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SOME ACOUSTICAL CHARACTERISTICS OF RENAISSANCE REED INSTRUMENTS

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1. INTRODUCTION

In his book "Instruments of the Middle Ages and the Renaissance" [1] David Munrow catalogued the many and varied musical instruments which were used in Western European music up to the end of the sixteenth century. He remarked that, with the current revival of interest in Renaissance music, these instruments were enjoying a new lease of life, and were well on the way to becoming more popular and widespread than they ever were during the Renaissance. This was written fifteen years ago; in the intervening period the number of manufacturers of reproduction instruments has grown dramatically.

While the acoustical principles governing the behaviour of instruments of the Renaissance are obviously the same as those which apply to the modern orchestral families, there are many significant differences in detail. These differences arise partly because the manufacturing techniques of the early instruments were in general much less sophisticated than those of the present. It must be remembered, however, that the musical taste of the time apparently relished bright, nasal timbres which were considered unacceptably coarse by later generations. This aesthetic divergence is particularly striking in the case of the reed woodwinds which are the subject of this paper.

The normal method of classification of reed woodwinds is to divide the group into conical and cylindrical families, with subdivision into single and double reeds. Single reed instruments were relatively insignificant in the Renaissance. Of the double reed instruments, the conical shawm was by far the most important. In the sixteenth century cylindrical crumhorns and racketts also enjoyed some popularity, as did the wind-capped shawm known as the rauschpfeiffe.

2. FREQUENCY SPECTRA

Sound spectra were measured for the lowest notes (all finger holes closed) of three crumhorns. The measurements were carried out in a moderately reverberant laboratory; details of the measurement technique are described elsewhere [2]. Fig. 1(a) shows the spectrum of a Körber tenor crumhorn playing C_3; Fig. 1(b) shows a Woods alto crumhorn playing F_3; Fig. 1(c) shows a Moeck soprano crumhorn playing C_4. For comparison, Fig. 1(d) shows a modern Howarth oboe playing C_4.

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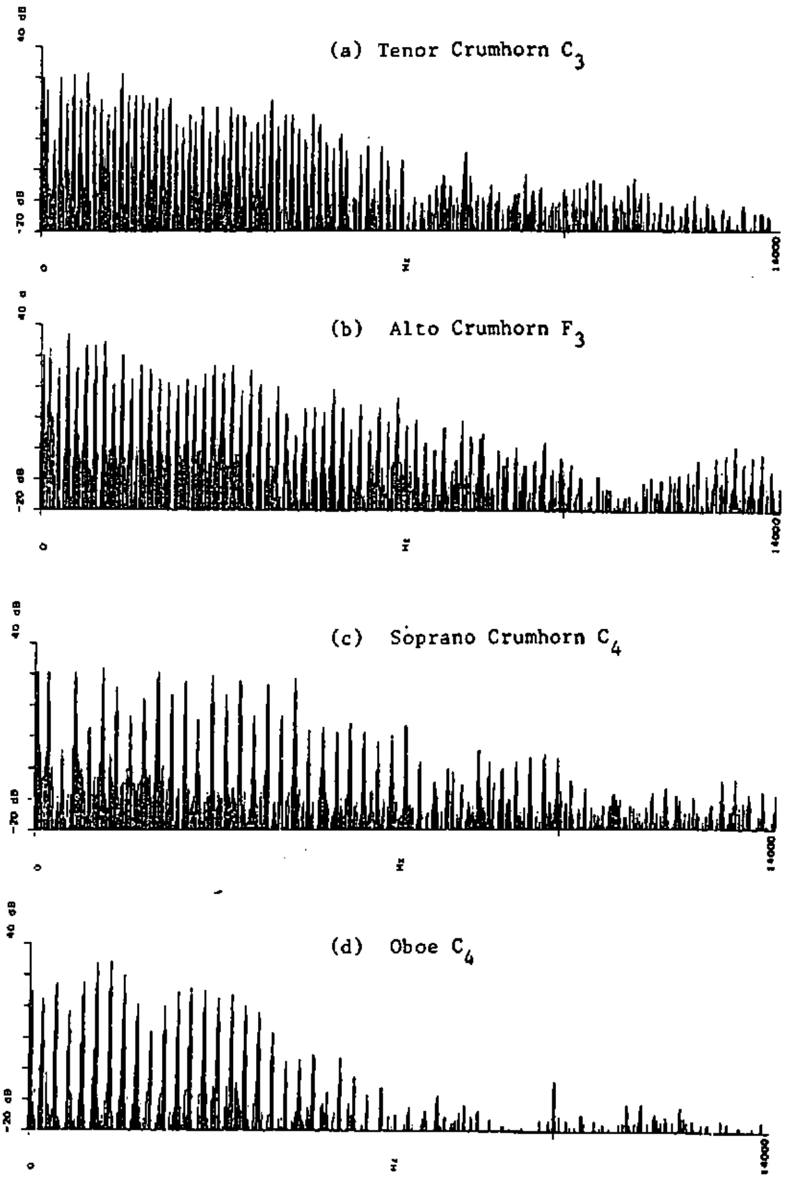

