Proceedings of The Institute of Acoustics

SPEECH PERCEPTION WITH ARTIFICIAL IMPAIRMENT OF FREQUENCY RESOLUTION

I.R. SUMMERS, A.D. AL-DABBAGH,
UNIVERSITY OF EXETER

Circuitry has been developed to simulate a loss of frequency resolution in the ear by producing a band of frequencies at the output for each single frequency component at the input. Fine detail in the spectrum thus becomes "blurred". A normally-hearing subject listening to speech via such a processing system experiences an impairment of perception analagous to that experienced by an observer looking through an out-of-focus optical system. (See Fig. 1.)

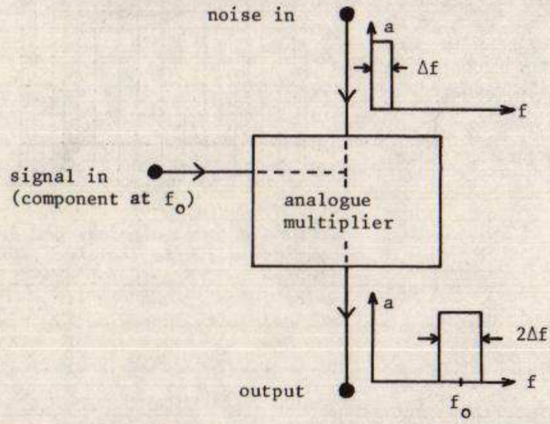

Fig. 1. Block diagram of the basic speech processing system.

Testing

Tests were carried out on normally-hearing young adult subjects to determine the effect of such "blurring" on speech perception. Subjects were asked to identify processed words presented at a nominal peak level of 65 dB(A) via a pair of loudspeakers in a soundproof testing room. Under some testing conditions additional filtering and a white noise background at 45 dB(A) were added to the processed signal. Different degrees of "blurring" were used for each of the four lists of ten words heard by a given subject - each frequency component in the unprocessed signal appearing as a band of width $2\Delta f$ = 400 Hz, 200 Hz, 100 Hz or in the original unprocessed form. Subjects' responses were scored on the basis of the percentage of words totally correct.

Test Results

The experimental results are shown in Fig. 2. Results for three different test

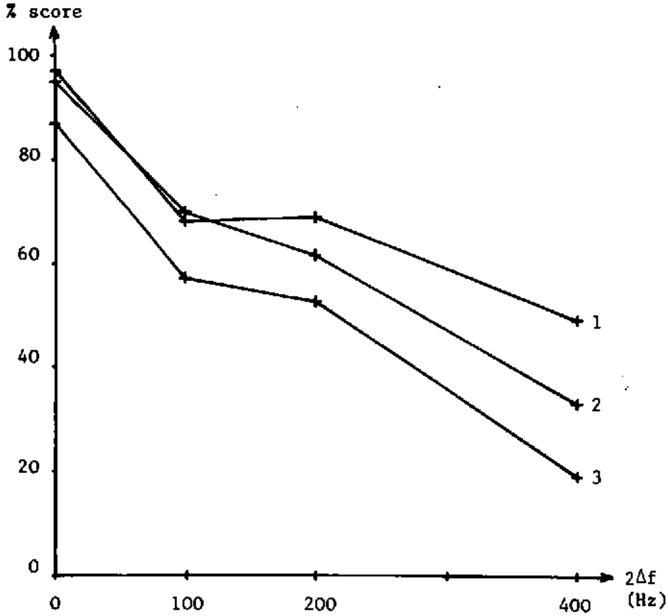

Fig. 2. Test results.

conditions are shown. In '1', subjects listened to the processed words with no noise background and no additional filtering. In '2' a white noise background was used, together with an A-weighting filter to give a more realistic threshold shape than with white noise alone. In '3' a low-pass filter was additionally introduced to simulate a high-frequency hearing loss. This has a flat response at low frequencies, is 9 dB down at 3 kHz and falls off at 36 dB/octave at high frequencies. (Three second-order Butterworth stages at 3 kHz in tandem.) Each point in the figure represents an average from 20 subjects each responding to 10 words.

In condition '1', speech perception was seen to fall off as Δf was increased. The scores for $2\Delta f$ = 100, 200 Hz may simply reflect subjects' unease at listening to speech sounds distorted into an unfamiliar form. However, the considerable drop in scores for $2\Delta f$ = 400 Hz is probably due in part to a loss of resolution of the formant structure.

Performance in conditions '2' and '3' was essentially similar, although the additional noise background and filtering caused a further drop in performance, especially in the difficult region of high Δf, as might be expected.

Future Plans

It is hoped to develop this system into a device which could form part of a realistic simulation of sensorineural hearing loss. The most obvious modification required for this is the splitting of the audio spectrum into many different frequency bands, each of which can be processed individually, as required.

As well as shedding some light on the speech perception problems of patients with hearing loss, a realistic simulation of a particular sensorineural loss would be of assistance in the design and testing of a hearing aid to compensate for that loss. (For example, an aid could be designed to incorporate the "inverse transform" of features in the hearing loss.)