The Same Vowel Is Measured More Coarsely the Higher the Voice

— A uniform tube of **0.175** m resonates at **490.000000**, **1470.000000** and **2450.000000** Hz, in odd multiples, the second being exactly **3.000000** times the first — the separator is whether the envelope is sampled or falls between the samples — [Paper 703]

Yuuki YAMAGISHI (山岸 勇輝)
Yamagishi Complexity Torus Lab, Japan
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— *From thinking to syncing.* —

Abstract

Pitch and vowel can be varied independently: a vowel stays itself at any pitch.But that independence belongs to the producing side, and on the receiving side a high voice is at a disadvantage. That disadvantage is given a number here.No new theorem or law is claimed. First, the resonances do not depend on pitch——the first resonance of a uniform tube of 0.175 m is 490.000000 Hz whether the fundamental is 100 Hz or 400 Hz (Section 2). **Second, they do depend on the length of the tube——612.500000 Hz at 0.140 m and 451.315789 Hz at 0.190 m: a vowel is fixed by the shape of the mouth, not by the pitch** (Section 2). **Third, and this is the core. On the receiving side a high voice offers fewer samples——the harmonics below 3000 Hz number 30 for a 100 Hz voice and 7 for a 400 Hz one, a coarseness differing by 4.285714** (Section 3). **Fourth, a resonance can fall between the samples——the nearest harmonic to the first resonance at 490 Hz lies 10.000000 Hz away for the 100 Hz voice and 90.000000 Hz away for the 400 Hz one** (Section 3). **Fifth, so "independently variable" belongs to the producing side alone——source and filter multiply, but the listener sees only the samples of the product** (Section 3). **Sixth, the separator is whether the envelope is sampled or falls between the samples——the shape may be there, and without a point landing on it nothing can be read** (Section 4). **Keywords**: source and filter, formants, resonance of a uniform tube, harmonic spacing, sampling of an envelope, fundamental frequency.

Scope of this paper (scope note): **No new theorem or law is claimed——the source-filter separation, the resonances of a uniform tube and formants are all standard (Fant 1960, Stevens 1998).The vocal tract is fixed to a uniform tube——in real vowels the first and second resonances move because the cross-section varies along the tract. Only the uniform tube is examined.The source is not treated——the shape of the glottal wave and the falloff of its harmonics are not treated; harmonics are taken to stand at equal intervals.Identification is not discussed——whether vowels are actually distinguished, and the performance of speech recognition, are not the subject.Synthesis is not evaluated——the naturalness of synthetic speech is not treated.Relation to earlier papers**: **Paper 654 showed that choosing a window is choosing the answer, and that lowering the leakage loses the power to split close tones——there the width of the window fixed the resolution; here the spacing of the harmonics fixes the fineness of sampling. Two different constraints, width and spacing, bear on the same spectrum.**What is added is **confirming numerically that the resonances do not depend on the source**, **tabulating the resonance against the length of the tube**, **putting the coarseness of sampling at $\mathbf{4.285714}$ from the number of harmonics below 3000 Hz**, **contrasting the distance to the nearest harmonic at $\mathbf{10.000000}$ and $\mathbf{90.000000}$ Hz**, and **placing the separator on falling between the samples**.

1. Notation and the Question

Setting: **take a voice as the product of a source (the vibrating folds) and a filter (the resonances of the tract). In a uniform tube of length L closed at one end, the resonances stand at odd multiples.**

$$f_k = \frac{(2k-1)c}{4L}, \qquad c = 343\ \mathrm{m/s}, \qquad N(f_0) = \left\lfloor \frac{3000}{f_0} \right\rfloor$$

$N(f_0)$ is the number of harmonics a voice of fundamental f_0 places below 3000 Hz.

Question: **if source and filter are independent, are they independent on the receiving side too?**

2. On the Producing Side They Are Independent

Computation 2.1: **the resonances of a tube of 0.175 m were derived.**

resonance	frequency
first	$\mathbf{490.000000}$ Hz
second	$\mathbf{1470.000000}$ Hz
third	$\mathbf{2450.000000}$ Hz
fourth	$\mathbf{3430.000000}$ Hz

The second is exactly 3.000000 times the first: they stand at odd multiples.

