Sliding Two-tube Model for Vowel Production*

○Takayuki Arai (Sophia Univ.)

1 Introduction

A two-tube model (Fig. 1) is often used to simulate vowels because resonances of the entire model are approximated by those of each individual tube (the coupling between the two tubes is discussed by Stevens [1]). Figure 1 shows the cross-sectional dimensions of the two-tube model, where the first tube has a smaller area than the second tube. In this case, the model approximates a low vowel, such as /a/. In this configuration, the narrow tube has the area of A_1 and its length is L_1, whereas the wide tube has the area of A_2 and its length is L_2. If L_1+L_2 is constant, we can discuss the lower resonance frequencies of the two-tube model as a function of the location of the boundary between the two tubes. To demonstrate that the acoustic outcome from the two-tube model and its resonances are approximated from a simple acoustic theory of a uniform tube, we developed two types of sliding two-tube (S2T) model in this study.

2 Two types of S2T model

In this section, we introduce the two types of S2T model. These models are similar to the sliding three-tube (S3T) model proposed by Arai [2]. Like the S3T model [2], the two types of S2T model are made of acrylic materials. One can slide the inner bar, so that L_1 and L_2 vary while the total length remains constant.

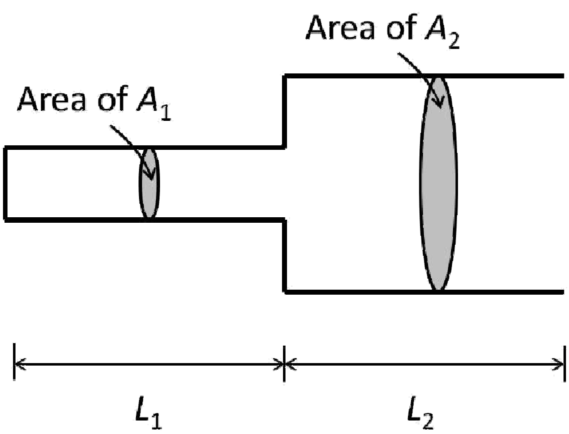

Fig. 1: Configuration of two-tube model.

2.1 S2T Model 1

Figure 2 shows a photograph of S2T Model 1. The top panel (a) shows its side view. The black arrow indicates that there is a small hole for an input signal. When we attach a driver unit of a horn speaker by inserting the neck of the driver unit into the hole, a sound source can be fed into the model.

The bottom panel (b) shows the view of the mouth end, which looks like the combination of a large square (30 mm by 30 mm) and a small square (10 mm by 10 mm). Therefore, area A_1 is 10 x 10 = 100 mm^2 and area A_2 is 100 + 30 x 30 = 1000 mm^2.

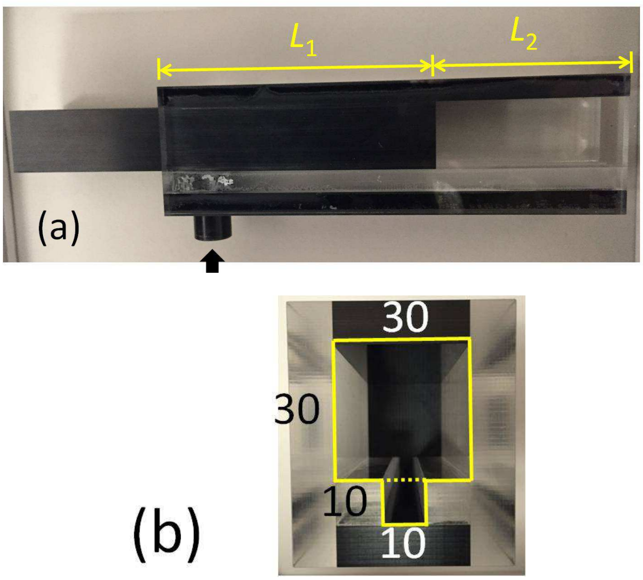

Fig. 2: S2T Model 1. (a) Side view. (b) View of mouth end (the unit is mm).

