Proceedings of the Institute of Acoustics

SOME OBSERVATIONS OF THE OUTPUT AND DISTRIBUTION OF ORGAN SOUND.

P. J. Comerford Microcomputer Music Research Unit, University of Bradford
L. K. Comerford Microcomputer Music Research Unit, University of Bradford

1. INTRODUCTION

The authors are engaged in a European-funded research project to examine, and propose remedies for, the shortcomings of pipeless organs. This work is in three areas:

- sound quality as influenced by synthesis hardware
- sound output and distribution
- sound control interfaces

In the second of these areas, sound output and distribution, it was considered advisable first to examine the sound output and distribution characteristics which are an integral part of pipe tone, since pipe tone is the reference point by which pipeless organs are judged. This paper is based on a part of this ongoing work.

2. PIPES IN ORGANS

The way in which sound output from a pipe in a pipe organ is be perceived by the listener will be influenced by a number of factors related to the acoustic environment in which it is heard. In addition to those which affect any sound – such as the proportion of direct to indirect sound, and the colouration imparted by accentuation or attenuation of particular frequencies – there are some which are specific to organs. Some of these are summarised here, to provide context for the measurements of pipe output to be reported below.

Organs are laid out in a variety of different patterns, dependent upon tradition, style, and upon more pragmatic considerations like the space available. Similar influences influence the position of the pipes within the building

2.1 Pipe Layouts within Departments

Most organs are divided into departments, with the pipes of each department grouped together and controlled principally from a particular keyboard. In all but very old organs, the layout of pipes within each department can be symmetrical, with no need to position the pipes above the corresponding note. A common layout is for each rank of pipes to be mounted in a line, parallel with the front of the organ. In some cases, the pipes are arranged into c and c# sides. The size of each pipe tends to determine spacing between pipes of a rank, although the pipes of smaller ranks are often allocated the same space as is taken by a large-sized stop, so are more widely spaced. Where ranks are lined up one behind the next, the gap between the ranks varies with the space available. Where there is space to position pipes so that they are not blocked badly or completely by one another, the sound from the pipes is able to reach beyond the pipe area with increased clarity. Some pipes, especially the largest ones, may be positioned off the main of the main soundboard.

2.2 Departmental Layouts in Relation to One Another

- **Horizontal plane layout**
  The layout of departments in relation one to another is often determined largely by the height available. This has in turn influenced the development of different styles of organ tone depending on where the organ is traditionally placed within the building, and to how much height there is therefore available. Height is restricted when organs are sited in a recess at the side of a chancel, as in many English Parish Churches, or in side aisles with low roofs. In such cases, the departments have to be laid out in a horizontal plane, more or less on a single level. This means that one department will inevitably by placed behind another. For example a common departmental layout in instruments of average size with restricted height is to place the Great department at the front of the organ, the Swell department in an expression box behind and often slightly above the Great, and for the Pedal department to be placed at the back and sides. Even where height is available, some organs adhere to this tradition of layout and of position within a chambered area to the side of the chancel. Very little direct sound will reach the listener from organs with a blocked or semi-blocked layout of this nature. The sound is heard through the filter of other pipes. This disperses the sound, and means that sounds may tend to become more indistinct when heard from a distance than in a more open plan; in particular, high frequencies are heavily attenuated. Indirection will be further increased where the pipes are located off the main axis of the building.

- **Vertical plane layout**
  Where height is not a restriction, departments can be placed in a vertical rather than a horizontal plane. Hauptwerk is often central, with Oberwerk above and Brustwerk below, above the music desk; Pedals are on either side. None is thus positioned behind another. The organ disposition is therefore in general taller, wider, and shallower than with a horizontal plane instrument. The pipes of each department are commonly housed in a shallow case with a roof. They may be in rows parallel with the front of the organ, or they may be laid out from back to front, with small pipes at the front and large at the back so that no pipes are blocked from speaking directly forwards.
  A higher proportion of direct sound tends to be heard from such organ; perceptually, the tones seem to have greater clarity and be less dispersed. Where the instrument is sited on the main axis of the building, for example in a west end gallery, this effect is accentuated.

