Figure 3 shows the set of points used in this example. Figure 3 shows cross section through a venue 10 with the line array 1 suspended at one end. A set of location points 11 is shown which are typical of where the audience would be on banked seating. Since this is a vertical 2D slice through the venue (in particular through the array elements and on the axis thereof) and since that is being taken as representative of the whole venue the points are termed “audience planes”. Non-audience points or “planes” are defined at the ceiling of the venue or unused audience planes.

The optimisation method used expects an objective function that returns a single real positive number because that is simple to compare with the previous value to determine which is better. Below are given various examples for the objective function used. These objective functions would be suitable for use with the many other optimisation methods that exist.

In terms of complex pressure amplitudes **P** at audience planes, it could, as a first example, which is in accordance with the invention, be desired that the pressures have the same fixed magnitude everywhere at all frequencies.
Our experience has demonstrated that uniform pressure amplitude at every position and frequency is not very useful target and it conflicts with an audiences’ psychoacoustic expectations.

In a second example, which is in accordance with the invention, the target $P_{targ}(\mathbf{r}_a,\mathbf{f})$ is defined as follows. P_{targ} is defined only at audience positions and its value elsewhere is not taken into account in the objective function. A target shape for the pressure distribution on audience planes is set by choosing a ’mix’ position $\mathbf{r}_{mix}$ at some point away from the array on the audience planes section, and choosing sound levels, ΔP_{start} and ΔP_{stop}, relative to the arbitrary pressure at $\mathbf{r}_{mix}$ for positions at the extremes of the audience planes section. In between each extreme point and the mix position the target pressure has a constant gradient. The mix position is intended to be that at or for which the mixing engineer mixes the sounds being produced by the speaker array.

Typical values create a target that progressively drops in amplitude with increasing distance from the array. A flat frequency response at all positions is stipulated in the target P_{targ} so that mixing engineers can globally adjust the spectrum to their liking.

The objective function for those two examples compares, at each point, the pressure produced by the speaker array as calculated with the target pressure and sums a measure indicative of those differences.

In a third example the objective function may have in addition to the primary criterion of a target pressure, a measure that indicates the flatness of the frequency response at each audience position. For each point the mean pressure amplitude over frequency is determined; a flatter response is indicated by calculating a measure of how close the pressure values, at all frequencies at that position, are to the mean.

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In a fourth example, which is in accordance with the invention, the objective function has in addition to the primary criterion of a target pressure, a second measure that quantifies the "leakage field", defined as measure indicative of the relative size (for example the ratio) of the total pressure delivered to the non-audience positions compared to the total pressure delivered to audience positions.

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As a third example, which is in accordance with the invention, the effect of including ε_{leak} as well as ε_{targ} is shown in Figure 9, which has three 3D plots with increasing values of c_3 for the leakage component. As more account is taken of the leakage the sound concentrates at the central audience positions.

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Similar results were obtained for the first unconstrained example above. Figure 8 shows this array performance for that example. The routine used a mesh size and time limit stopping criteria. After 20 mins and over 800 function evaluations the routine was stopped. Other runs allowing more time produced little further improvement before being stopped by the mesh size criteria.

For a fourth example of the invention, Figure 10 shows the effect of including ε_{fresp} in addition to ε_{targ}. The frequency responses for this example are noticeably flatter than for the other examples and at a little expense of being less close to the target.

Note that in the examples above changing the splay angles of the line array elements affects their position, since the more curved the array becomes the further back the lower elements move with respect to the audience positions. The optimisation takes this into account by calculating the new positions of the elements each time the splay angles are changed. These new positions are taken into account by the sound field calculation for the new array configuration.

CLAIMS:

1. A method of configuring an array of speaker elements for use in a venue, comprising

(a) providing an initial candidate configuration for the array and iterating the steps of:

(i) computing, with a computer and using a radiation model, the sound field produced by the array having the selected configuration at a plurality of points in venue, and

(ii) evaluating, with a computer an objective function involving the calculated sound field at a plurality of audience positions in the venue,

(iii) selecting a new candidate configuration for the array,

and (b) configuring the array in accordance with a selected one of the configurations of the array produced by the iterations,

wherein the objective function comprises a sum over a plurality of audience positions of a measure indicative of the difference between the magnitude of the sound field and a target value for the magnitude of the sound field at those positions and a measure indicative of the relative size of the total pressure delivered to non-audience positions compared to the total pressure delivered to audience positions.

