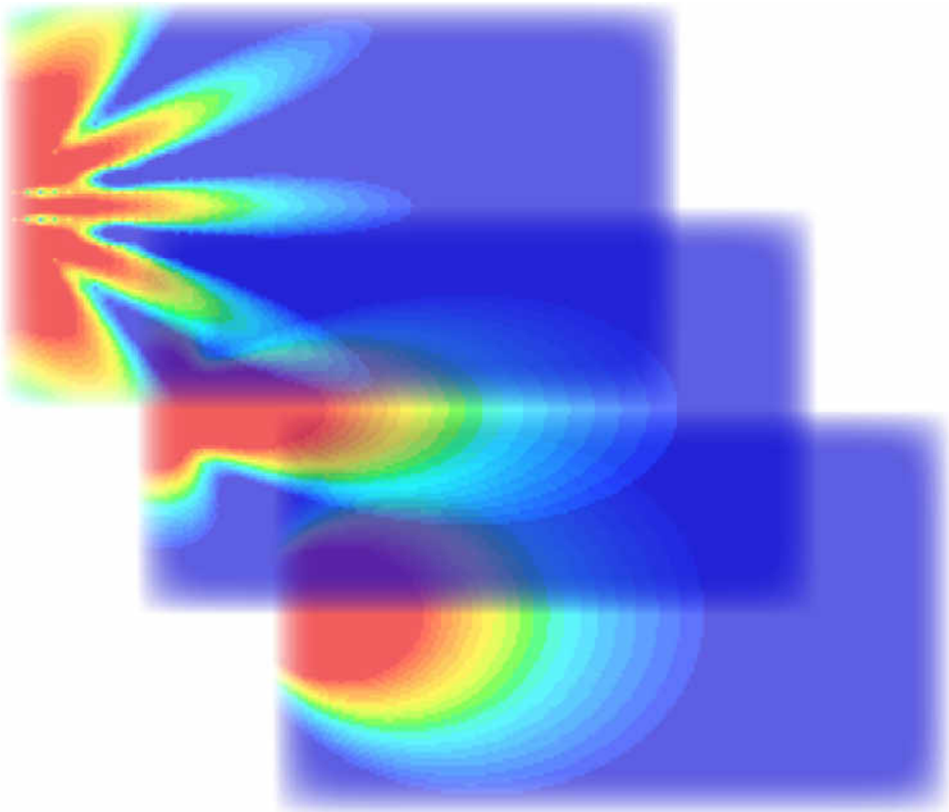
A Practical Guide To Bass Arrays

part 1

by Rog Mogale

Produced in conjunction with Void Acoustics LTD



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This guide will primarily deal with the problems encountered when locating and using multi element bass systems in medium to large scale sound reinforcement. The majority of this guide is based around complex simulations that have been correlated to real world measurements to check for accuracy and consistency. All of the simulation examples shown do not contain or show the effects of boundary reflections from walls or corners, so it can be assumed the measurements were taken in free space away from any boundaries. But, as many of the simulations contain bass enclosures that sit on the floor, ground reflections and the resulting SPL gain from mirroring are included. The floor in all cases can be assumed to be solid with zero absorption and all measurements were taken at an average ear height, the figure being 1.65 m (65") above ground.

There have been other papers written on the effects and location of bass arrays, many have assumed that each bass enclosure was a point source. This can limit the accuracy of the measurements, so the simulations shown in this guide were made with all the test enclosures physical and technical parameters taken into account. The simulation software is not only aware of where the enclosure is located, but also knows its radiation pattern at all relevant frequencies. Detailed polar plots were made of the real test enclosure, these as well as the enclosures physical and technical properties were used as the bases for all simulations. It was decided to use a double 18" reflex enclosure for the bases of all simulations as many operators around the world use such setups. Each test enclosure measures 122 cm (48") high x 61 cm (24") wide x 76 cm (30") deep and contains two 18" woofers that receive 800 watts rms each. Filter settings were 30Hz HP and 120Hz LP and it is to be assumed that all frequencies between 30 and 120hz have equal output. Each enclosure is capable of 132dB peak at 1 m (39.4") when driven with 1600 watts and it is this figure that is used as the starting SPL for all simulations.

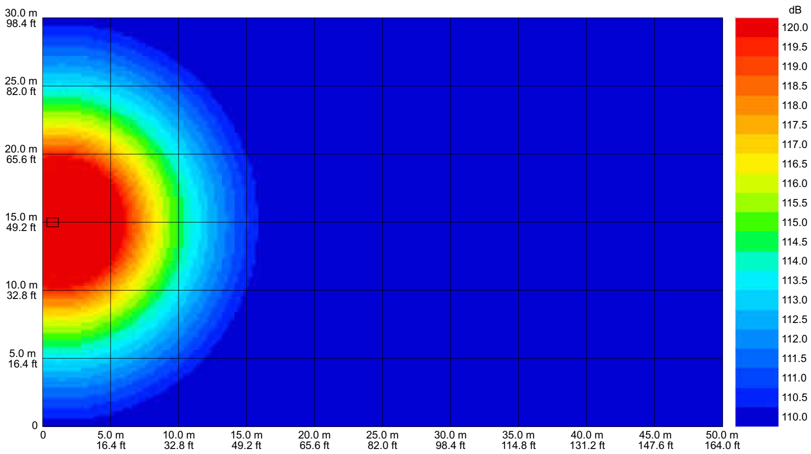

fig 1. single vertically positioned enclosure 50Hz

450 Litre (15.9 cu ft) double 18" reflex test cabinet

fig 1. shows the radiation pattern of a single test enclosure sitting on the floor measured at 50Hz. The enclosure is positioned vertically, i.e. one driver above the other and the front of the enclosure is positioned 1.4 m (55") into the test area. The test area is completely flat and measures 50 m (164 ft) deep by 30 m (98.4 ft) wide. The SPL test range covers 10dB with red representing 120dB and blue representing 110dB. There would be a further decrease of SPL with distance, but because of its relevance will not be shown in many of the simulations in this guide. fig 2. shows what happens when two enclosures are positioned next to each other at 50Hz, while fig 3. shows two enclosures next to each other one octave higher at 100Hz. Its clear that even with two enclosures side by side at 50Hz a very small amount of beaming is taken place and at 100Hz the effect is quite noticeable.

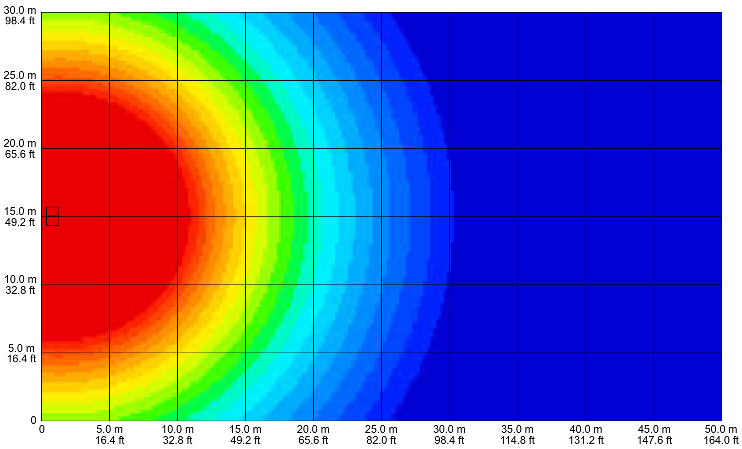

fig 2. two vertically positioned enclosures horizontally arrayed 50Hz

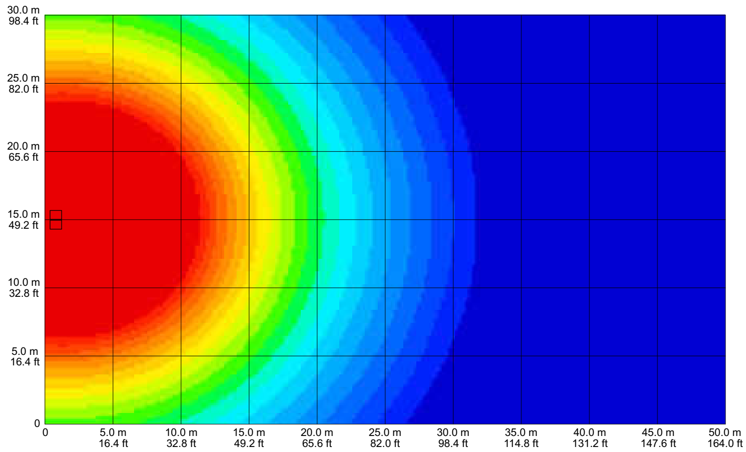

fig 3. two vertically positioned enclosures horizontally arrayed 100Hz

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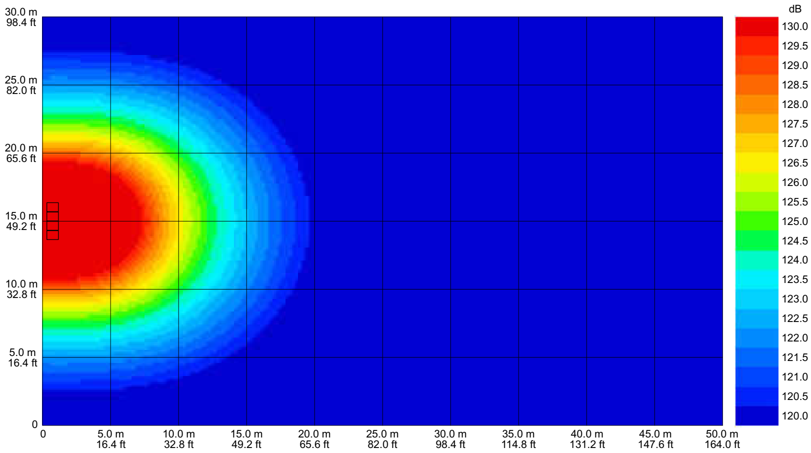

fig 4. four vertically positioned enclosures horizontally arrayed 50Hz

fig 4. shows what happens if we create a horizontal array with four enclosures positioned vertically. The SPL test range has had to increase because of the greater output of four enclosures, so red now represents 130dB and blue represents 120dB. Its easy to see that the side attenuation has become more pronounced and that some forward gain is evident. The front to side rejection is 5dB at 50Hz, which rises to around 12dB at 100Hz. This clearly depicts that lower frequencies maintain a less directional radiation pattern than higher frequencies.

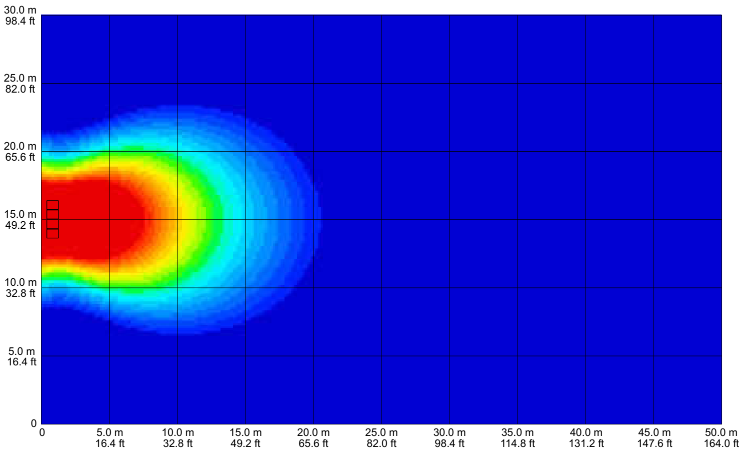

fig 5. four vertically positioned enclosures horizontally arrayed 100Hz

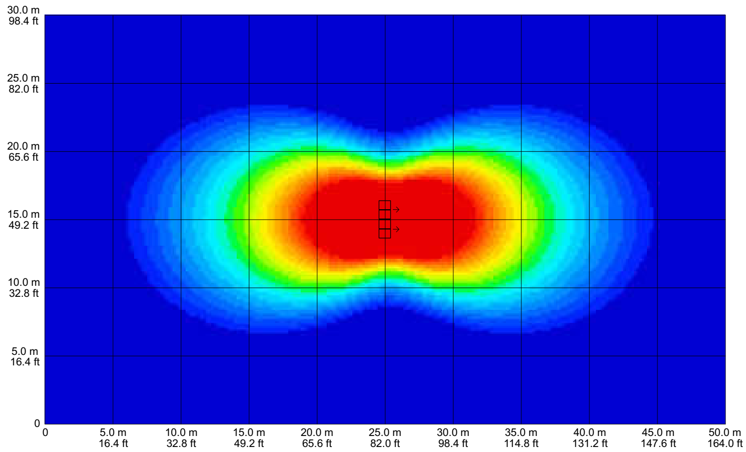

fig 6. four vertically positioned enclosures horizontally arrayed 100Hz

The simulation in fig 5. was made at 100Hz with four vertically positioned enclosures horizontally arrayed. There are significant nulls at both sides of the array, but as can be seen in fig 6. which depicts the array in the middle of the test area, the array is still dipole in operation. There is also a small amount of front to back rejection, meaning the amount of forward to rear radiation is unequal. This is also evident in fig 7. but to a lesser degree, which shows the same configurations as fig 6. but one octave lower at 50Hz.

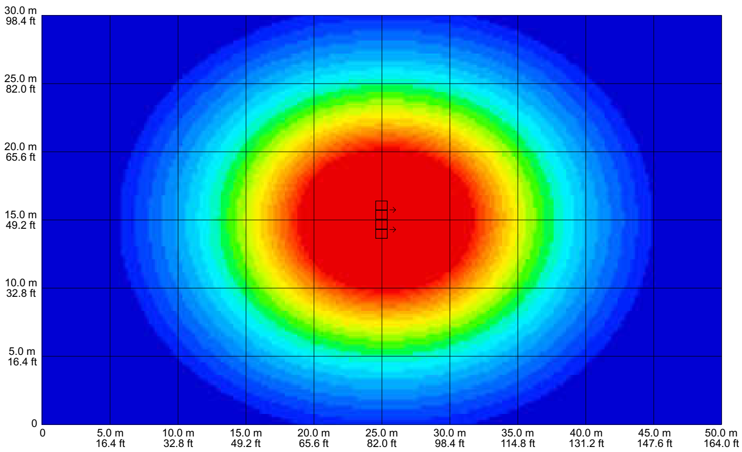

fig 7. four vertically positioned enclosures horizontally arrayed 50Hz

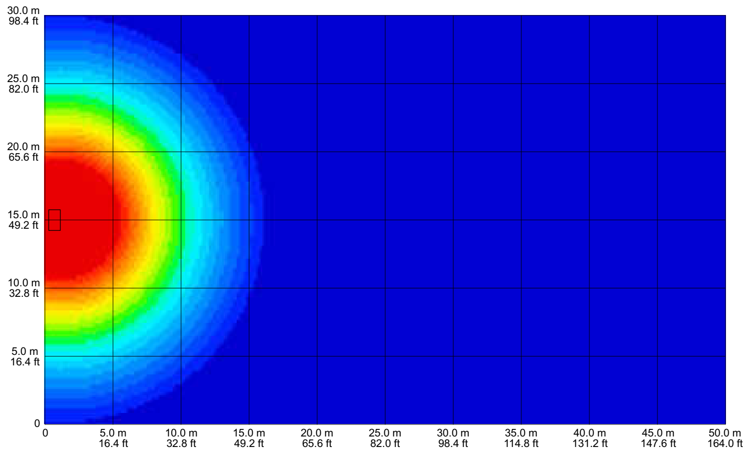

fig 8. four horizontally positioned enclosures vertically arrayed 100Hz

From the above simulations it is evident that horizontally arrayed bass enclosures have an effect on the directionality of the radiation pattern. It will also be shown that the longer the horizontal array the more directional the radiation pattern becomes. fig 8 shows four enclosures horizontally positioned and vertically arrayed at 100Hz. If you compare fig 8. with fig 5. which shows the same four enclosures but horizontally arrayed, you can see that a vertical array has little or no effect on the radiation pattern in the horizontal plane. The radiation pattern remains omni directional with the vertical array of four enclosures even at 100Hz. This comes at the expense of front to side rejection, with the four enclosure vertical array being 2dB quieter at 15 m (49.2 ft) out compared with the horizontal array. The simulation for all frequencies below 100Hz is the same as the 100Hz sim, so there is no point in showing a 50Hz sim of a four enclosure vertical array.

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The last set of simulations dealt with four enclosures that were mostly horizontally arrayed. fig 9. shows the radiation pattern for six enclosures at 50Hz that have been vertically positioned and horizontally arrayed. The front to side rejection is around 8dB, which at 50Hz is quite considerable considering the array only measures 3.66 m (12 ft) across. At 100Hz as shown in fig 10. the front to side rejection is a massive 17dB and the width of radiation is only just wider than the array itself.

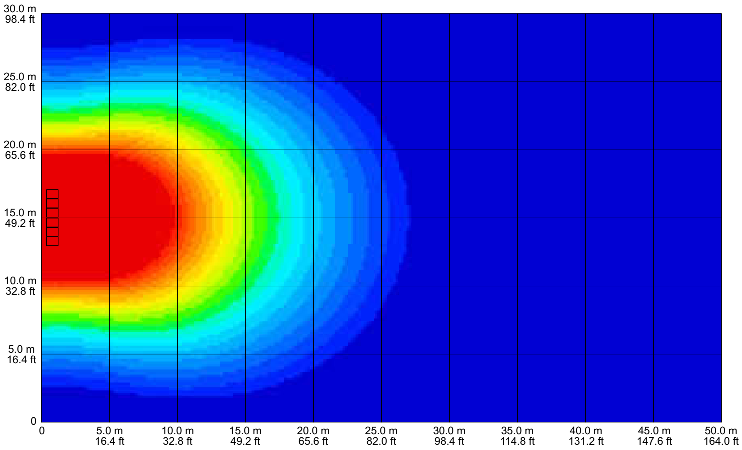

fig 9. six vertically positioned enclosures horizontally arrayed 50Hz

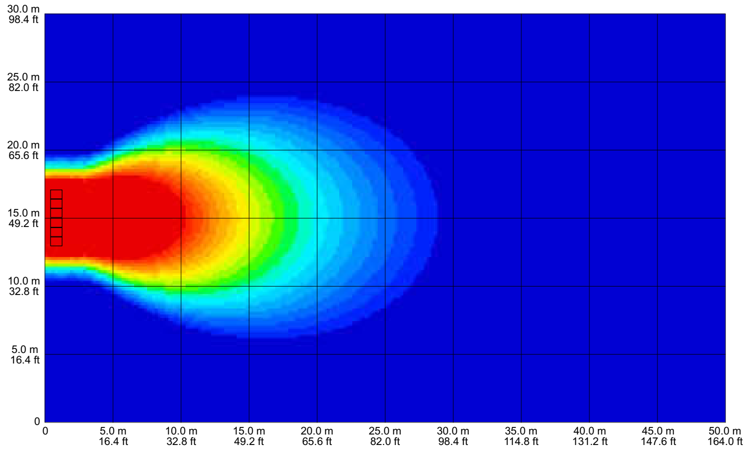

fig 10. six vertically positioned enclosures horizontally arrayed 100Hz

While some applications could benefit from the increase in directivity of a six enclosure horizontal array, there are times when a wider dispersion is called for. With the use of delays the radiation pattern of a horizontal array can be broadened. fig 11 and 12 show the effect of adding 3.6 ms of delay to the outer most enclosures (A and F) of the array. The effect is apparent at 50Hz but is significant at 100Hz where the radiation pattern has almost become omni directional. Delays in the range of 1.4 ms to 4 ms can be used with the higher end of the range giving a bigger increase in width. At 4.1 ms the array will have a virtually flat wavefront at 100Hz, increasing the delay further will start to cause a null at the front centre of the wavefront whilst the side radiation continues to broaden. At 7.4 ms the radiation pattern resembles a triangle and any further delay starts to create a pattern with severe interference containing one primary frontal lobe with two distinct side lobes at 90 degrees to the primary.

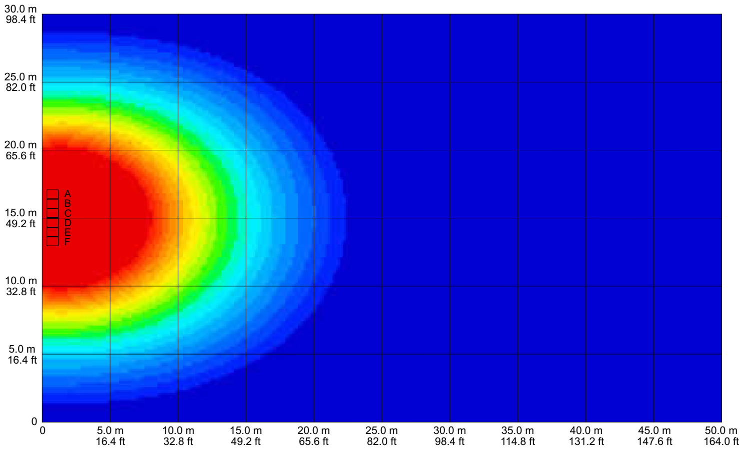

fig 11. six vertically positioned enclosures horizontally arrayed 50Hz
3.6 ms delay applied to enclosures A and F

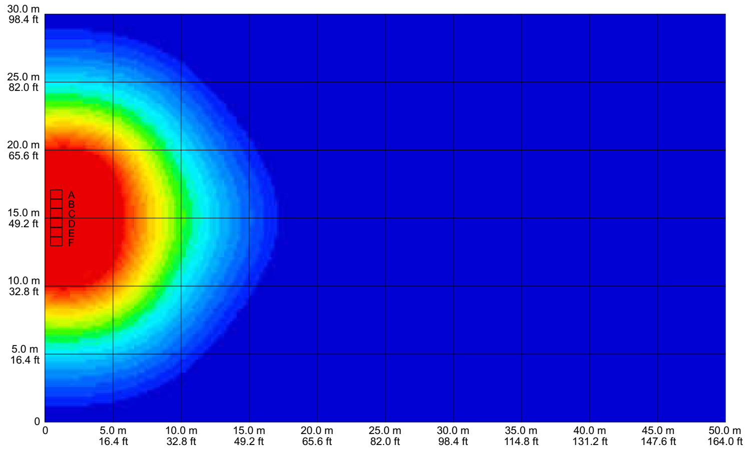

fig 12. six vertically positioned enclosures horizontally arrayed 100Hz
3.6 ms delay applied to enclosures A and F

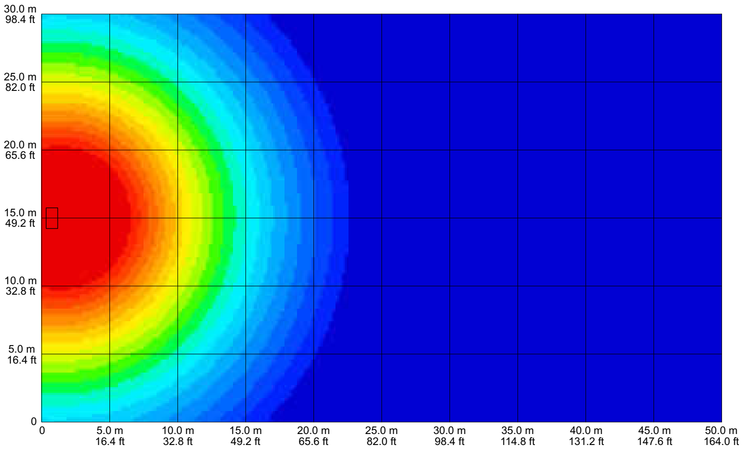

fig 13. six horizontally positioned enclosures vertically arrayed 100Hz

fig 13. shows a six enclosure vertical array at 100Hz for comparison. The difference between the horizontal array at 100Hz in fig 10. and the vertical array at 100Hz in fig 13. is significant. The radiation pattern of the vertical array is omni directional with a front to side rejection of zero. Worth noting is that the vertical radiation pattern of the vertical array would look like the horizontal radiation pattern of the horizontal array in fig 10. To obtain the full output SPL from the vertical array would mean having to be within the arrays physical height itself. Listening points higher than the array would result in a reduction in SPL, especially at higher frequencies.

