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A perceptual function of the 'singing formant'

Sundberg, J.

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III. MUSICAL ACOUSTICS

A. A PERCEPTUAL FUNCTION OF THE 'SINGING FORMANT'*

J. Sundberg

1. Introduction

The 'singing formant' is typical of vowels produced in male and generally also female opera singing (see e.g. Bartholomew, 1951). Our previous investigations have shown that it arises as the acoustical consequence of certain modifications of the normal speech articulation. Thus the singer abandons his normal articulatory habits with the result that the 'singing formant' is generated (Sundberg, 1970; 1971; and 1972). This can be interpreted as an indication that this spectrum envelope peak is desirable for some reason.

2. A perceptual explanation

An explanation to the fact that the 'singing formant' seems to be desirable would be that it makes the voice appear more clearly when sounding together with a loud orchestral accompaniment. The sound effect generated by a modern orchestra exceeds that of a professional singer by a couple of decibels, on the average. Therefore the orchestra would easily mask the sound of the singer. In order to find out if this is a realistic hypothesis two questions have to be answered. First, what is the spectral nature of the orchestral sound, and second, what are the masking effects of this sound?

An approximate view of the orchestra sound can be provided by an average spectrum. Such spectra were obtained from a computer statistically operating the output information of a filter-bank spectrum-analyzer (Blomberg & Elenius, 1970). In Fig. III-A-1 the mean spectral level is given for various types of grammophone recorded music. All curves display a maximum at about 450 Hz that was used for normalizing the curves with respect to intensity in the figure. In the low frequency region the Mozart passage played in piano gives the largest amplitudes and the forte

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* This is a condensed version of the author's paper given at the 11th Congress of International Musical Society, Copenhagen, August 1972.

