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THE NEED FOR CALIBRATION IN THE COARSE-FINE ACOUSTIC TELESCOPE

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1. INTRODUCTION

For a given aliasing length the coarse-fine array yields a sharper image than an equispaced array employing the same number of microphones. Indeed results are presented here in which a 10 microphone coarse-fine array shows a great improvement on a 14 microphone equispaced array. However, in extracting an image of greater detail from an equivalent or less amount of microphone data the coarse-fine array is seen to be much more sensitive to errors in microphone placement. Using correlation techniques corrections are calculated and applied within the telescope computational process and errors as great at 5% of the separation distance in the microphone position can be virtually eliminated. To enhance the image quality further it was felt that the quantisation in time due to the rate of sampling should be reduced. Since a higher sampling frequency was ruled out by hardware limitations a method of linear interpolation was devised; however, the results presented here show only a marginal improvement by its use.

The noise under investigation is likely to contain bursts of increased activity and other off focus signals may enter the system such as wind noise or electrical disturbance. For differing focus positions such activity may appear in the time series or may be excluded by the "tilt" of the delay table values and this may cause the burst to have the illusion of structure which could obscure the true source shape. To improve the quality of the source image a differential delay table could be used in which wave fronts representing signals from different focal points are adjusted to occupy as nearly the same area in the data buffer as possible so as to make uniform the influence of the transient disturbances described above.

2. SENSITIVITY TO MICROPHONE PLACEMENT ERROR

The equispaced array is computationally equivalent to a coarse-fine array in which the same microphones are used for both the coarse and fine sub-arrays. Signals from the two sub-arrays are summed, applying appropriate shifts from the delay table, and then are correlated using transform methods. The correlation may thus be seen as the sum of all the combinations of individual correlations of one microphone taken from each sub-array. It has been shown[1] that these correlations are characterised by the microphone separations and that for a 14 microphone equispaced array some of the 27 different channel separations ranging from − 13D to + 13D may be represented by as many as 13 separate terms. Because of the multiplicity of contributions for each spacing errors in microphone placement will to some extent be averaged out. It is seen that the image of Figure 1(e), in which there are no deliberate microphone errors, is only slightly degraded in Figure 1(d) where deliberate errors have been introduced. In the case of the coarse-fine array in contrast each microphone separation is represented by only a single correlation term. In the 10 microphone example presented here, 55 different separations are represented.

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In the absence of averaging, the sensitivity to microphone misplacement is much more acute and it is seen that the image in Figure 1(a) is severely degraded.

The calibration process is based on the use of a nominal point source of sound; a loudspeaker was used for these tests. One microphone is chosen as a reference channel and cross correlations are taken of the signals from this and each of the other channels in turn. The positions of the correlation peaks are compared with the delay table values constructed from the nominal sensor positions. The errors in peak positions can then be used to compute and effective correction to be made in each sensor position. At the same time these corrections take into account other errors such as misalignment between the recording and replay heads on the tape recorder. If two calibration sources are used both radial and lateral corrections can be computed. However, a major contribution comes from radial errors and lateral errors are unlikely to be sufficiently gross for their second order effects to become noticeable. Figure 1(b) shows the effectiveness of the calibration algorithm in producing a sharp source image - in this case an image of the loudspeaker itself.

3. THE INTERPOLATED DELAY TABLE

Figure 1(c) shows the results of using an interpolated delay table for analysing coarse-fine telescope data. The true delay value will not in general be an integer and the error may be as much as half of one sample interval. An attempt is made to provide interpolation by allowing two samples to be selected and summed with weightings of 4-0, 4-1, 2-2 or 1-3, thereby hopefully limiting the effective rounding error to one-eighth of the sample and giving a similar effect to the quadrupling of the sample rate. To achieve this result the width of the delay table is increased by a factor of four and little modification is required in the routine which constructs the sub-array time series. It is unlikely that the further improvement in quality will be felt to warrant the increase in processing time.

