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Dichotic Presentation of Speech Signal Using Critical Filter Bank for Bilateral Sensorineural Hearing Impairment

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Abstract: Sensorineural hearing impaired listeners face a particular problem in view of decrease in frequency resolving capacity of ear due to spread of spectral masking along the cochlear partition. Filtering speech signal by bank of critical band filters and adding signals from alternate bands for presenting to the two ears, is likely to reduce this effect, and thus may help in improving the speech intelligibility. We have implemented this processing scheme with eighteen critical bands for experimental evaluation. Listening tests were carried out using twelve vowel-consonant-vowel and consonant-vowel nonsense syllables presented in quiet, on ten subjects with mild-to-very severe sensorineural hearing loss. The stimulus response confusion matrices were analyzed for obtaining recognition scores and information transmission. The relative improvement in recognition scores is up to 25 percent. Information transmission analysis indicated that the overall improvement is contributed by improvements in transmission of place and manner features. The mean response time has also been found to significantly decrease.

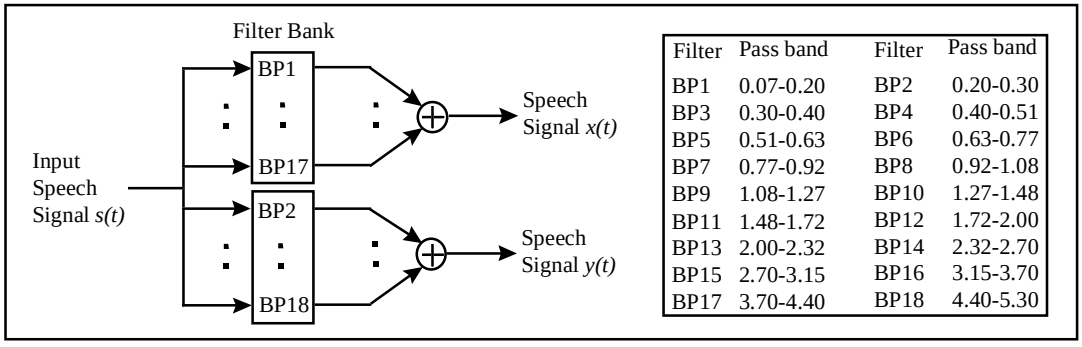
INTRODUCTION

One of the characteristics of the sensorineural hearing impairment is loss of frequency resolving capacity due to spread of masking. The spread of spectral masking, during the auditory processing along the cochlear partition, results from masking of adjacent frequency components. By splitting speech into two complementary parts based on frequency and presenting it dichotically might improve speech reception in cases of bilateral sensorineural hearing impairment with some residual hearing. Binaurally receiving and perceptually combining the information from both ears for improving speech perception has been established earlier (1).

Lunner et al (2) reported the improvements in speech perception during experiments with hearing impaired subjects by partitioning speech for dichotic presentation on the basis of frequency with 8-channel constant bandwidth filtering. We have implemented the scheme of splitting of speech in two signals with complementary spectra based on critical band filtering for binaural dichotic presentation and tested on normal hearing subjects with varied degree simulated sensorineural hearing loss. The results from listening tests indicated improvement in recognition scores and transmission of features (3). In this paper, we present the results of listening tests with ten subjects with mild-to-very severe sensorineural hearing loss.

METHOD

The speech signal is partitioned based on multiple critical band filtering with bandwidths selected as that of auditory filter bandwidths reported by Zwicker (4). The alternate bands are summed together for dichotic



Filter	Pass band	Filter	Pass band
BP1	0.07-0.20	BP2	0.20-0.30
BP3	0.30-0.40	BP4	0.40-0.51
BP5	0.51-0.63	BP6	0.63-0.77
BP7	0.77-0.92	BP8	0.92-1.08
BP9	1.08-1.27	BP10	1.27-1.48
BP11	1.48-1.72	BP12	1.72-2.00
BP13	2.00-2.32	BP14	2.32-2.70
BP15	2.70-3.15	BP16	3.15-3.70
BP17	3.70-4.40	BP18	4.40-5.30