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We have seen the results of vertical and horizontal bass arrays containing four and six enclosures, now we concentrate on arrays with eight enclosures. The simulation in fig 14. was made with eight enclosures vertically positioned in a horizontal array at 50Hz. fig 15 shows the same array at 100Hz where the interference caused by the array has produced a primary frontal lobe and two smaller secondary lobes at 90 degrees. The secondary lobes give the array a wider dispersion at 90 degrees from the array in the 100Hz sim compared to the 50Hz sim. But this comes at the expense of 2 very deep nulls at 45 degrees from the primary frontal lobe that deepen with an increase in frequency.

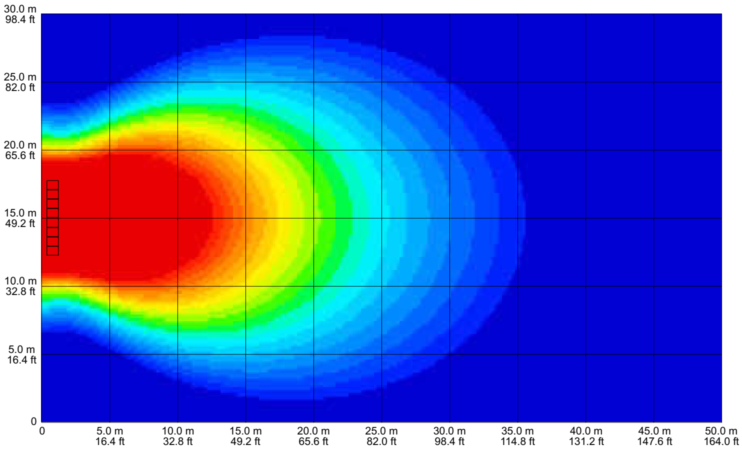

fig 14. eight vertically positioned enclosures horizontally arrayed 50Hz

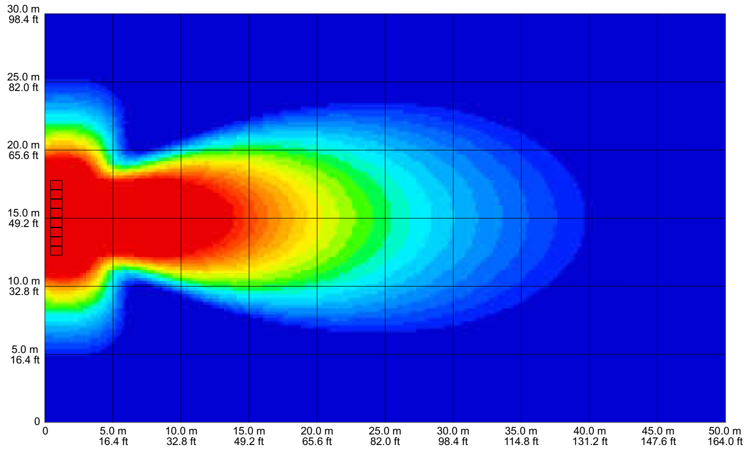

fig 15. eight vertically positioned enclosures horizontally arrayed 100Hz

As with the six enclosure horizontal array, delays can be added to widen the dispersion of an eight enclosure array. fig 16 and 17 show the effect of of delaying enclosures A and H by 4.2 ms and enclosures B and G by 1.1 ms. An even greater increase in radiation pattern width can be produced by applying a longer delay time to enclosures B and G, but after 1.8 ms a null starts to appear at the front centre of the wavefront. The same will also happen if delay times longer than 4.8 ms are applied to enclosures A and H. It can been seen that applying delays can broaden the dispersion of a horizontal bass array, but the price to pay is a reduction in SPL compared with a vertical array at the same distance using the same amount of enclosures.

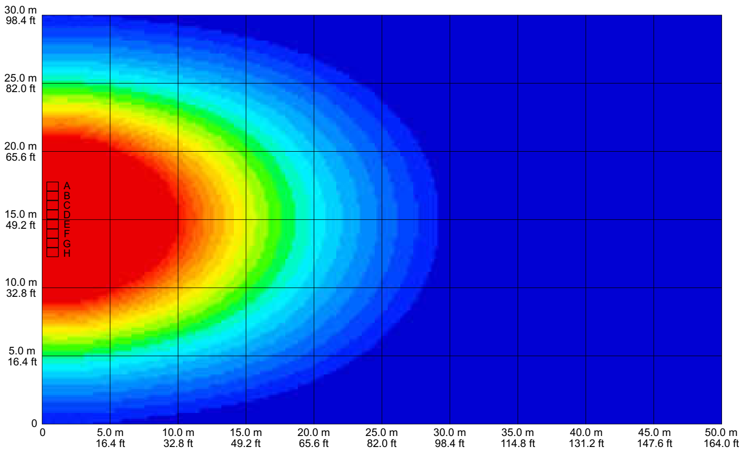

fig 16. eight vertically positioned enclosures horizontally arrayed 50Hz
3.6 ms delay applied to A and H, 1.1 ms delay applied to B and G

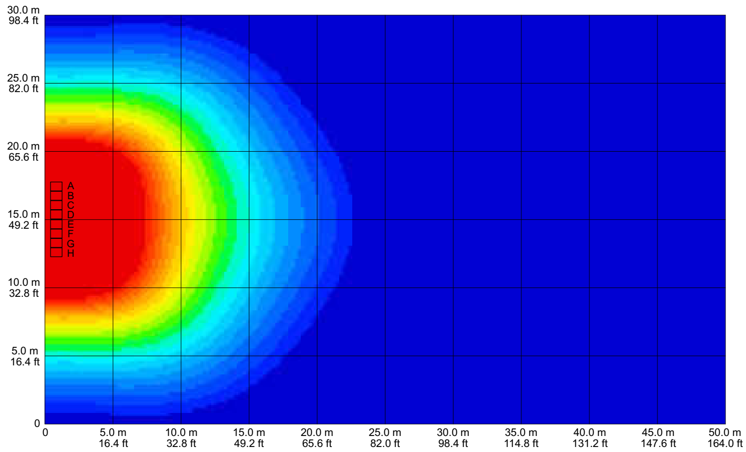

fig 17. eight vertically positioned enclosures horizontally arrayed 100Hz
3.6 ms delay applied to A and H, 1.1 ms delay applied to B and G

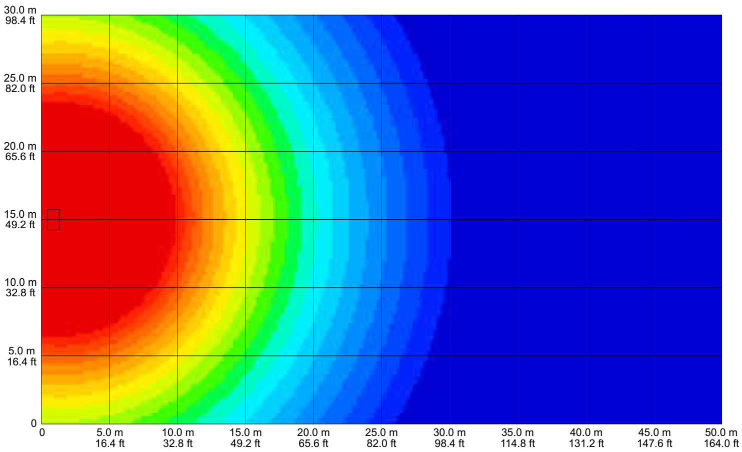

fig 18. eight horizontally positioned enclosures vertically arrayed 100Hz

If we compare a delayed horizontal array at 100Hz with eight enclosures such as in fig 17. with the six enclosure vertical array in fig 13. we find nearly identical SPL's in front of the array at all distances. The six enclosure vertical array also has a wider radiation pattern in comparison. If we compare fig 17. to fig 8. which depicts a four enclosure vertical array, we find that both share a nearly identical width in there radiation pattern. If fact the four enclosure vertical array is only 3.7dB down in SPL at all distances in front of the array compared with the eight enclosure horizontal array. For comparison, fig 18. shows a vertical array of eight enclosures at 100Hz.

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So far we have looked at enclosures placed in a straight line to form either a horizontal or vertical array. For single bass arrays its quite clear from the simulations that a vertical array has many advantages over a horizontal array. The vertical array will be less directional and for the same amount of enclosures can produce a greater SPL than a horizontal array that has had to be delayed to widen its dispersion. But what happens if the array is positioned to form a curve. fig 19. shows the effect of arraying 4 vertically placed enclosures with a 12 degree angle between enclosures at 50Hz. The results for the same array but at 100Hz cab be seen in fig 20. Its apparent that four enclosures placed in a curved formation have a slightly wider radiation pattern. Fig 5 shows a straight horizontal array of four enclosures at 100Hz, its front to side rejection is 12dB. The front to side rejection for the curved horizontal array at 100Hz in fig 20. is 10.5dB.

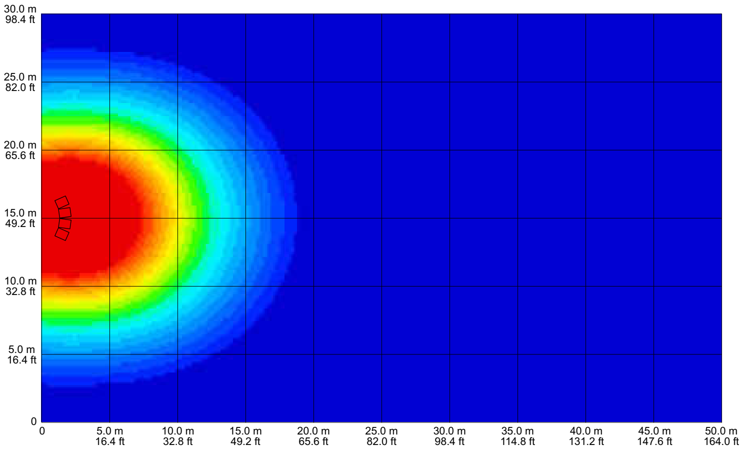

fig 19. four vertically positioned enclosures horizontally arrayed 50Hz
12 degree spacing between enclosures forming a curve

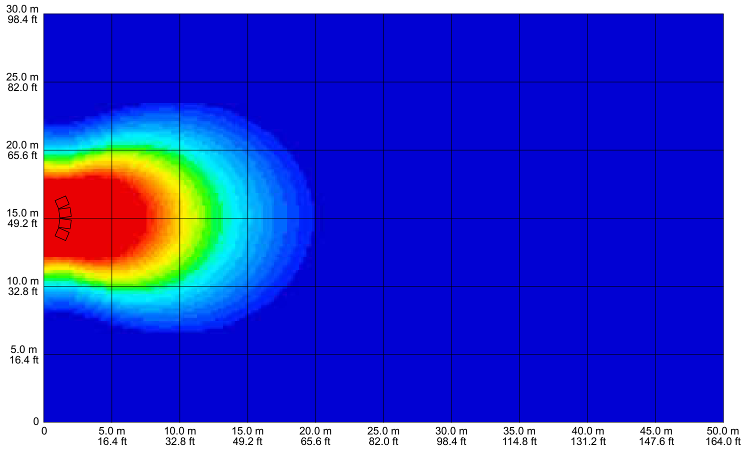

fig 20. four vertically positioned enclosures horizontally arrayed 100Hz
12 degree spacing between enclosures forming a curve

If a horizontal array of four enclosures is curved to from an inverted arc then front to side rejection at 100Hz becomes 8.5dB. fig 22. shows such an array and it can be seen that an inverse arc array of four enclosures produces a slightly wider radiation pattern than either a straight or curved array, as can be seen by comparing with fig 20 and 24. For comparison fig 23 shows a vertical array of four bass enclosures at 100Hz.

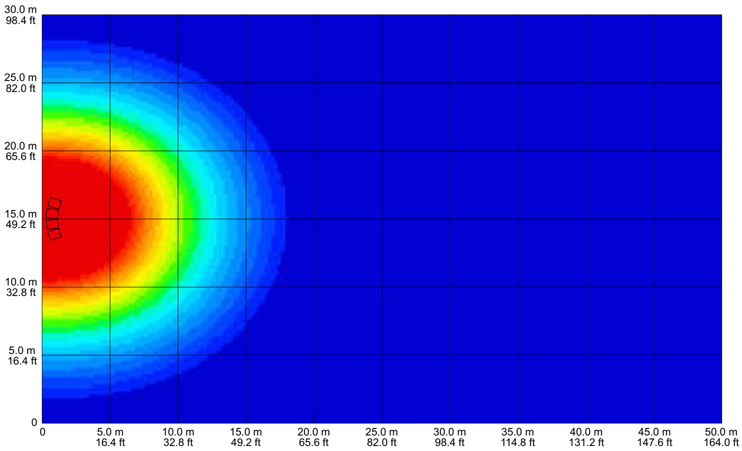

fig 21. four vertically positioned enclosures horizontally arrayed 50Hz
12 degree spacing between enclosures forming an inverted arc

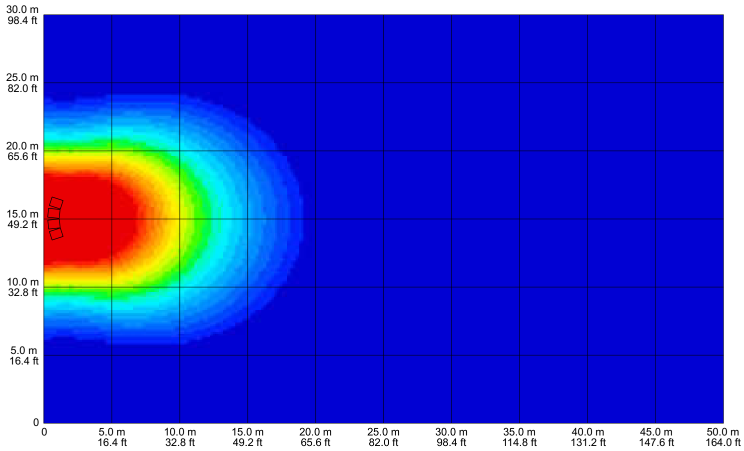

fig 22. four vertically positioned enclosures horizontally arrayed 100Hz
12 degree spacing between enclosures forming an inverted arc

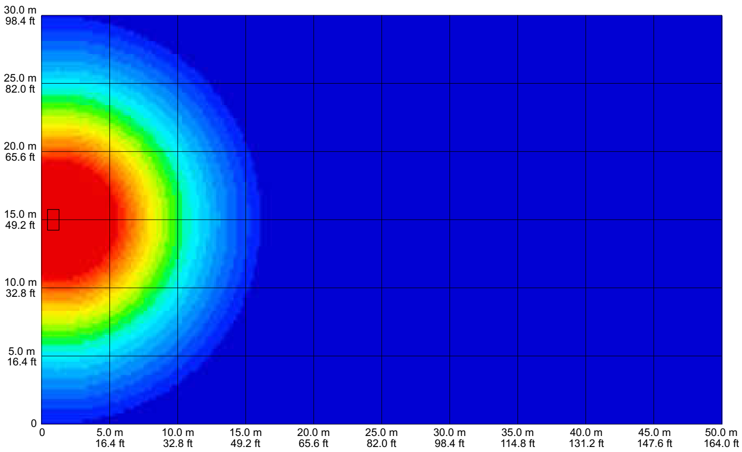

fig 23. four horizontally positioned enclosures vertically arrayed 100Hz

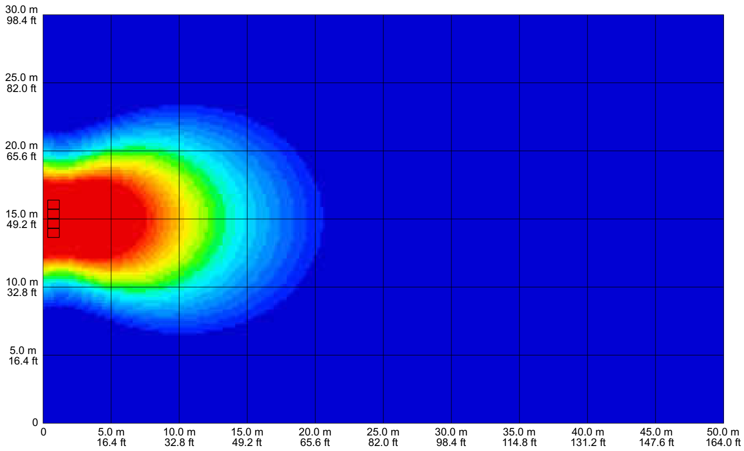

fig 24. four vertically positioned enclosures horizontally arrayed 100Hz

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The previous page dealt with four enclosure arrays, but now we look at six enclosure arrays and discover some major differences. fig 26 shows six vertically positioned enclosures horizontally arrayed with a 12 degree spacing between enclosures. It very obvious that the radiation pattern has become very directional, with much of the radiation being only just wider than the arrays physical width. This can also be seen in fig 30. which shows the same array in a straight formation. The difference between the four and six enclosure array is the arrays physical length. Four enclosures measure 2.44 m (8 ft) across, this equates to one wavelength at 141Hz. Any frequency being reproduced below 141Hz is larger than the arrays physical width and will not be subjected to much interference. A six enclosure array measures 3.66 m (12 ft) across which equates to one wavelength at 94Hz. If we try to reproduce 100Hz though this array there will be severe interference along the longest dimension of the array, as one wavelength at 100Hz is 3.44 m (11.3 ft) which is smaller than the arrays longest physical dimension. This means frequencies which have wavelengths smaller than the arrays physical width or line length will be subjected to extreme attenuation in the horizontal plane.

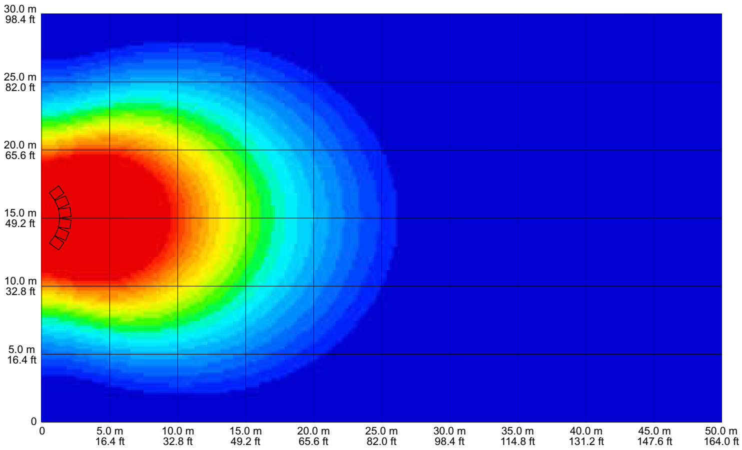

fig 25. six vertically positioned enclosures horizontally arrayed 50Hz
12 degree spacing between enclosures forming a curve

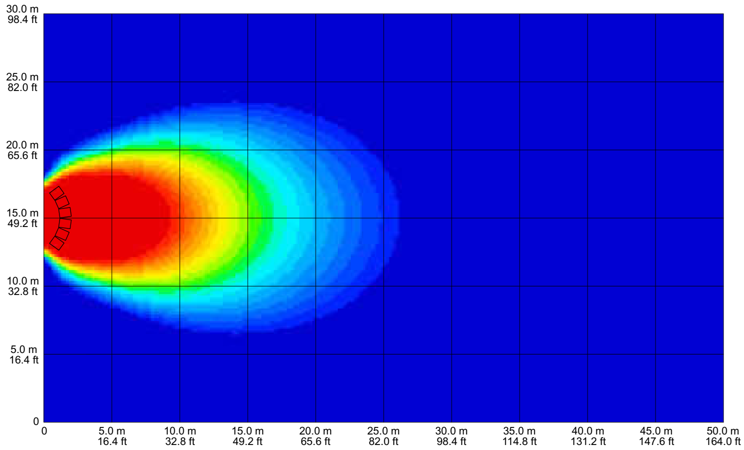

fig 26. six vertically positioned enclosures horizontally arrayed 100Hz
12 degree spacing between enclosures forming a curve

fig 27 - 28 show the effect of an inverted arc and its inherently wider radiation pattern compared to fig 26 and 30.