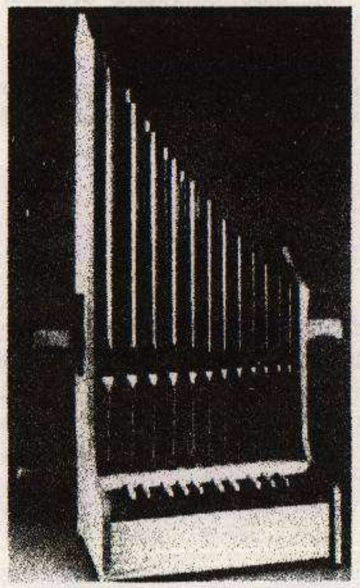
3. METHODS

The measurements reported in this paper were made using a portative pipe organ sited in different locations:

- in an acoustic anechoic chamber of 9.9 cubic metres
- in a small empty hard-surfaced chamber-like area of 13.2 cubic metres

(In addition, some of the measurements were repeated in a chamber-like area at the end of a larger space, with the presence of additional pipes; these measurements are not reported in this paper.)

3.1 Portative organ



The use of the acoustic anechoic chamber placed restrictions upon the size of instrument which could be measured. In addition it was important that the pipe-blowing mechanism should not introduce extraneous noise. The pipe organ used in the measurements was a 2' portative instrument; this means that the resonating length of the longest pipe was 2', which sounds at a frequency of 262Hz. The organ has 25 pipes, mounted in two parallel rows on behind the other in a wooden rack.

At the back of the mounting is a hand-blown vertical bellows; the air is supplied to the pipes by closing the bellows in succession of single strokes. Such a wind supply is silent, but does not provide as steady a supply as an electric blower. Preliminary tests ensured that a steady enough wind supply could be obtained to produce broadly repeatable results from the each pipe.

The pipes in the organ were used in two ways in the measurements:

- **Solo mode**
  In this mode, only a single pipe was left in the soundboard at any one time. Pipes with fundamental frequencies of 329Hz (note e3) and 659Hz (note e4) were used. Both of these pipes stand in the back row of the portative organ.

- **Combined mode**
  In this mode, all pipes were present in the soundboard, although only one pipe was played at a time. Since the pipes measured were in the back row, they were screened by the front row of pipes when played in combined mode. The measurements of sound output in combined mode could therefore be compared with those taken in solo mode to look for differences in spectra which might indicate the effects of deflections and resonances from other pipes.

3.2 Measurement Procedure

In each of the locations, and in each mode, the output from each pipe played was measured in 1/3 octave frequency bands from 250Hz to 20KHz. The measurements were taken at between 0.8m and 0.9m distance from the sounding pipe, in three positions:

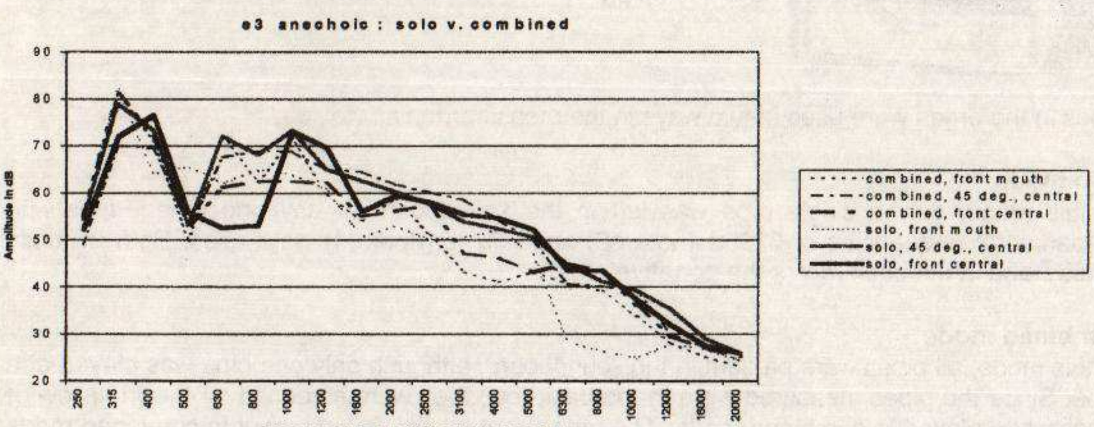
- in front of the pipe at mouth height
- in front of the pipe at a height half way between the mouth and the top of the pipe
- at a 45 degree angle in front of the pipe, at a height half way between the mouth and the top of the pipe. (In order to avoid the sound being obscured by the vertical wooden struts at either end of the case, the pipe of 329Hz fundamental frequency was measured 45 degrees to left, and the pipe of 659Hz fundamental frequency was measured 45 degrees to right.)

