EXPERIENCES WITH LINE ARRAYS

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1 INTRODUCTION

Line arrays continue to proliferate in the worldwide professional audio market. This paper seeks to cover some of the key differences in practical and audio terms that these systems present. Furthermore it seeks to offer some basic guidelines to the practitioner who has heard that they need a line array, but is not so sure of why and how best one should be deployed. Results and experiences will be related from both R&D and real-world testing and evaluation with a view to providing a better understanding of the “articulated line array” and the differences scaling the size of the array elements can make.

2 PRACTICAL USAGE OF TEMPORARY SOUND SYSTEMS

2.1 Practical Considerations

Aside from the clear acoustical considerations that we need to meet in today’s increasingly demanding market (SPL, Coverage, STI etc) we are also subject to a number of physical and practical limitations on what we can provide. The most obvious of these is usually the constraints of the budget, but others are less obvious – especially to someone not familiar with audio installation or rental.

There are two installation cases to consider, temporary and permanent. For the main part we will consider the aspects of the temporary installation, typical for the tour sound industry.

2.2 Tour Sound – Conflicts of Interest

The hirer of any sound system will, of course want the best system available for the least money. The tour sound company clearly has to manage their inventory carefully in order that they can provide what the customer wants for the vast majority of the time without having stock that is under utilised. The ideal inventory for any audio rental company would be to have one type of speaker that can be used in any application and that the only question is how many. This ideal is met for the majority of situations with an articulated line array. The array can easily be configured to provide a “far throw” section by using small angles and a “near fill” or “under hang” system by using the larger angles.

2.3 Weight In One Place

Fan shaped, arrayed “Point and Shoot” systems typically use a number of “hangs”; these could generally be taken from a few different places with the clear benefit of spreading the load.

A typical three-way enclosure might weigh approx 105kg. A fan shaped array of 3x3 might be able to be suspended from three locations – this would give a total load of 945kg or 315kg per suspension point.

Observation of the "state of the art" line array products revealed typical element weights of 80-150kg. This could lead to problems in certain venues with large array hangs. However, this does depend on the number of elements required.

We would likely cover a similar area with 6x Line Array Elements. In fact, in each mid-size enclosure (VT4888) we have 8 components against the fan arrayed system's three, and, as ever in audio – "it depends…" – but for the sake of illustration:

Each VT4888 element weighs 49kg; this would need to be suspended from one point. With a total load of just under 300kg we can see that our load "per hang" is maintained.

3 SPECIFYING THE SYSTEM

3.1 Why Should I Use a Line Array?

Probably the main reason is because you are being asked for it. Sound rental companies are in the business of making money – at least the successful ones are – and therefore demand must be met to keep the customers loyal.

There have been many discussions on the advantage of the line array, the line array effect, frequency dependency, types of array etc. but this paper is more interested in the practical upshot of these advantages than with their mathematical derivations.

In practical terms the most significant acoustical advantage is the ability to provide more even coverage (SPL) from the front to the back of the auditorium than with a traditional "point and shoot" system.

As Ureda[1] shows, utilising the right type of array for a certain venue can offer coverage over tens of meters if not hundreds, with minimal drop in SPL across the listening plane, from one location.

Interestingly, as Button[2] shows, the near field area is an area of destructive interference, thus all other things being equal, the line array does not increase the SPL at long distances, it just provides the ability to maintain them without blowing the eardrums of the people in the front rows. As an added benefit, the increased directivity of the array increases the direct to reverberant ratio and provides a better listening experience for the audience and an easier mixing reference for the sound engineer.

3.2 How Many Do I Need?

This is the most frequent question for any tour sound company. The calculations for maximum SPL, coverage etc. can be difficult until sufficient experience with a system has been attained.

Fortunately, experience with the JBL's VerTec large element array (VT4889) has given some very easy "rules of thumb" with which to make judgements. Figs 1-3 overleaf show the coverage at 2kHz from 6,12 and 18 boxes (250Hz and 8kHz are shown in Appendix 1):

Figs 1-3; Results from JBL's Line Array Calculator (LAC)

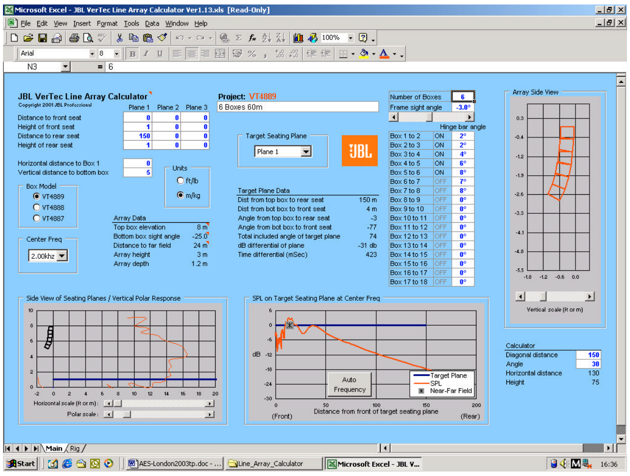

Fig 1. (A2) 6 Boxes [VT4889 489mm] At Angles 2,2,4,6,8 at 2kHz [~60m]

