ON PITCH DISCRIMINATION OF RESIDUE TONES

R. J. Ritsma

Pitch is that subjective attribute of sound which admits of a rank ordering on a scale ranging from low to high. For pure tones the pitch correlates strongly with frequency. The pitch discrimination of pure tones has been explored extensively by Shower and Biddulph [1]). The relative j.n.d. ($\Delta p/p$) for pure tones presented binaurally at 40 db sensation level is given in fig. 2 as a function of pitch (p).

The pitch of a complex sound need not necessarily correspond with any one frequency in the signal. The residue, that is the joint perception of a number of neighbouring higher harmonics of a periodic signal, can have a decidedly low pitch provided the constituent frequencies fulfil certain conditions [2]). Consequently one may conclude that one and the same area of the basilar membrane may give rise to sensations of widely different pitch, depending upon the time pattern of stimulation. In the case of steady-state signals the place of maximal stimulation may be taken to be a measure of timbre whereas the pitch will depend on the (quasi)-periodicity of the signal [3]).

Flanagan and Saslow [4]) found that a pitch discrimination of artificially generated vowel sounds is somewhat nicer than the pitch discrimination of a pure tone of the same fundamental frequency and intensity as the vowel. Assuming that their subjects have indeed distinguished changes in pitch, the Flanagan and Saslow's measurements would seem to indicate that the periodicity detected in a vowel leads to a better discrimination by the ear than the periodicity of a pure tone of the same fundamental frequency. However, a change of the pitch of a vowel can not be brought about without changing the frequencies of the Fourier components. Therefore, their results can be more readily interpreted by assuming that the subject in determining the j.n.d. in pitch of a vowel react to a shift of those components at which the j.n.d. in pitch is smallest rather than to a change of periodicity pitch. With this interpretation in mind the Flanagan and Saslow-data do not give conclusive evidence about the accuracy of the pitch of complex sound.

A better insight in the j.n.d. in pitch of a complex sound may be obtained by making use in the experiment of a characteristic feature of the residue. This is constituted by the fact that the centre frequency and the periodicity can be shown to be independant parameters. No such possibility of separately dealing with frequency and periodicity exists when working with pure tones or limited bands of noise. This implies that a residue consisting of the frequencies 1800—2000—2200 cps can be matched as to pitch with a residue consisting of the frequencies 1200—1400—1600 cps. Both signals have the same pitch (200 cps); however, they differ clearly in timbre. In matching two residue signals with different centre frequency the j.n.d. in pitch of a complex sound can be determined without the possibility of coinciding components causing a disturbing influence in the results.

On the strength of this principle the j.n.d. in pitch of a residue consisting of three components has been determined for a pitch range from 60 to 600 cps. with two well-trained subjects.

Fig. 1 shows a diagram of the experimental set-up.

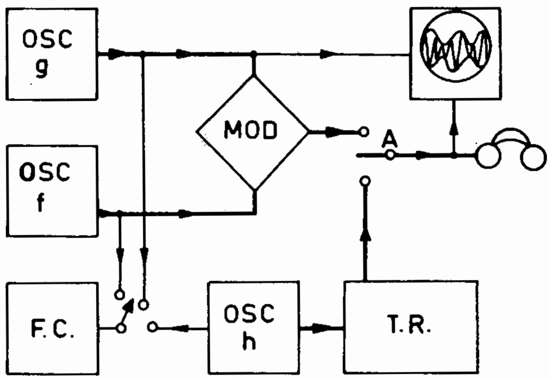

Fig. 1.

A test residue is generated with the aid of a modulator (MOD) and two sine wave oscillators (Osc f and Osc g). In general a f/g-value = 10 is taken. As a matching signal a different residue tone from a tape recorder is used (T.R.). For this matching residue a f/g-value = 7 is taken. By varying the tape speed all components of the matching signal are multiplied by the same factor. In this way the pitch of this matching signal can be changed (Osc. h). A crystal controlled frequency counter (F.C.) is used for measuring the frequencies of the oscillators.

The accuracy of the total apparatus was about 1‰. Listening was performed binaurally with PDR 10 headphones at 40 db sensation level. By pressing one of two buttons (A) the subject could listen to either the test signal or the matching signal. He was free to press the buttons in any order, without time limitation. Simultaneous pressing of both buttons was not allowed. The subject had to vary the tape speed in such a way that the variable residue would match the test stimulus. The matchings made by the subject were registered by means of a frequency counter. In every test situation 80 measurements were taken, spread over several days.

The standard deviation obtained from these 80 measurements was taken to be a measure of the j.n.d. in pitch. The f/g values for test- and matching signals were 10 and 7 respectively. Only at a pitch of 600 cps these values were 6 and 4 respectively. Control measurements were carried out at four pitches with f/g values of 8 and 5 respectively. The results for only one subject are illustrated in fig. 2 since they differ very little from those of the second subject.