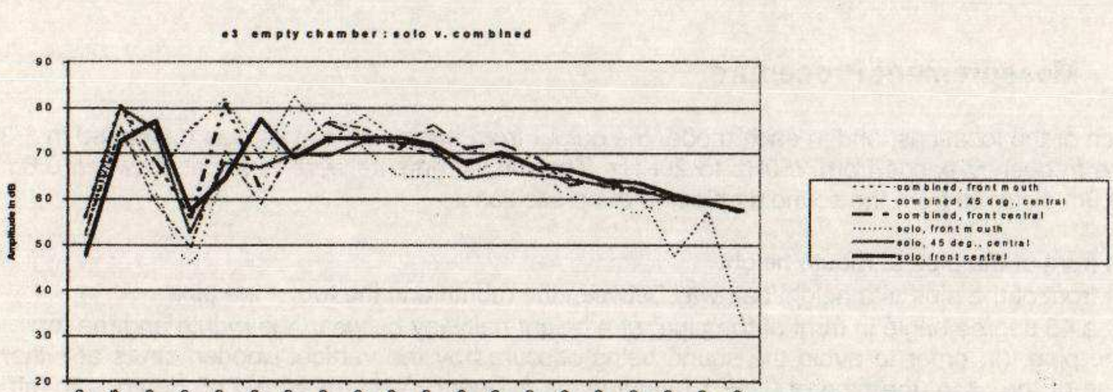
Additional measurements were taken 0.3m above the top of the pipe sounding at 659Hz fundamental frequency; these measurements are not reported in this paper.

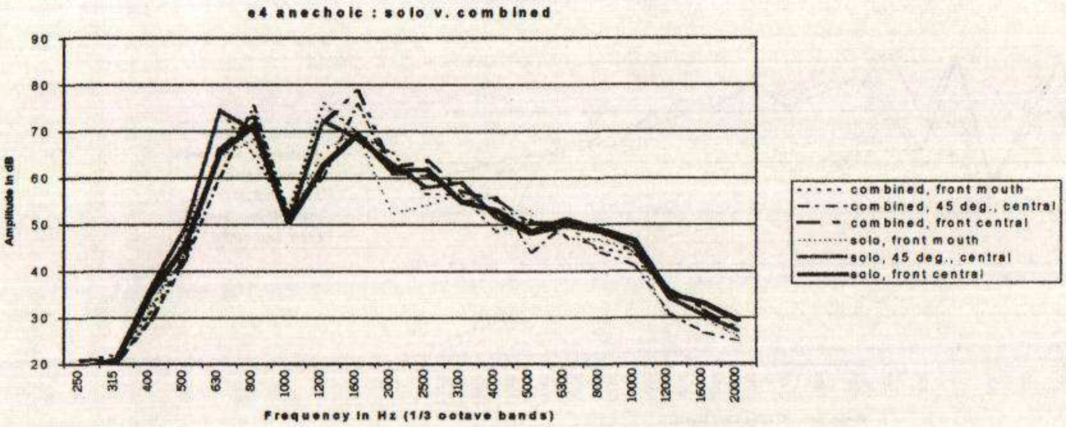
Where a range of output values was measured for a frequency band, the average value was used in calculating the results reported in this paper, although the full range of values was recorded for possible later use.