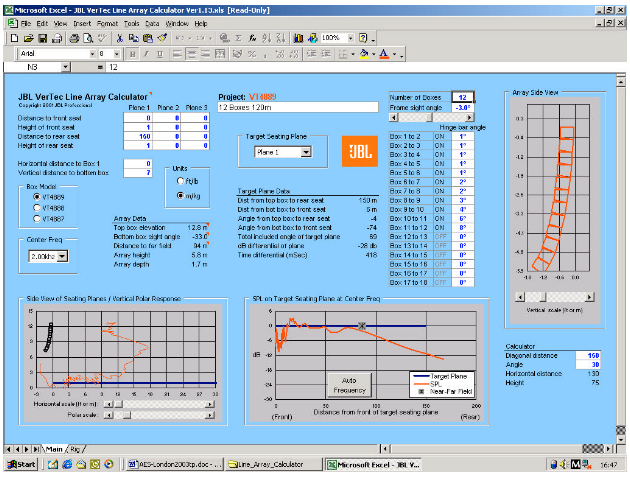

Fig 2. (A5) 12 Boxes [VT4889 489mm] At Angles 1,1,1,1,1,2,2,3,4,6,8 at 2kHz [~120m]

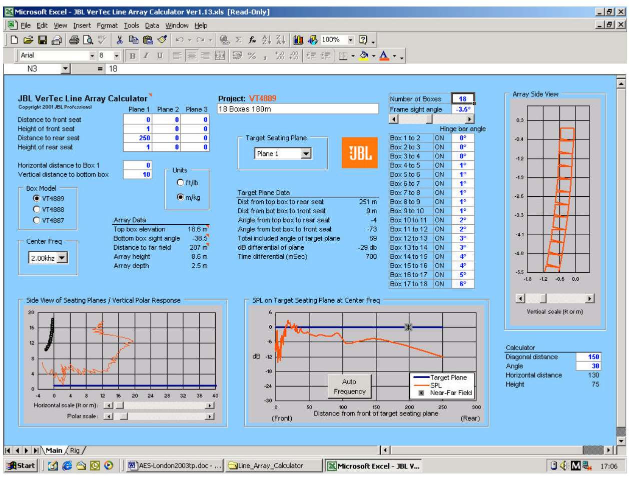

Fig 3. (A8) 18 Boxes [VT4889 489mm] At Angles 0,0,0,1,1,1,1,1,1,2,2,3,3,4,4,5,6 at 2kHz [~180m]

3.3 An Easy Equation, or Approximation

As can be shown from the results, the “equation” works out neatly to approximately:

$$\text{Coverage } (x) \approx 10n \text{ (m)}$$

Coverage distance required = x (metres)
Number of boxes = n (VT4889 [489mm] enclosures)
Works as an approximation only for flat listening planes.

The maximum SPL can be conservatively calculated to be approximately 109dB, 106dB and 104dB at the edge of each of the coverage zones.

To put this another way, if you wish to cover a flat listening area from 60-180m you can provide >104dB providing you utilise one enclosure for every 10m you wish to cover. The average difference front to back should be no more than 6dB. This normally equates to the requirements for most amplified music.

4 ISSUES OF UTILISATION

4.1 The Importance of Aiming

It’s well known that speaker with a coverage of 90x50 doesn’t suddenly stop producing sound at the edge of its coverage pattern – neither does a line array, but the SPL roll off with a line array system is so significant we really need to consider the system far more carefully in respect of its directional response.

Here is the LAC result from a recent outdoor 6-box deployment:

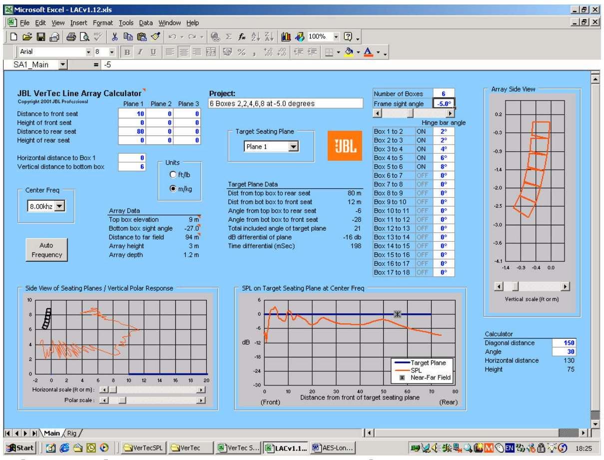

Fig 4. 6 boxes 2,2,4,6,8 at –5degrees

You can see the system providing 8kHz all the way out to 60m and beyond. The system here worked very well, but consider if we had miss aimed the system by 3 degrees:

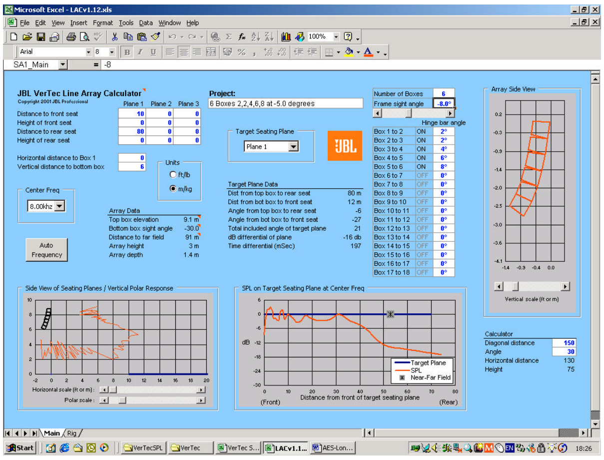

Fig 5. 6 boxes 2,2,4,6,8 at –8degrees

One could well imagine someone listening to the system in Fig 5, walking beyond 30m and then concluding that the HF is not 'throwing' to the back…and that therefore the line array has somehow 'broken down'. In fact the *exact opposite would be the case*, the highly directional line array is simply not pointed to the back of the listening area. It is also worth noting that this issue is not so noticeable at 1kHz (as can be seen in fig 6 – Smaart measurement of the 4 box array)

4.2 Field R&D Test Work

A notable discovery involved a 4-box (VT4889) array with all boxes set at 1-degree baffle splay angles. The array was set up and aimed as per the LAC predictions to cover a small area. The microphone was then placed in this location and the response measured using Smaart.