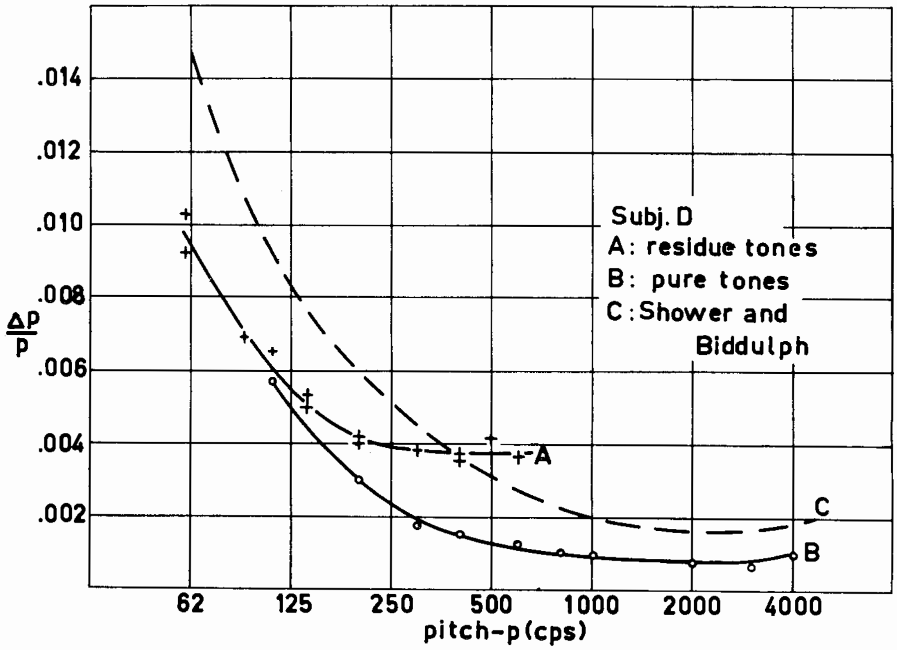

Fig. 2.

As a check of the method applied, either subject was also made to determine the j.n.d. in pitch for a pure tone. The results of these measurements for the same subject are also given in fig. 2.

From the results it appears that pitch discrimination of complex signals is poorer than that of pure tones. The outstanding feature is that at pitches above 200 cps the relative j.n.d. in pitch turns out to be all but constant whereas it increases at lower values of pitch.

LE POUVOIR DE DISTINCTION DU SON DES SIGNAUX DE CARACTÈRE DE RESIDU

Pour les sons purs la hauteur du son est directement couplée à la fréquence. Le pouvoir de distinction de la hauteur du son pour les sons purs a été déterminé par Shower et Biddulph [1]); leurs résultats en cas d'écoute binaurale à une intensité de 40 db sont réprésentés dans la figure 2.

Pour un son complexe la hauteur du son ne correspond pas nécessairement à une fréquence objectivement présente. La résidu. c'est à dire la perception commune d'un certain nombre de fréquences élevées voisines, évoquées par une impulsion périodique, peut provoquer une perception d'une hauteur de son basse [2]). Ceci veut dire qu'un seul endroit sur la membrane basilaire peut donner lieu à des perceptions différentes de la hauteur du son selon la stimulation en fonction du temps [3]).

Flanagan et Saslow ont trouvé que le pouvoir de distinction de la hauteur du son pour les sons complexes (tels que les voyelles) est meilleur que pour les sons purs [4]). Pendant leur mesure la comparaison de composants séparés peut avoir amené une perturbation dans leurs résultats.

Dans notre recherche nous sommes partis de 2 signaux de caractère de résidu et possèdant la même hauteur du son, mais dont les composants se trouvent dans des zones de fréquences différentes (une comparaison de composants individuels est de ce fait exclue). En comparant les 2 signaux à la hauteur de son, l'on peut déterminer le pouvoir de distinction de la hauteur du son pour la région de 60 à 600 Hz.

Pour essayer la méthode appliquée, on a également déterminé le pouvoir de distinction de la hauteur du son des sons purs. Les résultats sont réproduits dans la figure 2.

Dr R. J. Ritsma,
Instituut voor Perceptie Onderzoek,
Eindhoven — Netherlands.

References:

1. E. G. Shower and R. Biddulph — J. Acoust. Soc. Am. **3,** 275 (1931)
2. R. J. Ritsma — J. Acoust. Soc. Am. **34,** 1224 (1962)
3. J. F. Schouten, R. J. Ritsma and B. Lopes Cardozo — J. Acoust. Soc. Am. **34,** 1418 (1962)
4. J. L. Flanagan and M. G. Saslow — J. Acoust. Soc. Am. **30,** 435 (1958)