* 母音生成のためのスライド式２音響管モデル，荒井隆行（上智大）．

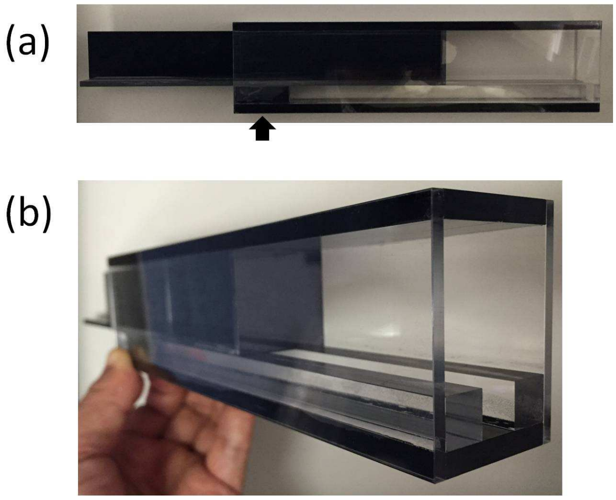

Fig. 3: S2T Model 2. (a) Side view. (b) View from different angle.

2.2 S2T Model 2

Figure 3 shows a photograph of S2T Model 2. The top panel (a) shows its side view. The black arrow indicates that there is a small hole for an input signal. This time, the hole is designed, so that a reed-type sound source can be attached.

The bottom panel (b) shows the side view from a different angle. The inner dimensions of the cross-section are exactly the same for S2T Models 1 and 2. The difference between them is mainly the thickness of the outer materials

3 Experiment

In this section, we recorded and analyzed an output signal when we produced sounds from S2T Model 2. Figure 4 shows a spectrographic representation of an output signal produced by blowing into a reed-type sound source attached to S2T Model 2 and sliding the inner bar simultaneously. The horizontal axis corresponds to the boundary of the back and front cavities (tubes); the short L_1 and the long L_2 are towards the left on this axis, and the long L_1 and the short L_2 are towards the right.

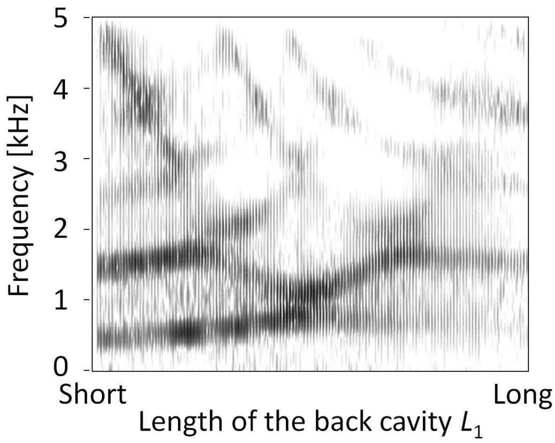

Fig. 4: Spectrographic representation of output signal produced by S2T Model 2.

4 Discussion and Conclusion

Using S2T Model 2, we can estimate its resonances by decoupling the front and the back cavities and approximating resonances from each of the uniform tubes. Both cavities have resonances at the frequency of $(2n\text{-}1)\ c\ /\ (4\ L)$, where c is the speed of sound, L is the length of the cavity, and n is an arbitrary natural number. As a result, the first and the second resonances become close together when L_1 and L_2 are equal (in the middle of the horizontal axis in Fig. 4), and this simulates the vowel /a/. In this case, Fig. 4 clearly shows the highest F1 and the lowest F2. Because a two-tube model is useful to explain an introduction to acoustic theories in vowel production, this sliding model can be an effective hands-on tool for students.

Acknowledgments

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References

[1] K. N. Stevens, *Acoustic Phonetics*, MIT Press, Cambridge, MA, 1998.

[2] T. Arai, "Sliding three-tube model as a simple educational tool for vowel production," *Acoustical Science and Technology*, 27(6), pp. 384-388, 2006.