The initial response was saved and observed and then some adjustment was made to the overall aiming angle of the array. This made a significant difference. It was realized that there was an initial aiming error of around 2 degrees by the set-up crew. When this was corrected the difference in SPL above 1kHz was dramatic: 10dB or more. (See fig 6)

On inspection of the initial response it was clear that without the knowledge that we had improperly aimed the PA, an inexperienced user could have spent some considerable time trying to EQ this response.

The screen capture below (Fig.6 – courtesy of JBL engineer Scott Opie) shows how truly directional the line array can be. The difference between the two traces was a few degrees of angle overall. All 4 boxes in this array were spaced at 1 degree.

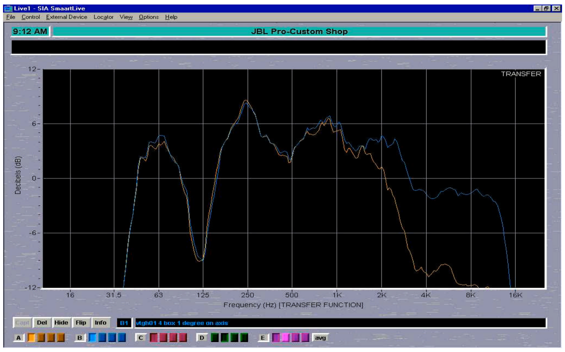

Fig.6 – Aiming change of 2 degrees

This dispels the idea that one can somehow look at an array and judge if you are in the coverage angle <u>if</u> you can see the box's HF section – a common misconception among line array users. The LAC clearly shows this:

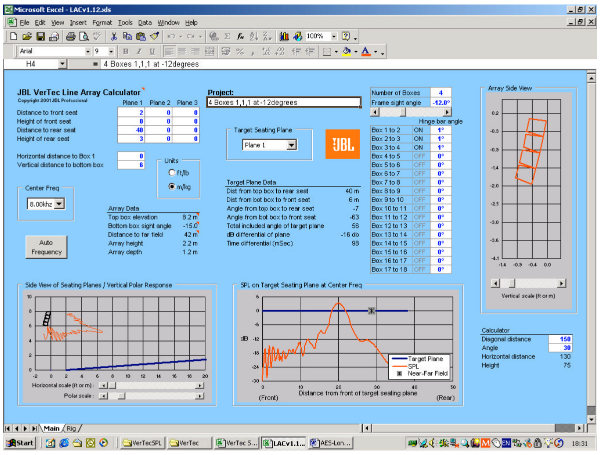

Fig 7. 4 boxes at 1 degree splay angles (8kHz)

This exercise showed the true accuracy of the LAC software application, and also the potential pitfalls if its predicted results are not acted upon.

It is clear from recent work and looking at the LAC that the HF <u>is</u> where the line array summation effect works best. This of course is not a surprise; numerous previous papers have shown that for a fixed array size, the far field is extended further as we go up in frequency. As a consequence, 8kHz is usually the best frequency to make initial LAC computations.

4.3 Small, Medium or Large?

(Or standard, large and extra large for those of you in marketing)

In developing three types of line array element, we offer three clear options to different sizes of Rental Company. However, we should consider how the arrays work in comparison with one another in order that we can best assess the earlier question of "How many do I need?"

For long throw situations, as one might expect, the length of the array is key. Let us consider the lengths of three line array elements:

Element Name	Height	Weight
VT4887	280mm	29kg
VT4888	355mm	49kg
VT4889	489mm	72kg

4.4 Straight Arrays

When looking at long throw, we should compare straight sections of the array. For ease of comparison, the following LAC results show all boxes at 0 degrees at 5m from the ground, -2.5deg aiming. Observe the difference at 300m:

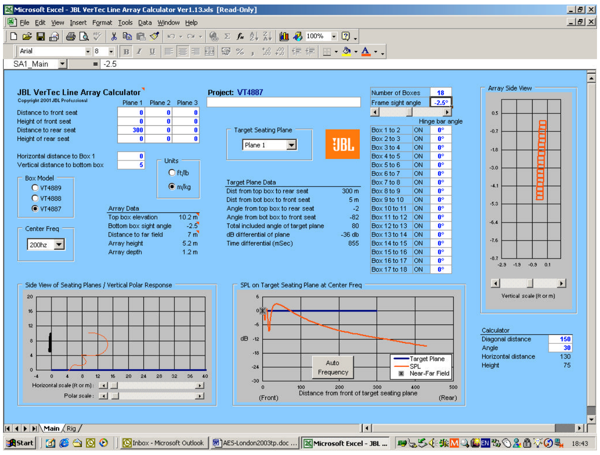

Fig 8. 18xVT4887 (small, 280mm element) at 0deg splay angle, 200Hz. [–12dB@300m]

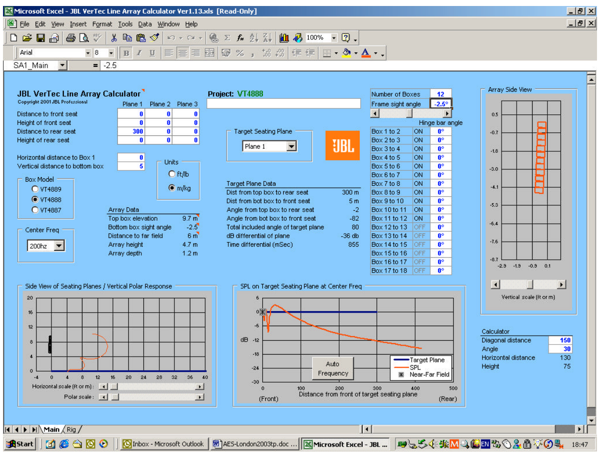

Fig 9. 12xVT4888 (medium, 355mm element) at 0deg splay angle, 200Hz. [–12dB@300m]

