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Frequency optimization according to various parameter changes in acoustic metamaterial cavity

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1. Main text

The underwater frequency selective channel shows a fast time-varying channel characteristic mainly due to time-dependent boundary and propagation medium characteristics fluctuations. [1,2] This characteristic causes ISI (Inter Symbol Interference) in the channel, thereby increasing bit errors.[3,4] In a previous researches[5,6], the underwater communication performance of underwater acoustic metamaterials was evaluated in a frequency-selective channel, and the numerical simulation results and experimental results were almost in agreement. As a result of the experiment, it was confirmed that the acoustic metamaterial was effective in improving the underwater communication performance.

In this study, based on the numerical simulation results and experimental results of this underwater acoustic metamaterial, we try to observe the peak frequency characteristics by changing various parameters - length, width, spacing, etc. - and provide results helpful for design.

2. An acoustic metamaterial and simulation configuration

Fig. 1 shows the composition of the acoustic metamaterials and its cross-section view of metamaterial slab. We will change the parameter s, d, and w for the peak frequency variations. The following paragraph is taken directly from Ref. 6 for explanatory purposes. The reflection R and transmission T coefficients for a plane wave normally incident on a slab with the mass density ρ_2 and the sound speed c_2 placed between two identical media with ρ_1 and c_1,

$$R = \frac{Z_2^2 - Z_1^2}{Z_1^2 + Z_2^2 - 2iZ_1Z_2 \cot\theta} \qquad (1)$$

$$T = \frac{1+R}{\cos\theta + \frac{Z_2 i\sin\theta}{Z_1}} \qquad (2)$$

whrer, $Z_i=\rho_i c_i$ is the acoustic impedance, $\theta=2\pi fh/c_2$, f is frequency of the acoustic wave, and w is slab thickness.

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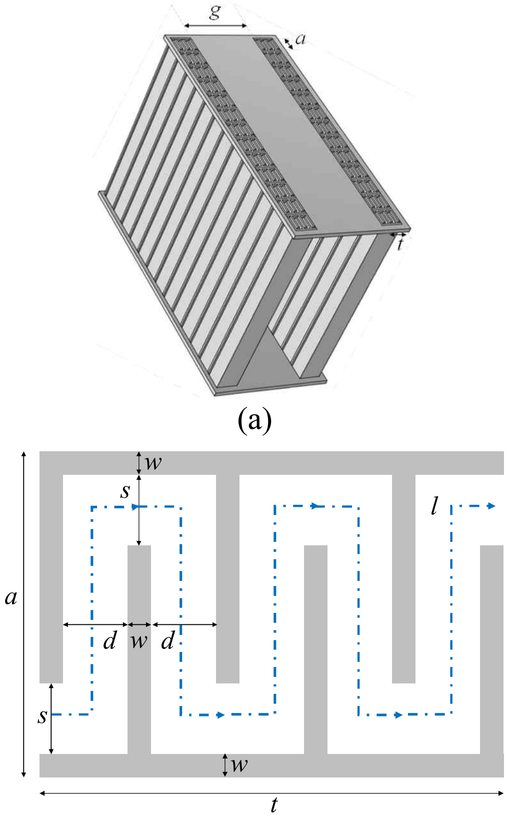

Fig. 1 (a) Underwater acoustic metamaterials[5] and (b) its cross-section view of metamaterial slab.

The SPL (Sound Pressure Level) was theoretically predicted and compared using COMSOL, a finite element software package, in the air condition. The medium used 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.

The parameters of the basic structure are shown in Table I, and the peak frequency at this time was 1041 Hz and 4595 Hz in the air and the water, respectively.

Table I. The experimental parameters.

a	t	s	d	w
10mm	11mm	1mm	1mm	1mm

3. Numerical simulations and results

First, we examined the characteristics of the peak frequency change when only *s*, with 1mm, 2mm, and 3mm was changed. It is assumed that the vertical width is widened and the horizontal width is the same in the passage through which the wave passes, and the peak frequencies are shown as **Fig. 2** with 1041 Hz, 1231 Hz, and 1525 Hz, respectively.

