3P6-2

Resonant frequency variation depending on the structure and parameters of the acoustic metamaterial cavity

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1. Main text

The characteristics of time-varying channels in underwater communications are frequently observed in frequency-selective channels due to the variation of boundary and propagation medium characteristics over time.[1,2] These characteristics cause inter-symbol interference in underwater communication channels, which in turn increases bit errors.[3,4] In previous studies[5,6], the evaluation and experimental results of underwater communication performance of underwater acoustic metamaterials in frequency-selective channels were almost identical, and the results confirmed that acoustic metamaterials are effective in improving underwater communication performance. In addition, based on these results, the peak frequency characteristics were observed by changing various parameters such as length, width, and spacing.[7] In this study, based on the basic characteristics of the Helmholtz resonator, the frequency variation effect according to the shape and size of the tube is investigated through simulation while keeping the length and volume as they are, and the application is intended to be applied to the design of filters required for underwater communications.

2. Basic Principle of Helmholtz Resonator and Simulation Models

A Helmholtz resonator is a device that operates on the principle of acoustic resonance, used primarily for analyzing or controlling sound characteristics. The basic structure and theory of a Helmholtz resonator can be mainly divided into two parts - a resonating chamber and a tube like as **Fig. 1**. The resonant frequency of a Helmholtz resonator can be described by the following,

$$f_0 = \frac{c}{2\pi}\sqrt{\frac{A}{V\,l}} \qquad (1)$$

where, c represents the speed of sound, which is set to 343.2 m/s at 20 degrees.

Fig. 2 shows the model used in the simulation. The frequency change due to bending was checked while the opening area(A) was fixed and the neck length(l) was also fixed. The neck length of each model was constant, but the number of bends was gradually increased. Table 1 shows detailed specifications.

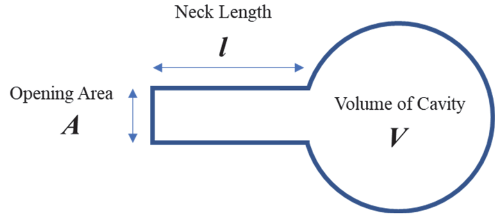

Fig. 1 A Helmholtz resonator.

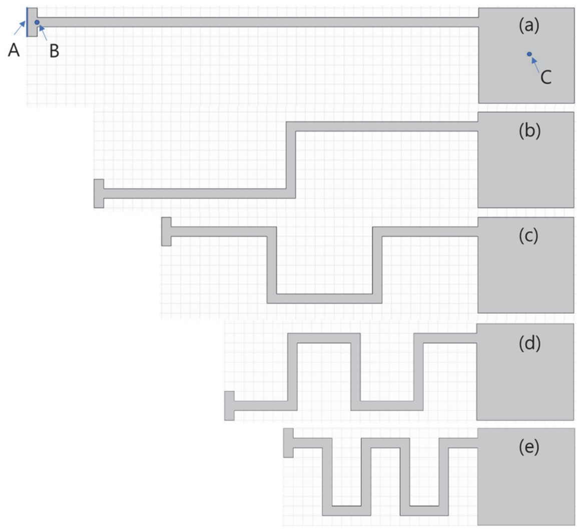

Fig. 2 Models to be simulated.

Table I. The experimental parameters.

A	1mm
l	46mm
V	10mm*10mm
Input(A)	Plane wave
Output(B)	Value near input for reference
Output(C)	Output inside the volume

The SPL (Sound Pressure Level) was theoretically predicted and compared using COMSOL Physics, a finite element software package, in the air condition. The used medium is aluminum, and its physical parameters are a density of 2.7E3 kg/m^3, a Poisson's ratio of 0.35, and a Young's modulus of 70E9 Pa.

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3. Numerical simulations and results

First, for the comparison, the theorical resonance frequency was calculated by Eq. (1), as given 796.74Hz. **Fig. 3** shows SPL result according to frequency of model (a) - (a) is result from Point C and (b) is result from ratio of point C / point B. **Fig. 4** shows SPL distribution of model (a) at 690Hz.