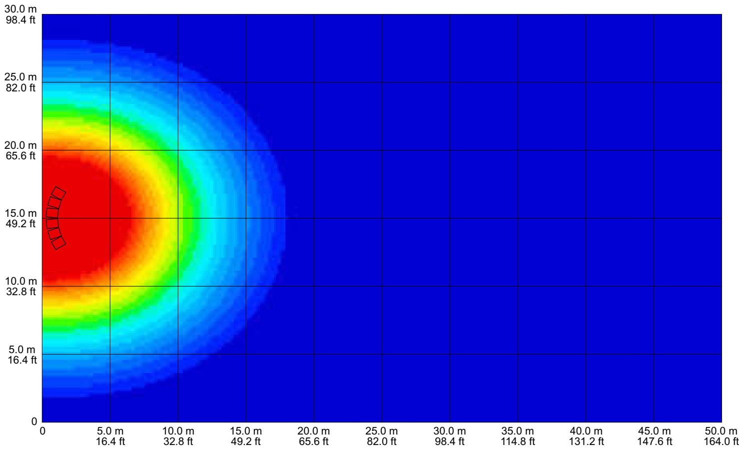

fig 27. six vertically positioned enclosures horizontally arrayed 50Hz
12 degree spacing between enclosures forming an inverted arc

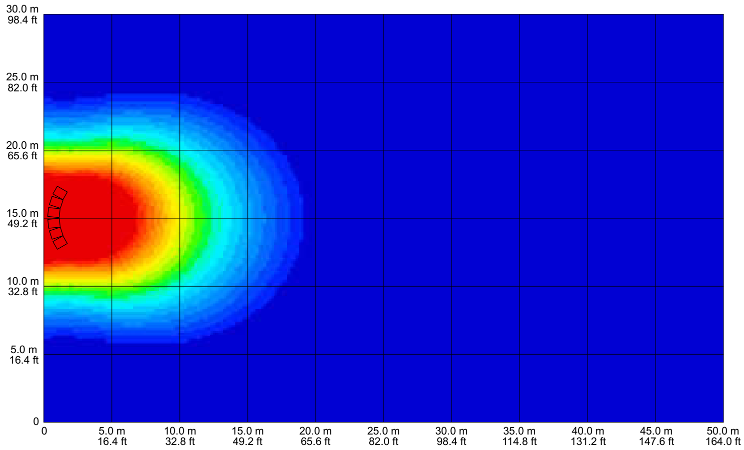

fig 28. six vertically positioned enclosures horizontally arrayed 100Hz
12 degree spacing between enclosures forming an inverted arc

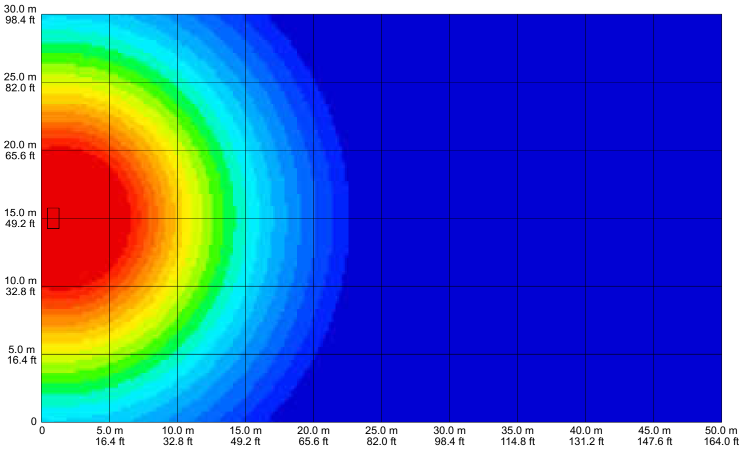

fig 29. six horizontally positioned enclosures vertically arrayed 100Hz

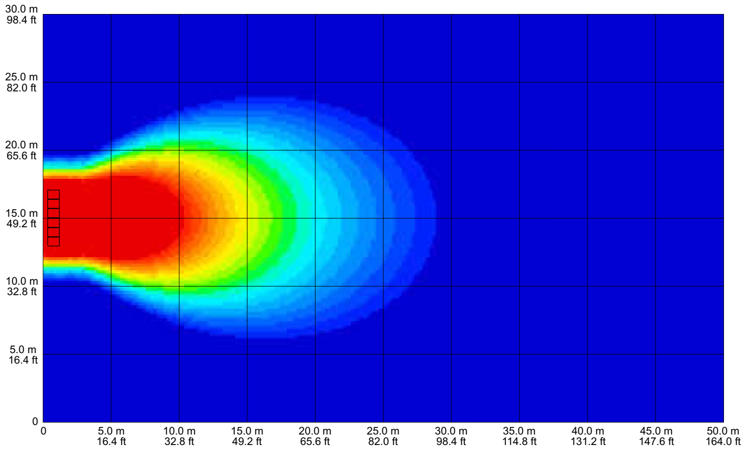

fig 30. six vertically positioned enclosures horizontally arrayed 100Hz

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The jump from six to eight enclosure arrays further highlights the problems that occur when the arrays line length is larger than the wavelengths being reproduced. It is the transition for a wave that is either larger or smaller than the arrays line length that causes the radiation pattern to vary and become more directional with increasing frequency. It explains why adding delay to the outermost enclosures in a long horizontal array will widen the radiation pattern. All you do when you delay the outermost enclosures is bring them closer to the centre point of the array, thus making the array look physically shorter. It also explains why an inverted arc has a wider radiation pattern than either a straight or curved formation. The centre point of the array to the furthermost woofers centre varies with different types of formation. For a curved array with 12 degree spacing, the distance around the front of the enclosures and hence the shortest path from array centre to furthermost woofers centre in an eight enclosure array is 2.69 m (8.8 ft). The distance for the same eight enclosures in an inverted arc has a distance 2.08 m (6.8 ft) if you measure the shortest path from array centre to the centre of the furthermost woofer. This is a difference of 1.22 m (4 ft) across the entire arrays width, giving an inverted arc with eight enclosures the same line length as a curved array with six enclosures, explaining why both have a similar radiation pattern.

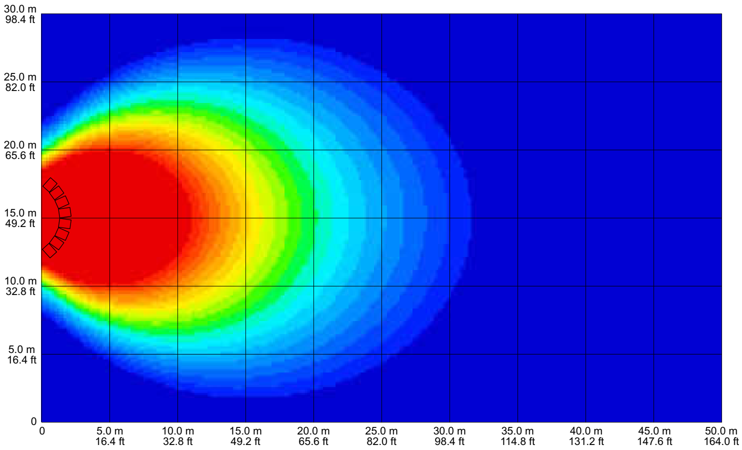

fig 31. eight vertically positioned enclosures horizontally arrayed 50Hz
12 degree spacing between enclosures forming a curve

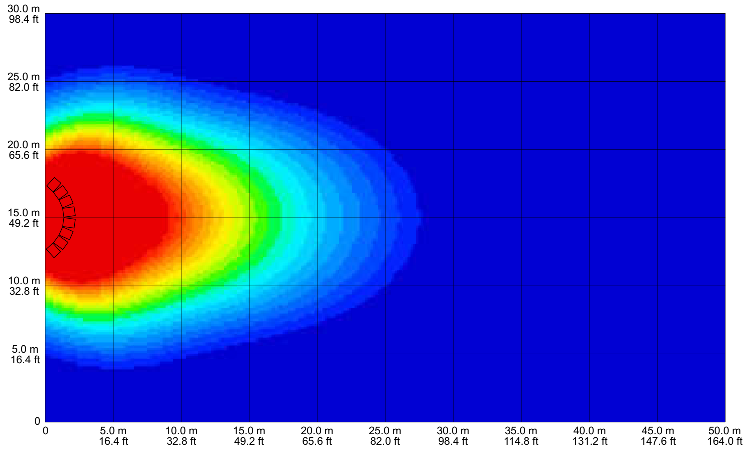

fig 32. eight vertically positioned enclosures horizontally arrayed 100Hz
12 degree spacing between enclosures forming a curve

fig 31 - 32. show eight enclosures forming a curve, while fig 33 - 34. show the effect of an inverted arc.

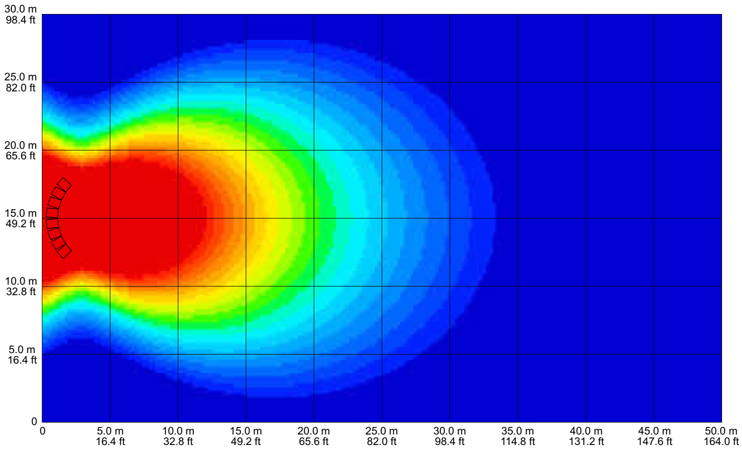

fig 33. eight vertically positioned enclosures horizontally arrayed 50Hz
12 degree spacing between enclosures forming an inverted arc

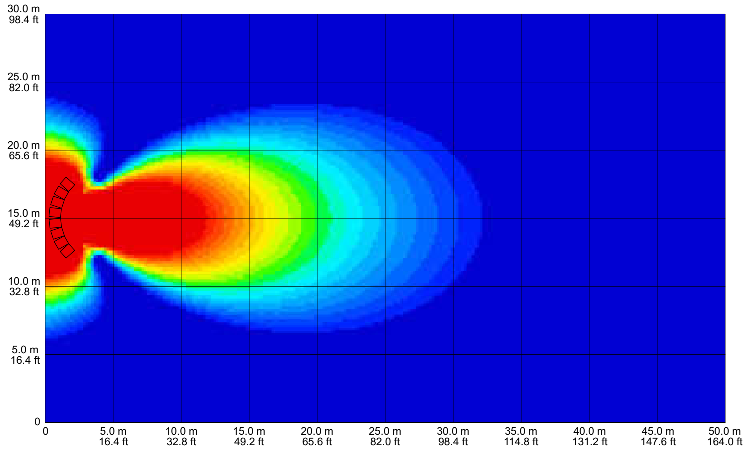

fig 34. eight vertically positioned enclosures horizontally arrayed 100Hz
12 degree spacing between enclosures forming an inverted arc

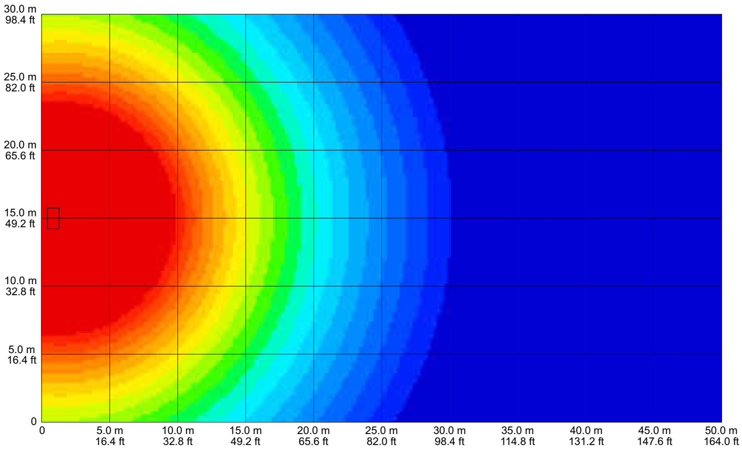

fig 35. eight horizontally positioned enclosures vertically arrayed 100Hz

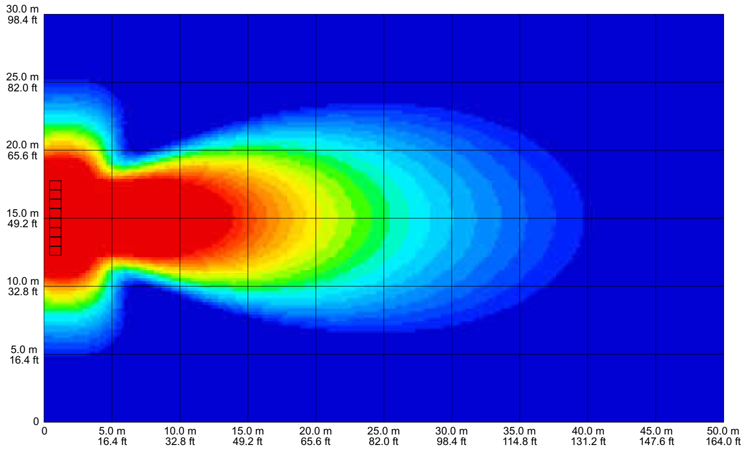

fig 36. eight vertically positioned enclosures horizontally arrayed 100Hz

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The next thing to examine is what happens when two arrays or elements are used together but at a distance from each other. The next few pages of simulations show what's happening with the majority of sound reinforcement systems when bass enclosures are located either side of a stage. We will first look at a single enclosure per side then move on to multiples and larger arrays. Because of the drop in output from using single enclosures for these simulations the SPL test range has reverted to red = 120dB and blue = 110dB. Also note that the enclosure spacing distance refers to the woofer centre to centre distance, not the enclosure edge to edge distance. fig 37 and 38. show the effect of a 1 m (3.3 ft) spacing at 50 and 100Hz respectively.

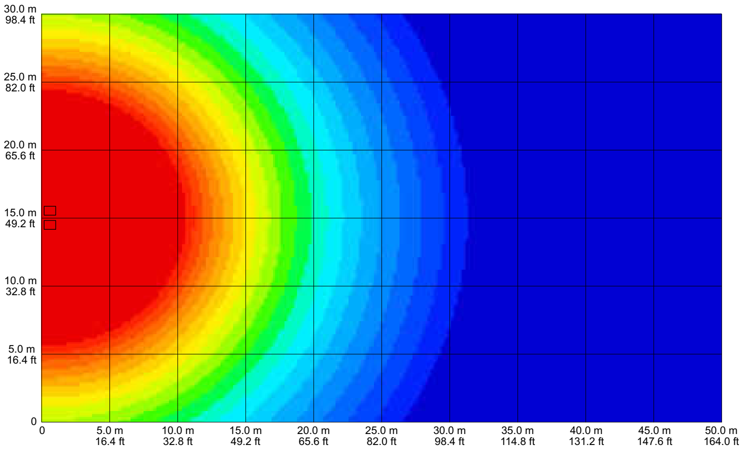

fig 37. two vertically positioned enclosures 1 m (3.3 ft) spacing 50Hz

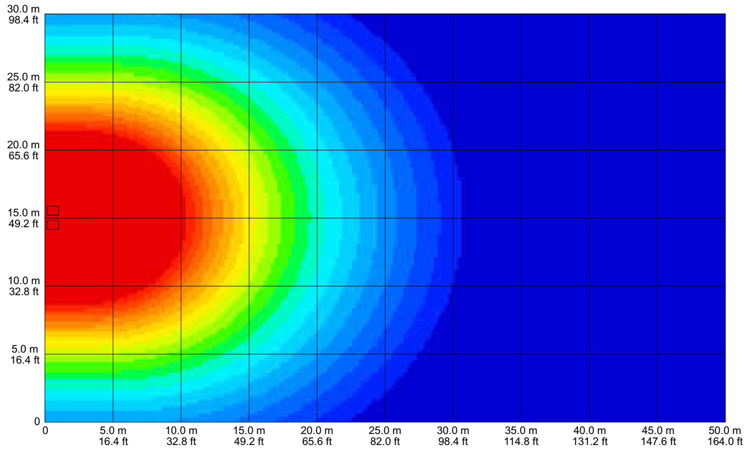

fig 38. two vertically positioned enclosures 1 m (3.3 ft) spacing 100Hz

fig 39 and 40. show the same two enclosures but with a 2 m (6.6 ft) spacing. It evident that the radiation pattern at 100Hz has become very directional with deep nulls at 90 degrees to the primary frontal lobe.

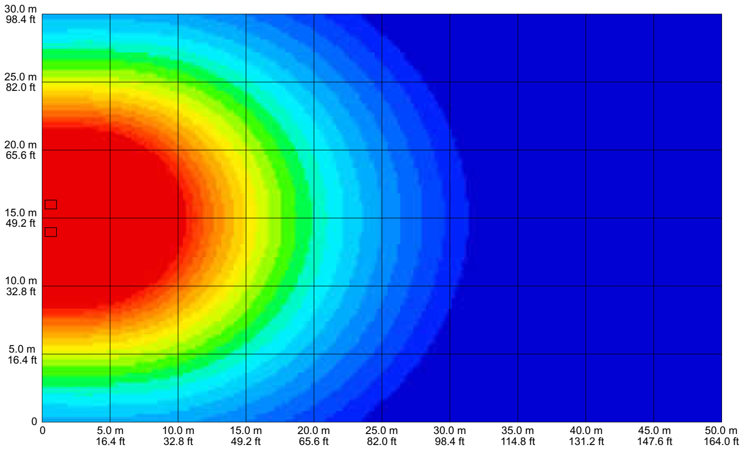

fig 39. two vertically positioned enclosures 2 m (6.6 ft) spacing 50Hz

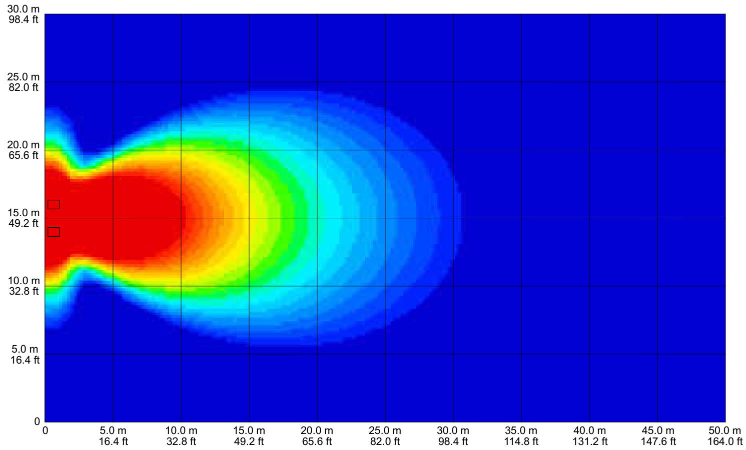

fig 40. two vertically positioned enclosures 2 m (6.6 ft) spacing 100Hz

fig 41 and 42. show a 4 m (13.1 ft) spacing between woofers at 50 and 100Hz. Even at 50Hz a considerable amount of interference is taken place. Note how the sim for the 2 m (6.6 ft) spacing at 100Hz in fig 40. looks almost identical to the sim made with a 4 m (13.1 ft) spacing an octave lower at 50Hz in fig 41. The 100Hz sim in fig 42. shows very deep nulls at 45 degrees from the primary frontal lobe.

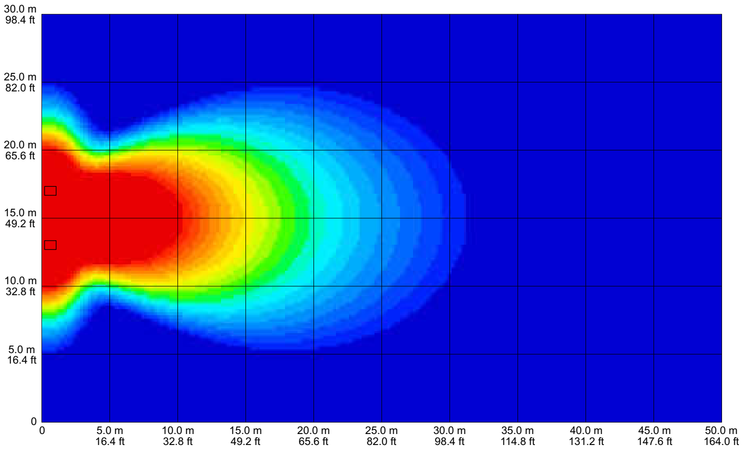

fig 41. two vertically positioned enclosures 4 m (13.1 ft) spacing 50Hz

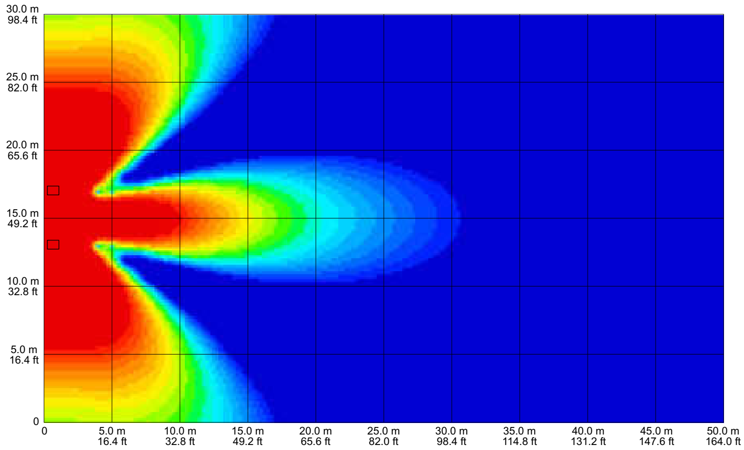

fig 42. two vertically positioned enclosures 4 m (13.1 ft) spacing 100Hz

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This page covers 8 m (26.2 ft), 16 m (52.5 ft) and 24 m (78.7 ft) spacings between enclosures. fig 43. shows an 8 m (26.2 ft) spacing which equates to one wavelength at 43Hz. 50Hz has a wavelength of 6.89 m (22.6 ft) which is shorter than the spacing between enclosures, hence a single frontal lobe and 2 deep nulls at 45 degrees are visible. fig 44. shows the same 8 m (26.2 ft) spacing but at 100Hz. The wavelength for 100Hz is 3.44 m (11.3 ft) which is over twice as short as the enclosure spacing and as can be seen form the radiation pattern 3 frontal lobes are now visible. Therefore the amount of frontal lobes present are proportionate to the amount of times a wavelength can be divided into the enclosure spacing distance.

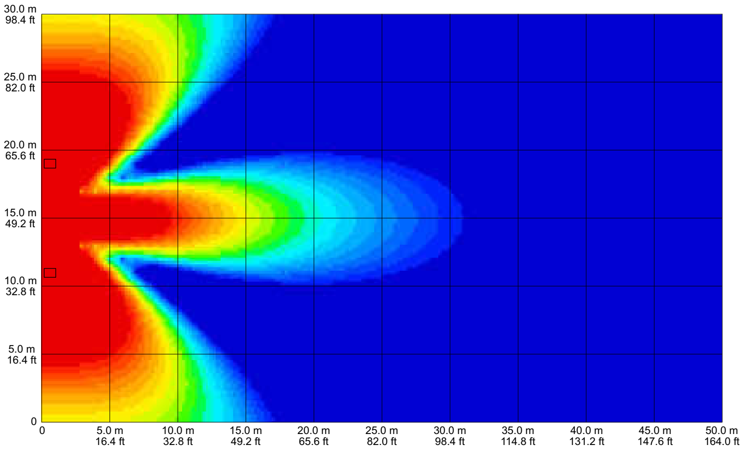

fig 43. two vertically positioned enclosures 8 m (26.2 ft) spacing 50Hz

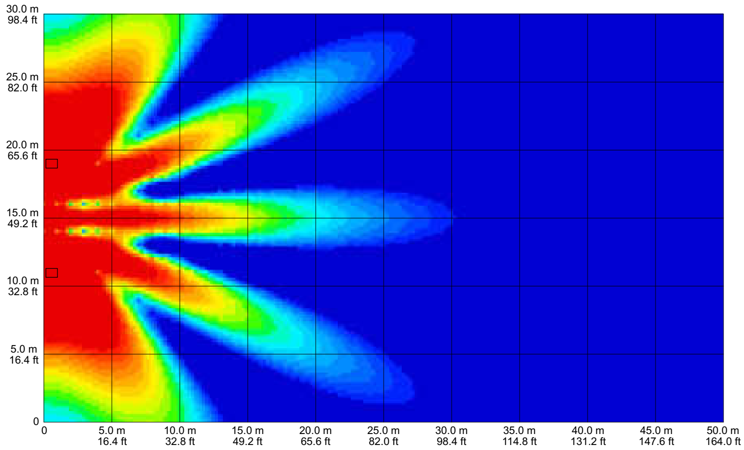

fig 44. two vertically positioned enclosures 8 m (26.2 ft) spacing 100Hz

fig 45. show the same two enclosures but with a 16 m (13.1 ft) spacing. As a 50Hz wavelength is over half the length of the enclosure spacing we again see 3 frontal lobes in the radiation pattern. fig 46. shows 100Hz with its 3.44 m (11.3 ft) wavelength. This wavelength is some 4.6 times shorter than the enclosure spacing distance and 7 frontal lobes are now visible in the radiation pattern.

