Spectrographic measurements

Lindblom, B.

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B. FORMANT FREQUENCY MEASUREMENTS

1. Spectrographic measurements

5 subjects were asked to determine the positions of $F_1$, $F_2$, and $F_3$ of 6 synthetic vowels [a:, e:, i:, u:, o:, ae:] on wide-band spectrogram and on wide-band section. Each vowel has 6 pitches. This gives a total of 540 measurements for each method. Mean values of errors in each $F_0$-class are shown in Fig. I-5, where the lower diagram pertains to the mean of absolute values of errors. An error is simply defined as the deviation of a measured value from the known pole frequency.

Analysis of high-pitched voices with 600 c/s filter, which implies a reduction of the speed of the input signal by a factor of 2 and the use of a magnified frequency scale, produces a spectrographic display which makes accurate measuring very difficult (cf. table I-1). Moreover, the effect of the 6 dB/octave bass attenuation is particularly noticeable in this method. In a systematic investigation subjects consistently located low formants much too high, e.g., $F_1$ of [i:] at about 400 c/s instead of 240 c/s pole.

<table>
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<th>Factors influencing measurements:</th>
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<td>(1) uncertainty in calibration, position of zero line</td>
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<td>(2) pre-emphasis: +6 dB/octave (of importance in the case of 600 c/s filter)</td>
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<td>(3) position of partial within the formant (see Fig. I-6)</td>
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<td>(4) relation between filter width and fundamental pitch</td>
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The effect of a continuous rise in $F_0$ on the appearance of human and synthetic vowels may be studied in Fig. I-6.

In order to perform an auditory evaluation of the above-mentioned wide-band (300 c/s) spectrogram measurements a preliminary listening test has been carried out. Subjects were asked to state
Fig. 1-5 Mean values of errors in spectrographic measurements, with signs retained (above) and means of absolute values (below). Triangles pertain to spectrograms and circles to wide-band sections.
Fig. 1-6  The effect of a gliding pitch change on broad-band spectrogram of a vowel [æ]. The human speech and the synthetic speech sample show similar jumps in the locations of the formant bands.
whether pairwise stimuli consisted of sounds that were the same or different with respect to phonetic quality. A pair contained two synthesized vowels; one of the sounds used for the above-mentioned spectrogram study plus its measured counterpart specified by the spectrogram data. Subjects were unanimous in reporting that one or two out of 36 sounds differed considerably whereas the rest had remained practically unchanged with respect to phonetic quality.

E. Lindblom

2. Formant-tracking

A few pilot experiments on the use of phase detection methods in formant frequency trackers have been undertaken. The methods we have tried were:

(1) Measuring the phase difference between the input and the output of an anti-resonance circuit of variable center frequency.

(2) Measuring the phase difference between the outputs of two anti-resonance circuits spaced 250 c/s apart.

(3) Measuring the phase difference between the outputs of two resonance circuits spaced 100 c/s apart.

Of these methods only the last one gave results which were judged to be of any practical use. However, a large pitch variation alone could give a phase shift of a formant frequency. The results were better for $F_2$ and $F_3$ than for $F_1$. No further work on phase methods will be undertaken until sufficient experience has been gained from spectral maximum selectors.

A. Krokstad