ACHIEVING WIDE DISPERSION IN SINGLE-BOX, STEREO SPEAKER SYSTEMS

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1 INTRODUCTION

The single-box music playing system, or 'audio console', has been a mainstay of the audio industry since the early days of sound reproduction. Recently, we have seen renewed interest in this format[1] with the main input music sources being the streaming of music over the internet and internet radio, with external inputs being available for other common sources such as CD player, turntable and USB-based digital audio. In these systems, the physical separation of the left and right speaker elements can be as little as 50 to 70cm. This places a significant restriction on the ability of the system to provide clear, high-quality sound over a wide listening area, or to generate a 'room-filling' sound. However, with the addition of side firing midrange and high-frequency drivers whose output is carefully integrated with that of the front units, the coverage area can be significantly increased. This paper discusses how this is achieved; the technical, subjective and customer benefits and looks at developments that can add further performance and refinement.

2 ACHIEVING WIDER DISPERSION

2.1 Acoustic format

Figure 1 shows the geometry of the present implementation where the midrange and high frequency units on the front baffle are complemented with a mirror image set on the side panel. The side mounted unit receives a level adjusted and low-pass filtered version of the signal applied to its front mounted partner. The outputs of the front and side-mounted units are carefully combined to create the desired radiation patterns in the midrange and high-frequency ranges.

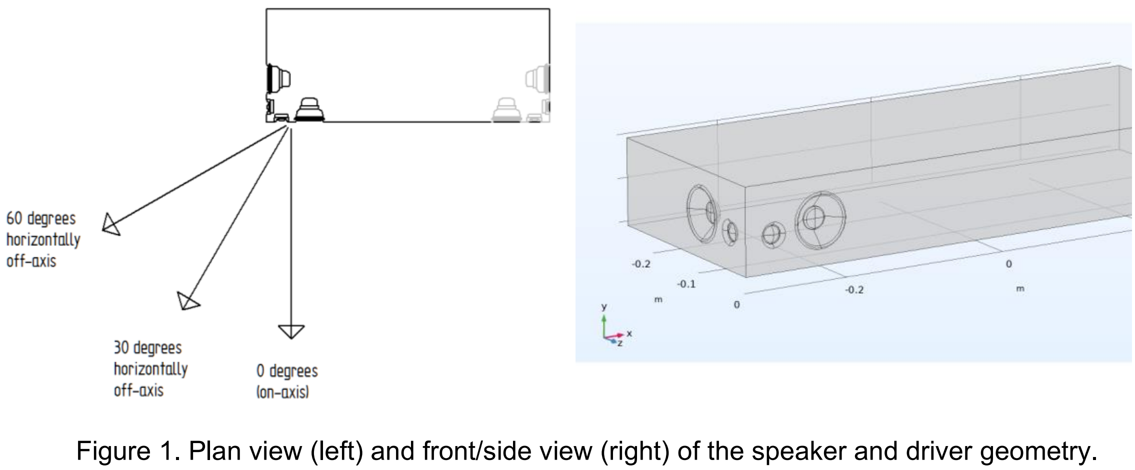

Figure 1. Plan view (left) and front/side view (right) of the speaker and driver geometry.

For each of the two arrays the upper frequency limit for effective control of the radiation pattern is related to the physical separation of the front and side units (where the driver separation is approximately equal to a half- to a full wavelength of the radiated sound frequency). In practice, therefore, the units will be positioned as close to the cabinet corner as possible. The other physical and acoustical parameters that are applicable are (a) the radiation patterns (vs. frequency) of the front and side units (b) the angular separation of the side unit normal axis relative to that of the front unit, (c) the extra processing applied to the side unit to optimize the combined radiation pattern and (d) the horizontally off-axis angle of the measurement. For the tweeter section the existing directivity comes mainly from the drive unit itself, for the midrange section is comes from both the drive unit and the shape of the cabinet.

2.2 Analogy with the bass-unit configuration of the 2.5-way system format

The described wide dispersion technique can be considered analogous to the bass unit configuration in the well-known 2.5-way system format. In this widely-used method, a second bass unit is added to a standard 2-way speaker to supplement the output of system in the low bass region, where it operates in parallel with the main bass/midrange driver. At higher frequencies its output is progressively reduced so that it does not interfere with the integration of the main unit and the tweeter. The role of the second bass driver can be considered a correction for that part of the output of the main driver that is lost in the rearward direction due to the frequency dependence of cabinet directivity (the 4pi to 2pi transition)[2].

In the described wide dispersion method, a second driver is mounted in the side wall of the cabinet, as close to the main unit as practically possible and, as a result, its output is directed at 90 degrees to the forward direction. Its output is adjusted so as to enhance the performance of the front firing unit (widen the dispersion) up to a frequency where its contribution would become negative – whereupon its output is progressively reduced with a first order low pass filter.