Fig. 1. Frequency spectra of crumhorns and oboe.

The striking feature of each of the crumhorn spectra is that the harmonic series continues with significant amplitude into the very high frequency range of the audible spectrum. For the soprano crumhorn C_4 the 38th harmonic, with frequency just under 10 KHz, is less than 30 dB down on the fundamental. In sharp contrast, the oboe spectrum illustrates a much more refined sound for which the 18th harmonic is the last within -30 dB of the peak amplitude (in this case the 6th harmonic).

The double reed in the crumhorn is enclosed within a chamber (the windcap). To sound the instrument the player blows through a slot in the windcap. The controlled damping of the reed of the oboe by the lips of the player is one of the factors contributing to the reduction in high harmonic content in comparison with the uncontrolled reed of the crumhorn.

The rackett provides an ingenious method of obtaining a long tube within a small volume. Nine parallel cylindrical channels are drilled into a wooden block and connected alternately at top and bottom. Thus although the great bass rackett is only 40 cm high its lowest note is C_1, only a tone above that of the contrabassoon. The spectrum of this note is shown in Fig. 2. Although the sound is radiated through a hole of only 5 mm diameter, there is still a significant output of energy at the fundamental frequency of 33 Hz. Over 130 harmonics are distinguishable in this remarkable spectrum.

The conical shawm developed through the Renaissance, from the pungent sound of a relatively uncontrolled reed which still characterises many folk shawms of the present towards a more veiled and flexible sound obtained by increased lip control of the reed. The later sound is typefied by the spectrum of Fig. 3(a). The rapid decrease of harmonic amplitude above 5 kHz, and the strong suggestion of formant structures below this frequency, are features reminiscent of the oboe spectrum of Fig. 1(d). The addition of a windcap to the shawm is the essential feature of the rauschpfeiffe; the absence of reed control again results in a fiery sound rich in high harmonics (Fig. 3(b)).

3. ODDNESS PLOTS

To the extent that a woodwind instrument behaves like a simple cylindrical bore closed at the reed end, the tube resonances should occur at frequencies given by

$$f_n = nf_1 \quad : \quad n = 1, 3, 5......$$

To examine the applicability of this idealisation to the crumhorn and the rackett, the spectra were re-evaluated to calculate the oddness

