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Why /i/ and /e/ Can Be Effective Belting Vowels

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IT HAS BEEN SHOWN that one acoustic feature of belting is the dominance of harmonic energy above the first harmonic (the fundamental), especially in females.¹ This dominance is also observed in brass instruments,² hence the timbre of belt is often considered to be brass-like. For vowels such as /a/ and /æ/ in the pitch range of G_4 to E_5 (396–660 Hz), the second harmonic $2f_0$ is dominant due to its proximity to the first resonance of the vocal tract. (Note: For this discussion, resonance frequencies of the vocal tract will be equated with formant frequencies, even though measured formant frequencies are sometimes only approximations of resonance frequencies.)

Strong second and higher harmonics are spectral features that lead to a brass-like timbre. Figure 1 shows a vowel chart in which the first formant frequency F_1 is plotted along the horizontal axis and the second formant frequency F_2 is plotted along the vertical axis. IPA phonetic symbols of nine vowels are used as data points to indicate possible formant frequencies for an adult female. Also plotted are grid lines that represent the harmonic frequen-

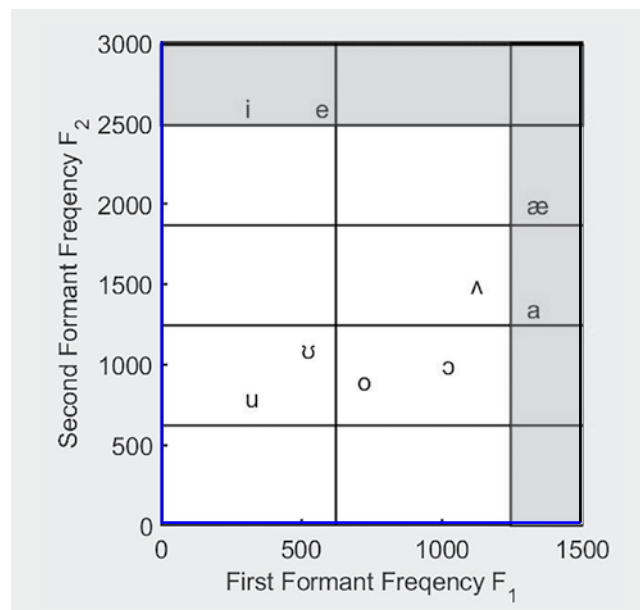


Figure 1. Acoustic-phonetic vowel chart showing the relation between harmonics of the note $E\flat_5$ (grid lines) and the formant frequencies of nine vowels. The darker shaded areas on top and to the right are the “vowel-stretch” regions for belting.

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cies of the note E^b_5 (622 Hz) along both axes. (The reason for choosing this note is explained below). Thus, in the horizontal direction we see two grid lines representing the first harmonic f_0 at 622 Hz and the second harmonic $2f_0$ at 1244 Hz. In the vertical direction, we see four grid lines representing f_0 at 622 Hz, $2f_0$ at 1244 Hz, $3f_0$ at 1866 Hz, and $4f_0$ at 2488 Hz.

The E^b_5 note of interest is sung on the first syllable of the word “easy” in the phrase “Touch me, it’s so easy to leave me . . .” in the song “Memory” from the Broadway musical *Cats*. It can have a belt-like timbre. Figure 1 shows that the second formant frequency for both the vowels /i/ and /e/ is slightly above the fourth harmonic frequency ($4f_0$), suggesting that the F_2 resonance could give a major boost to this fourth harmonic. This is similar to the boost that the second harmonic $2f_0$ can get from the first resonance F_1 of the vowels /a/ and /æ/, as shown on the right side of the plot. The two shaded areas (top and far right) represent the “vowel-stretch” regions for belting, whereas the unshaded area represents vowels generally not perceived as belt-like. The exception is the vowel /ʌ/, which is borderline in this binary classification and could be in the “vowel-stretch” region with a wider-than-normal mouth opening that raises F_1 .