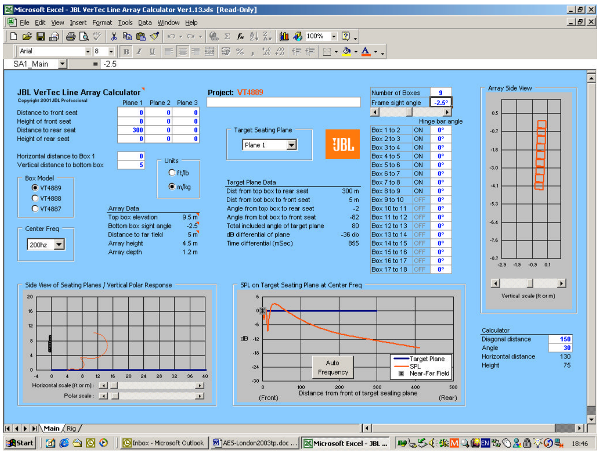

Fig 10. 9xVT4889 (large, 489mm element) at 0deg splay angle, 200Hz. [–12dB@300m]

We can see in Figs 8-10 that for similar lengths of array we have a similar drop at 300m at 200Hz. It must be remembered that the absolute SPL will of course be different due to the different maximum SPL outputs of the array elements.

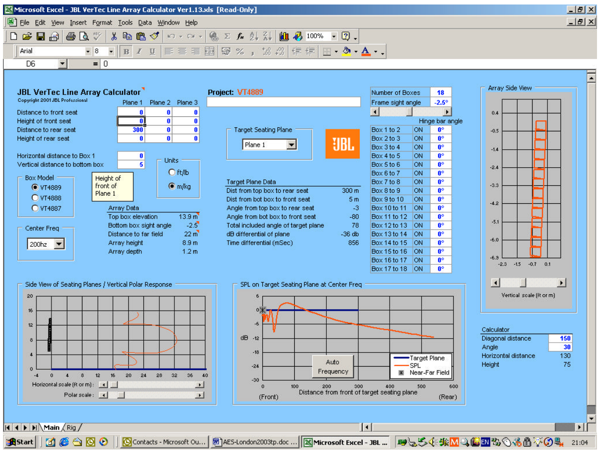

Fig 11. 18xVT4889 (large, 489mm element) at 0deg splay angle, 200Hz. [–6dB@300m]

Fig 11 illustrates that doubling the length of the array reduces the difference across the plane to –6dB at 300m at 200Hz. It should be noted that this 6dB improvement is not a 'rule' and is dependent on the array configuration.

4.5 Curved Arrays

The changes in requirements for arenas or areas with steep gradients are quite different however. While 200Hz shows the same similarity, 8kHz defines the responses most clearly. The following figures show defined coverage from around 3m to 22m.

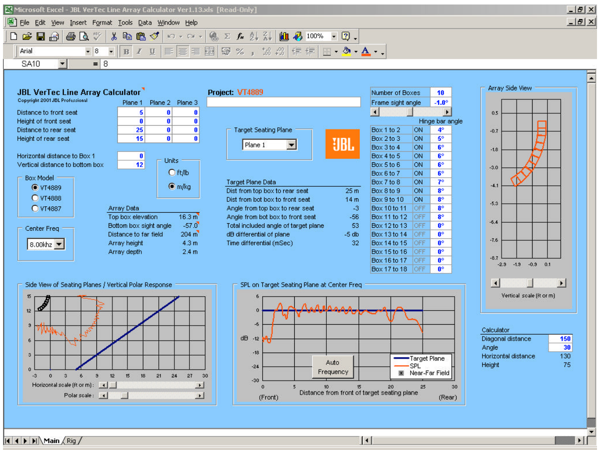

Fig 12. 10xVT4889 (large, 489mm element) Angles 4,5,6,6,6,6,7,8,8 [8kHz]

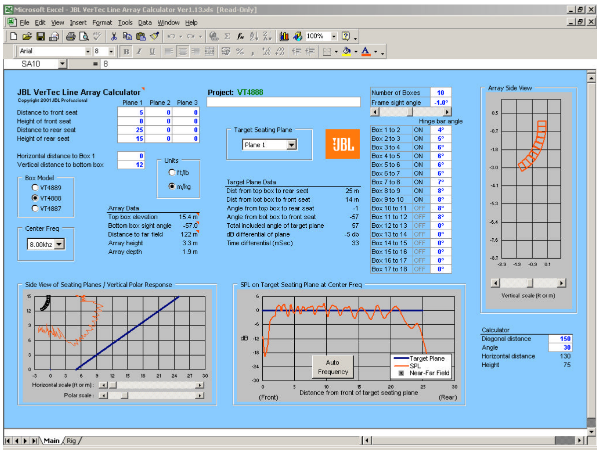

Fig 13. 10xVT4888 (medium, 355mm element) Angles 4,5,6,6,6,6,7,8,8 [8kHz]