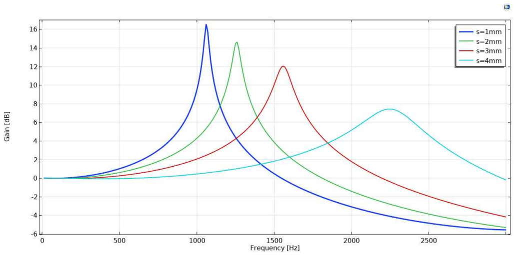

Fig. 2 The peak frequency distribution with variation *s*.

Second, by setting s and d to the same value, it is assumed that the horizontal and vertical widths are the same in the passage through which the wave passes, and the peak frequencies are shown as **Fig. 3** with 1041 Hz, 1440 Hz, and 1721 Hz, respectively.

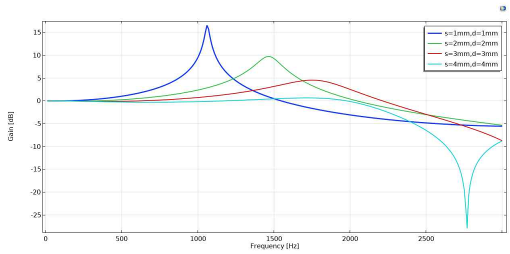

Fig. 3 The peak frequency distribution with variation *s* and *d*.

Third, it is assumed that the length of wave passing is increased by changing w, and the peak frequencies are shown as **Fig. 4** with 1041 Hz, 968 Hz, and 900 Hz, respectively. In this case, the value of *t* also increases by 6 mm from 11 mm.

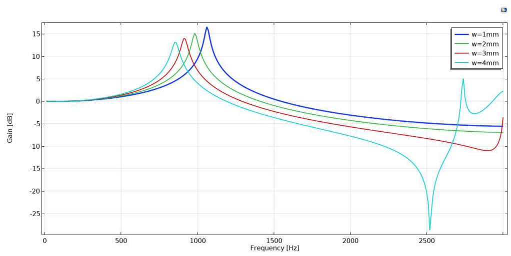

Fig. 4 The peak frequency distribution with variation *w*.

Finally, it is assumed that the slab is connected in parallel from one(11mm) to two(21mm) and three(31mm) in parallel to increase *t* to make the wave passing length long. The peak frequency are shown as **Fig. 5** with 1041 Hz, 668 Hz and 502 Hz.

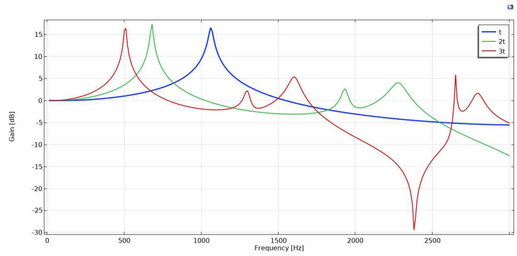

Fig. 5 The peak frequency distribution with variation *t*.

In the above numerical simulations, it is understood that the peak frequency tends to rise when the wave passing width is increased, and the peak frequency tends to decrease when the wave length increases. Based on this inference, we calculated the peak frequency for the length of the wave in each simulation, and the result is shown in **Fig. 6**.

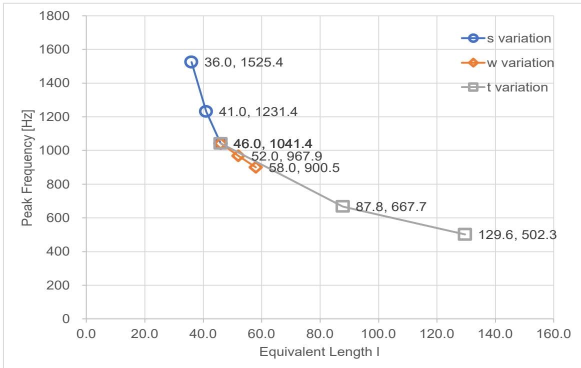

Fig. 6 The peak frequency distribution with variations *s*, *w* and *t*.

4. Conclusions

In order to find the desired peak frequency, the parameters were changed by trial and error, and the change in the peak frequency was observed according to the length of the wave passing. In order to predict the exact peak frequency, it is considered that the equivalent parameter by each parameter needs to be obtained more carefully. More details will be reported at the presentation.

References

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