FIGURE 1. Splitting of speech signal using multiband bandpass (BP) filtering.
The 3 dB cutoff frequencies of the bands are in kHz.

presentation, as shown in Figure 1. Test material consisted of nonsense syllables using twelve English consonants /*p, b, t, d, k, g, m, n, s, z, f, v*/ in vowel-consonant-vowel (VCV) and consonant-vowel (CV) context with the vowel /*a*/, and acquired using antialiasing filter (cutoff = 4.8 kHz) and 16-bit ADC at a rate of 10 k Sa/s. The processing was done off-line by digitally filtering speech with bandwidth equal to critical bands of auditory filters. The input and processed speech signal with the said scheme was presented to two ears through DAC, smoothing filter and power amplifier. Both the signals were spectrographically (5,6) analyzed in order to verify the signal processing. Ten hearing impaired subjects in the age group of 18 to 58 years participated in the experiments. The subject had mild-to-very severe bilateral sensorineural hearing loss. The test material was presented binaurally at the individual subject's most comfortable listening level.

Listening tests were carried out for finding confusion among the set of twelve consonants in VCV and CV context. The tests were conducted in an acoustically isolated chamber, using an automated test administration system (3). The confusion matrices and response time statistics are stored at the end of each session. The test was administered for each subject for (i) the same unprocessed speech presented to the two ears and (ii) processed speech presented dichotically to the two ears. Subjects were also asked to narrate about the qualitative assessment of the test material.

RESULTS AND DISCUSSION

Listening tests were conducted with ten subjects in VCV and CV context. All the subjects have shown significant improvement in recognition scores and significant decrease in response time. The results for a typical subject are given in Table 1.

For studying the reception of specific consonant features, the information transmission analysis was carried out on stimulus-response confusion matrices (7). The test results for all the subjects have shown improvements in relative information transmission in place and manner features. The results for a typical subject are given in Table 2. The improvement is maximum for the place feature. As the place information is subject to frequency resolving capacity of the auditory processing, one can say that the implemented scheme has reduced the effect of spectral masking.

TABLE 1. Recognition scores (%) for subject SG for unprocessed and processed speech.

Context	Score for Unprocessed speech		Score for Processed speech		Relative improvement (%)	p value for 2-tailed test
	mean	s. d.	mean	s. d.		
VCV	48.8	4.2	61.0	6.1	25.0	< 0.005
CV	62.7	3.1	71.8	3.3	14.5	< 0.001

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TABLE 2. Relative information transmitted (%) for subject SG for unprocessed and processed speech.

Feature	VCV context		CV context	
	Unprocessed	Processed	Unprocessed	Processed
Manner	47	64	50	55
Place	17	33	29	39
Voicing	49	54	100	96
Overall	58	68	74	73

REFERENCES

1. Moore, B. C. J., *An Introduction to Psychology of Hearing,* New York: Academic, 1982.
2. Lunner, T., Arlinger, S., and Hellgren, J., *Scandinavian Audiology Supplement* **38**, 75-81 (1993).
3. Chaudhari, D. S., and Pandey, P.C., "Splitting of speech signal by critical band filtering for bilateral sensorineural hearing impairment," *Proceedings of the 18th Conference of Indian Association of Biomedical Scientists*, New Delhi, V/4-5, 1997
4. Zwicker, E., *Journal of Acoustical Society of America* **33**, 248 (1961).
5. Rabiner, L. R., and Schafer, R. W., *Digital Processing of Speech Signals*, Englewood Cliffs, NJ: Prentice Hall, 1978.
6. Thomas, T. G., Pandey, P. C., and Agashe, S. D., *Journal of IETE (India)* **40**, 105-108 (1994).
7. Miller, G. A., and Nicely, P. E., *Journal of Acoustical Society of America* **27(2),** 338-352 (1955).