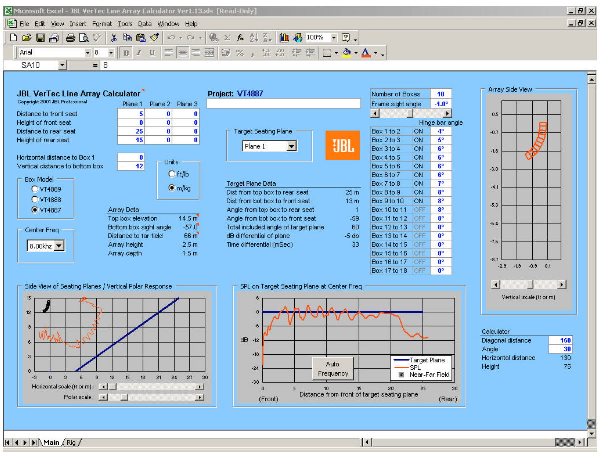

Fig 14. 10xVT4887 (small, 287mm element) Angles 4,5,6,6,6,6,7,8,8 [8kHz]

It can be seen in figures 12-14 that actually the number of elements is crucial here. This is because the most important factor is the included angle required to cover the audience area. Again note that the max SPL will vary with the output capability of the elements used.

4.6 Spiral (Progressive) Arrays

Curiously enough, spiral arrays[1] seem to be more similar to the curved arrays in their performance per element array rather than line length. The following figures show this:

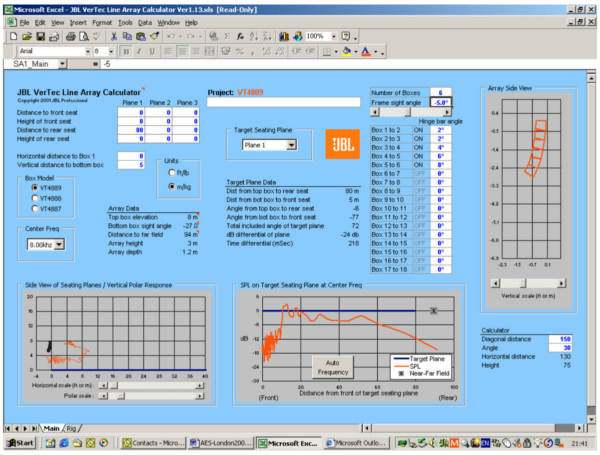

Fig 15. (A10) 6x VT4889 (large, 489mm element) Angles 2,2,4,6,8 at 8kHz

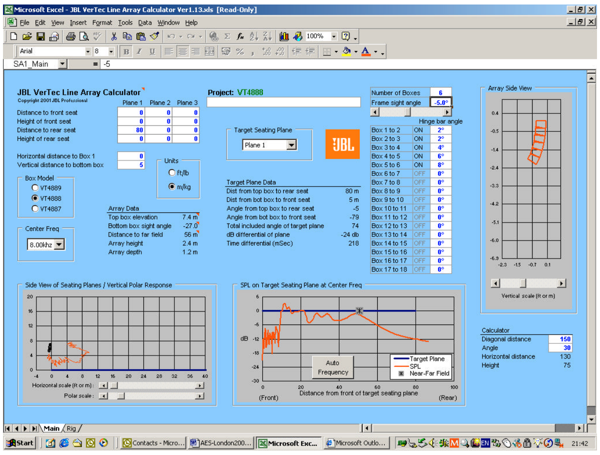

Fig 16. (A11) 6x VT4888 (medium, 355mm element) Angles 2,2,4,6,8 at 8kHz

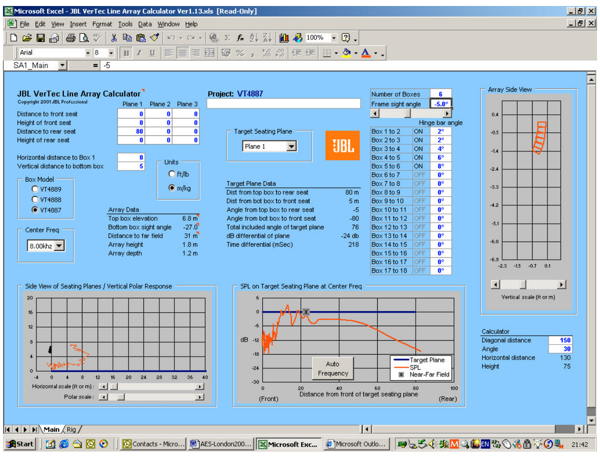

Fig 17. (A12) 6x VT4887 (small, 287mm element) Angles 2,2,4,6,8 at 8kHz

The data here and the results at 200Hz can also be found in Appendix 2. There is a slight degradation in the linearity of response with distance as the array is shortened, but it is not as great as one might expect.

5 CONCLUSIONS

Practical issues such as inventory management and the “single hang” requirements lead to a preference for a lightweight, single box solution. This has been attained here through high output neodymium components and a line array element with a maximum articulation of 10 degrees.

When choosing a line array, one can now consider maximum SPL and coverage linearity independently. Many “flat plane” applications can be covered with one VT element for every 10m distance that needs to be covered.

In terms of achieving even front-back coverage: The straighter the array, the greater the length of the array dominates, the more articulated it is, the number of elements in the array becomes more significant.

Aiming and configuring the array appropriately is crucial for optimum performance. The straighter the array, the more crucial the overall aiming angle becomes.

Line array technology, when correctly implemented, provides easier set-up and breakdown of the equipment for temporary installations. The arrays, when correctly configured, can offer superior coverage and direct to reverberant ratio than typical arrayed systems.

