Appearance and disappearance of laryngeal cavity resonance within a glottal cycle

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1. Introduction

The aim of this study is to explore acoustic effects of the time-varying glottal area during vocal fold vibration on the resonance of the laryngeal cavity based on vocal tract area functions and analysis of speech waveform. The laryngeal cavity consists of the vestibular and ventricular parts of the larynx. The cavity gives rise to a regional acoustic resonance within the vocal tract (Takemoto *et al.*, submitted), and the resonance (referred to as the laryngeal cavity resonance) is generally observed as the fourth formant of vowel spectra. The laryngeal cavity resonance may be affected by the open glottis because the laryngeal cavity is no longer a closed tube during the open-glottis period, in contrast to previous understanding of the vocal tract as a closed tube from the closed glottal-end to the open lip-end. This study therefore attempts to explore the effects of the open and closed glottis on the laryngeal cavity resonance within a glottal cycle.

2. Simulation of acoustic effects of glottal area using a transmission line model

Figure 1 depicts transfer functions of a vocal tract area function, which was measured from a volumetric magnetic resonance imaging data of a Japanese male subject during production of a Japanese vowel /a/. The three transfer functions were computed with a transmission line model after setting the glottal area to 0 cm^2 (complete closure), 0.1 cm^2, and 0.2 cm^2, respectively. Comparisons of the transfer functions reveal that one of the formants appears at approximately 3 kHz at the complete closure of the glottis and disappears in the glottal open state, whereas the other formants were damped and shifted by the glottal opening.

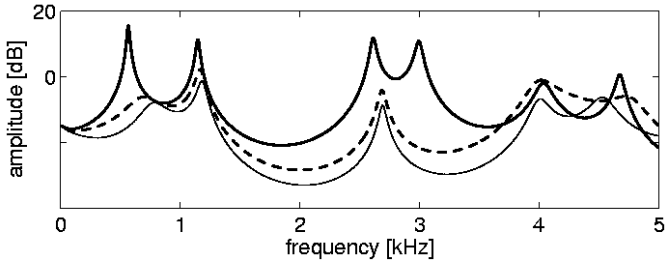

Figure 1: Acoustic effects of glottal area Ag on transfer functions in the vowel /a/ of a male speaker. The thick, dashed, and thin lines show those with Ag = 0.0 cm^2, 0.1 cm^2, and 0.2 cm^2, respectively.

3. Pitch-synchronous spectral observation

The above results suggest that the laryngeal cavity resonance is affected by the glottal states. To confirm it, a pitch-synchronous short-term spectral analysis was applied to speech data during the open- and closed-glottis periods to explore the appearance and disappearance of the laryngeal cavity resonance due to the glottal conditions.

Sustained Japanese vowels of a male subject were recorded with electroglottograph waveforms to estimate open- and closed-glottis periods. Power spectral densities (PSDs) of the speech waveform were calculated for the two glottal conditions using Burg's method. Figure 2 shows the estimated PSDs for the open- and closed-glottis periods of the vowels, demonstrating that one of the formants occurs in the closed-glottis period and diminishes during the open-glottis period.

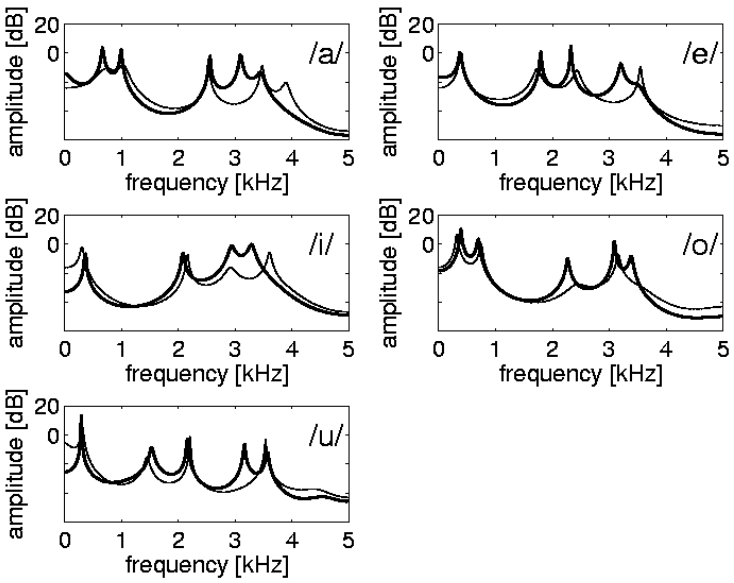

Figure 2: Power spectral densities of open- and closed-glottis periods of sustained vowels of a male subject. The thin lines denote those during the open-glottis period and the thick lines represent those in the closed-glottis period.

4. Discussion

Both the simulation and spectral observation show that one of the formants appears during the closed-glottis periods and disappears during the open-glottis periods. Takemoto *et al.* (submitted) showed that the same formant disappears when the laryngeal cavity was eliminated from the entire vocal tract and concluded that it can be regarded as the laryngeal cavity resonance. The findings from the present study indicate that the laryngeal cavity resonance shows an on-and-off pattern depending on the glottal conditions. The resonance can be explained by the fact that the laryngeal cavity acts as a closed tube to generate the resonance during closed-glottis periods, but damps the resonance off during open-glottis periods.

Acknowledgements

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References

Takemoto *et al.*, "Acoustic roles of the laryngeal cavity in vocal tract resonance," submitted to *J. Acoust. Soc. Am.*