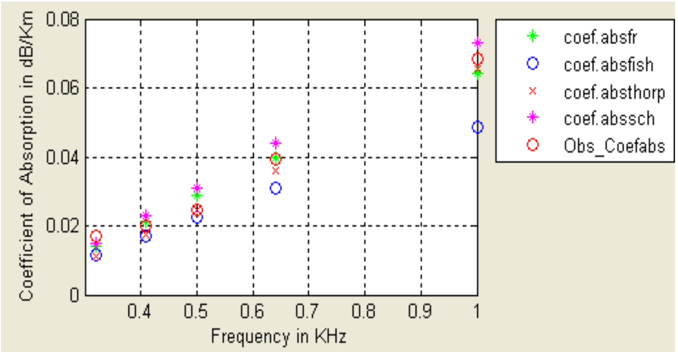

Fig.3 Comparison GUI model results with observed values of sound absorption (alpha) at Baffin Bay

The results obtained from GUI model for different methods on comparison with the observed values of coefficient of absorption clearly show that the results by Francois and Garrison method are closely match in with the observed values.

VI. CONCLUSION

The GUI model of sound absorption can predict the coefficient of absorption at any place on the earth which can be used to adjust the gain of an amplifier for faithful reception.

VII. ACKNOWLEDGMENT

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BIOGRAPHY

Dr. Mohite-Patil T. B. is currently working as a Principal of Dr. D. Y. Patil Pratisthan's College of Engineering Salokhe-Nagar Kolhapur. He has published about 30 papers in national and international journals. He has filed about six patents in various fields. He has designed and developed educational kits for power electronics and Industrial Electronics. His fields of interest are Power electronics; Digital signal processing and control systems. He has completed his post graduate diploma in business management, post graduation in control system, Ph. D. in the field of Electronics and persuing law degree from Shivaji University Kolhapur. Presently he is guiding Ph. D. students from various Universities.

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