4. THE DIFFERENTIAL DELAY TABLE

A conventional delay table is built of values which ensure that the various time series constructed from the wavefronts in the data buffer represent signals that originate simultaneously from the various focal points. Inevitably, the notional wavefronts over which signals are summed are shifted by the difference in the time of arrival of signals for different foci. The time series constructed from these wavefronts will be subjected to different ambient noise at the array. On the other hand, a differential delay table would introduce spurious doppler effects into the signals when they are emitted from a moving source. For stationary source, it is then possible to construct a differential delay table so that the source image is subjected to the same ambient disturbance when the array processes the signals from one focal point to another. For a differential delay table, the most tilted wavefront is selected as the reference and all other wavefronts will then be bounded and not lost when all wavefronts are shifted to the beginning of the data buffer to make more efficient use of the data. To choose a pivot point about which all other wavefronts could be made to coincide is quite arbitrary but choosing the common microphone in the case of the coarse-fine array seems to be a good compromise in most situations. No definite results have as yet been obtained on the use of differential delay table.

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5. CONCLUSION

It is shown here that a ten-microphone coarse-fine array can yield a sharper source image than a fourteen-microphone equispaced array for a given aliasing length. However, the coarse-fine array is more sensitive to errors in the microphone placement and must therefore be calibrated. The use of an interpolating delay table does not appear to be worthwhile in view of the substantial increase in computation time.

6. REFERENCE

1. J. Billingsley, "A Study of the Computational Principles of the Acoustic Telescope and Polar Correlation, with special reference to the elimination of aliasing"., March, 1978, Internal Report No. 7/78, Department of Electrical and Electronic Engineering, Portsmouth Polytechnic.

7. ACKNOWLEDGEMENT

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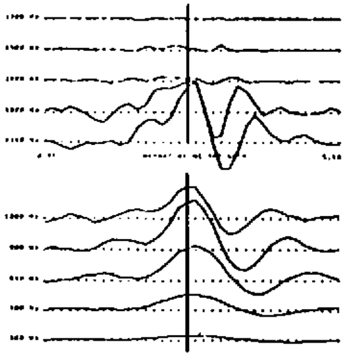

Fig 1a. Coarse-fine with errors - uncalibrated.

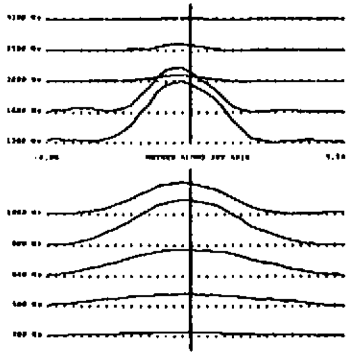

Fig 1d Equispace with errors.

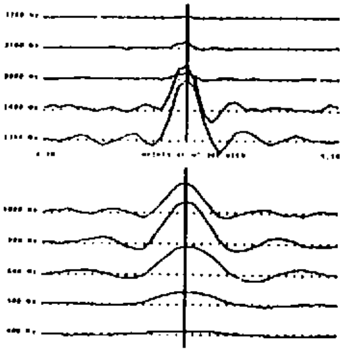

Fig 1b Coarse-fine with errors - calibrated.

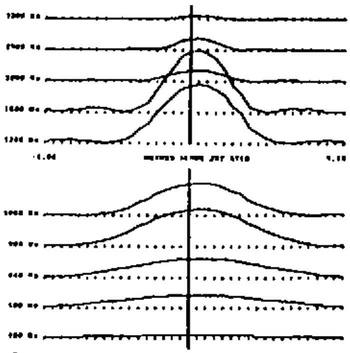

Fig 1e. Equispace without errors.

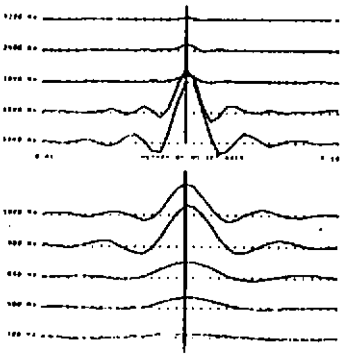

Fig 1c Coarse-fine with errors - calibrated and interpolated.

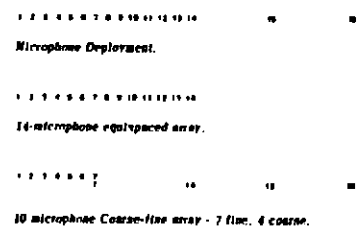

Fig 2 Microphone arrangement for comparison tests.