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CASE STUDIES USING CURRENT TECHNOLOGY STEERABLE LINE ARRAYS

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1. BACKGROUND INFORMATION

In the course of our work we have been fortunate to be engaged on a number of prestigious albeit difficult projects. I use the word 'fortunate' with tongue in cheek since the projects to which I am about to refer all have difficult acoustics.

A further complication has arisen in that all three projects, Paddington Station, Great Court British Museum and Birmingham New Street Station were due to be completed and commissioned by this September giving just sufficient time to report the results. In the event, for a variety of different reasons, none are complete. This Paper will therefore concentrate on the design considerations and processes.

2. STEERABLE ARRAYS

It would be fair to say that current steerable arrays 'employ new technology to exploit an old principle'.

The old principle is that of constructive and destructive interference of two or more coherent sources which is embodied in the following well known formula:

$$R\theta = \frac{SIN[NkdSin\theta]}{NSin[KdSin\theta]}$$

where: $R\theta$ = Angular response (vertical plane only)
N = Number of devices in the array
$k = \frac{\pi f}{c}$ where f = frequency and c = velocity of sound
d = device spacing
θ = angular displacement in radians.

From the foregoing it can be deduced that as N and f increases then the unit becomes more directional in the vertical plane. The interference effects however are static since they are dependent upon the relative positions of the transducers.

This dependence upon column length and frequency means that the directivity of the unit is not constant over the frequency range. This problem was partly overcome a number of decades ago by what is known as tapering. This effect endeavors to, by filtration, modify the column length with frequency i.e. as frequency increases then the effective length of the column reduces. Even so, 'constant' directivity was still not possible.

The ability to steer the array again is not new. In an attempt to produce a loudspeaker that did not detract from the vertical lines of Westminster Abbey, P.H. Parkin et al designed a column loudspeaker that bent the output beam downwards thereby allowing the loudspeaker to be mounted flush on the structural column but projected its main output level downwards. This design was successfully used in Canterbury Cathedral and subsequently by AIRO Ltd. who were given licenses to exploit the patent in York Minster and other major religious buildings. In Parkin's design he contrived that only was the transducer spacing not regular but the phase angle was also varied. Once again the steering is static.

That the principle has been around for a very long time is no discredit to present designers who have nobly employed the latest digital processing to control the effects of tapping and beam bending.

Suffice it to say that the latest technology is able to focus and bend or both in combination.

It is necessary to note however that the basic principles shall apply in regard of directionality and frequency dependence. Hence, some of the latest technology columns are extremely tall (3-5m).

3. DESIGN CONSIDERATIONS

Since most of the spaces/systems in which we are involved have safety considerations, then either or both of BS5839: Part 8 or BSEN60849 will be cited.

Both Standards have intelligibility requirements and hence any design must include a prediction or at least an estimate of this quantity.

Hence we need to know the RT in the space together with the spatial S/N (signal-to-noise ratio) and D/R (direct-to-reverberant ratio).

Under normal circumstances we would calculate the sound power output of the device from:

$$L_w = L_{p,d} - 10Lg\frac{Q}{4\pi r^2}$$

where: L_w = Sound Power Level dB re 10^{-12} Watt
$L_{p,d}$ = Direct sound Pressure Level dB re 20μPa
Q = Directivity Factor
r = distance form source (m).

$L_{p,d}$ is deduced from the sensitivity of the device given as dB @ 1W@1m.

The reverberant level $L_{p,r}$ is then calculated from:

$$L_{p,r} = L_w + 10Lg\left(\frac{4}{R_c}\right)$$

where: R_c = room constant m^2.

The problem arises in that the steerable arrays may be focused at a distance from the source hence instead of the usual expanding wave front it is contracting - see figs. 1a and 1b.

An estimate of the sound power output of the device may be made by assuming that the product of area and pressure is a constant (see fig. 2).

If this is the case then we may write:

$$L_{p,d} = L_w + 10Lg\frac{A}{4\pi r^2}$$

where: A = included beam area. Hence $L_{p,r}$ may be calculated in the normal way from Lw.

Unfortunately theory and practice are not in harmony. Firstly, at the focus $A \Rightarrow 0$ and hence gives an anomalous result. Secondly, the product of area and pressure is not constant.

Hence although the foregoing provides a useful check and a check that should be made, we are reliant upon a modeling simulation. At present we believe that only CATT Acoustics software models latest technology steerable arrays. As these devices assume high profile, it is expected that other modeling and simulation software will include steerable array technologies.

Once armed with the relevant acoustical and noise data, intelligibility is predicted by AMS Acoustics RASTI computational engine.

4. PROJECTS UNDER CONSIDERATION

We are presently working on three major projects, Paddington Station, Great Court British Museum and Birmingham New Street.

The following table provides the expected RASTI performance together with the mid-frequency reverberation time.

Space	Mid-Frequency RT (secs.)	RASTI		
		Min.	Av.	Max.
Paddington	Measured (3.5)	0.10	0.41	0.87
Great Court	Calculated (7.0)	0.08	0.52	0.70
Birmingham New Street	Measured (2.7)	0.60	0.70	0.82

As stated earlier at the time of writing this paper none of the systems have been commissioned. Some sample measurements have been made at Paddington and they were in the range 0.40 to 0.85.

Speech from the Paddington system at an early trial was excellent and a massive improvement over the existing distributed system.

5. FINAL DISCUSSION

These types of units are most applicable in large reverberant spaces where the reduction in sound power output reduces the degrading effects of reverberation products.

The highly directional properties of these devices bring with them two potential problems.

Firstly, because they are directional then coverage can often be patchy which can be a problem if the space is beset with high noise levels. For certain types of spaces such as railway stations, this can be an advantage by maintaining good local coverage.