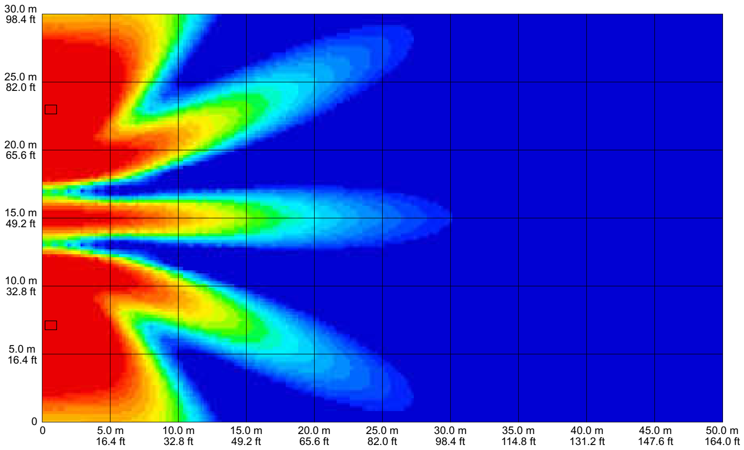

fig 45. two vertically positioned enclosures 16 m (52.5 ft) spacing 50Hz

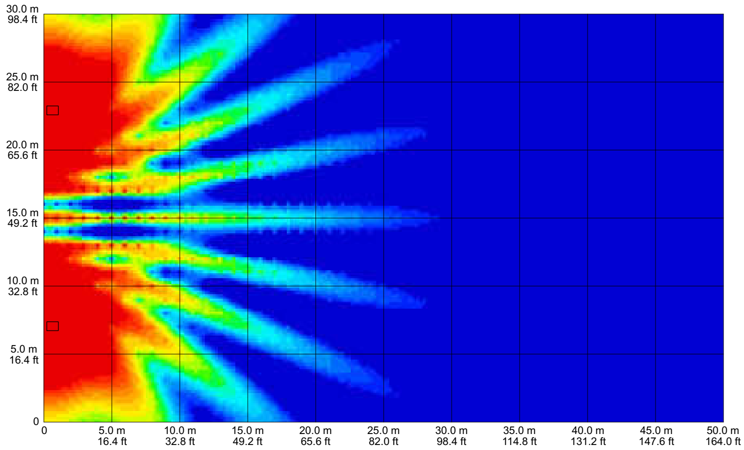

fig 46. two vertically positioned enclosures 16 m (52.5 ft) spacing 100Hz

fig 47 and 48. expand the enclosure spacing distance to 24 m (78.7 ft), where the interference taking place is very high. SPL deviations of up to 8 dB would be evident by taking one step forwards or backwards around a lobe.

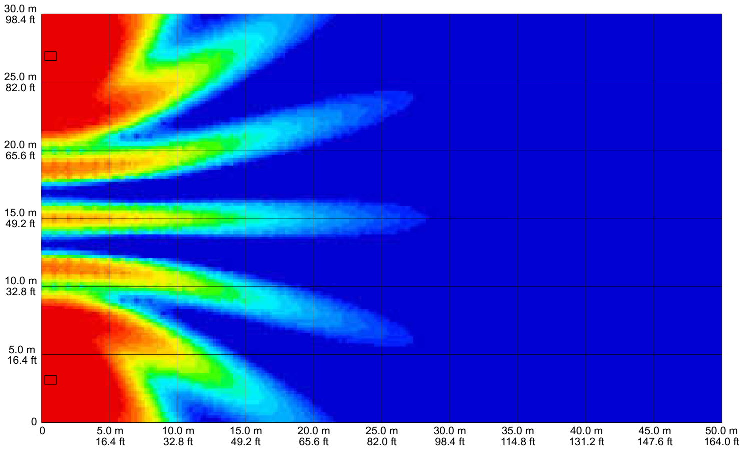

fig 47. two vertically positioned enclosures 24 m (78.7 ft) spacing 50Hz

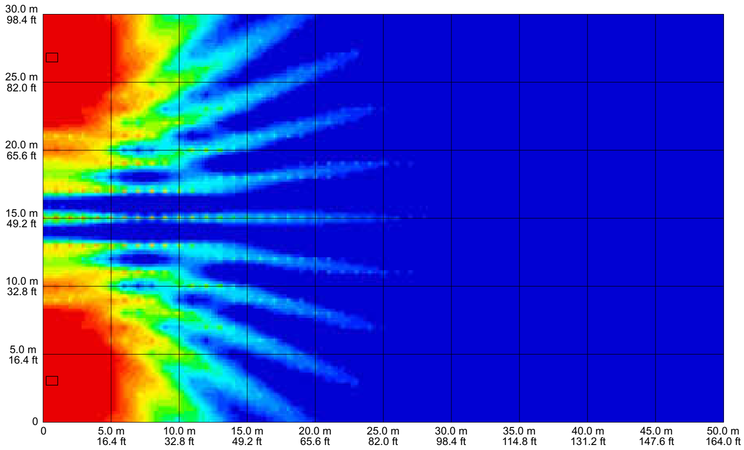

fig 48. two vertically positioned enclosures 24 m (78.7 ft) spacing 100Hz

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Over the next few pages we will look at multiple enclosure configurations both vertically and horizontally arrayed at distances of 6 m (19.7 ft), 12 m (39.4 ft) and 24 m (78.7 ft). Because multiple enclosures are used in these simulations the SPL test range has reverted to red = 130dB and blue = 120dB. The spacing distance refers to the distance from the centre of one group of enclosures to the centre of the other group of enclosures. fig 49. shows a simulation of two groups of enclosures that have been spaced by 6 m (19.7 ft) at 50Hz. Each group contains two test enclosures vertically positioned. fig 50. shows the same configuration but at 100Hz.

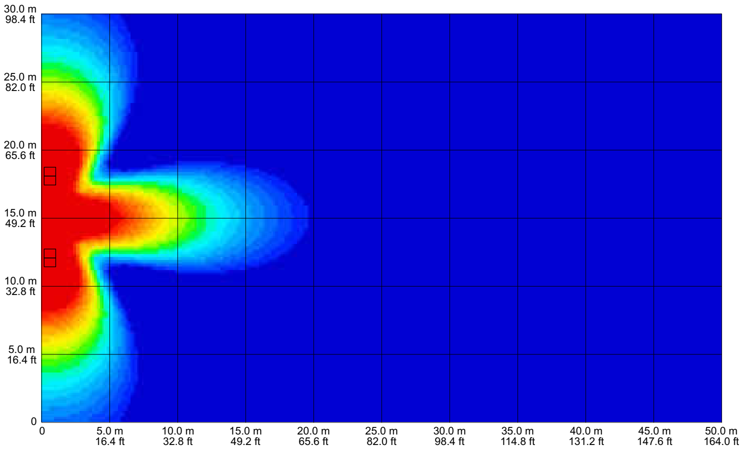

fig 49. two groups of two vertically positioned enclosures
6 m (19.7 ft) spacing 50Hz

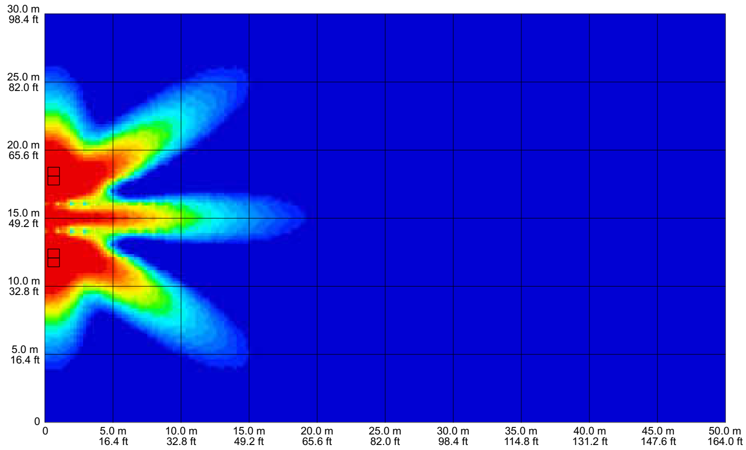

fig 50. two groups of two vertically positioned enclosures
6 m (19.7 ft ft) spacing 100Hz

fig 51. shows the same two groups of enclosures but with a 12 m (39.4 ft) spacing at 50Hz. The 100Hz simulation for the same configuration is shown in fig 52.

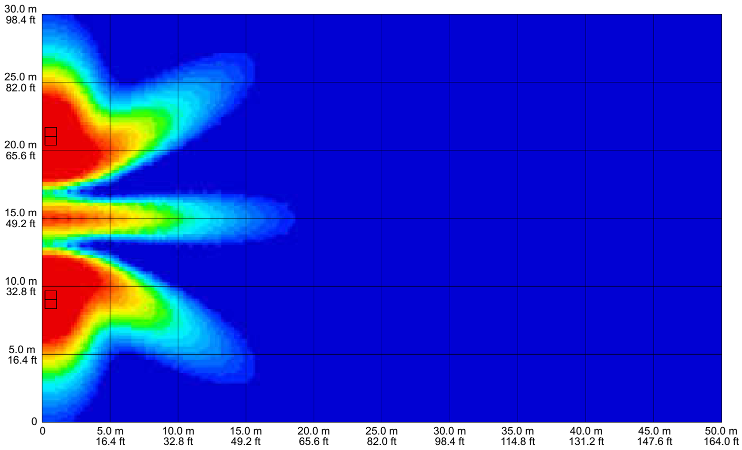

fig 51. two groups of two vertically positioned enclosures
12 m (39.4 ft) spacing 50Hz

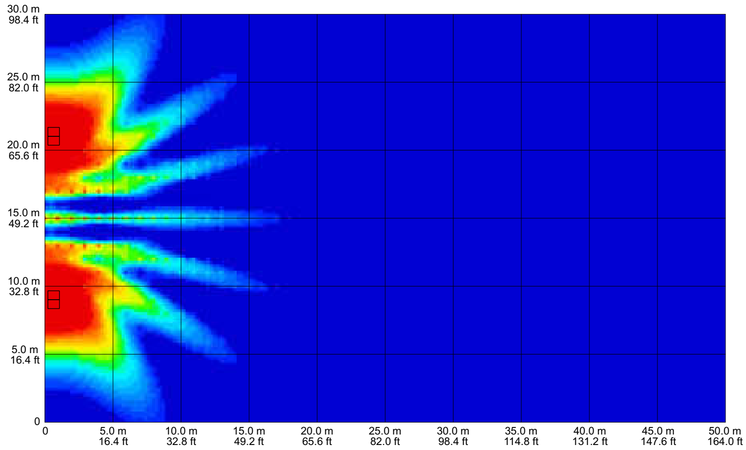

fig 52. two groups of two vertically positioned enclosures
12 m (39.4 ft) spacing 100Hz

fig 47 and 48. expand the enclosure spacing distance to 24 m (78.7 ft) and show both the 50Hz and 100Hz simulations.

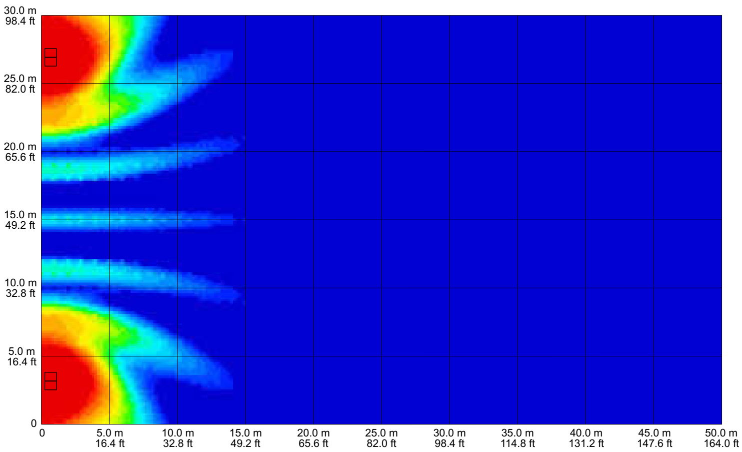

fig 53. two groups of two vertically positioned enclosures
24 m (78.7 ft) spacing 50Hz

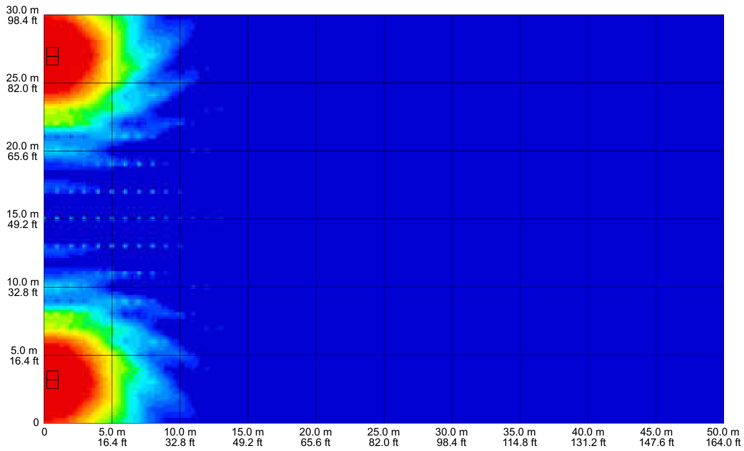

fig 54. two groups of two vertically positioned enclosures
24 m (78.7 ft) spacing 50Hz

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This page covers multiple enclosure configurations horizontally arrayed at distances of 6 m (19.7 ft), 12 m (39.4 ft) and 24 m (78.7 ft). fig 55. shows a simulation of two groups of enclosures that have been spaced by 6 m (19.7 ft) at 50Hz. Each group contains four test enclosures vertically positioned. fig 50. shows the same configuration but at 100Hz. Note the similarities in the radiation pattern of the 6 m (19.7 ft) configuration at 100Hz in fig 56. with the 12 m (39.4 ft) configuration at 50Hz in fig 57. A definite pattern is emerging when either the frequency or distance is doubled or halved.

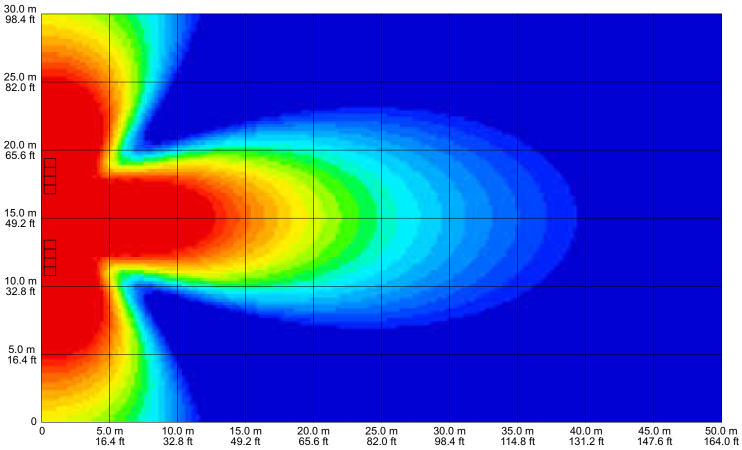

fig 55. two groups of four vertically positioned enclosures
6 m (19.7 ft) spacing 50Hz

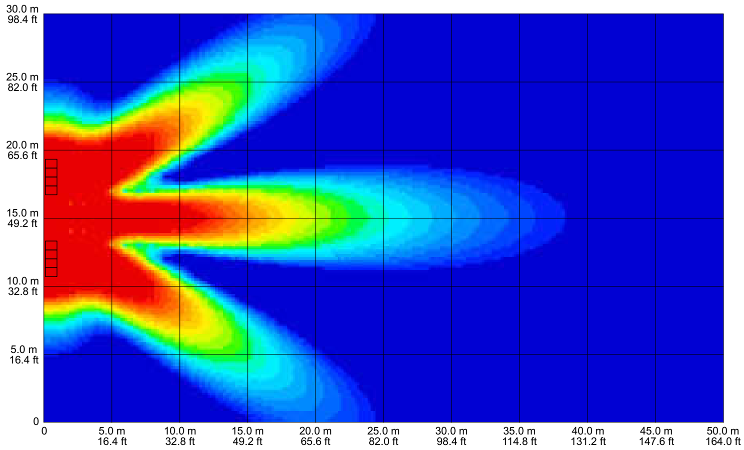

fig 56. two groups of four vertically positioned enclosures
6 m (19.7 ft ft) spacing 100Hz

fig 57. shows the same two groups of enclosures but with a 12 m (39.4 ft) spacing at 50Hz. The 100Hz simulation for the same configuration is shown in fig 58.

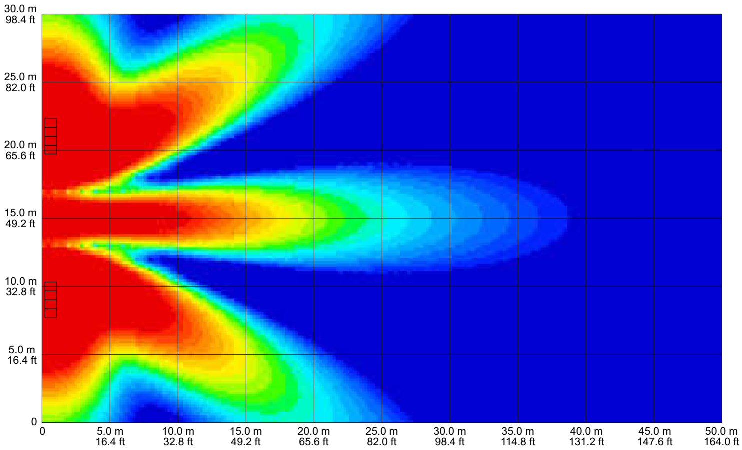

fig 57. two groups of four vertically positioned enclosures
12 m (39.4 ft) spacing 50Hz

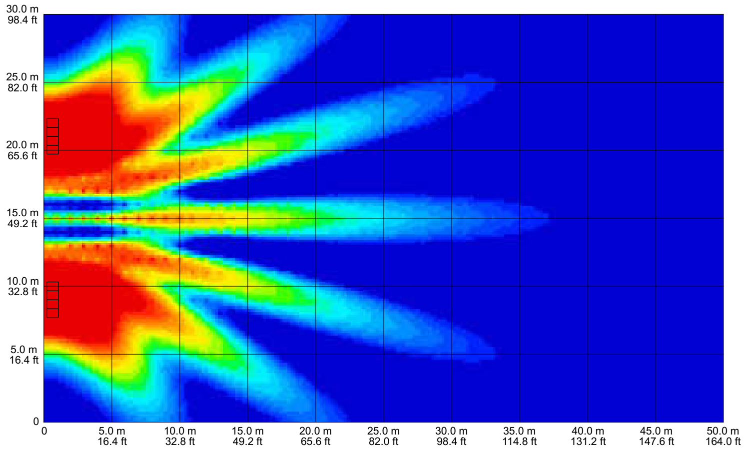

fig 58. two groups of four vertically positioned enclosures
12 m (39.4 ft) spacing 100Hz

fig 59 and 60. expand the enclosure spacing distance to 24 m (78.7 ft) and show both the 50Hz and 100Hz simulations.

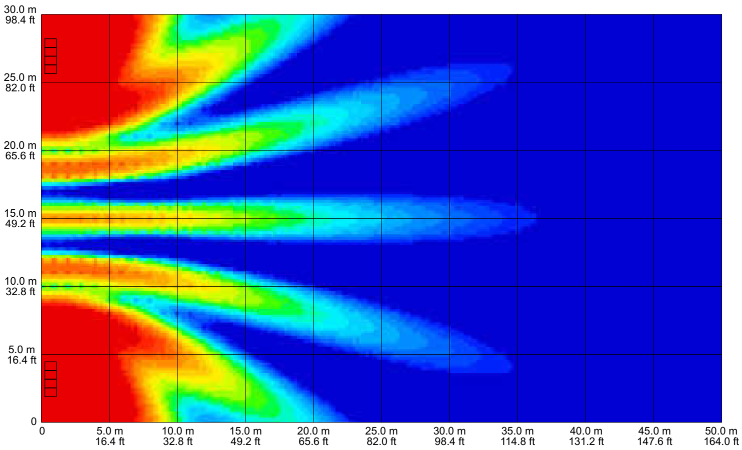

fig 59. two groups of four vertically positioned enclosures
24 m (78.7 ft) spacing 50Hz

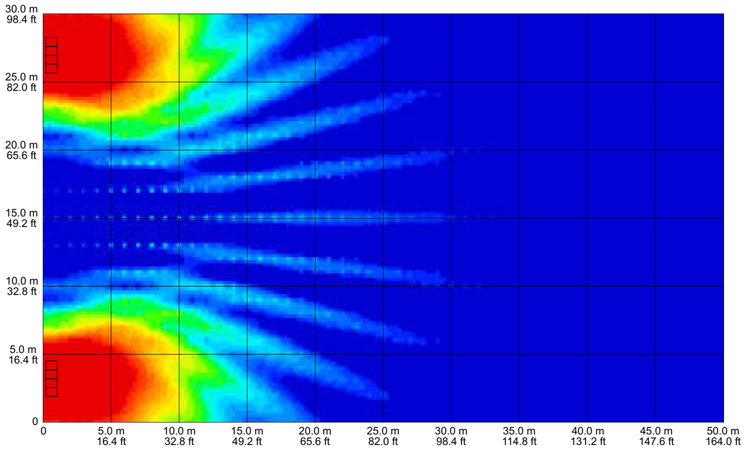

fig 60. two groups of four vertically positioned enclosures
24 m (78.7 ft) spacing 50Hz

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Over the next two pages we are going to look at vertically arrayed grouped configurations. The simulations below were made with two enclosures vertically arrayed into two groups spaced at distances of 6 m (19.7 ft), 12 m (39.4 ft) and 24 m (78.7 ft). fig 61. shows a simulation of two groups of enclosures that have been spaced by 6 m (19.7 ft) at 50Hz. Each group contains two test enclosures horizontally positioned and vertically arrayed. fig 61. shows the same configuration but at 100Hz. With only two enclosures per group the radiation patterns look almost idenitcal to the two enclosure vertically positioned groups shown on page 10. It would appear that when using two enclosures per group that either vertical or horizontal poisitioning of each group gives the same results.