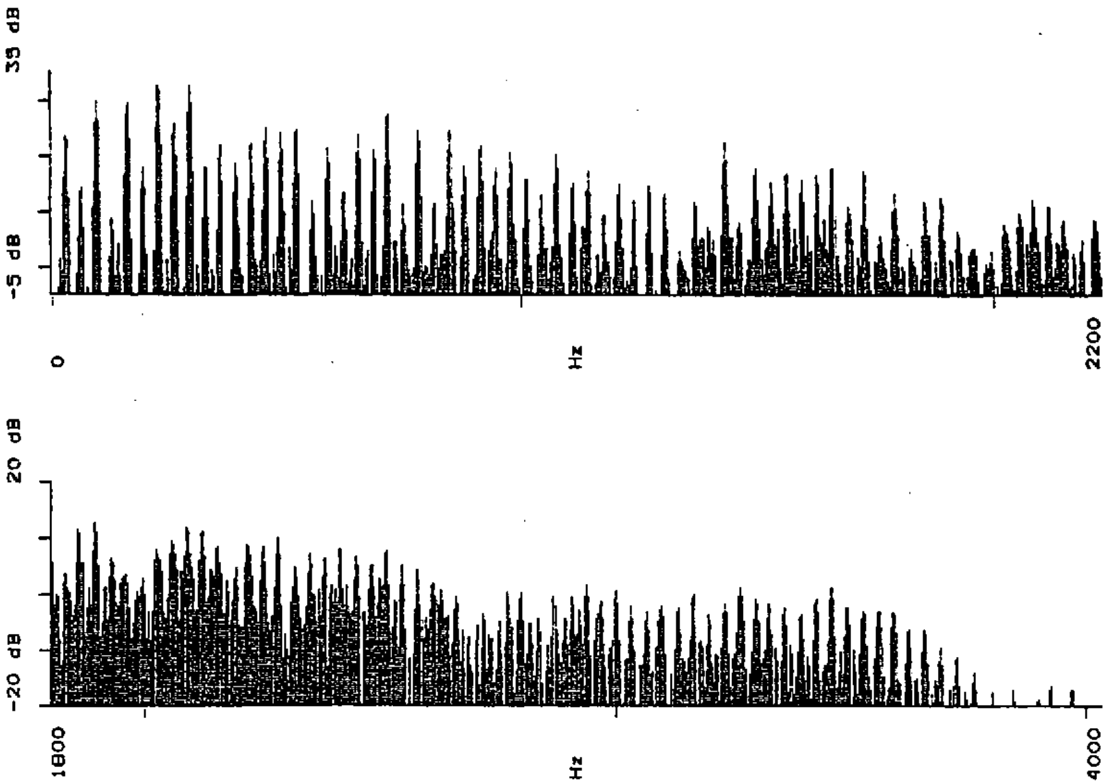

Fig. 2. Frequency spectrum of great bass rackett playing C_1. A single measurement is displayed in two overlapping frequency ranges.

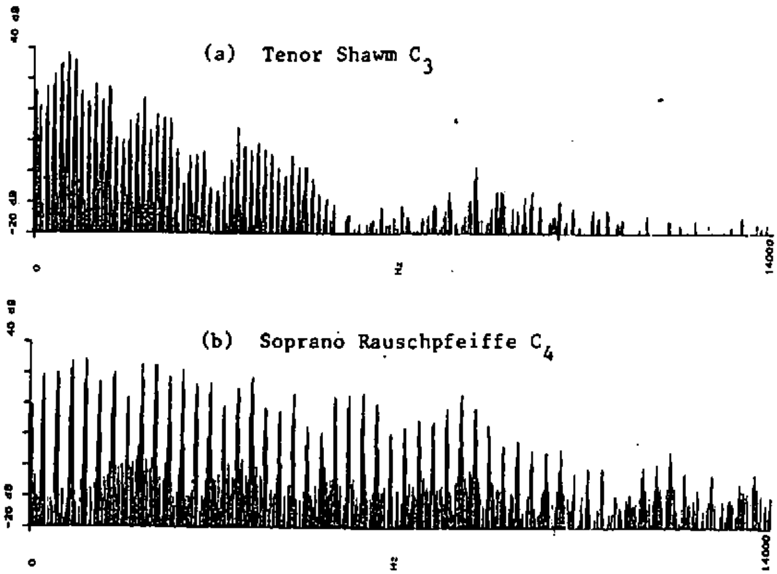

Fig. 3. Frequency spectra of shawm and rauschpfeiffe.

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parameter

$$\Omega = \tfrac{1}{2}(A_{n+1} + A_{n-1}) - A_n \quad : \quad n = 2, 4, 6......$$

where A_n is the sound pressure level (in dB) of the nth harmonic.

Fig. 4(a) shows a plot of Ω against n for C_3 on the tenor crumhorn. Up to n = 10 odd harmonics are indeed stronger than even harmonics; at higher frequencies, however, the tendency is for the reverse to be true. The tenor shawm spectrum should show no preference for odd over even harmonics, since the shawm has a conical bore. It is seen from Fig. 4(b) that this is approximately true for the first few harmonics only.

