A STUDY OF WEIGHTING UNDERWATER SOUND SCALE

K.Oimatsu[1], S.Kuwahara[1], K.Kuramoto[1] and S.Yamaguchi[2]
[1]Japan Coast Guard Academy, [2]Yamaguchi University, Japan

Introduction In order to measure the sensational underwater noise level as a same amount of that in air, we need a weighting scale such as the A-weighting scale in air. The current widely used weighted noise levels in air are based upon the A-weighting sound level scale, which in turn is related to the loudness of 40 phon of hearing. The most efficient and practical approach to setting up weighting underwater sound scale is the transposition of the A-weighting sound scale from in air to underwater. This can be achieved with knowledge of loudness in the two media. This study describes experimental results on the frequency compensation characteristics for measurement of weighted underwater sound levels.

Method In order to transpose the A-weighting sound scale in air to its underwater, firstly we re-examine the minimum audible field (MAF) and then carried out equal-loudness levels test under free field listening condition. In loudness experiment, the reference stimulus was 120 dB (re 1μPa) and 1kHz pure burst tone. Test frequencies were selected from the every center frequency of 1/3 octave-band from 50 to 8kHz defined at ISO266. 120 dB was selected according to the supplementary experiments carried out to examine the relation of equal-loudness levels between in air and its equivalent in water. We used the method of limits to get the minimum audible sound fields. On the other hand, the method of self-adjustment was used to obtain equal loudness levels. The subject was one male with normal hearing in air and was tested without removal of air from the external ear canals. All experiments were carried out in the water-tank (1m×2m×1m) installed on wooden absorber in order to reduce the background noise in the tank. The sound pressure level of ambient noise in the water tank was 52 dB/Hz at 1 kHz, it was more than 20 dB below the minimum audible sound pressure level at that frequency.

Results Fig.1 shows the results of equal loudness levels for 120 dB and MAF obtained by the hearing experiments. Minimum audible level at the frequency 1 kHz is 77dB and most sensitive at about 500Hz. Roughly speaking, MAF levels obtained in this experiment are nearly equal to the data reported by previous researchers. But it should be noted that as seem in the air there is a peak at about 7, 8 kHz. Equal-loudness level contour for 120 dB in water below 1kHz shows that underwater sensitivity increases in keeping with frequency and have almost same gradient as that in air.

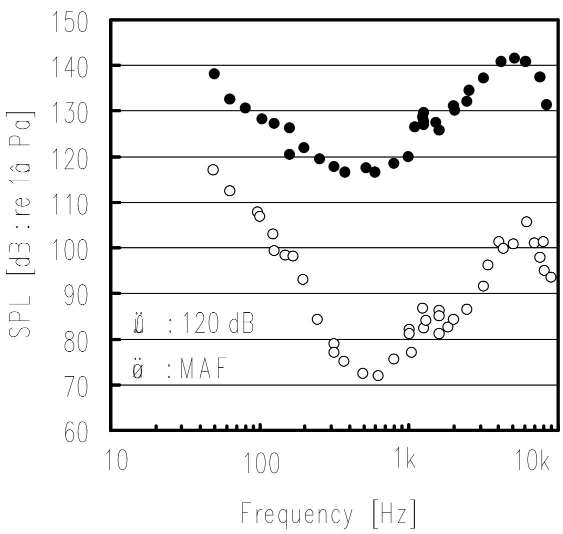

Figure 1. Loudness levels of 120 dB [re 1μPa] and minimum audible levels in water.

But from 1 kHz to 7 kHz, underwater sensitivity decreases steeper than that in air.

Discussion To obtain sensational underwater noise level as a same amount of that in air, we need a weighting scale such as an A-weighting scale in air. Hereafter we call it as a W-weighting scale. A-weighting scale is constructed from the contours of 40-phon in air so the W-weighting scale should also construct by same way. As indicate in Fig. 2, it is reasonable to assume that the differences between A-weighted levels and 40 phon in air are equal to the differences between equivalent levels of 40 phon (120 dB re 1μPa at 1 kHz) and expected W-weighted levels in water at every frequencies.

Fig. 3 shows the W-weighting curve obtained by stated method at the frequency range from 50 to 8kHz and also A-weighted curve in the air. As shown in the figure, they are almost same at the frequencies below 1kHz, but upper 1kHz, the differences increase in keeping with frequency and has a dip of –28.5 dB at 5kHz.

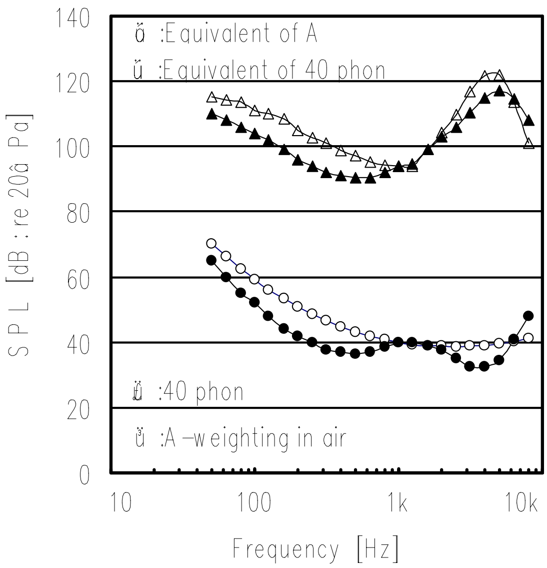

Figure 2. The relation between 40 phon and A-weighting curve in air and between equal loudness levels of 120 dB and estimated W-weighting curve in water.

Using A-weighting in air and proposed W-weighting scale in water, weighted sound levels were calculated respectively for several kinds of example noises. These results are summarized in Table 1.

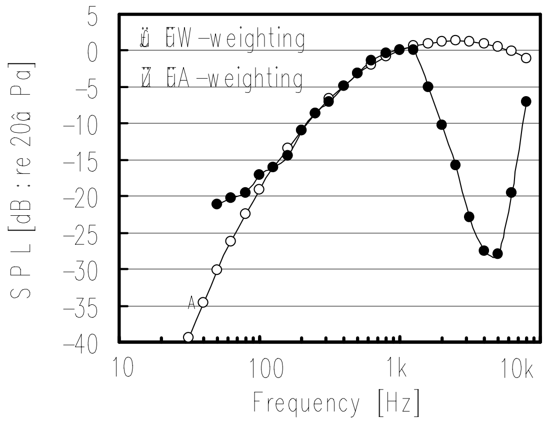

Figure 3. A-weighting curve in air and W-weighting curve in water estimated from equal loudness levels of 120 dB.

Table 1. Simulation for the example noises.

	Flat	W	A
White noise	[dB] 72.1	62.7	71.7
Pink noise	75.3	68.0	73.5
Noise in sea	100.6	90.5	101.0
Hydro craft	155.2	146.9	149.5
Ferry boat	151.6	150.0	149.6

Keywords: underwater noise, A-weighting scale, underwater hearing, loudness, minimum audible field.

References

1) M. Al-Masri, A. Martin and J. Nedwell : "Underwater Hearing Thresholds and Proposed Noise Exposure Limits," Subtech '93, Vol.31, pp.259-266 (1993).

2) R. J. Urick : Principles of underwater sound, 3rd ed. (McGraw-Hill, New York, 1983).