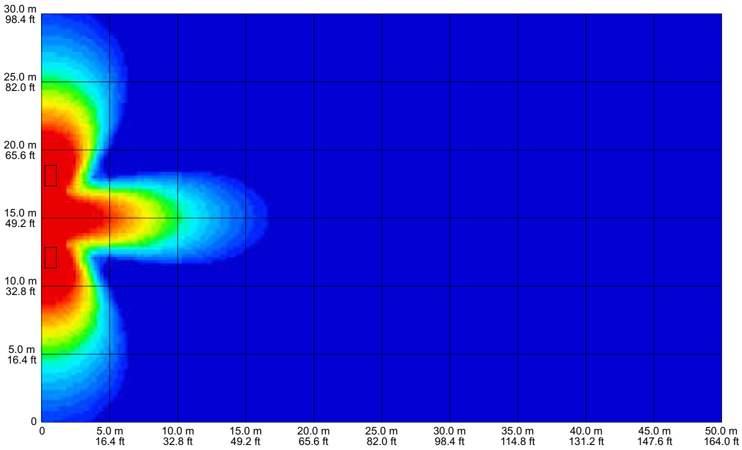

fig 61. two groups of two horizontally positioned enclosures vertically arrayed with a 6 m (19.7 ft) spacing 50Hz

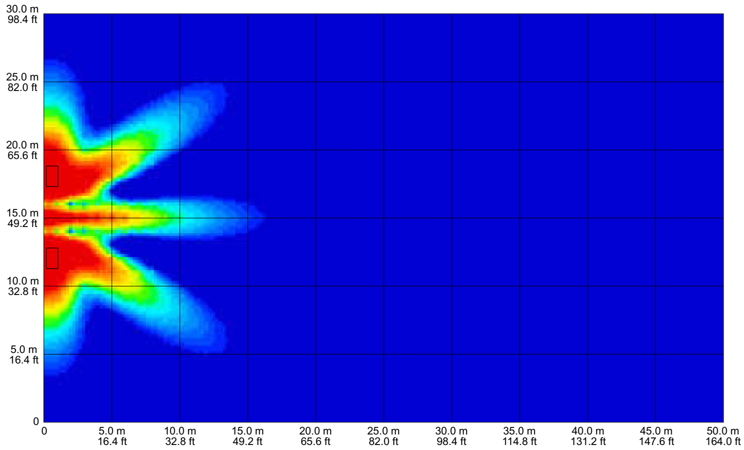

fig 62. two groups of two horizontally positioned enclosures vertically arrayed with a 6 m (19.7 ft ft) spacing 100Hz

fig 63. shows the same two groups of enclosures but with a 12 m (39.4 ft) spacing at 50Hz. The 100Hz simulation for the same configuration is shown in fig 64.

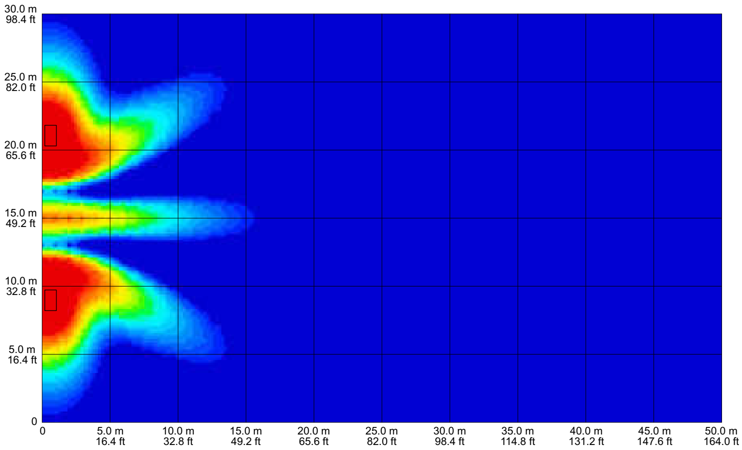

fig 63. two groups of two horizontally positioned enclosures vertically arrayed with a 12 m (39.4 ft) spacing 50Hz

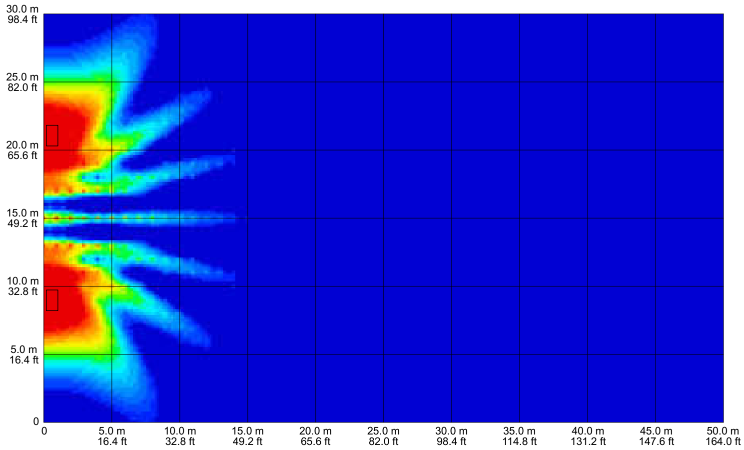

fig 64. two groups of two horizontally positioned enclosures vertically arrayed with a 12 m (39.4 ft) spacing 100Hz

The simulation for a spacing distance of 24 m (78.7 ft) at 50Hz is shown in fig 65. while fig 66. shows the 100Hz simulation for the same two groups.

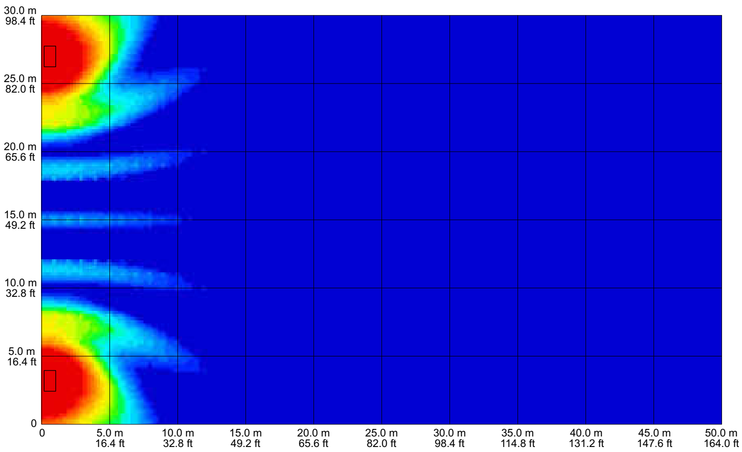

fig 65. two groups of two horizontally positioned enclosures vertically arrayed with a 24 m (78.7 ft) spacing 50Hz

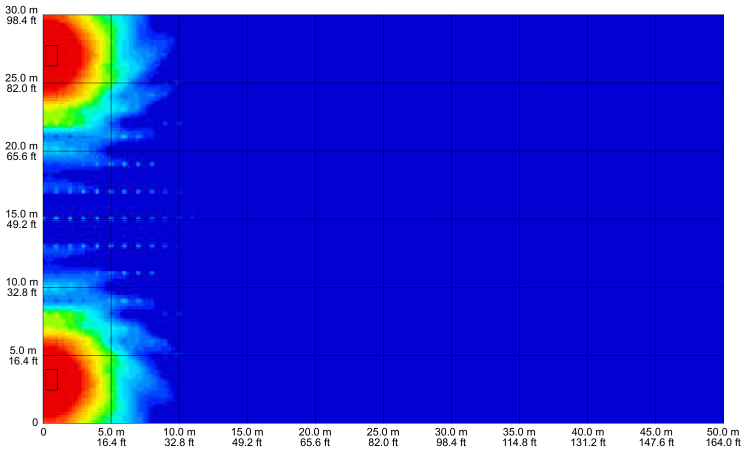

fig 66. two groups of two horizontally positioned enclosures vertically arrayed with a 24 m (78.7 ft) spacing 50Hz

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The simulations below were made with four enclosures vertically arrayed into two groups spaced at distances of 6 m (19.7 ft), 12 m (39.4 ft) and 24 m (78.7 ft). fig 67. shows a simulation of two groups of enclosures that have been spaced by 6 m (19.7 ft) at 50Hz. Each group contains four test enclosures horizontally positioned and vertically arrayed. fig 61. shows the same configuration but at 100Hz. With four enclosures per group vertically arrayed the radiation patterns show less side rejection and forwards beaming when compared to the four enclosure vertically positioned groups shown on page 11. The greater width in dispersion comes at the expense of a reduction in SPL at distance, this being more apparent at greater spacing distances and or higher frequencies.

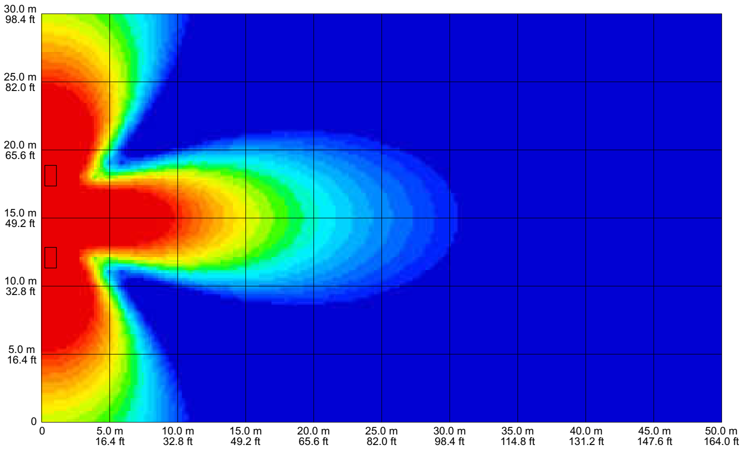

fig 67. two groups of four horizontally positioned enclosures vertically arrayed with a 6 m (19.7 ft) spacing 50Hz

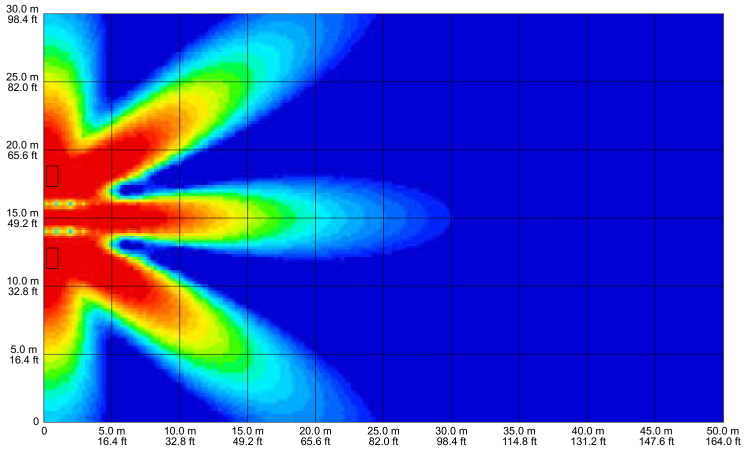

fig 68. two groups of four horizontally positioned enclosures vertically arrayed with a 6 m (19.7 ft ft) spacing 100Hz

fig 69. shows the same two groups of enclosures but with a 12 m (39.4 ft) spacing at 50Hz. The 100Hz simulation for the same configuration is shown in fig 70.

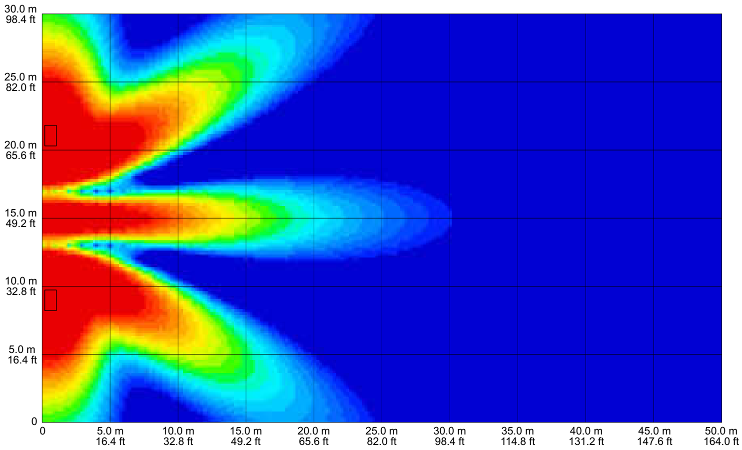

fig 69. two groups of four horizontally positioned enclosures vertically arrayed with a 12 m (39.4 ft) spacing 50Hz

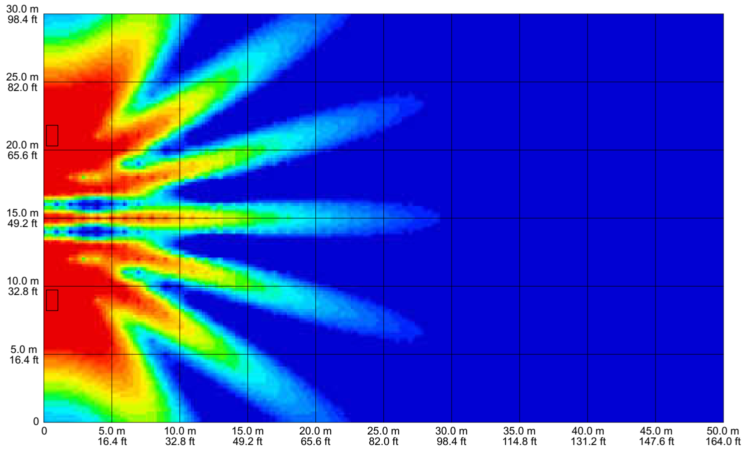

fig 70. two groups of four horizontally positioned enclosures vertically arrayed with a 12 m (39.4 ft) spacing 100Hz

The simulation for a spacing distance of 24 m (78.7 ft) at 50Hz is shown in fig 71. while fig 72. shows the 100Hz simulation for the same two groups of four enclosures.

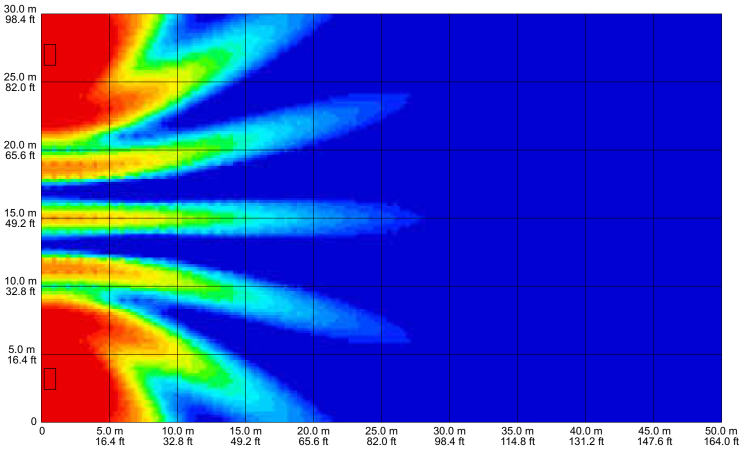

fig 71. two groups of four horizontally positioned enclosures vertically arrayed with a 24 m (78.7 ft) spacing 50Hz

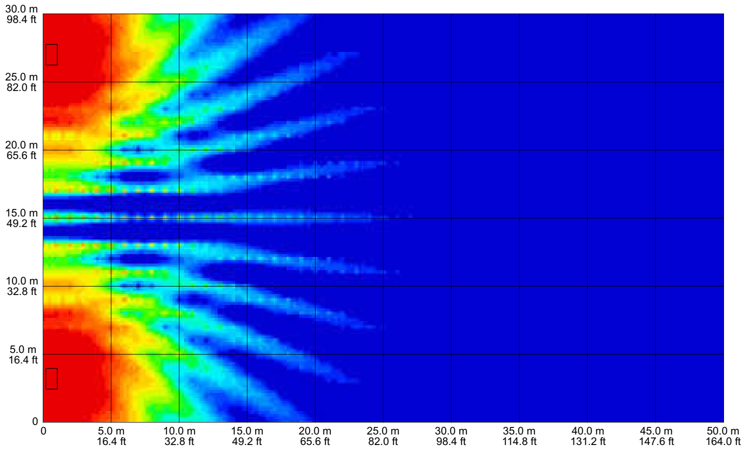

fig 72. two groups of four horizontally positioned enclosures vertically arrayed with a 24 m (78.7 ft) spacing 100Hz

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Before we look at some typical multi array setups its worth looking at some directional configurations. fig 73. shows two test enclosures sitting back to back horizontally positioned at 50Hz. Enclosure A faces forwards and B faces backwards. Enclosure B has its phase reversed with 1 ms of delay applied. fig 74. shows the same configuration but at 100Hz. For the depth of enclosures used 2.2 ms would be the optimal delay time to give similar front to back rejection from 63Hz and above. Below 63Hz the overall SPL will be reduced as this type of arrangement can only operate effectively over 1 octave from 62.5Hz to 125Hz. Because of the drop in output from using single enclosures for these simulations the SPL test range has reverted to red = 120dB and blue = 110dB.

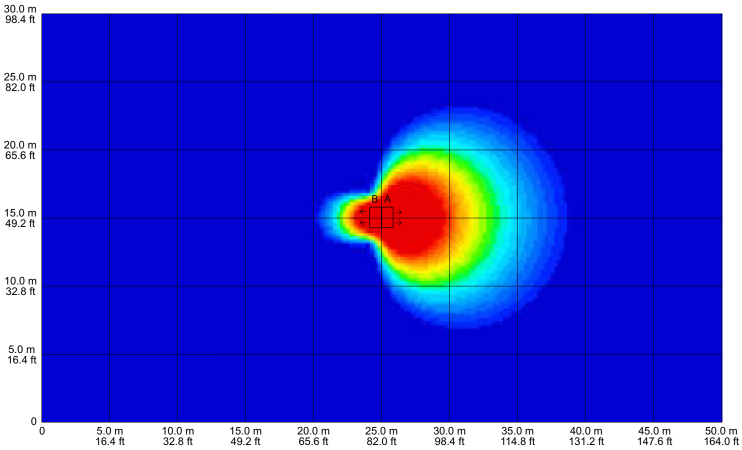

fig 73. two horizontally positioned enclosures back to back enclosure B phase reversed with 1 ms delay 50Hz

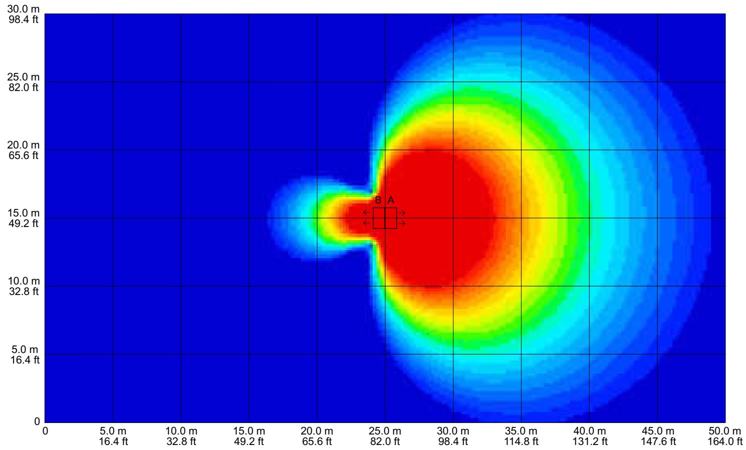

fig 74. two horizontally positioned enclosures back to back enclosure B phase reversed with 1 ms delay 100Hz

If the the delay setting for enclosure B is changed from 1 ms to 2 ms we see an increase in front to back rejection. fig 75. shows the effect of a 2 ms delay at 50Hz and fig 76. the effect at 100Hz.

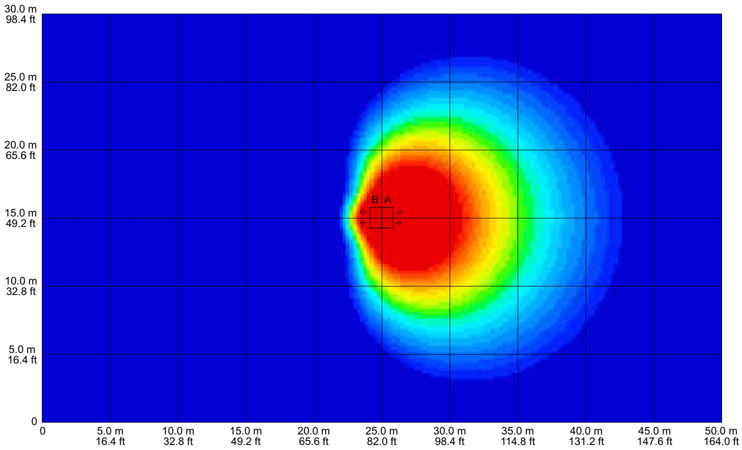

fig 75. two horizontally positioned enclosures back to back enclosure B phase reversed with 2 ms delay 50Hz

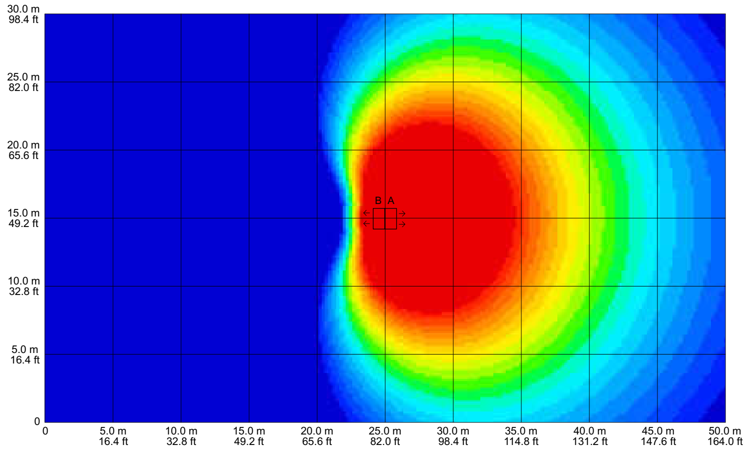

fig 76. two horizontally positioned enclosures back to back enclosure B phase reversed with 2 ms delay 100Hz

The simulation for a 3 ms delay applied to enclosure B at 50Hz is shown in fig 77. while fig 72. shows the 100Hz simulation for the same arrangement.