The suggestion of a cyclic variation of Ω with n in Fig. 4(a) is stronger in the oddness plot of the great bass rackett (Fig. 4(c)). One possible explanation of this behaviour is that the tube resonances are more widely spaced than a true harmonic series. To test this hypothesis the input impedance of the great bass rackett was measured by a method described elsewhere [3]. The deviation of the resonance frequencies from a true harmonic series was evaluated by plotting $\Delta = f_n/f_1 - n$ as a function of n, for n = 1, 3, 5.... (Fig. 5).

A comparison of Fig. 4(c) with Fig. 5 offers some limited support to the hypothesis. For $n \doteq 12$, $\Delta \doteq 0.5$; the resonance peaks are then half way between odd and even harmonics, and neither set are favoured. Ω passes through 0 at about this value. For $18 \leq n \leq 24$, Δ fluctuates around 1; for $\Delta = 1$ the resonances coincide with even rather than odd harmonics, driving Ω negative.

It must be borne in mind, however, that the impedance measurements yield passive resonance frequencies, and the influence of the reed is allowed for only by the insertion of a compensatory volume V_R at the input. The effective volume of the reed under playing conditions is difficult to estimate. The static volume of the reed with the upper end closed was 1.2 mℓ; using this value for V_R gave curve (a) in Fig. 5. Increasing this volume to 3.6 mℓ gave curve (b). Further studies of the effect of reed volume on resonance frequencies are in progress.

REFERENCES

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[3] D.M. CAMPBELL, "Input impedance measurements on historic brass instruments", Proc. I.O.A. 9 (3), 111-118 (1987).

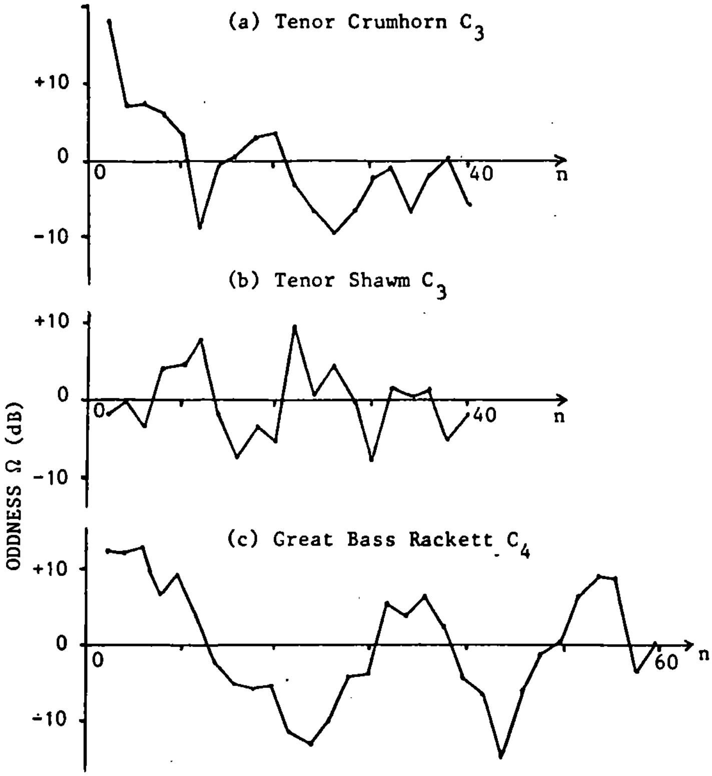

Fig. 4. Oddness plots for crumhorn, shawm and rackett.

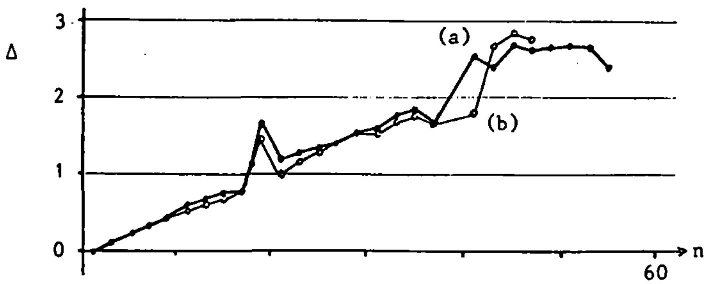

Fig. 5. Deviation Δ of resonance frequencies of great bass rackett from odd harmonic series.
(a) filled circles $V_R = 1.2$ mℓ ; (b) open circles $V_R = 3.6$ mℓ.