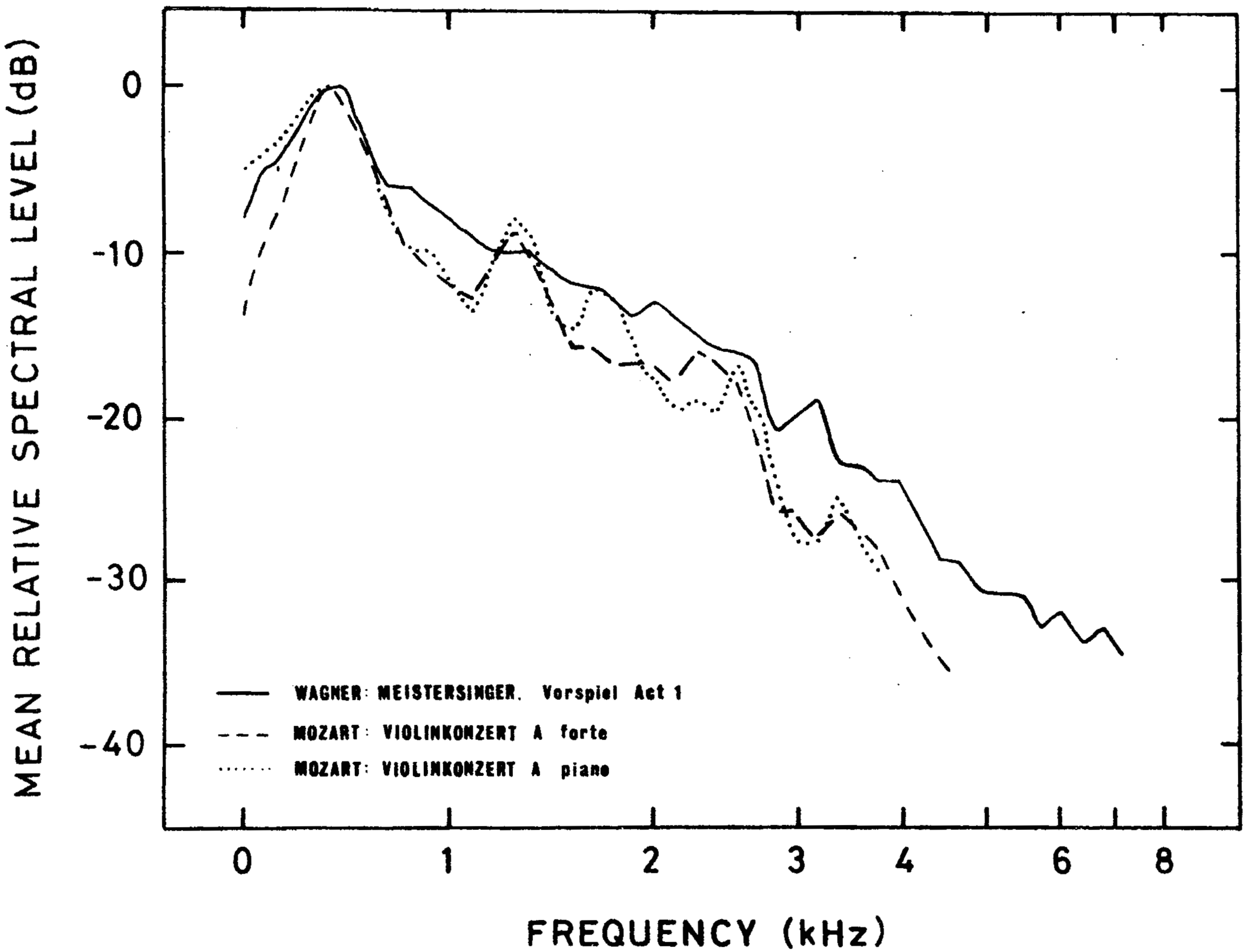

Fig. III-A-1. Average spectra of various types of grammophone recorded orchestra music.

passage the smallest. This was expected since musical instruments tend to produce spectra with relatively less energy in the low frequency region when played forte. Above the peak the three curves show a similar slope eventhough Wagner's piece gives the highest values. Disregarding such minor differences the three curves may be described as follows: a curve with a peak at 450 Hz and an average slope of about 9 dB/octave above this frequency.

The next question regards the masking effects of such a sound. Consulting textbooks leads us to guess that the amplitude of a just audible sinusoid sounding together with this sound would approximately parallel the spectrum envelope of the masker as obtained with analyzer bandwidths equal to the critical bandwidths of the ear. Experiments were made in which one subject adjusted the amplitude of a sinusoid to the threshold of audibility in the presence of a masker noise matching the average orchestra spectrum. Particularly for a masker overall SPL of 70 dB the masking curve parallels the spectral envelope of the masker rather closely, Fig. III-A-2. Extensive work is needed in order to arrive at a detailed understanding of how the masking effect depends on the exact spectral envelope of the masker. The results obtained so far are however sufficient for the present purpose. Fig. III-A-2 indicates that every partial that is of the same order of magnitude as the masker spectral level is likely to contribute to the perceptability of a complex tone.

The average spectrum differences between normal speech and orchestral music with and without a solo singer are compared in Fig. III-A-3. The 'singing formant' is recognized as the only point in which the orchestra with and without singing differ substantially. The figure can be interpreted in the following way: Suppose that the overall sound pressure level of the orchestra is 90 dB in the opera hall. At 3 kHz the sound level of the orchestra has dropped about 25 dB, i.e. to 65 dB. In speech this drop would be about 15 dB or more, but in professional singing it is only about 6 dB on the average. Therefore a singer generating a 'singing formant' will have to produce an overall sound pressure level of only around 70 dB instead of some 80 dB in order to produce some perceptible partials. The 'singing formant' is generated by passive resonance effects mainly. Therefore it can be said to allow the orchestra to play louder without masking the singer's voice or overdoing his resources of energy.