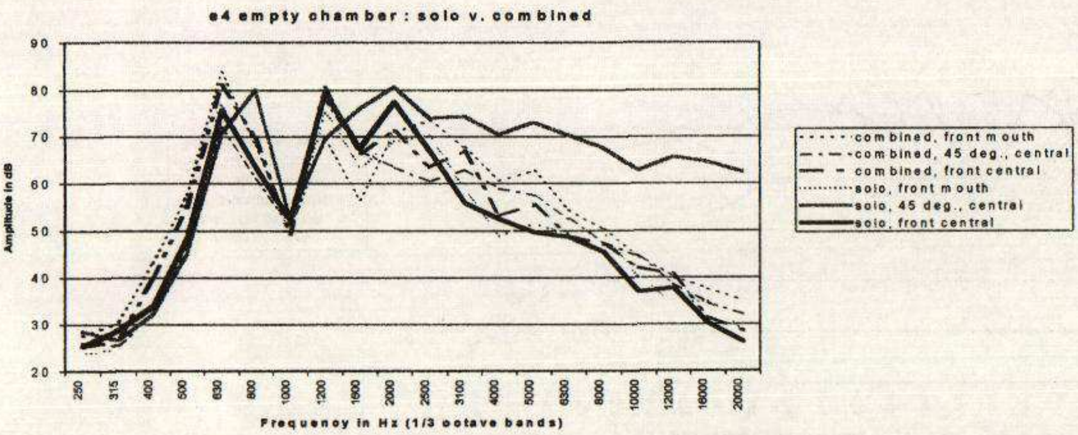
4. RESULTS

A comparison between the measurement taken in solo and combined modes showed no very marked differences between the output of the pipe sounded alone and in the presence of other pipes, either in terms of overall output or in relation to outputs at different angles and heights. There was a slight tendency for the output of combined mode to the higher than that from solo mode. The following four figures illustrate this.

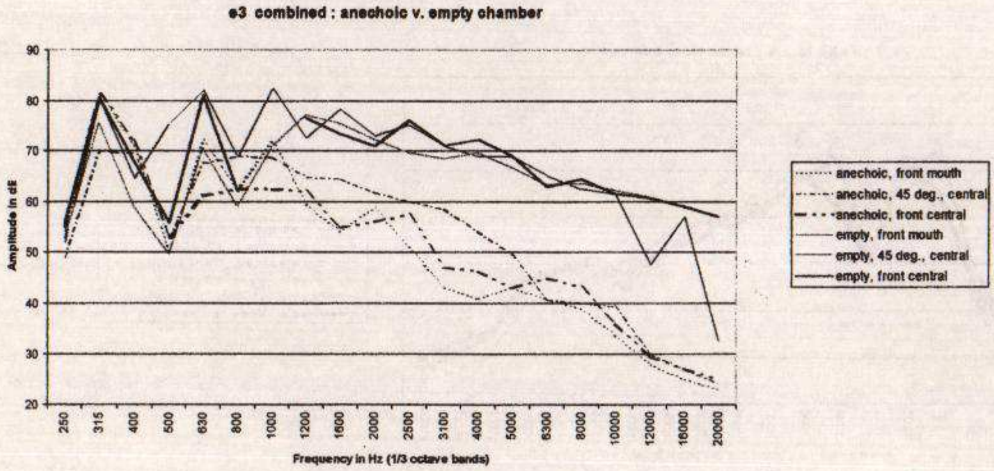


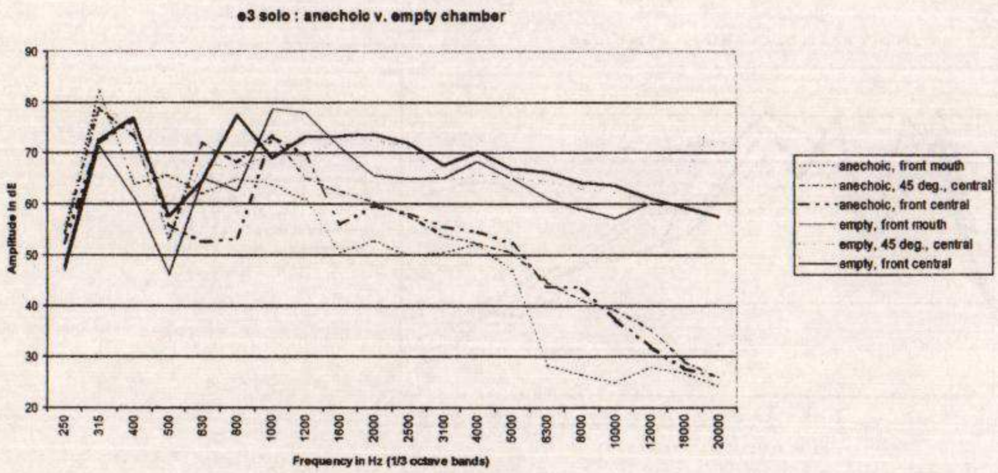






A comparison of the measurements taken in the acoustic anechoic chamber with those from the hard walled chamber show that higher measurements were recorded in the latter venue, most particularly at higher frequencies. This effect was plain from both pipes, but was more marked at 329Hz fundamental frequency. The following two figures illustrate this effect.