6 REFERENCES

1. Doug Button “A High Frequency Device for Vertically Articulated Line Arrays” Institute of Acoustics Reproduced Sound 18, November 2002

2. Mark Ureda “J and Spiral Arrays” 111th AES Convention 21-24 Sept 2001

Appendix 1

JBL's Line Array Calculator (LAC) Results

6 Boxes, Covering from 10 to 70m (60m total)

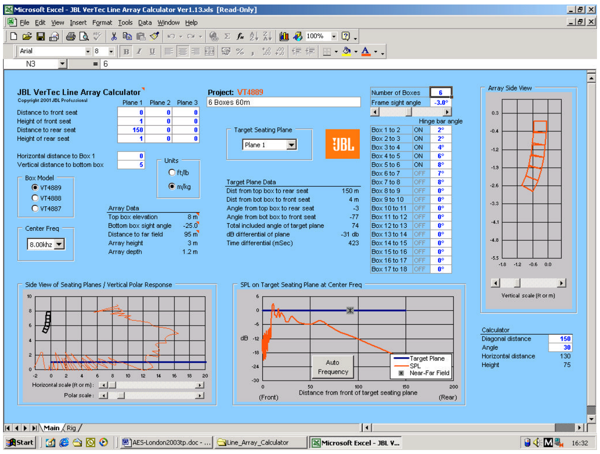

Fig A1. 6 VT4889 (large, 489mm element) Boxes at Angles 2,2,4,6,8 at 8kHz

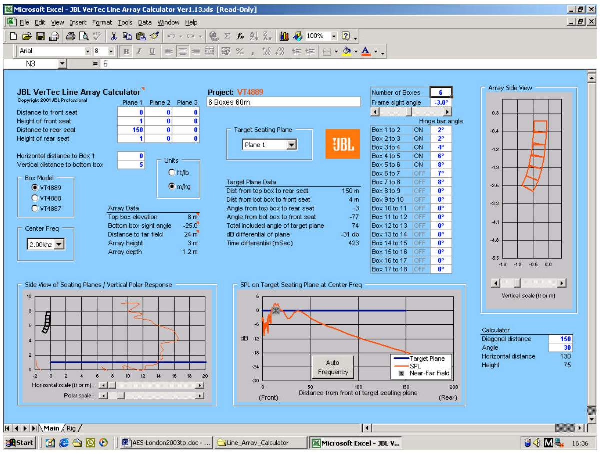

Fig A2. 6 VT4889 (large, 489mm element) Boxes at Angles 2,2,4,6,8 at 2kHz

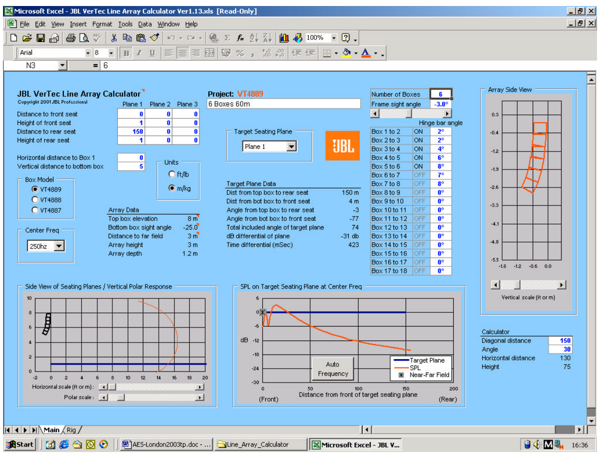

Fig A3. 6 VT4889 (large, 489mm element) Boxes at Angles 2,2,4,6,8 at 250Hz

Appendix 1 (cont'd)

12 Boxes, Covering from 11m to 125m (114m total)

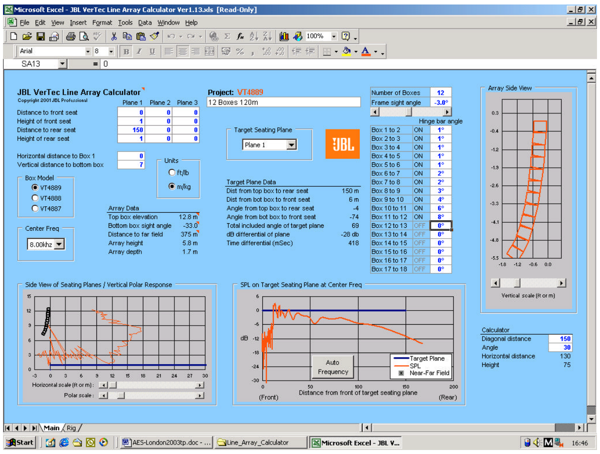

Fig A4. 12 VT4889 (large, 489mm element) Boxes at Angles 1,1,1,1,1,2,2,3,4,6,8 at 8kHz

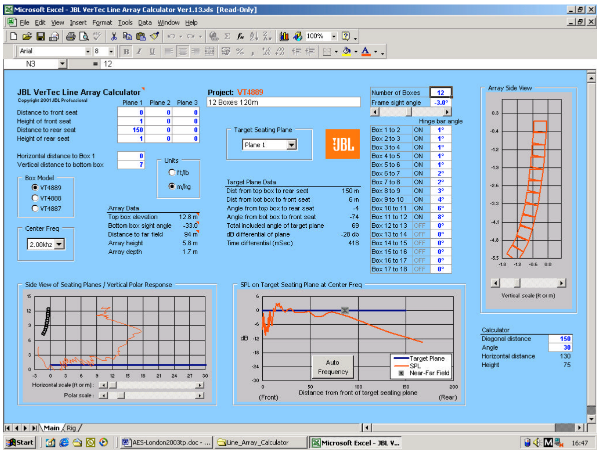

Fig A5. 12 VT4889 (large, 489mm element) Boxes at Angles 1,1,1,1,1,2,2,3,4,6,8 at 2kHz