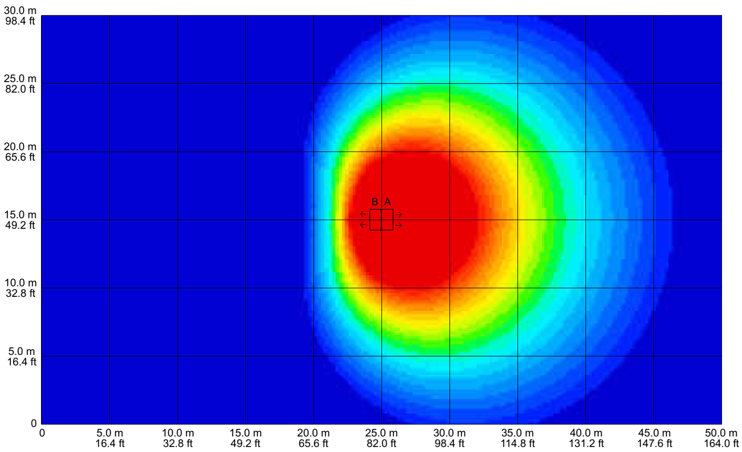

fig 77. two horizontally positioned enclosures back to back enclosure B phase reversed with 3 ms delay 50Hz

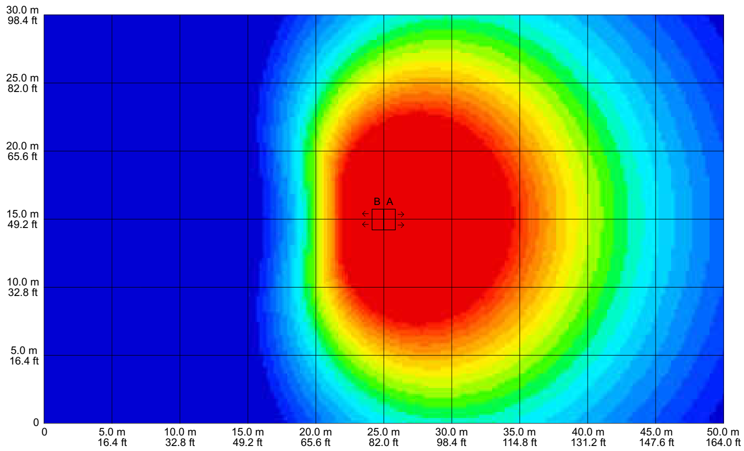

fig 78. two horizontally positioned enclosures back to back enclosure B phase reversed with 3 ma delay 100Hz

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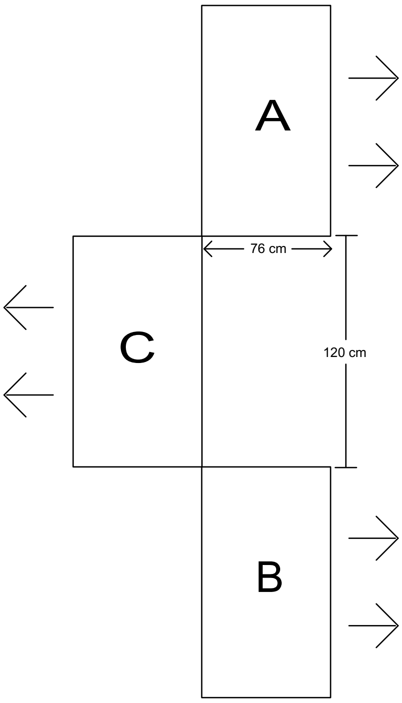

fig 79. Delta Array Configuration

While the directional arrangement on the previous page can provide 15 to 20dB of front to back rejection the overall output SPL compared to the same amount of enclosures all facing forwards in phase will always be less. The price to pay for greater front to back rejection is a decrease in overall SPL, especially at lower frequencies. To overcome the problem of decreasing output at low frequencies and to provide greater front to back rejection I have created what I call the Delta Array. The arrangement uses a minimum of three horizontally positioned enclosures and can be built to any height to form a vertical Delta Array. fig 79. shows a typical Delta Array arrangement.

The arrangement requires two channels of processing. Enclosures A and B are fed the same signal and can be parallel wired. Enclosure C is facing backwards and is phase reversed with 2.5 ms of delay applied. The same amount of power should be applied to all the enclosures. To form a vertical Delta Array duplicate the bottom row settings for all the enclosures that sit above. Different size enclosures could be used but enclosure C's delay time would need to be recalculated due to the new spacings. Fig 80. shows a two enclosure high Delta Array using six enclosures at 50Hz, while fig 81. shows the same six enclosures at 100Hz. Note that the SPL test range has reverted to red = 130dB and blue = 120dB for these simulations.

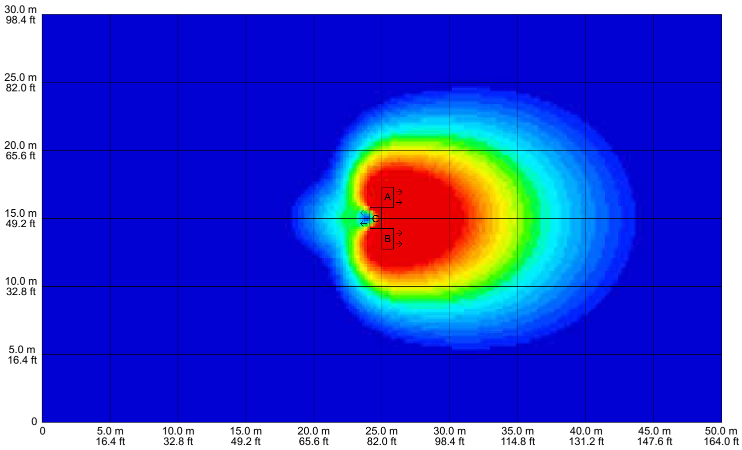

fig 80. two enclosure high Delta Array 50Hz

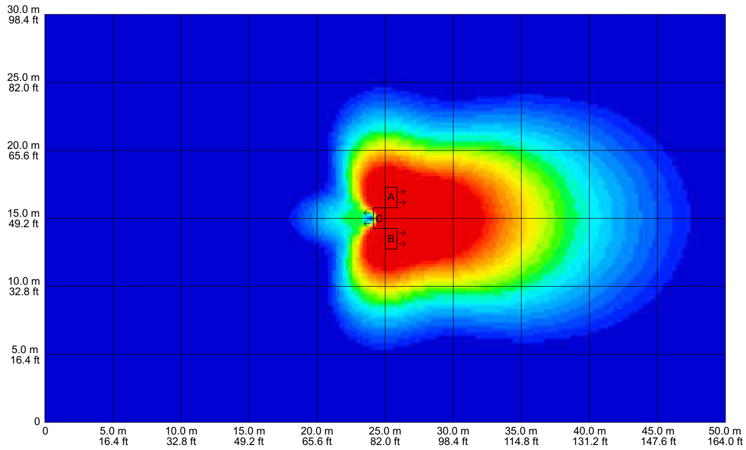

fig 81. two enclosure high Delta Array 100Hz

A Delta Array can be steered by reversing the phase on enclosure A or B. For a 90 degree left steer as looking from the front of the array, reverse the phase of enclosure A. For a 90 degree right steer reverse the phase of enclosure B. Note that a 5.1 ms delay has the same effect as a phase reverse. fig 82. shows a steered Delta Array with enclosure A phase reversed or a 5.1 ms delay applied at 50Hz. fig 83. shows the same configuration at 100Hz.

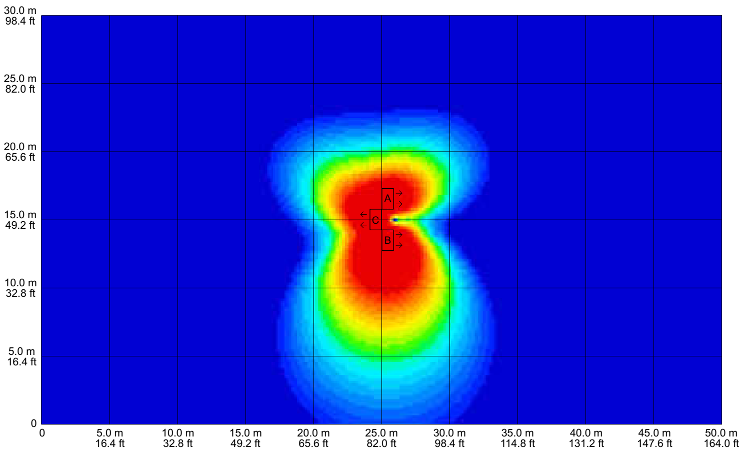

fig 82. two enclosure high Delta Array
Enclosure A phase reversed 50Hz

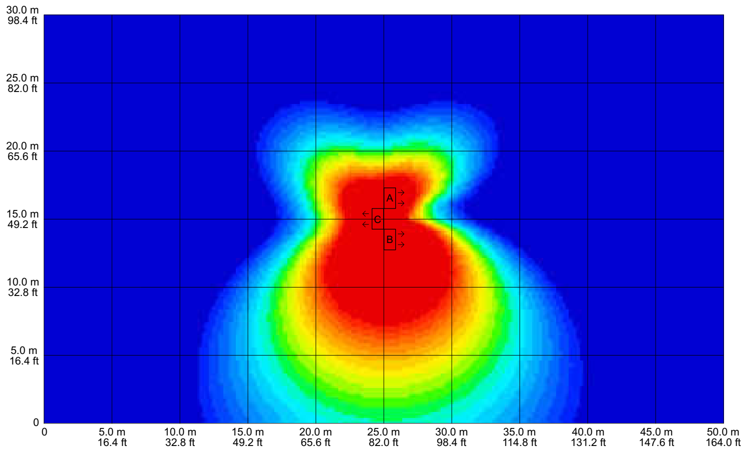

fig 83. two enclosure high Delta Array
Enclosure A phase reversed 100Hz

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fig 84. four enclosure high Delta Array

The simulations below were all made with twelve test enclosures. fig 85 and 86 show the radiation pattern of a four high Delta Array as pictured in fig 84. Both the forwards facing stacks of eight vertical enclosures are receiving the same signal, whilst the rear facing four enclosures are all reversed phased and are delayed by 2.5 ms.

The array shows good coherence with the SPL at distance showing similarity, there is only a 1.5dB decrease in SPL at 50Hz compared to 100Hz.

If we compare the twelve forwards facing enclosures in fig 87 and 88 with the Delta Array in fig 85 and 86 we find that the Delta Array is only 0.5dB down in output at 100Hz and 1.5dB down at 50Hz. These are very small losses compared to the amount of front to back rejection obtained.

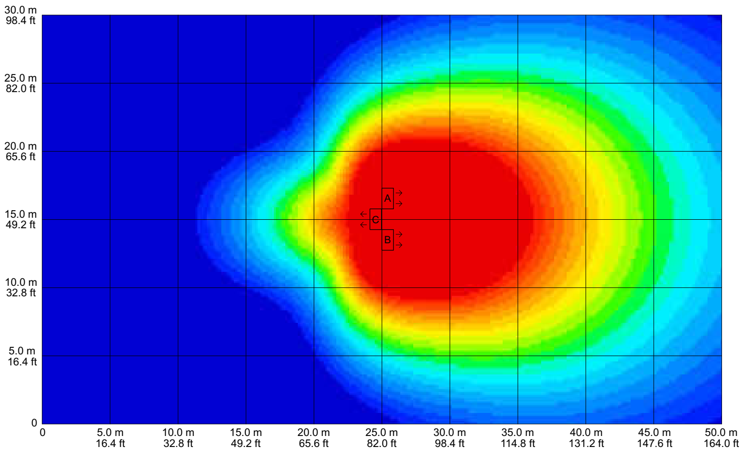

fig 85. four enclosure high Delta Array 50Hz

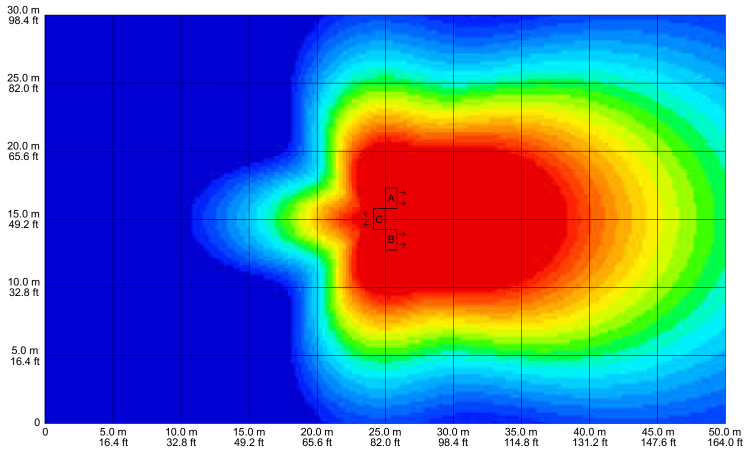

fig 86. four enclosure high Delta Array 100Hz

figs 87 and 88 show the radiation patterns for an array of twelve enclosure that are all facing forwards and are in phase. They are arranged in a four high by three wide configuration, each enclosure receives the same signal and power level. Note how the width of the radiation pattern out at 10 m (32.8 ft) varies considerably between the 50Hz and 100Hz simulations. If we look at the radiation width for the Delta Array out at 10 m (32.8 ft) we find the difference to be only 1dB between the 50Hz and 100Hz simulations. Do not be tempted to move the rear facing enclosures in a Delta Array forwards so they align with the front enclosures. Doing this destroys the arrays directional properties even if the delay times are changed, the resulting radiation pattern will then resemble those of figs 87 and 88. The array has directional properties only when the three elements form a triangle.

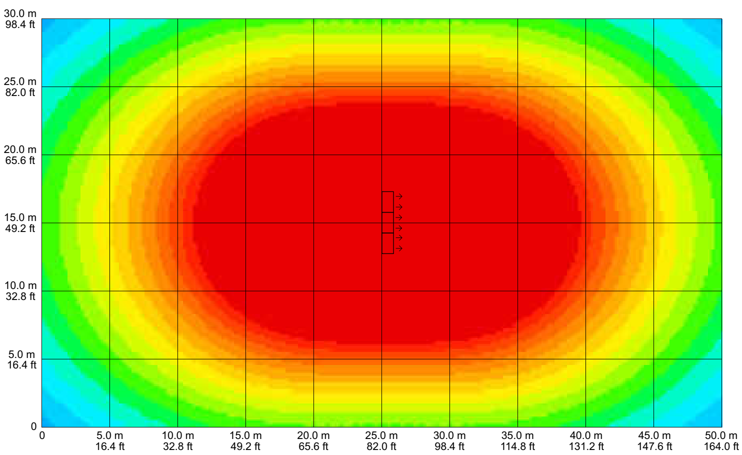

fig 87. twelve enclosure Array
three wide x four high 50Hz

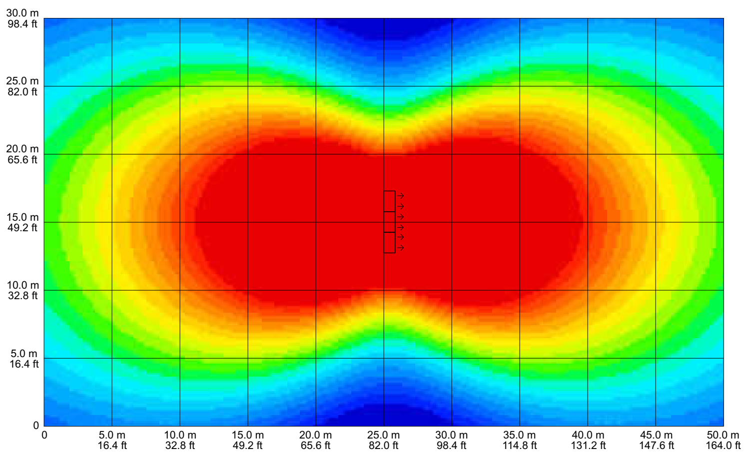

fig 88. twelve enclosure Array
three wide x four high 100Hz

VOID

fig 89. shows a horizontal Delta Array made up of three smaller arrays. All the forward facing enclosures (A) are fed the same signal and power levels, the rear facing enclosures (B) are all fed the same phase reversed signal that has been delayed by 2.5 ms. fig 90 and 91 show the effect of this three wide Delta Array. As can be seen from the simulations the radiation pattern is very directional and the front to side rejection is very high. The amount of loss at low frequencies is also small compared with other directional configurations, it being 2dB from 100Hz to 50Hz. Front to back rejection is also high, making this type of configuration suitable for use directly in front of a stage as a fill between the main L/R FOH arrays.

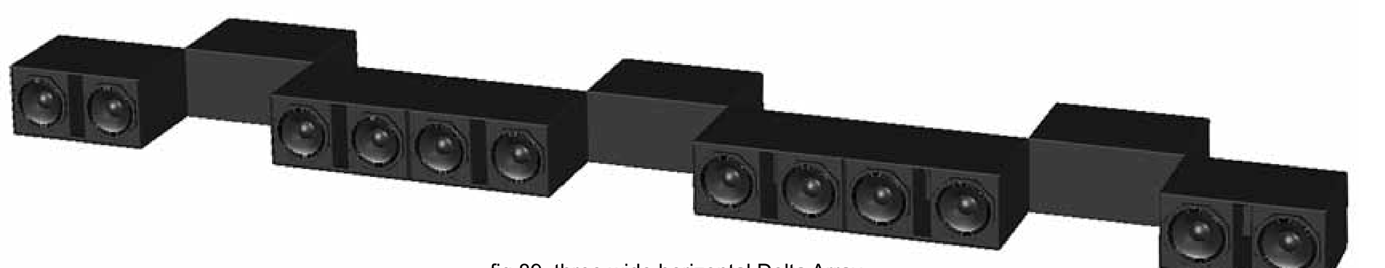

fig 89. three wide horizontal Delta Array

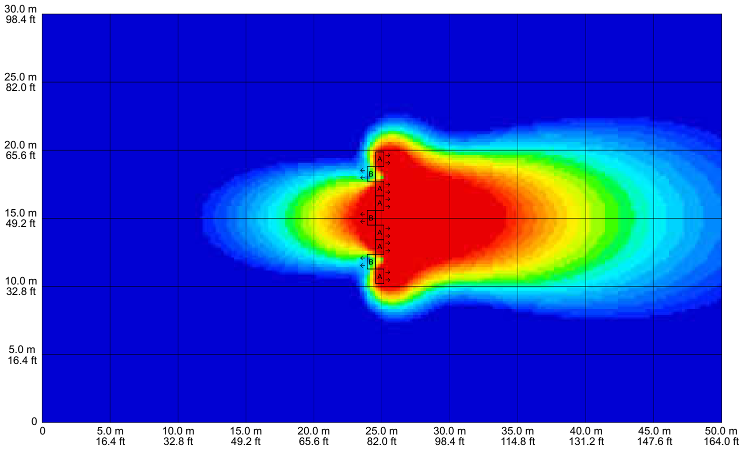

fig 90. four enclosure high Delta Array 50Hz

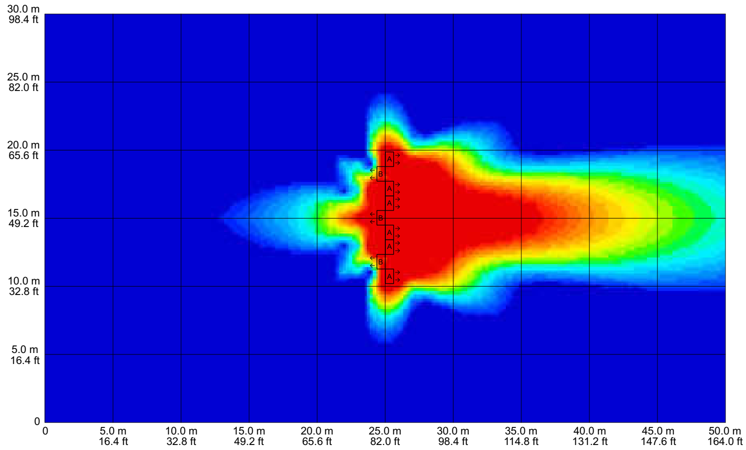

fig 91. four enclosure high Delta Array 100Hz

If on stage levels of bass must be kept to a minimum then the endless configuration show in fig 92. offers even higher levels of front to back rejection. The array is constructed the same as the three wide horizontal array in fig 89. but the enclosures are vertically positioned and the end pair of enclosures are left out. All the front facing enclosures (A) still receive the same signal and the rear facing enclosures (B) are still phase reversed but the delay time is now 1.8 ms. The simulations in figs 93 and 94 show that the rear attenuation is very high, even at close distances from the rear of the array.

fig 92. three wide endless Delta Array

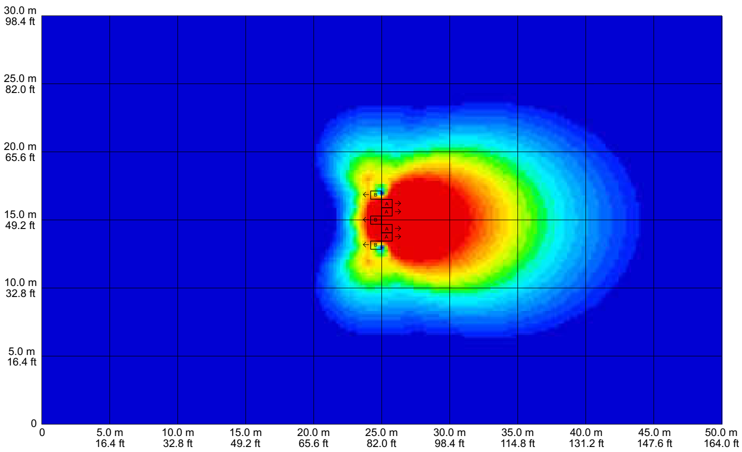

fig 93. three wide endless array 50Hz

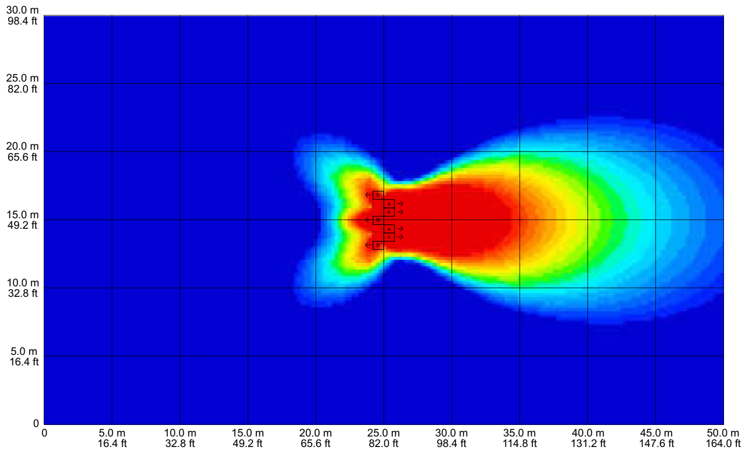

fig 94. three wide endless array 100Hz

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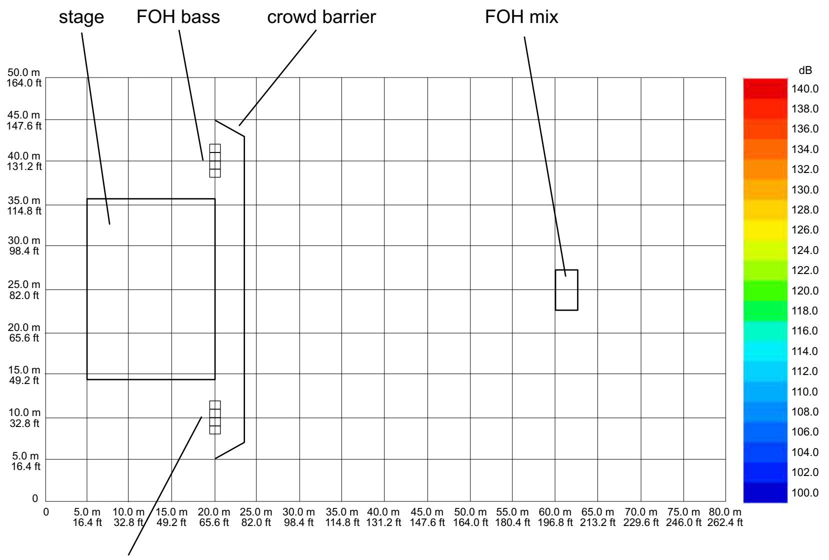

fig 95.