No clearly identifiable effect on the patterns of sound dispersion, shown by large differences in measurements taken at different angles around the pipe, was associated with either of the playing modes or with either location for either note.

5. DISCUSSION

The idiosyncratic character of the pipe blowing mechanism means that only very marked trends are likely to show up, since small differences in blowing pressure will tend to cancel out smaller effects. Even where marked trends are apparent, it is therefore sensibly cautious to view the results as indicative rather than significant. Similarly, the limited size and consequent high pitch of the pipes measured, and the fact that they were all metal flues, should be borne in mind when discussing the wider applicability of the results to pipes of other pitches and types. In addition, most organs will contain more pipes than the portative organ.

The increase in output level measured in the hardwalled empty chamber in comparison with the acoustic anechoic chamber is a predictable result, given that measurements in the former location will include indirect reflections as well as sound measured directly from the sound source. In organ installations where there are hard flat surfaces close to the pipes, this will be an important factor affecting the perceived tone of the instrument; for example, in an organ with vertically disposed departments with pipes laid out with as little blocking as possible, a case placed around the pipes of each department will throw amplify and project the sound forward, which means that the same output of sound can be achieved at a lower wind pressure for blowing the pipe [1], with consequent effects upon the tone.

This supports the empirical observations of the authors that the quality of perceived organ tone is enhanced when pipes (or loudspeakers) are placed in the context of hard surfaces which can produce a high proportion of indirect sound over a wide frequency range.

It should be noted that where the chamber walls enclose a large number of pipes, with a small opening for sound egress, the amplifying effects within the chamber itself of the hard surfaces are mitigated to the listener beyond by blocking from other pipes and the difficulty of getting the sound out of the chamber.

There was a slight indication of increased output when a pipe sounds in the presence of others. The absence of a more pronounced effect may in part be due to the fact that only a small number of pipes were present and that they were all of high frequency. This would mean that there was no opportunity for sympathetic resonance of higher partials of lower pitched pipes.

It has been observed empirically by the authors that, in a large pipe organ, where a large chord is sounded, a continued low level resonance is detectable from within the pipe chamber when the chord is released; if this is sympathetic resonance from non-sounding pipes in a large instrument, it could be that the small pipes played individually in the measurement experiments do not produce a sufficient volume of sound to excite such sympathetic resonance.

No identifiable effect was discernible, from the outputs measured at different positions, on patterns of sound dispersion in either playing mode or in either acoustic. It should be noted that because of the construction of the portative organ, measurements could not be taken from the back of the pipes, nor from a side angle of 90 degrees.

Work is in progress to measure the output and distribution of sound from pipes sounding within installed organs, to assess the effects of the position of the pipes within the building. The measurements reported in this paper, which were taken with small pipes in experimental locations, will thus be supplemented with data from less controlled but more typical situations and using a wider range of pipe types. Together the measurements will form an interesting complement to the measurements of the loudness of organ choruses reported by Oswin and Rock [2].

When the study to measure the output and distribution of sound from pipe organs is complete, the findings will be used in a further stage of the project; the aim of this is to contrast the output of sound from pipes with that from the pipeless organ, in order to propose improvements to the latter. A yet further stage of the research programme will consider effective electronic means, both internal and external to the synthesis system of the pipeless organ, of enhancing the distribution and perception of pipeless organ tone in unfavourable acoustic environments. This work will be reported elsewhere.

6. REFERENCES

[1] Norman, J. The organs of Britain. David and Charles 1984.
[2] Oswin, J. R., and Rock, G.A.A. *Simple measurements of sound pressure levels of pipe organs.* Proceedings, Institute of Acoustics, Vol. 19, pt. 5, 1997, pp. 327-332 (International Symposium on Musical Acoustics, Edinburgh)

Acknowledgements
The work reported in this paper was in part carried out with funding from European Commission Directorate General 12, under the CRAFT programme. Particular thanks are due to Mr. R. Wood and Mr. J. Askey of J. Wood and Sons Ltd, one of the partners to the CRAFT programme, who provided the portative pipe organ from the Early Music Shop for use in the measurements, and advice about the experimental method; to Mr. D. Spinks and Mr. J. Browning of the Department of Electrical and Electronic Engineering at the University of Bradford for facilitating use of the anechoic chamber; to Mr. D. Beebe and colleagues and Mr. N Hulley for assistance with transport; and to Mrs. Lynda Harrison.