Secondly, considerable care is required when pointing the devices since at the focus point with high superficial energy density the potential for reflections turning into echoes is considerable.

Normal Line Array

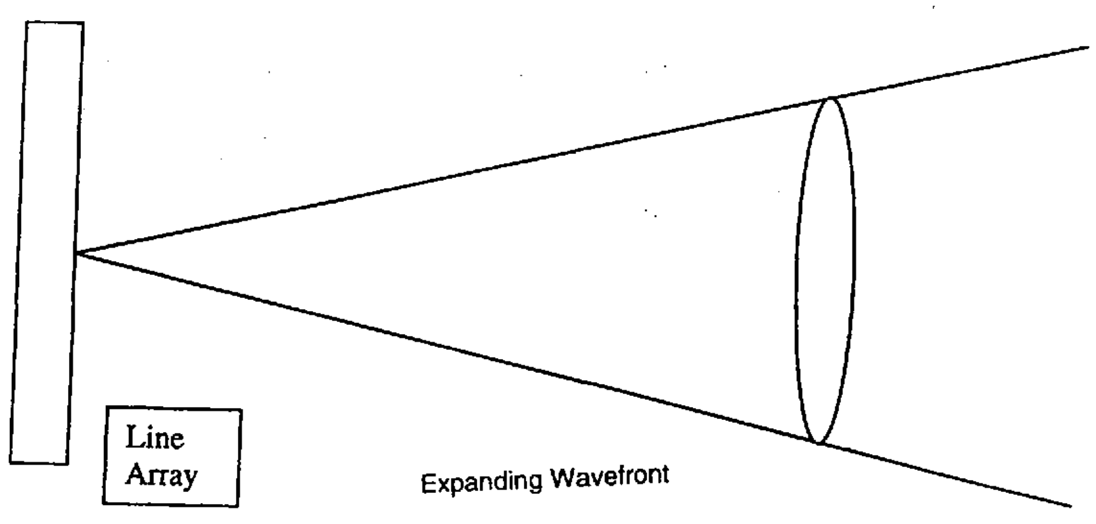

Fig. 1a

Steerable Array

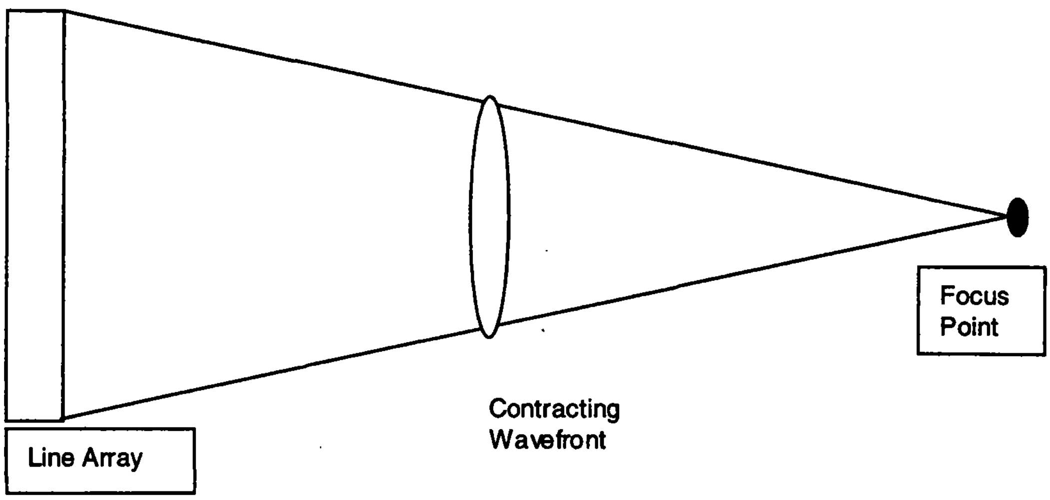

Fig. 1b

Steerable Array

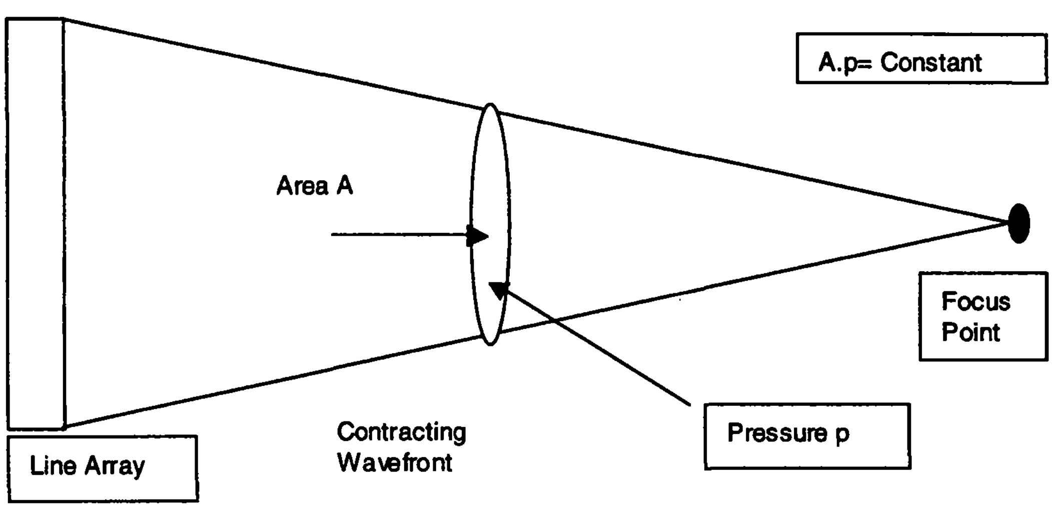

Fig. 2