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# Measurement of Absorption Loss Coefficients for 80 kHz Band in the Sea Water at the Dpeth of 1,000 m
深度 1,000m の海水中における 80kHz 帯の吸収減衰係数の計測

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## 1. Introduction

The acoustic wave is generaly used in the seawater, because the electric-magnetic wave is highly attenuated by seawater. There are many research of underwater communication using acoustic signals[1]. 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 higher. In Japan Agency for Marine-Earth Science and Technology (JAMSTEC), researches on short range and high speed underwater acoustic communication are in progress[2,3]. For this research, 80 kHz of the carrier frequency is been using. In such a high frequency (over 50 kHz), the absorption attenuation is larger than 10 dB/km. For estimating the communication range from the signal-to-noise ratio (SNR), the absorption attenuation should know as accurate as possible. The first measurement of absorption loss at this band at the sea by our group was carried out in February 2007[4]. The results of that measurement were that the absorption attenuation coefficients of 80±20 kHz was well fitted to the expression of Francois-Garrison. And the second measurement was carried out in February 2009 at longer propagation distance at almost the same depth and season. In this paper, the results of the second measurement of absorption attenuation coefficient of 60 to 100 kHz in the propagation distance of 530 to 700 m in about 1,000 m depth are described.

## 2. Absorption Loss

When the acoustic wave propagates in seawater, absorption loss occurs, aside from the spreading loss. The absorption loss is represented as $\alpha r$, where $\alpha$ is the absorption attenuation coefficient in dB/km and $r$ is the transmission distance in km. $\alpha$ is calculated by eq. (1).

$$\alpha = \alpha_1 + \alpha_2 + \alpha_3, \qquad (1)$$

where $\alpha_1$ is absorption by pure water, $\alpha_2$ is absorption of relaxation by magnesium sulfate, $\alpha_3$ is absorption of relaxation by boric acid. Those three parts have several parameters. There are various researches for determining those parameters. And expressions of absorption attenuation coefficient $\alpha$ were proposed on the basis of experiments. In this paper, 3 expressions for calculating the absorption loss are shown below.

The empirical expression of Thorp[5,6] is represented as a function of the frequency. The expression of Schulkin-Marsh[7] is represented as functions of the frequency, salinity, temperature, pressure, pH, and speed of sound. The expression of Francois-Garrison[8] is represented as functions of the frequency, salinity, temperature, pH, and depth.

## 3. Measurement and Results

The measurements were carried out at the north part of Suruga Bay on 17 February 2009. The transmitter was deployed near the sea bottom. The receiver was suspended from the surface ship. Pulse signals were transmitted between them. The pulse train consisted of tone burst pulses, which were 60 to 100 kHz in 2 kHz step. Length of each pulse was 1 ms. **Fig. 1** shows the relative receiver position from the transceiver. In this experiment, 32 packets were measured. The absorption attenuation coefficient was calculated from propagated signal like as below. (1) recorded signal level convert to acoustic received level (*RL*). (2) calculated absorption attenuation coefficient in each packet ($\alpha_{f,i}$) from the result of (1) by eq. (2).

$$\alpha_{f,i} = \left(SL_f - 20\log r - RL\right) \times 1000 / r, \qquad (2)$$

where $SL_f$ is source level of the transducer at $f$ kHz, $r$ is a slant range between the transmitter and the receiver in m. (3) calculated $\alpha_f$ by eq. (3).

$$\alpha_f = \frac{1}{N}\sum_{i=1}^{N} \alpha_{f,i}, \qquad (3)$$

where $N$ is number of data ($N = 32$).

**Fig. 2** shows characteristics of sound pressure level vs. slant range. Asterisks (*) are measured sound pressure level at each slant range. Dotted line shows sound pressure level with transmission loss of only spreading which is calculated by eq. (4). Solid line shows sound pressure level with transmission loss of both spreading and absorption which is calculated by eq. (5).

$$SPL_{r,f} = SL_f - 20\log r, \qquad (4)$$

$$SPL_{r,f} = SL_f - 20\log r - \alpha_f \frac{r}{1000}, \qquad (5)$$

where $SPL_{r,f}$ is sound pressure level at $r$ m and $f$ kHz. We can see that points of measured sound pressure level are well fitted to the transmission loss curve of considering both of spreading and absorption loss in each frequency.