2.3 The subjective benefits of wider dispersion

The target for the acoustic performance of the system was (a) smooth variation in frequency response in the main forward listening area, (b) maintaining this balance to at least 60 degrees off-axis, (c) a natural sounding balance that does not compromise the audibility of, or exaggerate, the wide dispersion. The side units function so as to ‘fill in’ off axis energy that would be missing with just the front mounted units. This results in a system that sounds naturally ‘spacious’ with a clear and accurate sound out to angles well off the main listening axis. This makes the speaker quite flexible with regards to positioning. The wide dispersion also results in a natural balance in the side wall reflections which helps the sense of ‘room-filling’ sound and spaciousness.

3 SIMULATIONS

The method was investigated using boundary element simulations with a normal acceleration being applied to the surfaces of the drivers, equivalent to pistonic motion. The side tweeter level is set at -6dB relative to the front tweeter, with a first order low pass filter set at 2.3kHz(-3dB). The side midrange level is set at -15dB with no low pass filter. The front and side tweeters are positioned at 35mm from the cabinet corner, the midrange units at 95mm from the corner.

3.1 Tweeter section

Figure 2 (a) and (b) show the acoustic output at 1m distance, from on-axis(red) to 120 degrees horizontally off-axis(green) in 15degree intervals with the side mounted unit off (a) and on (b). Top to bottom: red=on-axis, green=15deg, blue=30, magenta=45, cyan=60, yellow=75, black=90, red=105, green=120deg.

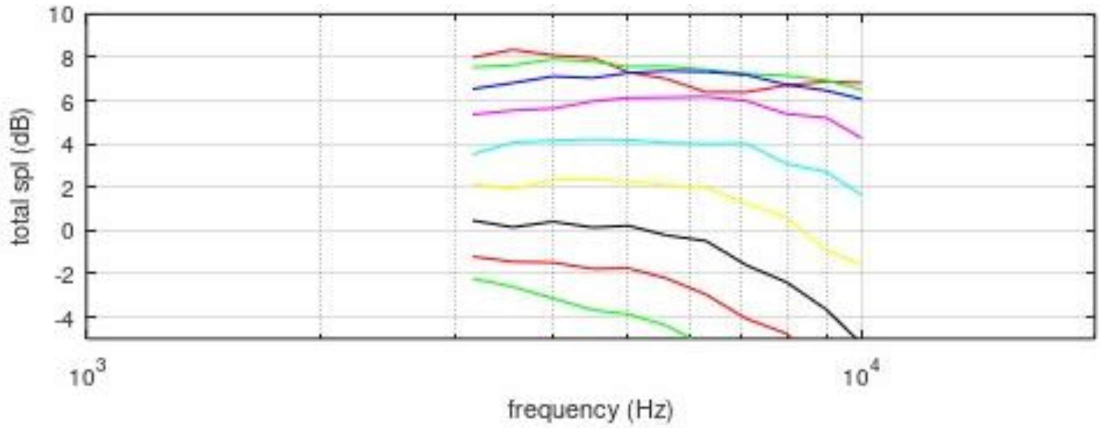

Figure 2 (a): Tweeter section – side mounted unit off

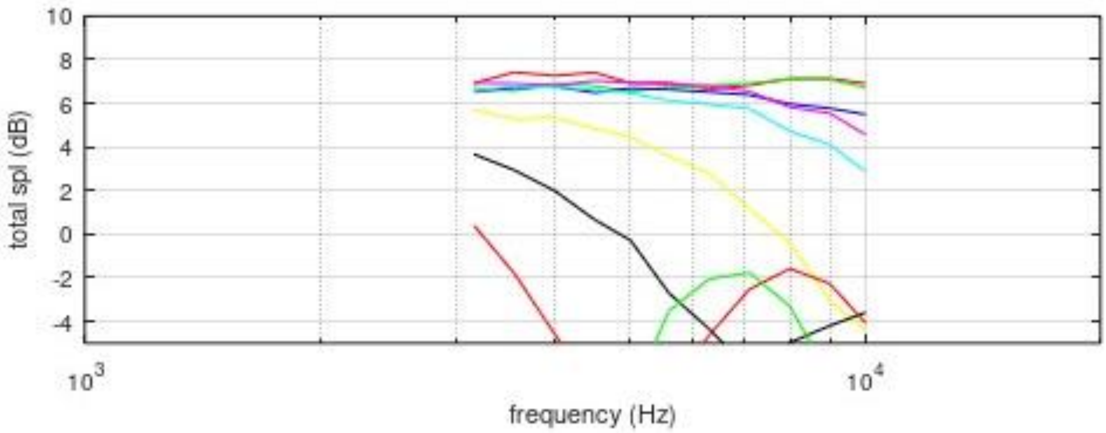

Figure 2 (b): Tweeter section – side mounted unit on.

