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CHARACTERISATION OF INSTRUMENT TONE BY FORMANT EXTRACTION

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INTRODUCTION

The sound of musical instruments is commonly discussed in terms of formants, it being asserted that differentiation between similar instruments such as violin and viola, and the identification of instruments, relies in part upon the recognition of formant characteristics by the same mechanism as the recognition of vowel formants in speech [1, 2, 3 - among many others]. This is generally stated as a matter of principle and not illustrated by experimental observation. Where measurements of musical sounds are reported, they are single examples obtained laboriously. The formant character of a good and a bad violin is shown by Hutchins [4], using a loudness curve which relies on the ability of a player to produce comparable notes accross the instrument range. Seymour [5] and Sundberg [6] have analysed the spectra of the singing voice obtained from tape loops.

The use of formant extraction to characterise vowel sounds in speech is well known, and the low-pass filtering of the cepstrum to give a liftered spectrum is a standard technique [7] which on modern frequency analysers offers a rapid means of obtaining information. The present work aims to assess the applicability of the technique to musical instruments, as a means of characterising instruments and identifying desirable formant character in good instruments.

FORMANTS OF THE SINGING VOICE

The use of the method for musical sound was initially tested on the singing voice, the technique being well validated for the voice, and Sundberg's work offering clear indications of results to be expected. In each case, the subject was asked to speak a pure (non diphthong) vowel sound, and then sing the same sound first badly and then well. Although not professional singers, all subjects had received voice training and were able to sing either "breathy" notes in the manner of the untrained voice, or with a reasonable degree of voice production technique. The sounds were recorded and analysed by a B&K 2034 analyser, using microphone input. No direct correction was made for room effects, but similar measurements were made in two very different rooms and showed no greater variation than that between tests in a single room.

The formants of the spoken vowel sounds compare well with published examples [2, 3, 6, 8]. The poorly sung examples show the characteristic patterns much less clearly. The well sung vowels show improved forms as compared with the poorly sung examples, and

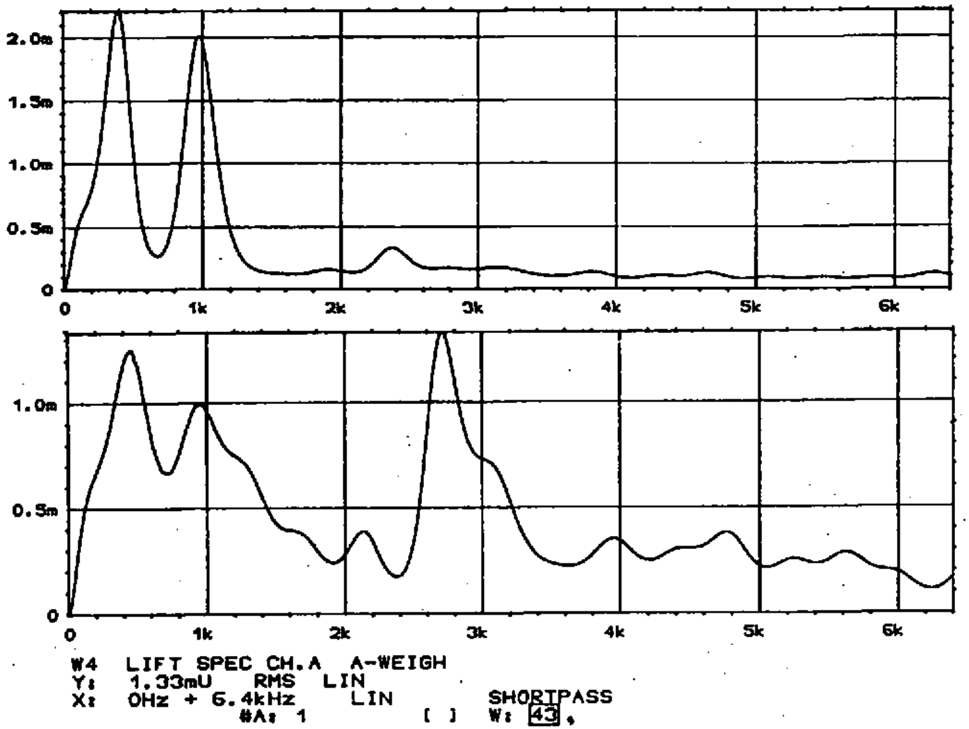

Figure 1: Liftered spectra of spoken and sung "oo" vowel, with "singers' formant".

have an additional formant in the region of 3 kHz. The centre frequency varies between individuals but is consistent for any one person and lies in the range 2.5 kHz to 3.5 kHz (figure 1).

The method therefore seems satisfactory in application to the singing voice. It demonstrates simply the existence of the "singers' formant" identified by Sundberg. Certain observations of singers and teachers are also confirmed. The unpractised singing voice does not naturally produce clear vowels, but good production technique clarifies the vowels as well as improving tone. The tests seemed to be of considerable interest to the subjects, who were provided with a visual means of assessing their technique by observing the both vowel definition and the singers' formant; the assessment of correct voice production by the singer is notoriously difficult, and relies on a teacher who can assess results but can only see (and correct) some aspects of technique. An objective assessment of results is helpful to the student seeking correct technique. The distortion of some vowel sounds also provided some subjects with confirmation of their teachers' complaints of poor diction!

TREBLE VIOL TONE

Stringed instruments in general are the classic category for description in terms of formants, with attention being paid to the main internal air resonance of the instrument body and the main resonances of the top plate. It was anticipated that there would be difficulties in obtaining consistent formant patterns from vibration at a wide range of excitation frequencies, since string vibration provides nearly harmonic partials which are widely separated in the main region of interest, and it was expected that features seen when using a low note might be absent when using a high note. In addition, the position of excitation on the string affects the relative proportions of these partials, imposing another formant characteristic on the sound.