2. A method as claimed in claim 1 wherein the target value at each audience position is taken to be relative to the mean value, at each iteration, of the magnitude of the sound field over a set of frequencies at that audience position.

3. A method as claimed in claim 1 or claim 2, wherein a target is defined at a first audience position and that for other positions is interpolated from that to respective

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2. A method as claimed in claim 1

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5. A method as claimed in any preceding claim wherein the objective function is or comprises

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target values at audience positions at a distance from that first audience position.

4. A method as claimed in any preceding claim wherein the objective function is or comprises a sum over a plurality of audience positions of a measure indicative of the rate of change of the sound field with respect to frequency.

5. A method as claimed in any preceding claim wherein the objective function is or comprises a sum over a plurality of audience positions of a measure indicative of the rate of change of the sound field with respect to position.

6. A method as claimed in any preceding claim wherein the objective function is or comprises a measure of the flatness of the frequency response over a set of audience positions.

7. A method as claimed in claim 6 wherein the measure of flatness is a measure of how close the magnitude of the sound field is, for a set of frequencies, to a mean value for the magnitude of the sound field at each audience point.

8. A method as claimed in any preceding claim wherein the magnitude of the sound field is in terms of the sound pressure level.

9. A method as claimed in any preceding claim wherein the selection of a new candidate configuration is subject to a constraint.

10. A method as claimed in any preceding claim wherein the configuration of the candidate array is parameterised in terms of the orientation of the elements of the array.

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11. A method as claimed in any preceding claim wherein the configuration of the candidate array is parameterised in terms of the position in the venue of the elements of the array.

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12. A method as claimed in any preceding claim wherein the configuration of the candidate array is parameterised in terms of the polarity of the connection of the sound signal applied to elements of the array.

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13. A method as claimed in any preceding claim wherein the configuration of the candidate array is parameterised in terms of the gain applied to the sound signal applied to position in the venue of the elements of the array.

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14. A method as claimed in any preceding claim wherein the configuration of the candidate array is parameterised in terms of the delay applied to the sound signal applied to position in the venue of the elements of the array.

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15. A method as claimed in any preceding claim wherein the array is a line array comprising a plurality of linked speaker elements, the angles between which can be adjusted.

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16. A method as claimed in claim 15 wherein the candidate configuration determines the angles between the elements and the values for the angles are constrained so that in one direction along the array the angle between each element and the next element is the same or larger than the angle between that element and the previous element.

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17. A method as claimed in claim 15 wherein the candidate configuration determines the angles between the elements and

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the values for the angles are free, independently of each other, to adopt values between two limit values.

18. A computer program product that is arranged, when executed, to perform the calculation steps of the method of any preceding claim.

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19. A computer program product comprising the following modules:

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an input module arranged to receive a description of a venue,

an input module arranged to receive a description of a speaker array,

a module arranged to receive or determine an initial set of parameter values for a candidate array,

a module arranged to determine a simulated sound field for a candidate array,

an objective function calculator arranged to evaluate the sound field produced by the sound field calculator,

an optimiser arranged to use the outputs of the objective function calculator to determine further candidate arrays parameter sets to be operated on by the sound field calculator and the objective function calculator and to determine when a preferred candidate array parameter set has been found,

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wherein the objective function calculator is arranged to evaluate the sound field produced by the sound field calculator with an objective function, the objective function comprising a sum over a plurality of audience positions of a measure indicative of the difference between the magnitude of the sound field and a target value for the magnitude of the sound field at those positions and a measure indicative of the relative size of the total pressure delivered to non-audience positions compared to the total pressure delivered to audience positions.

20. A computer system comprising a computer program as claimed in claim 18 or claim 19.

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21. A speaker array that has been configured according the method of any one of claims 1 to 17.

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