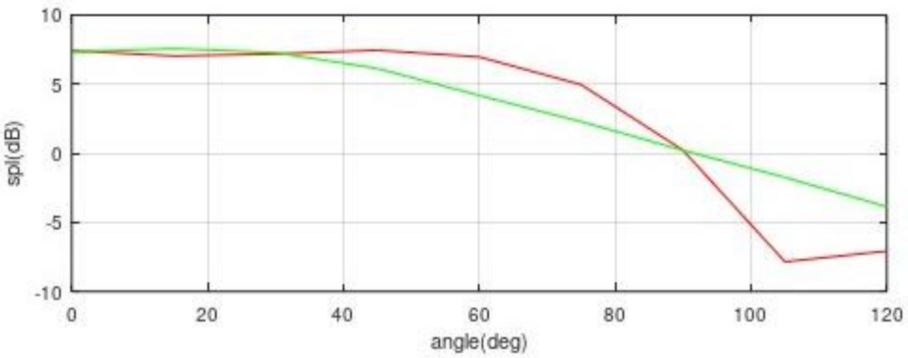

Figure 3. Acoustic output vs. horizontal angle at 5kHz for the tweeter section. Green - with side tweeter off and red - with side tweeter on.

The data shows a significant improvement (widening) of the dispersion out to around 60degrees (cyan curve) and up to around 8kHz. From 75 degrees and beyond we start to see some uneven-ness and lobing. The acoustic criteria for this ‘standard’ mode includes a requirement that the off-axis lobing should be no higher than -9 to -10dB relative to the on-axis output. Figure 3 below shows the data at 5kHz in spl vs. angle format.

3.2 Midrange section

Figure 4 (a) and (b) show the acoustic output at 1m distance, from on-axis(red) to 120degreees horizontally off-axis(green) in 15degree intervals with the side mounted unit off (a) and on (b). Top to bottom: red=on-axis, green=15deg, blue=30, magenta=45, cyan=60, yellow=75, black=90, red=105, green=120deg.