For the next set of simulations, which looks at a typical outside medium scale live event the test area has expanded to 50 m (164 ft) wide x 80 m (262.4 ft) deep. There is also a stage with a width of 22 m (72.2 ft) and depth of 15 m (49.2 ft). The front of the stage and the main FOH L/R bass arrays are set back 20 m (65.6 ft) from the start of the test area and the distance between the main FOH L/R bass arrays is 30 m (98.4 ft). A FOH mix position is included which is located 40 m (131.2 ft) back from the front of the stage.

Because of the large area and detail required the SPL test range covers 40dB, with red representing 140dB and blue representing 100dB. fig 95 shows the layout of the event.

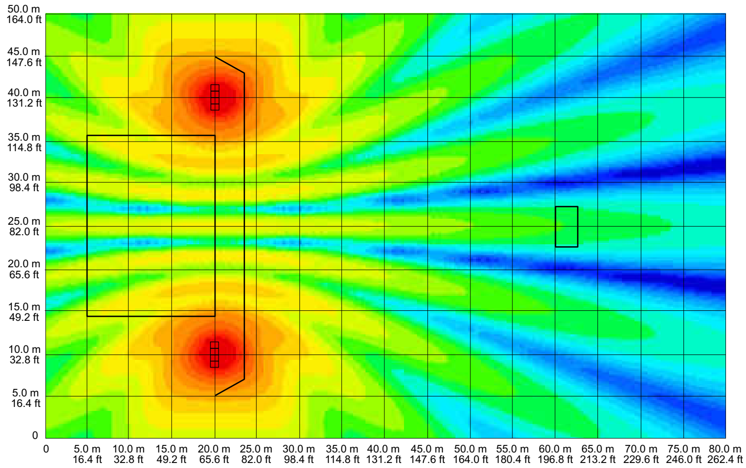

fig 96. two groups of four vertically positioned enclosures 50Hz

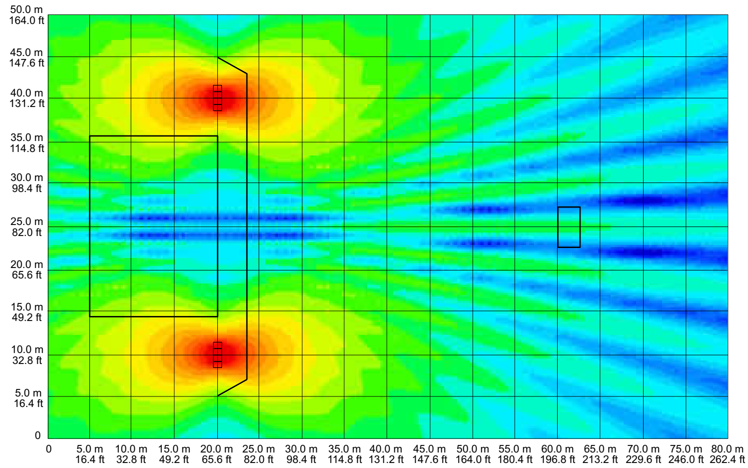

fig 97. two groups of four vertically positioned enclosures 100Hz

figs 96 and 97 show the effect of four vertically positioned enclosures each side of the stage sitting on the floor at 50hz and 100hz. As can been seen from the simulations this system if driven with 12,800 watts could produce 118dB at the FOH mix position, which is located 40 m (131.2 ft) back from the front of the stage. This would be the peak SPL value with the continuous SPL value being some 8 to 10dB lower. figs 98 and 99 show that positioning the bass arrays with a 15 degree toe in towards the FOH mix position reduces on stage levels and provides slightly louder SPL's in the audience area. My personal opinion is that by using just four enclosures per side for this size of event the system would have to be run at or beyond its operational capabilities to produce enough SPL

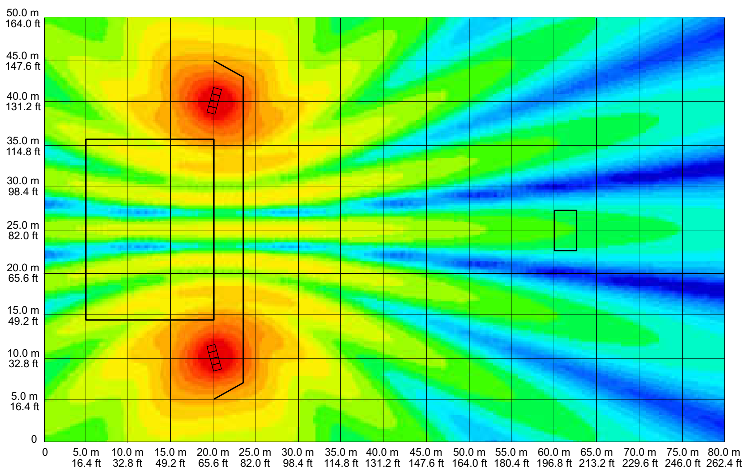

fig 98. two groups of four vertically positioned enclosures
15 degree toe in 50Hz

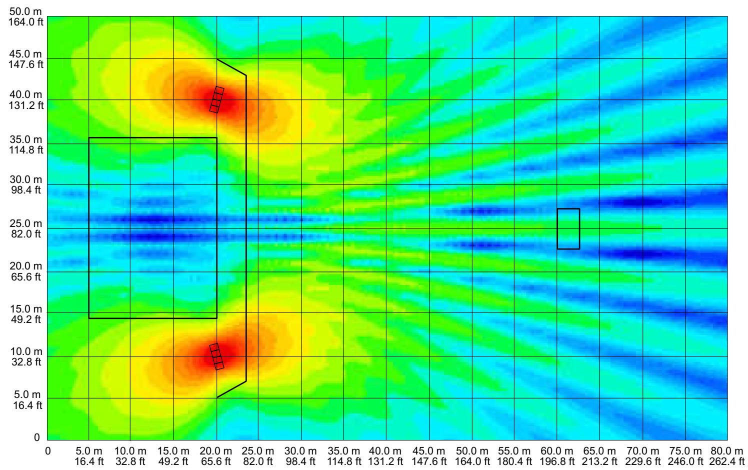

fig 99. two groups of four vertically positioned enclosures
15 degree toe in 100Hz

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The next few pages contain simulations of six enclosure per side at the same outside event. fig 100. shows six vertically positioned enclosures each side of the stage. The simulation for 100Hz fig 101 shows the SPL at the FOH mix position to have increased over the four enclosure simulation, unfortunately there is a low SPL zone right in front of the stage. Spill from the monitor mix and side fills would help fill in the low SPL zone, but not by much.

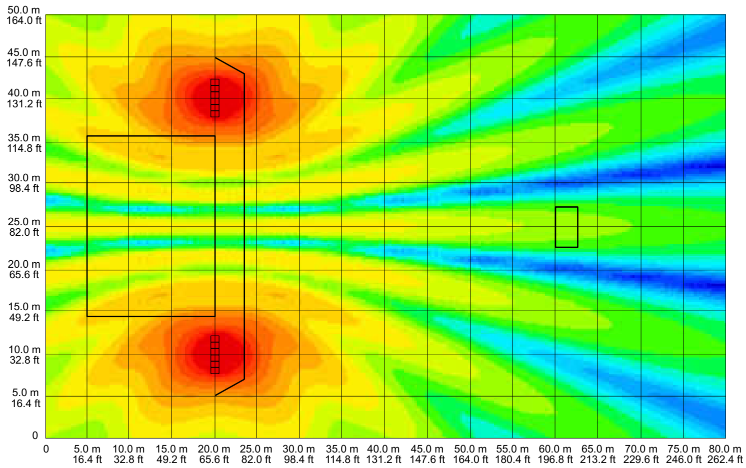

fig 100. two groups of six vertically positioned enclosures 50Hz

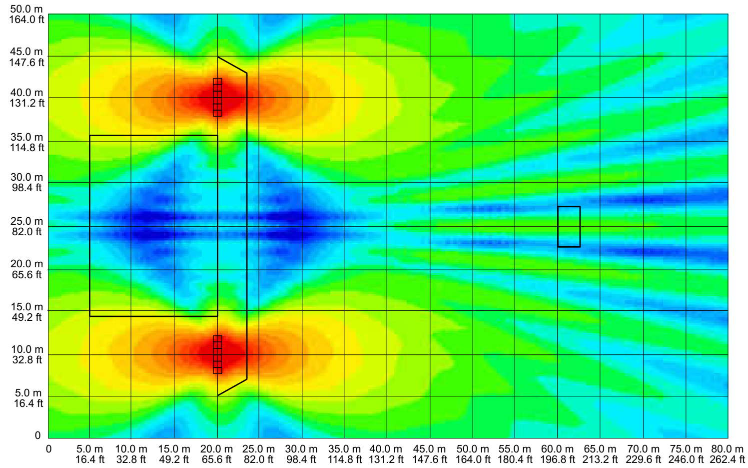

fig 101. two groups of six vertically positioned enclosures 100Hz

Earlier in the guide we saw how applying delays to the outer enclosures could widen the radiation pattern in horizontal arrays of six or more enclosures. Figs 102 and 103 show the effect of delaying enclosures A and F by 2.4 ms. The result is a reduction of SPL at the FOH mix position, but an increase in SPL in front of the stage.

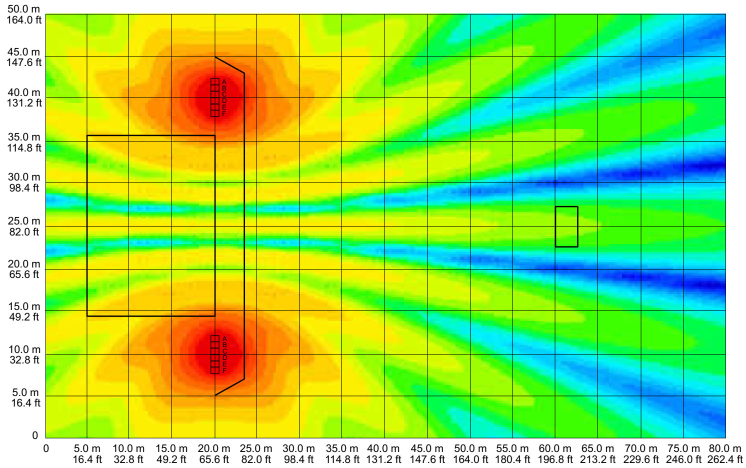

fig 102. two groups of six vertically positioned enclosures
2.4 ms delay applied to enclosures A and F 50Hz

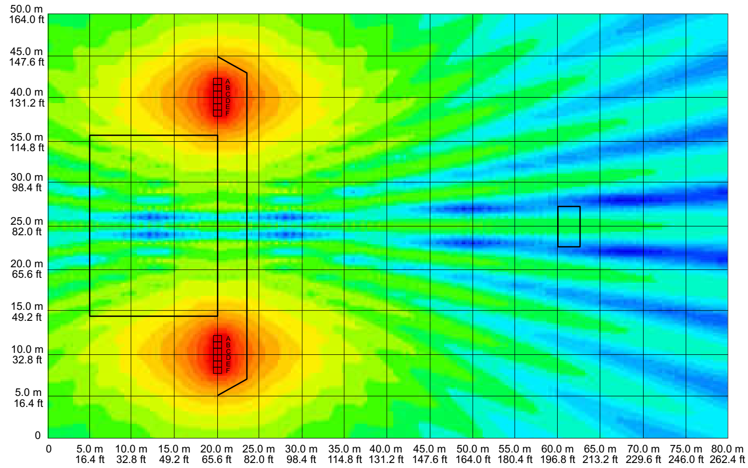

fig 103. two groups of six vertically positioned enclosures
2.4 ms delay applied to enclosures A and F 100Hz

If the delay time is increased to 3.6 ms there is a further reduction in SPL at the FOH mix position and an increase in SPL's around the stage. figs 104 and 105 show the effect of the increased delay time applied to enclosures A and F. Note how the effect is more pronounced at 100Hz than it is a 50Hz.

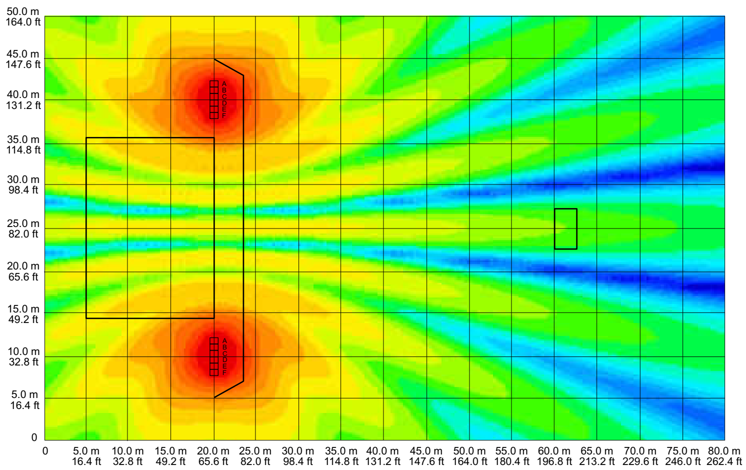

fig 104. two groups of six vertically positioned enclosures
3.6 ms delay applied to enclosures A and F 50Hz

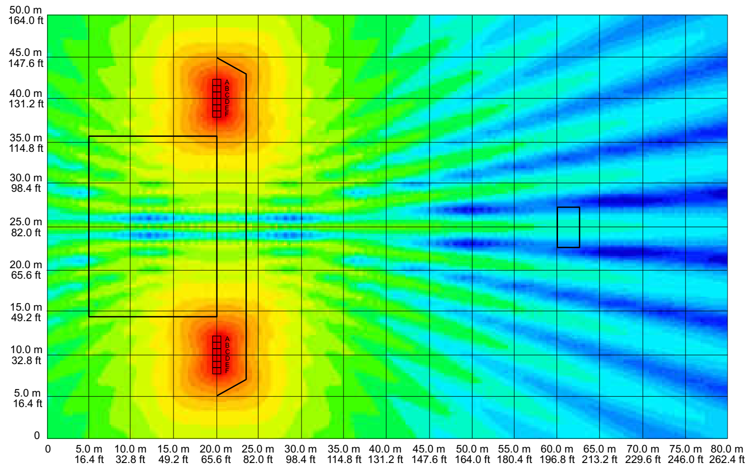

fig 105. two groups of six vertically positioned enclosures
3.6 ms delay applied to enclosures A and F 100Hz

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Staying with six enclosures per side fig 106 and 107 show the effect of positioning the arrays with an inward toe in of 15 degrees. The SPL at the FOH mix position has increased considerably and most of the audience would be exposed to higher SPL's compared with a parallel firing setup. Levels on stage are reduced but there is still a low SPL zone right in front of the stage at the upper range of bass frequencies.

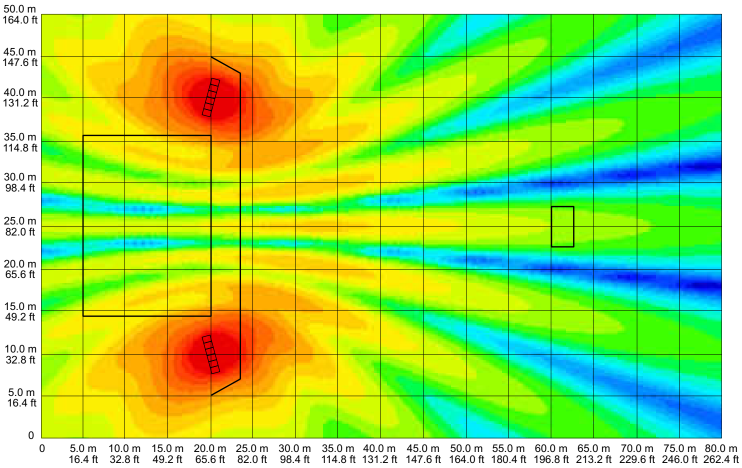

fig 106. two groups of six vertically positioned enclosures
15 degree toe in 50Hz

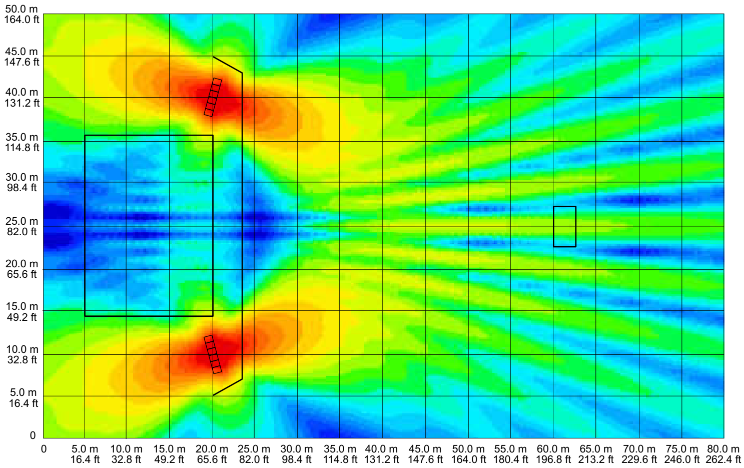

fig 107. two groups of six vertically positioned enclosures
15 degree toe in 100Hz

Figs 108 and 109 show the effect of positioning the enclosures to form a curve. SPL levels at the FOH mix position are slightly lower than for the straight array but are higher directly in front of the stage. On stage levels are slightly lower with the curved array too.

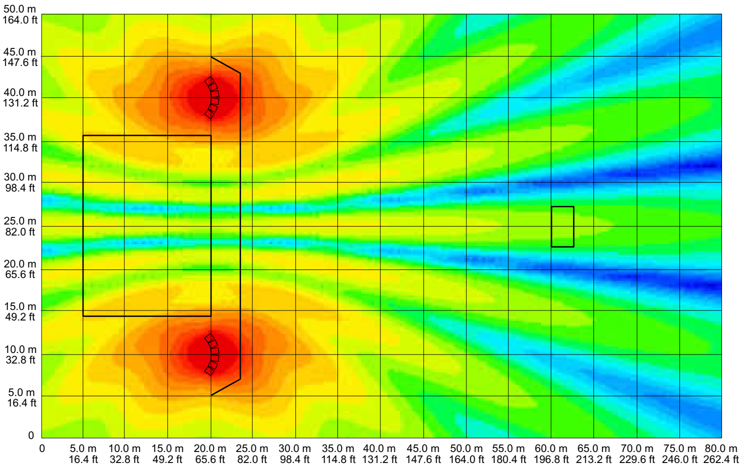

fig 108. two groups of six vertically positioned enclosures 50Hz
12 degree spacing between enclosures forming a curve

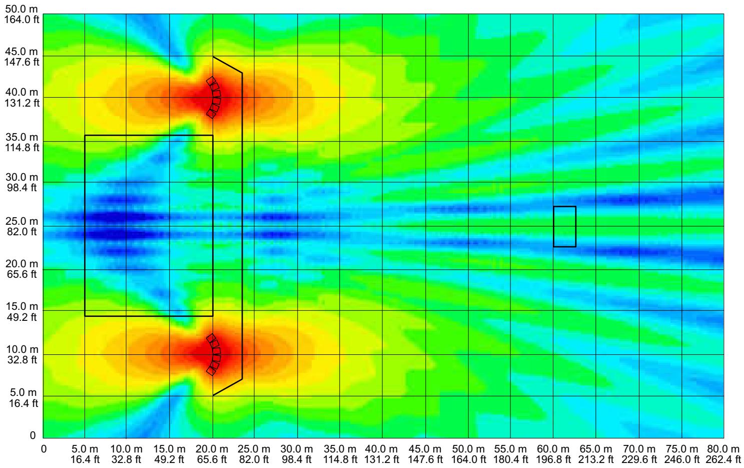

fig 109. two groups of six vertically positioned enclosures 100Hz
12 degree spacing between enclosures forming a curve

Positioning the curved array with an inwards toe in of 15 degrees produces the radiation patterns shown in figs 110 and 111. SPL levels for most of the audience and at the FOH mix position are higher compared to the parallel firing curved array. Levels in front of the stage are also higher with the 15 degree inward toe in configuration.

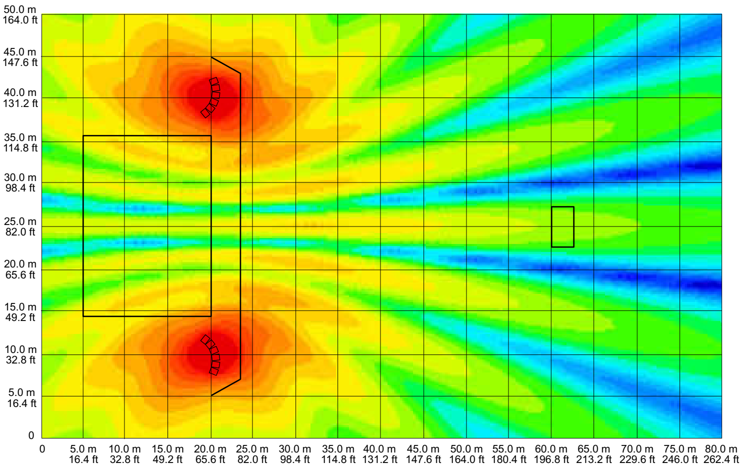

fig 110. two groups of six vertically positioned enclosures 50Hz
12 degree spacing between enclosures forming a curve with toe in

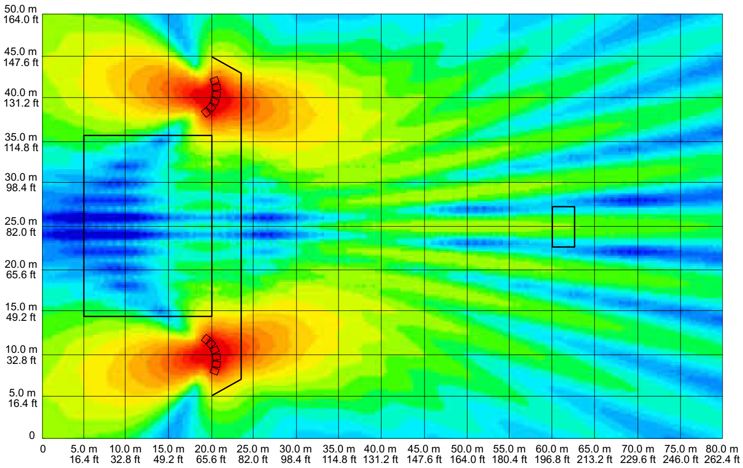

fig 111. two groups of six vertically positioned enclosures 100Hz
12 degree spacing between enclosures forming a curve with toe in

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Continuing with six enclosures per side figs 112 and 113 show the effect of positioning the enclosures to form an inverted arc. Because an inverted arc exhibits a wider radiation pattern at its rear, on stage levels are now louder and the SPL at the FOH mix position has slightly deceased compared to the parallel firing configuration in figs 100 and 101 on page 19.