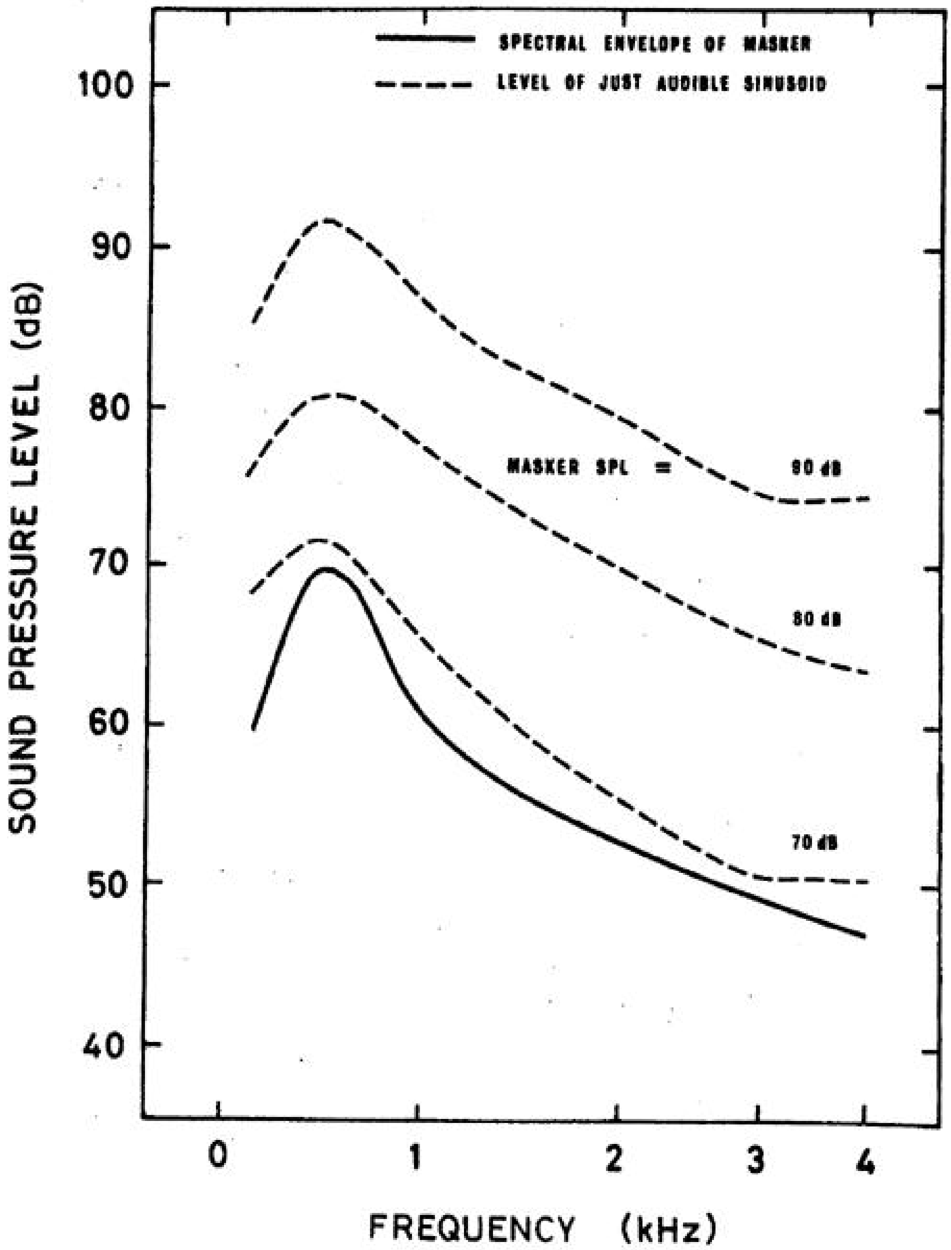

Fig. III-A-2. The masking effects of noise with a spectral energy distribution matching the average spectrum of orchestra music. The masker noise was presented at three overall SPL:s, as indicated in the figure.

