More About Resonant Voice: Chasing the Formants But Staying Behind Them

In most wind instruments, such as woodwinds and brasses, the resonances of the tube dictate the fundamental frequency (or pitch, in musical terms). The tube generally has a series of resonances that can be shifted around by opening and closing tone holes, by valving, or by changing the length of the tube (as in a trombone). If the sound is to be melodic with a sustainable pitch, the resonance frequencies need to be harmonically related; in other words, they need to be integer ratios of each other, such as 2:1, 3:1, 4:3, etc. Instrument makers spend much time shaping an instrument to achieve these integer frequency ratios.

A second requirement in wind instruments is that the source of the sound (the reed or the lips) must be flexible enough so that its vibration frequencies can be entrained (pulled into synchrony) with the resonance frequencies of the tube. Ideally, there will then be a match between the harmonics of the source and the harmonics of the tube. As the valves, tone holes, or tube length alter the resonance structure during playing, the reed or lip vibration frequencies follow. Thus, the tune is played on the resonator, and the source of sound becomes a slave to the resonator.

In singing, the situation is somewhat different. Because the vocal tract is so short in comparison to the tubes of wind instruments, a match between the harmonics of the source and the resonances of the vocal tract (the formants) is only partially achievable. On average, the formants are spread 1000 Hz apart, which means that source harmonics would need to widely spread to be collectively entrained by the vocal tract. This can work for some high pitches (500 Hz, 1000 Hz, 1500 Hz), but even then the prospect is dimmed by the fact that a variable vowel structure does not permit evenly spaced formants (except for the neutral schwa vowel /a/).

Thus, at best, one or two harmonics of the source can be entrained by the vocal tract, and then only if the vowel can be modified to accommodate the changes with pitch.

A more likely situation in singing is to allow the vocal folds to dictate the pitch and to use the vocal tract only as an acoustically short air column to assist vocal fold vibration. An acoustically short air column is also known as an inertive air column, one that resists acceleration and deceleration of the air en masse (as a unit). As seen through the glottis, the air above the vocal folds is sluggish in being moved forward and backward. This creates an acoustic pressure pattern in the glottis (a push-pull situation) that assists the vocal folds in their vibration.

Thus, to achieve a more resonant voice, a formant is not placed directly on a harmonic (as in so-called harmonic singing), but rather slightly above a harmonic. Stated conversely, the harmonic chases the formant, but never quite catches up with it. The advantage of this maneuver is a strengthening of all harmonics, not just a single one. Since vocal fold vibration is enhanced by the inertive air column, there will be a greater amplitude of vibration, yielding better glottal closure and an increase in all harmonic energy. The spectrum remains rich and less selective to a single frequency.

Consider an example. A singer or speaker wishes to achieve a resonant sound on the pitch C4 (262 Hz). Rather than moving the first formant F1 down to this exact frequency (which would require an /i/ or /u/ vowel), the vocal tract is shaped in the direction of an inverted megaphone with lip rounding and pharynx widening. This keeps F1 slightly above the fundamental frequency F0. The vocal tract air column will be inertive, helping the vocal folds in their vibration.
Now assume the pitch goes up an octave, to C₅ (523 Hz). The inverted megaphone shape may not be ideal for this pitch; rather, a more cylindrical tube should be approximated. Less lip rounding is needed, with a slightly more open mouth. F₁ should remain above 523 Hz, which would suggest a vowel closer to /e/ or /a/. Another octave higher (C₆ or 1047 Hz), the vocal tract needs to be in the noninverted megaphone shape, with a wide open mouth and perhaps a slightly raised larynx, to keep F₁ above 1047 Hz. This requires a very bright vowel, like /æ/ or /a/.

The vowel chart of Coffin provides an extensive exploration into this resonance phenomenon. The chart could be reinterpreted, however, with the current understanding that harmonic tuning is not the objective (except in harmonic singing), but rather a reinforcement of vocal fold vibration with an inertive vocal tract. Work is currently underway to revise the Coffin chart.

**NOTES**


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