Figure 2 shows a spectrum of a belted /i/ vowel on the E^b_5 note produced by a professional female singer during a live performance. The name of the singer is not revealed here. The spectrum was obtained from a YouTube recording of “Memory” with orchestral background, which means that spectral amplitudes could be contaminated with background sound, especially in the region of the fundamental around 600 Hz. In fact, the fundamental is not clearly identifiable in the graph. This is not a problem for the current discussion because the fourth harmonic amplitude is the focus here. It is unlikely that any sound recording, processing, or equalizing would affect only this harmonic frequency selectively. The spectrum was obtained with VoceVista. The range of frequencies is 5000 Hz and the fourth harmonic is where the cursor is placed (2496 Hz). The general spectral slope is observable by the surrounding harmonic amplitudes (second, third, fifth, and sixth).

This short essay should not be taken as a definitive study of pitch-vowel interaction in belting, but only as a precursor to a formal study with multiple singers and acoustically controlled environments. The main message is that the timbre in belting can be related not only to a strong $2f_0$ interaction with F_1 , but likely also a strong

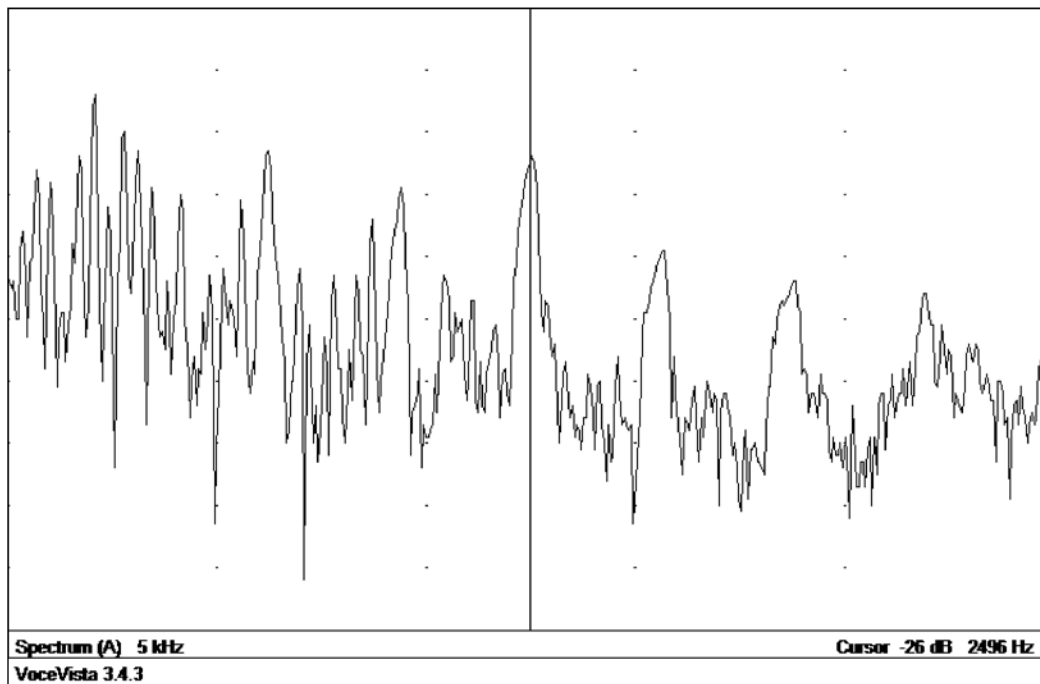


Figure 2. Amplitude spectrum of the note E^b_5 sung on the vowel /i/ by a professional female singer in a belt timbre. The vertical cursor line is on the fourth harmonic (2496 Hz).

$4f_0$ interaction with F_2 . It is not yet clear whether a $3f_0$ interaction with F_2 could also produce the belt timbre. The most important feature is probably the lack of energy in the fundamental rather than the dominance of any specific higher harmonic.

NOTES

1. I. R. Titze, A. S. Worley, and B. H. Story, "Source-Vocal Tract Interaction in Female Operatic Singing and Theater Belting," *Journal of Singing* 67, no. 5 (May/June 2011): 561–572.
2. D. E. Hall, *Musical Acoustics* (Belmont, CA: Wadsworth Publishing Company, 1985).

Evening, and all the birds
In a chorus of shimmering sound
Are easing their hearts of joy

For miles around.
The air is blue and sweet,
The few first stars are white,—
Oh let me like the birds
Sing before night.

Sara Teasdale, "Dusk in June"

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