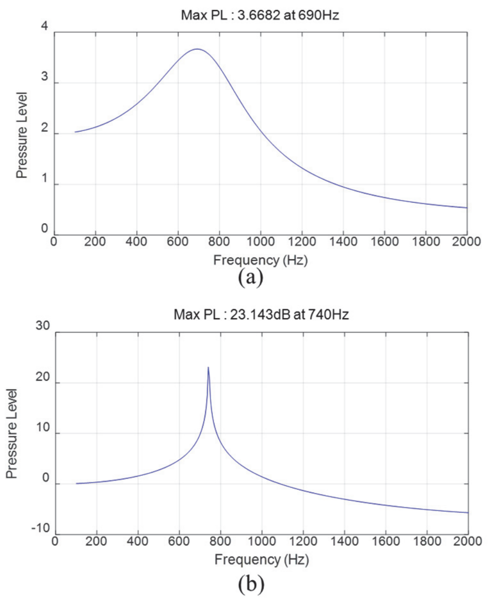

Fig. 3 PSL in frequency of model (a).

Table 2 shows the simulation results for each model in Figure 2. It was found that all models had some error compared to the theoretical values.

Table II. Comparison of simulation results.

model	Resonant freq.(Hz)	Error rate from theoretical value
(a)	690	13.3%
(b)	700	12.1%
(c)	705	11.5%
(d)	710	10.8%
(e)	710	10.8%

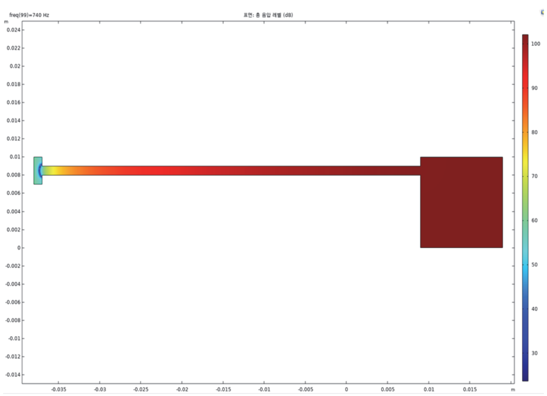

Fig. 4 PSL distribution of model (a).

The ratio of the sound pressure at point c to point b, which is located 1 mm away from the input, is shown in Table 3. Although the error is reduced compared to Table 2, it still shows an error of about 7%, and it seems that the parameters will need to be adjusted in the future to match the theoretical value with 2D or 3D modeling first. Table 4 shows the change in power according to the form of the model, and it can be confirmed that the value tends to decrease as the model becomes more complex.

Table III. Comparison of results at point C / point B.

Model	Resonant freq.(Hz)	Error rate from theoretical value
(a)	740	7.1%
(b)	750	5.8%
(c)	760	4.6%
(d)	765	3.9%
(e)	765	3.9%

Table IV. Comparison of maximum SPL.

Model	Maximum SPL	Reduction ratio with model (a)
(a)	3.67	0.0%
(b)	3.63	-1.0%
(c)	3.59	-2.1%
(d)	3.56	-3.0%
(e)	3.55	-3.3%

4. Conclusions

We observed the change in peak frequency according to the length by changing the shape of the model to find the desired peak frequency. Although there was a difference from the theoretical value, we were able to confirm that the more complex the shape of the model, the higher the peak frequency and the lower the power. We will report the details in the presentation.

References

1. J. Park, K. Park, and J. R. Yoon: Jpn. J. Appl. Phys. **49** (2010) 07HG10.
2. B. Katsnelson, V. Lynch, and J. Lynch: *Principles of Underwater Sound* (Springer, New York, 2012).
3. R.S.H. Istepanian and M. Stojanovic: *Underwater Acoustic Digital Signal Processing and Communication Systems* (Kluwer, 2002), p. 5.
4. M. BAE, J. Park, J. KIM, D. XUE and J. R. Yoon, Jpn. J. Appl. Phys. **55**, (2016) 07KG03.
5. K. Song, K. Kim, S. Hur, J. Kwak, J. Park, J. R.Yoon, and J. Kim: Scientific Reports **4** (2014) 1.
6. J. Park, H. Jeong, and K. Park, Pro. of Symp. on USE2018 (2018) 3P6-1.
7. J. Park, H. Jeong, and K. Park, Pro. of Symp. on USE2022 (2022) 2Pb4-2.