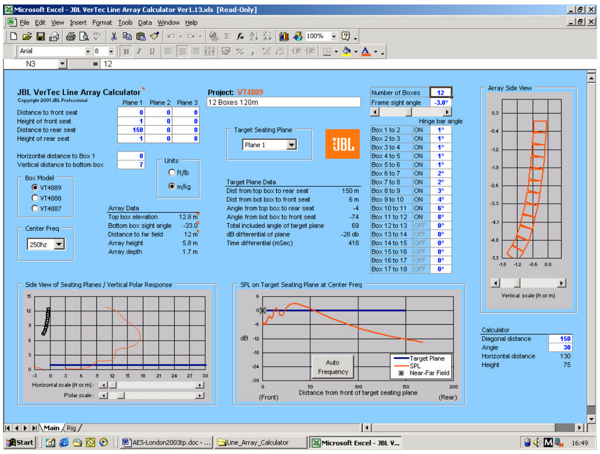

Fig A6. 12 VT4889 (large, 489mm element) Boxes at Angles 1,1,1,1,1,2,2,3,4,6,8 at 250Hz

Appendix 1 (cont'd)

18 Boxes, Covering from 15m to 200m (185m total)

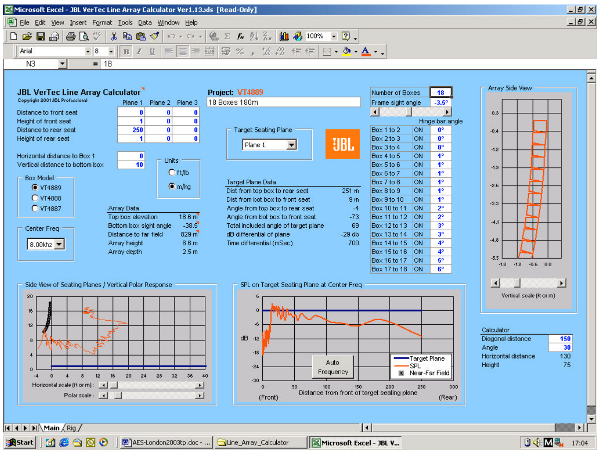

Fig A7.
18 VT4889 (large, 489mm element) Boxes at Angles 0,0,0,1,1,1,1,1,1,2,2,3,3,4,4,5,6 at 8kHz

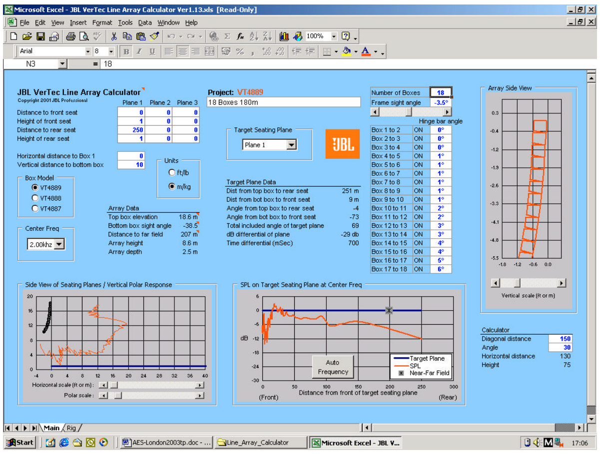

Fig A8.
18 VT4889 (large, 489mm element) Boxes at Angles 0,0,0,1,1,1,1,1,1,2,2,3,3,4,4,5,6 at 2kHz

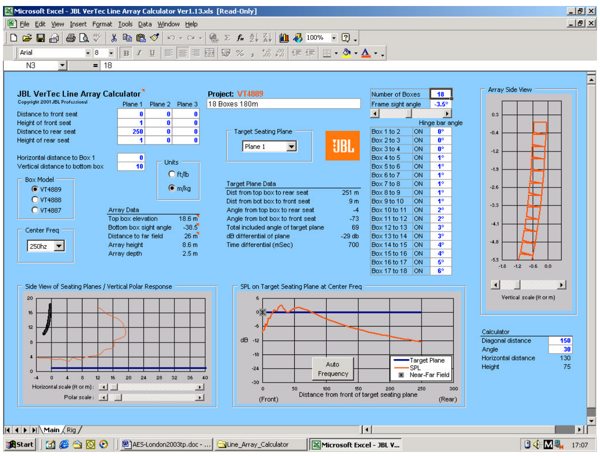

Fig A9.
18 VT4889 (large, 489mm element) Boxes at Angles 0,0,0,1,1,1,1,1,1,2,2,3,3,4,4,5,6 at 250Hz