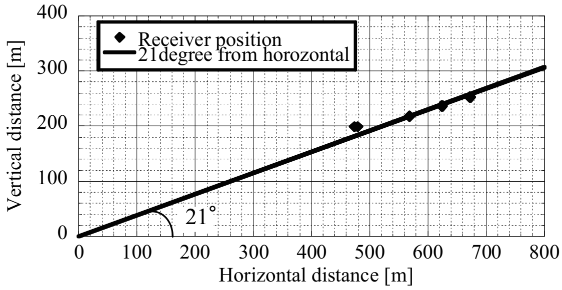


Fig. 1 Relative position of the receiver. (0,0): position of the transmitter.

Measured temperature, salinity and depth data were used for calculating each expression. Because no pH sensor was installed in the measurement system, the pH was assumed to be 7.7. **Fig. 3** shows the absorption attenuation coefficient vs. frequency characteristics. Broken line is the expression of Thorp, dotted line is the expression of Schulkin-Marsh and solid line is the expression of Francois-Garrison. And the measurement values ($\alpha_f$ calculated by eq. (3)) were plotted as square marks. From this figure, it is understood that the α is markedly different in three equations in the frequency range of 50 - 200 kHz. And It is understood that the measurement values fit well to the equation of Francois-Garrison.

Moreover, it is understood that there is a difference in the coefficient of absorption attenuation of about 8 dB in the band of this transducer. From these results, to design the wideband acoustic communication system, the level equalizing what in the frequency band must be considered. When we design a practical broadband communication system, it is important that we estimate the equivalent frequency characteristics of the transducer, hydrophone, and absorption loss. The equalizer which has inverse frequency characteristic of estimated frequency characteristic must be considered, and it is considered necessary to examine the optimization by putting a transmission signal through this equalizer.

## 4. Conclusions

For estimating the propagation loss in underwater acoustic communication, the absorption attenuation coefficients in the frequency range of 80 ± 20 kHz was measured at a 1,000 m depth. Under this condition, the absorption attenuation coefficients fit well to the equation of Francois-Garrison. This was the second measurement of the absorption attenuation coefficients of 80 kHz band at Suruga Bay in winter, and it matched well the equation of Francois-Garrison. The results were very similar to the first measurement[10]. The authors would like to merge the results of those two measurements as the next step.

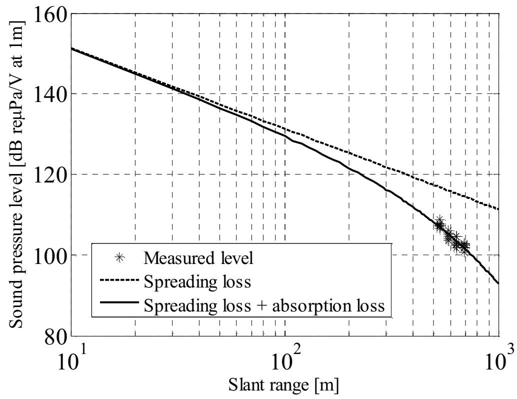


Fig. 2 Measured results of sound pressure level vs. slant range. (Frequency: 80 kHz.)

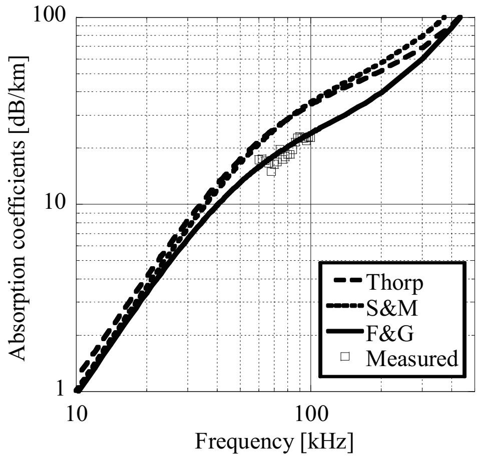


Fig. 3 Results of measurements.

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