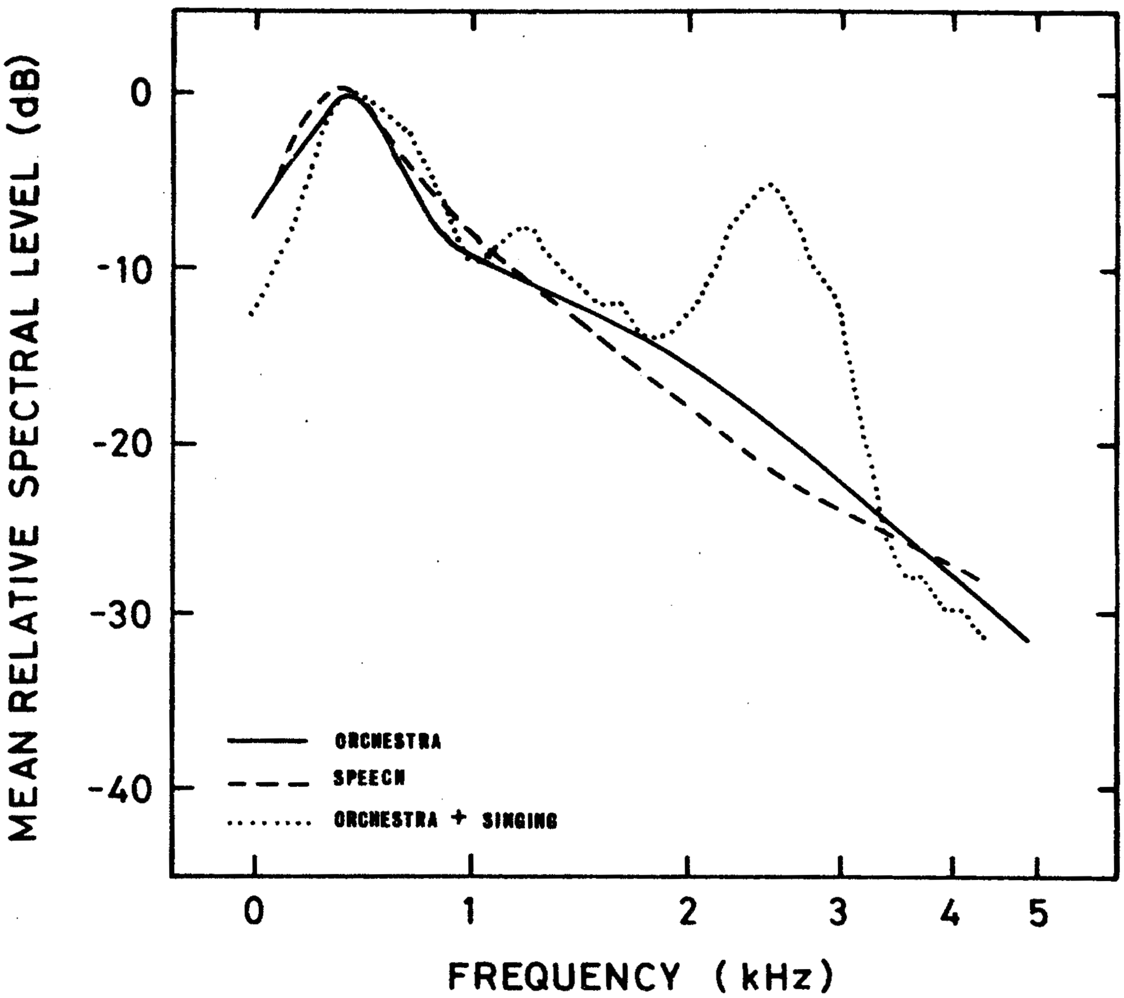

Fig. III-A-3. Idealized average spectra of normal speech and orchestra music. The dotted curve shows the average spectra of Jussi Björling singing with a loud orchestra accompaniment.

3. Discussion and conclusions

Our investigation indicates a correspondence between the singing technique and the accompaniment sound. If this is correct other singing techniques can be expected to occur when the accompanying sound is different from that of the modern orchestra. The sound effect produced by a lute, for instance, is apparently much lower than that of an orchestra. Therefore a singer accompanied by this instrument encounters no masking problem, and he has no need of a 'singing formant'. The style of singing is in this case also more speech-like. This is true also as regards the singing in modern pop-music, eventhough the accompaniment may be extremely loud. And no doubt, the singer would be completely masked had he not an electronic equipment taking care of his singing close to the lips. We may say that this equipment replaces the 'singing formant' in this case.

These examples support the hypothesis that the operatic style of singing is dependent on the spectral characteristics of the modern orchestral sound. We may therefore at least pose the question whether a more speech-like style of singing was cultivated in older times when the orchestra sounded more weak and rich in overtones.

It has been stressed that the 'singing formant' appears to have a definite perceptual function. It should however also be stressed that this does not exclude other advantages of a 'singing formant'. Possibly, the pitch control needed in operatic singing may be more easily acquired if the larynx is lowered. This will however remain a question for future research. At present we content ourselves with stating that the 'singing formant' seems to save the singer from wasting a lot of energy in the production of tones that are clearly audible in the presence of a loud orchestral accompaniment.

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