Appendix 2

JBL's Line Array Calculator (LAC) Results

<u>6 Boxes, Covering from approx 60m, Spiral Array.</u>

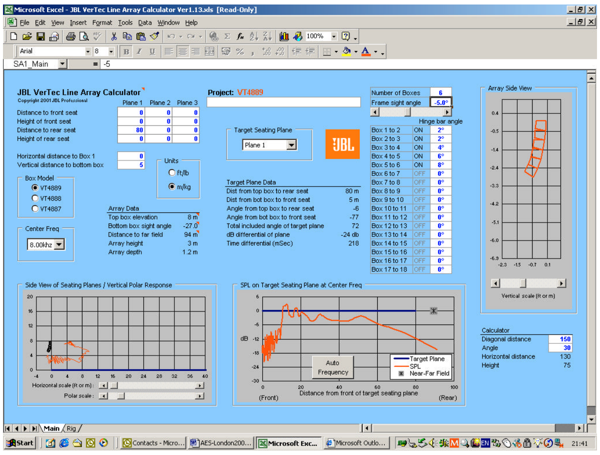

Fig A10. 6x VT4889 (489mm elements) at angles 2,2,4,6,8 at 8kHz

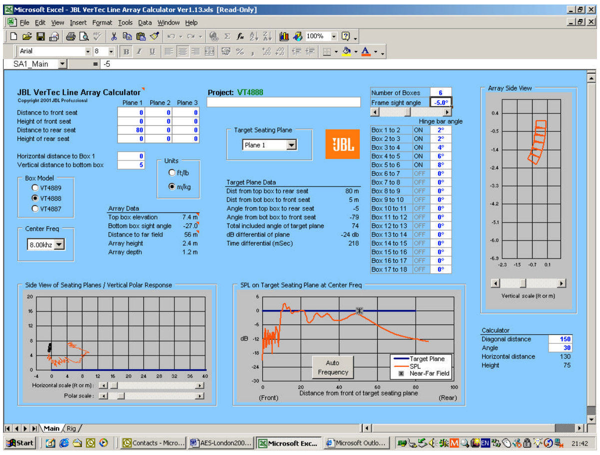

Fig A11. 6x VT4888 (355mm elements) at angles 2,2,4,6,8 at 8kHz

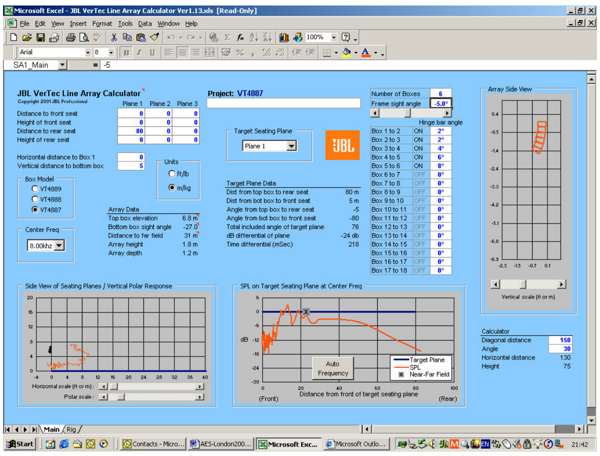

Fig A12. 6x VT4887 (287mm elements) at angles 2,2,4,6,8 at 8kHz

Appendix 2 (cont'd)

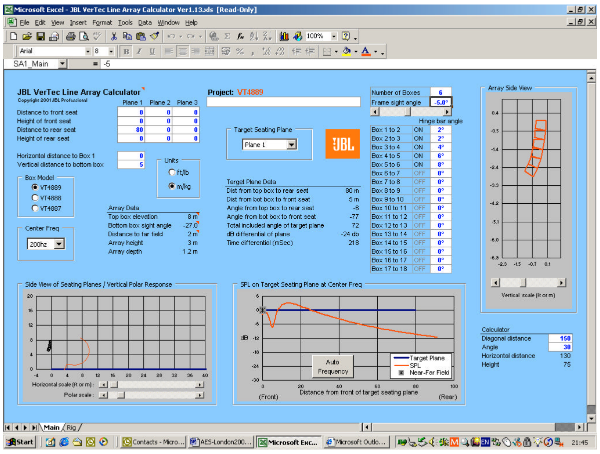

Fig A13. 6x VT4889 (489mm elements) at angles 2,2,4,6,8 at 200Hz

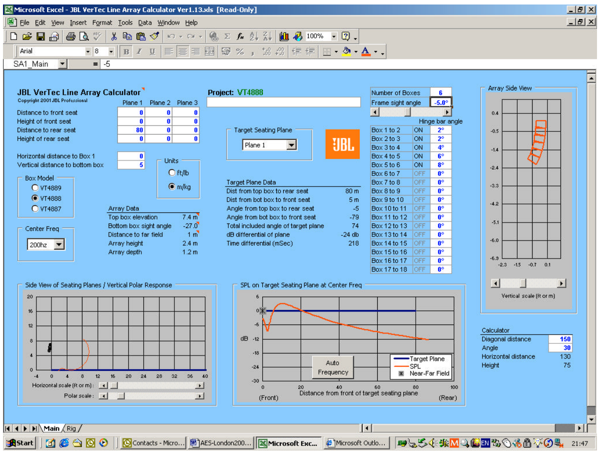

Fig A14. 6x VT4888 (355mm elements) at angles 2,2,4,6,8 at 200Hz

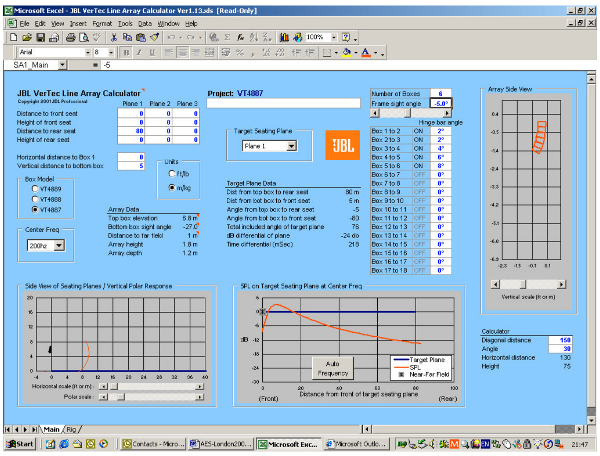

Fig A15. 6x VT4887 (287mm elements) at angles 2,2,4,6,8 at 8kHz