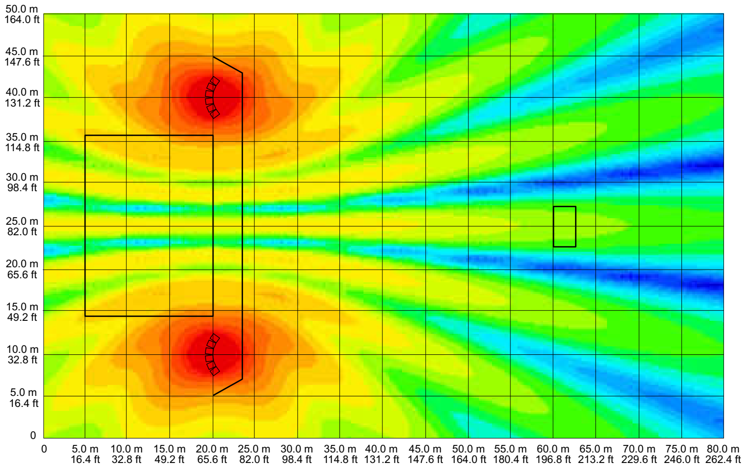

fig 112. two groups of six vertically positioned enclosures 50Hz
12 degree spacing between enclosures forming an inverted arc

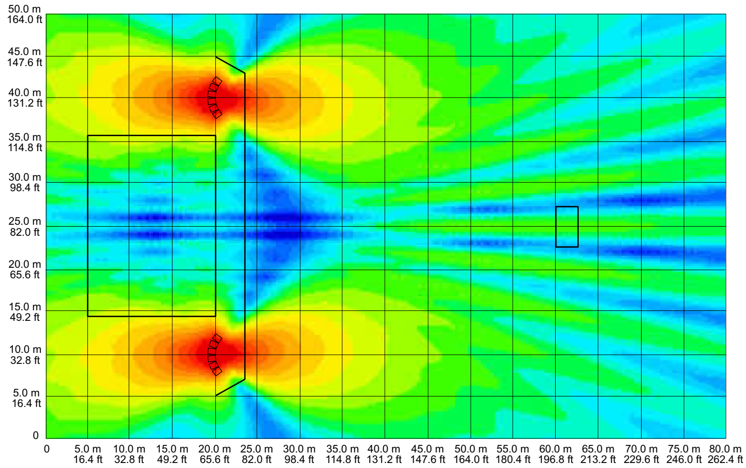

fig 113. two groups of six vertically positioned enclosures 100Hz
12 degree spacing between enclosures forming an inverted arc

Positioning the inverted arc with an inwards toe in of 15 degrees produces the radiation patterns shown in figs 114 and 115. SPL levels at the FOH mix position are higher compared to the parallel firing inverted arc configuration but on stage levels are louder compared to a curved or flat 15 degree toe in configuration.

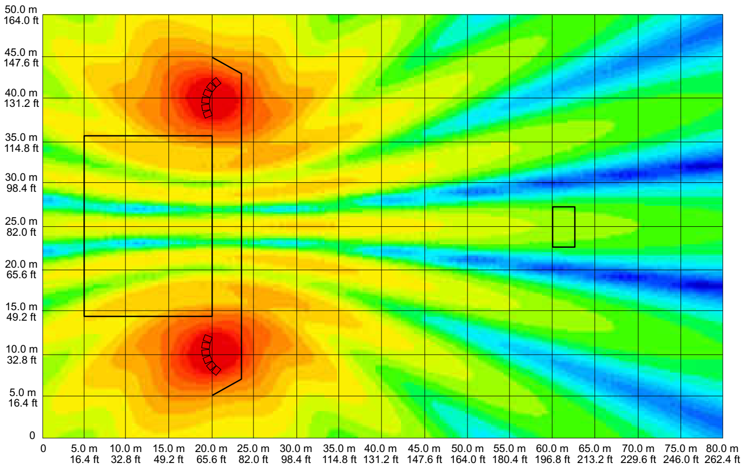

fig 114. two groups of six vertically positioned enclosures 50Hz
12 degree spacing between enclosures forming an inverted arc with toe in

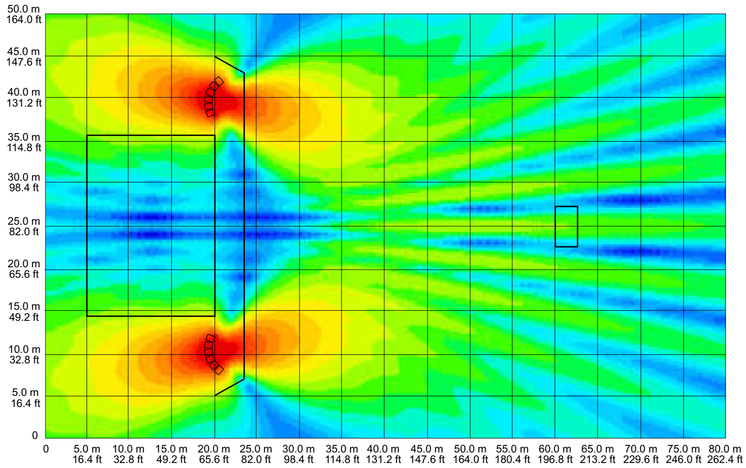

fig 115. two groups of six vertically positioned enclosures 100Hz
12 degree spacing between enclosures forming an inverted arc with toe in

Most of the 6 enclosure per side configurations show a low SPL zone right in front of the stage, to increase levels in this area it is possible to use a further 4 vertically positioned enclosures (fills) in the centre and to the front of the stage. Figs 116 and 117 show the radiation pattern with 4 centre fills which have all been delayed by 36 ms with respect to the main left & right arrays. While this fills in the low SPL zone the on stage levels are worryingly high.

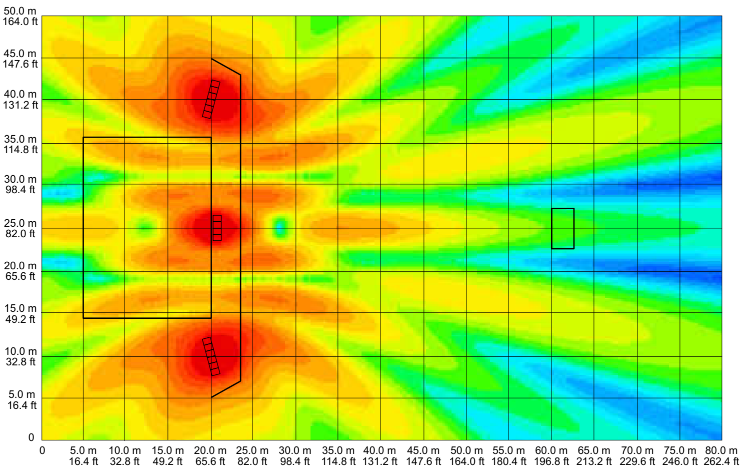

fig 116. two groups of six vertically positioned enclosures 15 degree toe in
with 4 vertically positioned centre enclosures delayed by 36 ms 50Hz

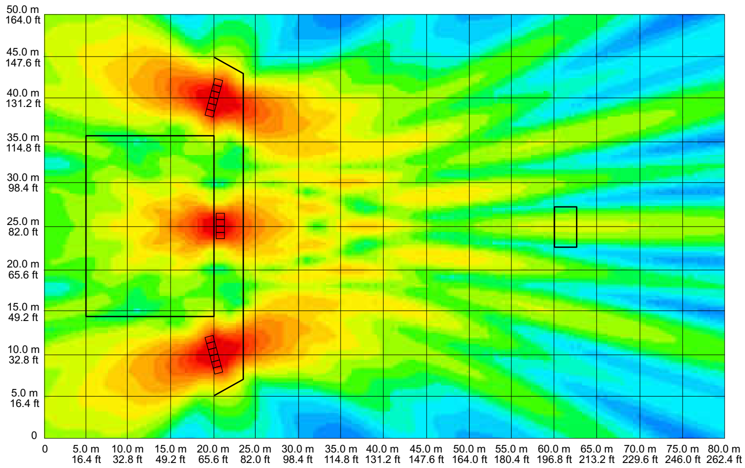

fig 117. two groups of six vertically positioned enclosures 15 degree toe in
with 4 vertically positioned centre enclosures delayed by 36 ms 100Hz

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The last two pages contain simulations of eight enclosure per side at the same outside event. Figs 118 and 119 show two groups of eight vertically positioned enclosures in a parallel firing configuration. Compared with the same six enclosure per side configuration in figs 100 and 101 on page 19, SPL levels at the FOH mix position have increased, but the low SPL zone in front of the stage has deepened and has moved towards the FOH mix position. This configuration would not be a good choice as most of the audience are in a low SPL zone at higher frequencies.

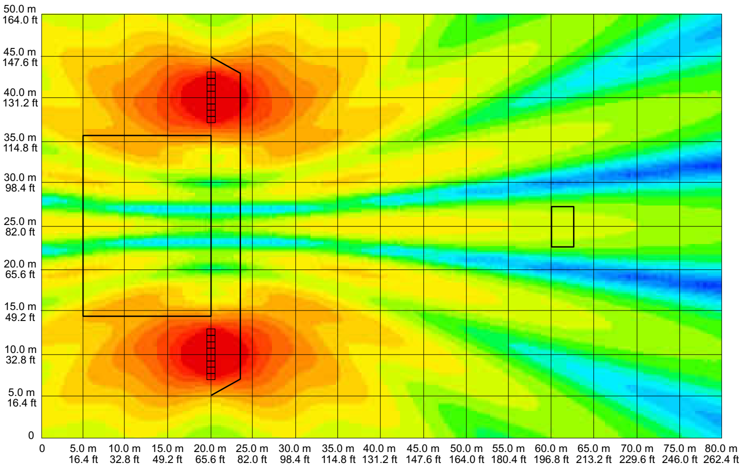

fig 118. two groups of eight vertically positioned enclosures 50Hz

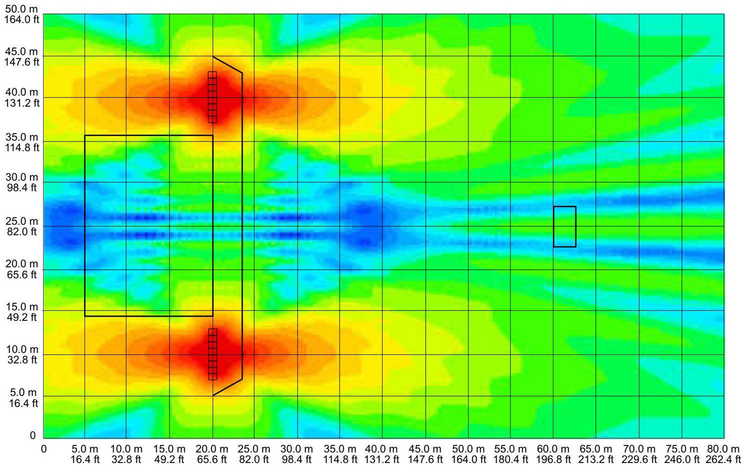

fig 119. two groups of eight vertically positioned enclosures 100Hz

The deep low SPL zone in fig 119 can be improved by delaying the outer two sets of enclosures. Figs 120 and 121 show the effect of applying the same delays as in figs 16 and 17 on page 4. As can been seen the effect of shortening the array by delays widens the dispersion and helps maintain a more even coverage.

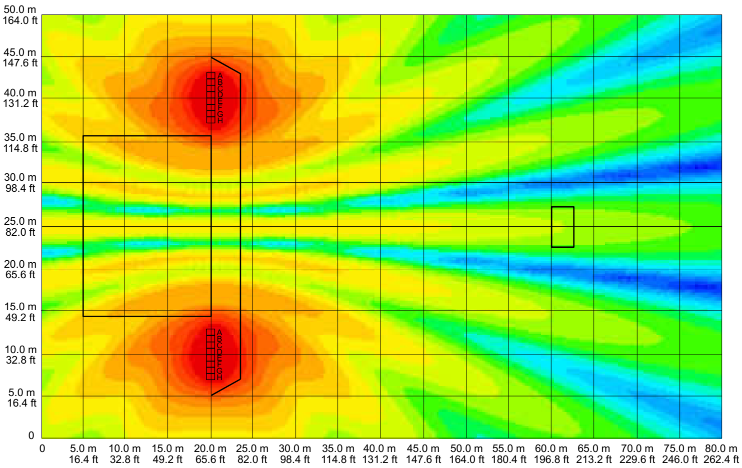

fig 120. two groups of eight vertically positioned enclosures 50Hz
3.6 ms delay applied to A and H, 1.1 ms delay applied to B and G

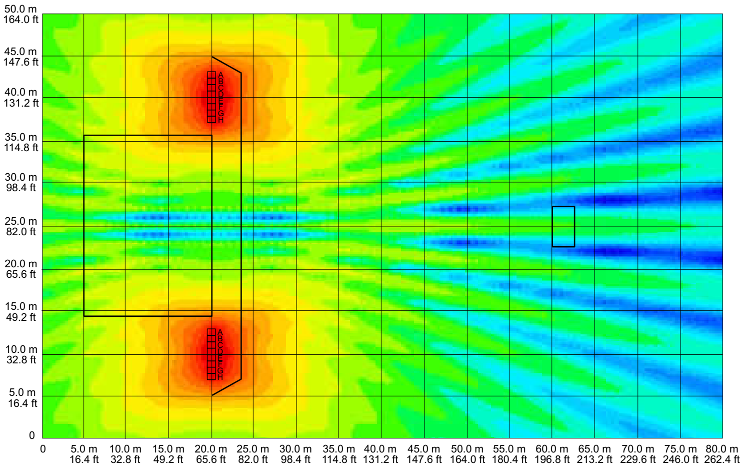

fig 121. two groups of eight vertically positioned enclosures 100Hz
3.6 ms delay applied to A and H, 1.1 ms delay applied to B and G

The next two simulations show the effect of toeing both groups of eight enclosures inwards by 15 degrees towards the FOH mix position. Fig 122 shows the radiation pattern at 50Hz, where very good audience coverage with low on stage sound is visible. At 100Hz a small low SPL zone has started to form which could be filled in by the use of a centre positioned three wide endless delta array high passed at 70Hz.

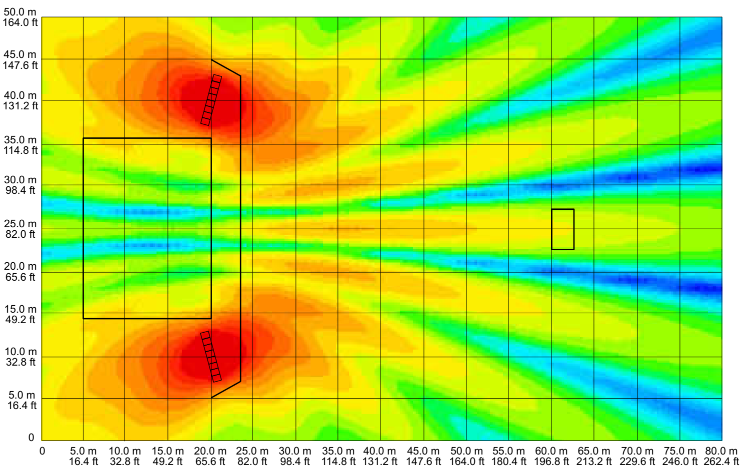

fig 122. two groups of eight vertically positioned enclosures
15 degree toe in 50Hz

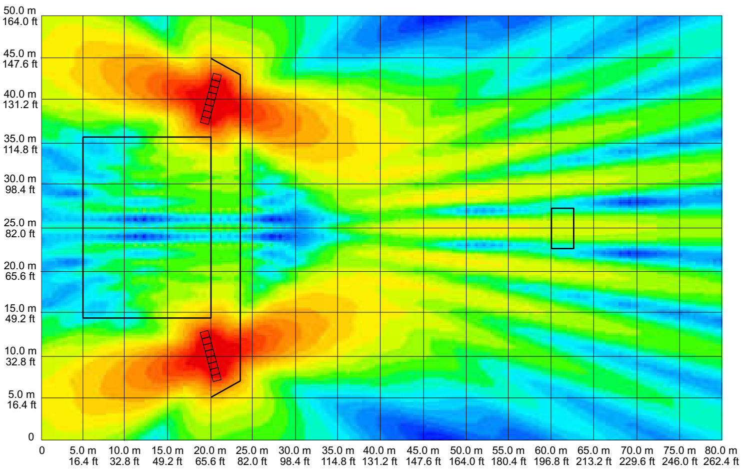

fig 123. two groups of eight vertically positioned enclosures
15 degree toe in 100Hz

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The simulations on this page show the effects of applying a delay to the centre four fill enclosures. Figs 124 and 125 show two groups of eight vertically positioned enclosures with a 15 degree toe in towards the FOH mix position. The centre four fill enclosures are being fed the same signal as the main left and right arrays with no delay applied.

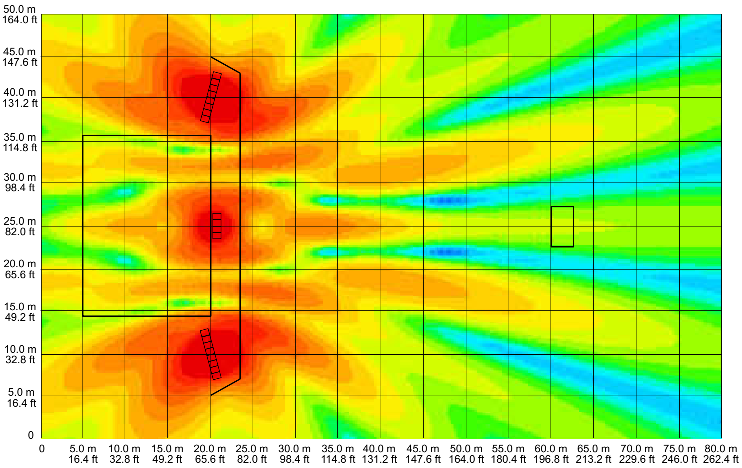

fig 124. two groups of eight vertically positioned enclosures 15 degree toe in with 4 vertically positioned centre enclosures not delayed 50Hz

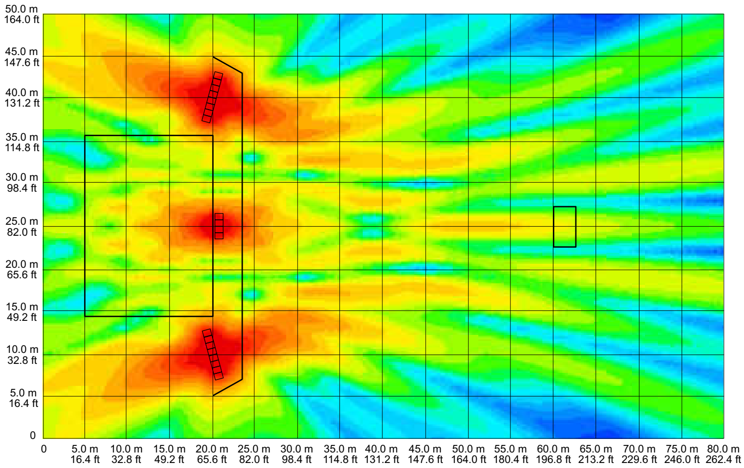

fig 125. two groups of eight vertically positioned enclosures 15 degree toe in with 4 vertically positioned centre enclosures not delayed 100Hz

Figs 126 and 127 show the effect of applying a delay of 36 ms of all the four centre fill enclosures. The difference is not radical and at first glance you might think the radiation patterns for the delayed and non delayed simulations are the same, but a closer inspection will reveal the differences. The configuration with the delayed centre fills has improved coverage for the audience and less SPL at the back of the stage at lower frequencies. This would help on stage feedback levels from a drum kit or pair or turntables at a dance event. The distance between the centre of one of the main left and right arrays to the centre of the four fill enclosures is 15 m (42.9 ft), the correct delay time for someone stood right in front of the centre fills would be 43.8 ms, but running tests and simulations found this time to be too long to have minimum interference. The best delay time was found to be 0.822 x the centre to centre path time. So first measure the distance from the centre of one of the main left and right arrays to the centre of the fill array. In our case this is 15 m (42.9 ft), which equates to 43.8 ms in time. Then calculate 43.8 x 0.822 and you arrive at 36 ms, which is the delay used in these simulations.

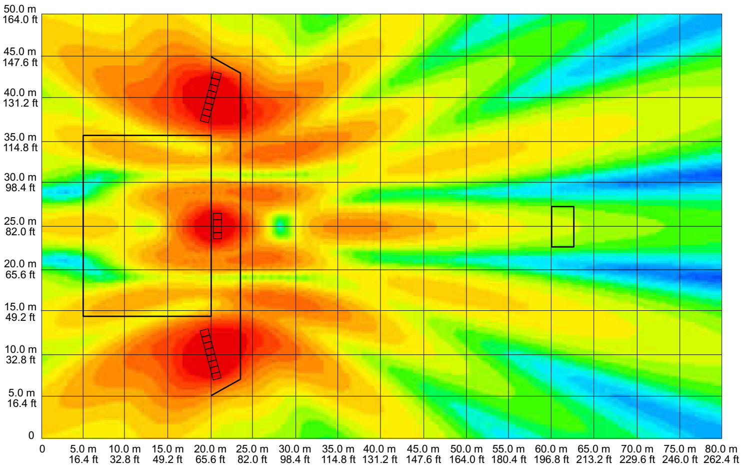

fig 126. two groups of eight vertically positioned enclosures 15 degree toe in with 4 vertically positioned centre enclosures delayed by 36 ms 50Hz

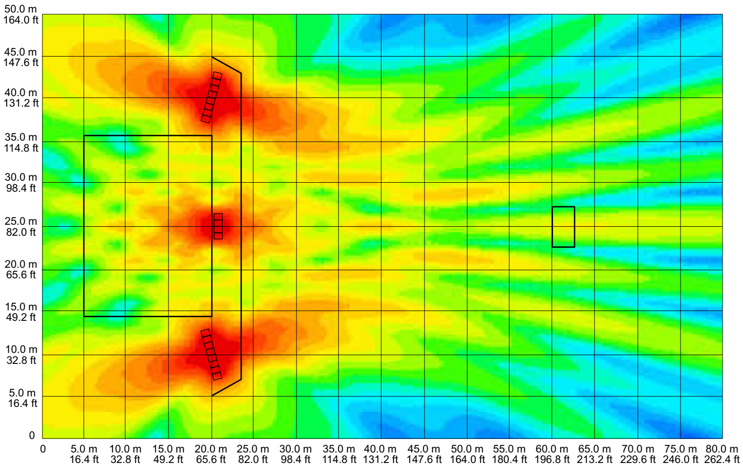

fig 127. two groups of eight vertically positioned enclosures 15 degree toe in with 4 vertically positioned centre enclosures delayed by 36 ms 100Hz

Part 2 of the practical guide to bass arrays explores using delta arrays and other cardioid configurations in the outside event simulation. It will also cover three and four array surround configurations, two way bass setups with regard to dispersion and throw, horn and other so called directional bass enclosures types relating to coupling, dispersion and distance/throw etc. Part 2 will also look at constructing the ultimate bass configuration using multiple enclosure configurations and how to best implement what you use already.