These difficulties were encountered in initial tests on plucked string intrments, and seemed to indicate that the apparent formant behaviour would be manifested very differently over a three octave range. However tests on bowed instruments have showed more consistency.

The treble viol was chosen, using open strings, because it is correctly supported between the knees; bowing with one hand enables the lone experimenter to operate the analyser with the other hand. The open strings cover a range from low D, approx. 147 Hz, to D 588 Hz. The position of the filter in the cepstrum was expected to vary with the excitation frequency, but it was found that increasing the quefrency at lower frequency excitation allowed harmonic excitation characteristics into the spectrum. The position of the filter was therefore kept constant for all excitation frequencies, with the position determined by the

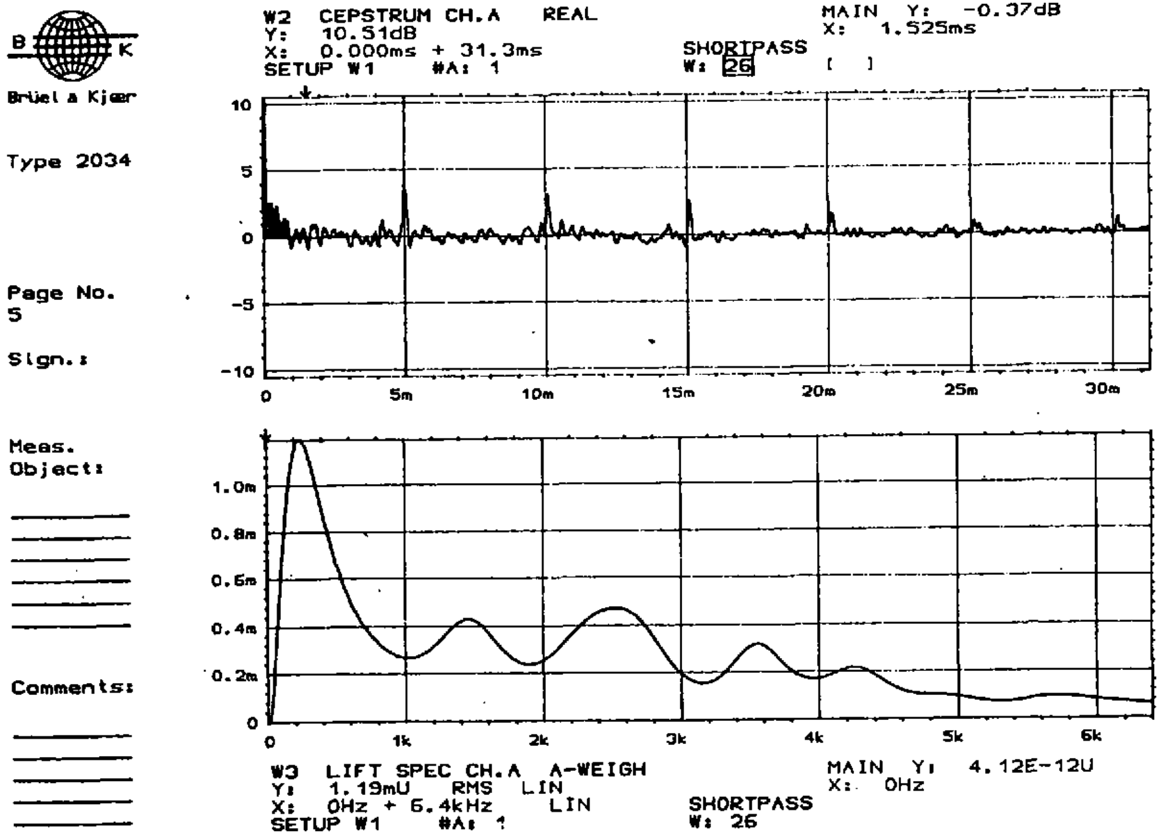

Figure 2: Cepstrum and liftered spectrum for treble viol, fifth string bowed.

requirements of the highest excitation frequency (figure 2). There are clear broad similarities in the patterns from all excitation frequencies, and it appears that the technique may well be applicable to bowed string instruments, with a single test at an an arbitrary frequency providing information which is characteristic of the instrument as a whole.

WIND INSTRUMENT FORMANTS

It was not expected that the method would provide meaningful information about the sound of wind instruments, since the pitch is determined by the characteristics of the air column and the sound radiated without the resonating mechanism of a stringed instrument body. The air column is changed as the pitch is changed, and therefore is unlikely to have a consistent effect on the sound. On the other hand, the tone of different wind instruments is recognisable.

Tests were carried out on a clarinet, which has a wide range (over three ocatves) and a wide interval (a twelfth) between registers. The three basic registers, and the intermediate "break" range, have tonal different characters. The notes initially tested were closely related either in musical pitch, being separated by exact octaves, or in the air column used, using the same fingering with only the register hole opened or closed. A selection of other notes was then tested.

As expected, a consistent formant character was not observed. In addition, there was difficulty in identifying the correct filter position for isolating formant character from excitiation frequency, although a rather high filter position (but still below the first excitation quefrency) resulted usefully in a spectrum which demonstrated very clearly the odd-harmonic nature of clarinet tone, which is often difficult to see in the complete spectrum. However, a consistent pattern of three formant peaks emerged, at frequencies which depend on the excitation pitch but are not simply related to it.

CONCLUSIONS

Initial tests indicate that the use of the filtered cepstrum to provide formant information is a valid method for investigating musical tone in some circumstances. It is hoped that a means of measuring many different instruments simply and rapidly will assist in relating constructional features to musical sound.

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