Computation 2.2: changing the length moves them: 612.500000 Hz at 0.140 m, 490.000000 Hz at 0.175 m and 451.315789 Hz at 0.190 m.

> **Observation 2.3**
>
> **a vowel is fixed by the shape of the mouth, not by the pitch.The fundamental does not appear in the formula, so raising it from 100 Hz to 400 Hz leaves the first resonance at 490.000000 Hz——"a vowel stays itself at any pitch" is a restatement of that formula.**

3. On the Receiving Side They Are Not

Computation 3.1: the number of harmonics below 3000 Hz was derived.

fundamental	harmonics
100 Hz	30
150 Hz	20
200 Hz	15
400 Hz	7

Between 100 Hz and 400 Hz the coarseness of sampling differs by 4.285714.

> **Observation 3.2**
>
> **this is the core: the shape of the filter is the same, and the number of points measuring it is not.The envelope is continuous, but sound is present only at the harmonics——what a listener receives is not the envelope but the envelope sampled at the harmonics.**

Computation 3.3: the nearest harmonic to the first resonance at 490.000000 Hz is the fifth at 500.000000 Hz for a 100 Hz voice, 10.000000 Hz away, and the first at 400.000000 Hz for a 400 Hz voice, 90.000000 Hz away.

Observation 3.4

a resonance can fall between the samples.For the 400 Hz voice not one harmonic stands on the first resonance——the shape may be there, and without a point landing on it nothing can be read.

Observation 3.5

so “independently variable” belongs to the producing side alone.Source and filter multiply, so on the producing side they are indeed independent——but the receiving side sees only the samples of the product, and there the source fixes the resolution.

4. The Separator

Observation 4.1

the separator is whether the envelope is sampled or falls between the samples.The same envelope cannot be read if the spacing of the samples is coarser than its structure——what cannot be read is not the fault of the envelope but of the spacing.

Observation 4.2

beside Paper 654.Paper 654 showed that choosing a window is choosing the answer, and that lowering the leakage loses the power to split close tones——there the width of the window fixed the resolution; here the spacing of the harmonics fixes the fineness of sampling. Two different constraints bear on the same spectrum.

Observation 4.3

what is not said.The tract is fixed to a uniform tube, and neither the source waveform nor the performance of identification is treated——what is shown is that independence on the producing side does not survive to the receiving side.

5. Roll Call and Closing

1. **first resonance 490.000000 Hz** (Computation 2.1): **a uniform tube of 0.175 m.**
2. **the second is 3.000000 times** (Computation 2.1): **odd multiples.**
3. **612.500000 Hz at 0.140 m** (Computation 2.2): **the mouth decides.**
4. **the fundamental is absent** (Observation 2.3): **no dependence on pitch.**
5. **30 harmonics at 100 Hz** (Computation 3.1): **the samples.**
6. **7 at 400 Hz** (Computation 3.1): **the core.**
7. **coarseness differs by 4.285714** (Computation 3.1): **the receiving side pays.**
8. **10.000000 Hz away** (Computation 3.3): **the 100 Hz voice.**
9. **90.000000 Hz away** (Computation 3.3): **the 400 Hz voice.**
10. **sampled or between samples** (Observation 4.1): **the separator; Paper 654.**

Closing: **The same vowel is measured more coarsely the higher the voice.The resonances of a uniform tube of 0.175 m, at 490.000000, 1470.000000 and 2450.000000 Hz, stand at odd multiples and do not move whether the fundamental is 100 Hz or 400 Hz——a vowel is fixed by the shape of the mouth, not by the pitch.Yet the harmonics below 3000 Hz number 30 for a 100 Hz voice and 7 for a 400 Hz one, a coarseness differing by 4.285714——what a listener receives is not the envelope but the envelope sampled at the harmonics.The nearest harmonic to the first resonance lies 10.000000 Hz away in one case and 90.000000 Hz in the other, and for the high voice not one harmonic stands on it——the shape may be there, and without a point landing on it nothing can be read.The separator is whether the envelope is sampled or falls between the samples.Placed among the earlier papers——in Paper 654 the width of the window fixed the resolution; here the spacing of the harmonics fixes the fineness of sampling.To be honest——the tract is fixed to a uniform tube and neither the source waveform nor identification is treated.**

References

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Yuuki YAMAGISHI (山岸 勇輝)

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