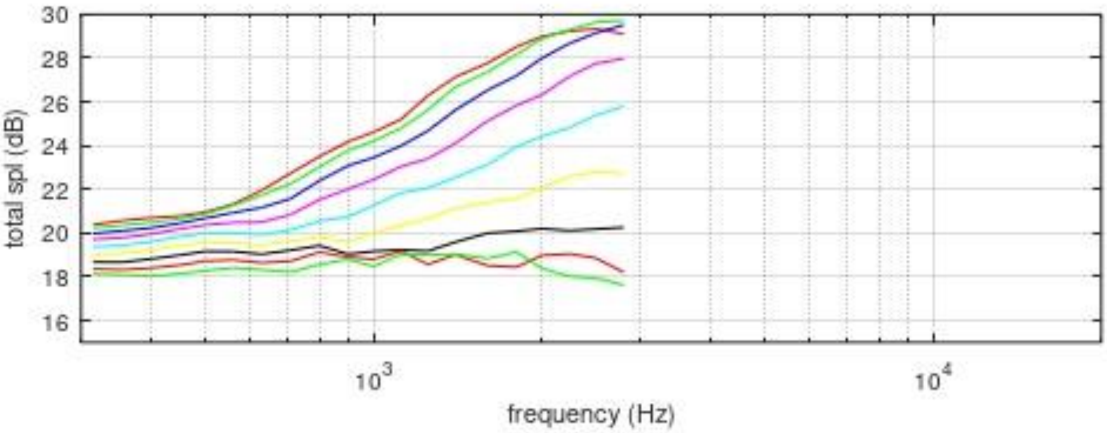

Figure 4 (a): Midrange section – side mounted unit off

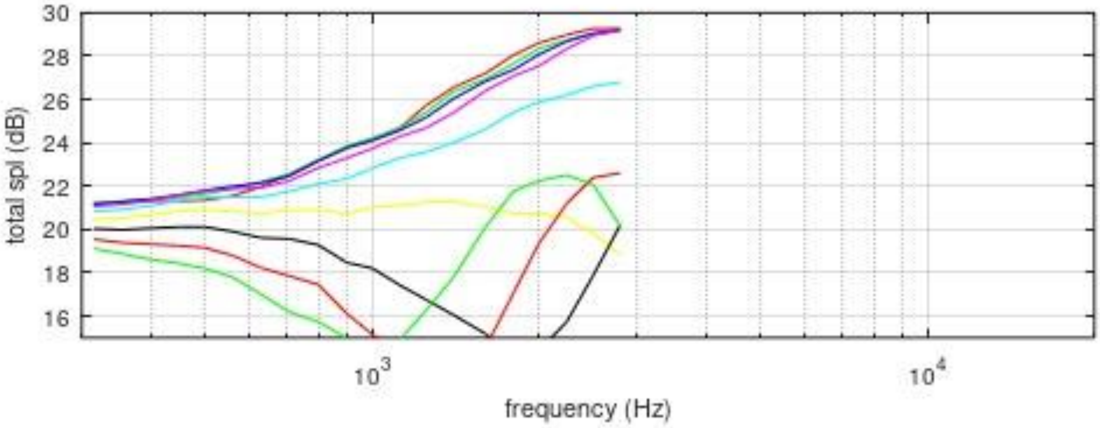

Figure 4 (b): Midrange section – side mounted unit on

As with the tweeter section, the data shows a significant improvement (widening) of the dispersion out to around 60degrees (cyan curve) and up to the crossover frequency of 3kHz. From 75 degrees and beyond we start to see some uneven-ness and lobing. The same acoustic criteria for off-axis lobing also applies to the midrange section, along with a requirement that any change to the on-axis response, and hence the tonal balance, should be minimal, hence the -15dB level setting. This was to allow the dispersion to be switchable with no need for tonal correction or equalization. Figure 5 below shows the data at 1.8kHz, in spl vs. off-axis angle format.

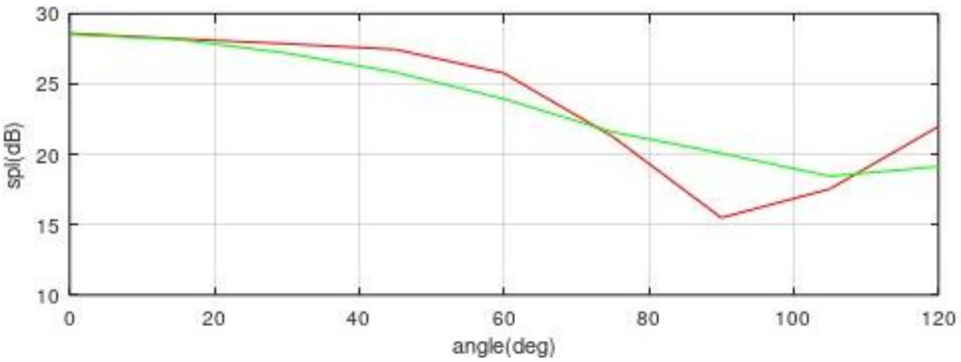

Figure 5., Acoustic output vs. horizontal angle at 1.8kHz for the midrange section. Green - with side unit off and red - with side unit on.

If the criterium for minimal change in tonal balance is relaxed, then the side midrange level is can be raised to -6db relative to the front midrange level with a corresponding widening of the midrange dispersion. With an adjustment to the tweeter delay to tilt the crossover interference lobe slightly outwards, this was termed the ‘super-wide’ mode, see below.

4 MEASURED DATA

Below is the measured response of the (prototype/pre-production) system in the three modes described: side units off, side units on (standard wide mode) and side units on (super-wide mode). Refer to the geometry in Figure 1.

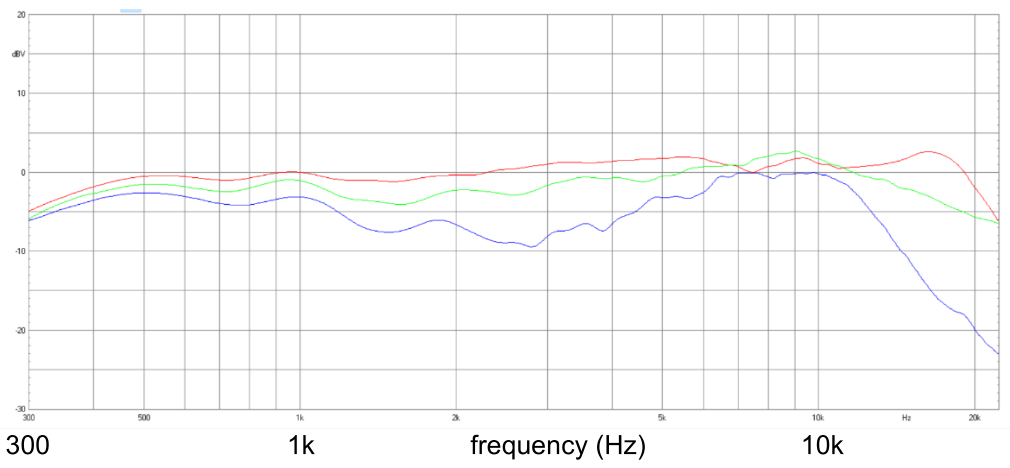

Figure 6 (a). System frequency response on-axis (red), and at 30 (green) and 60 (blue) degrees horizontally off-axis. (Vertical scale 5dB/div).

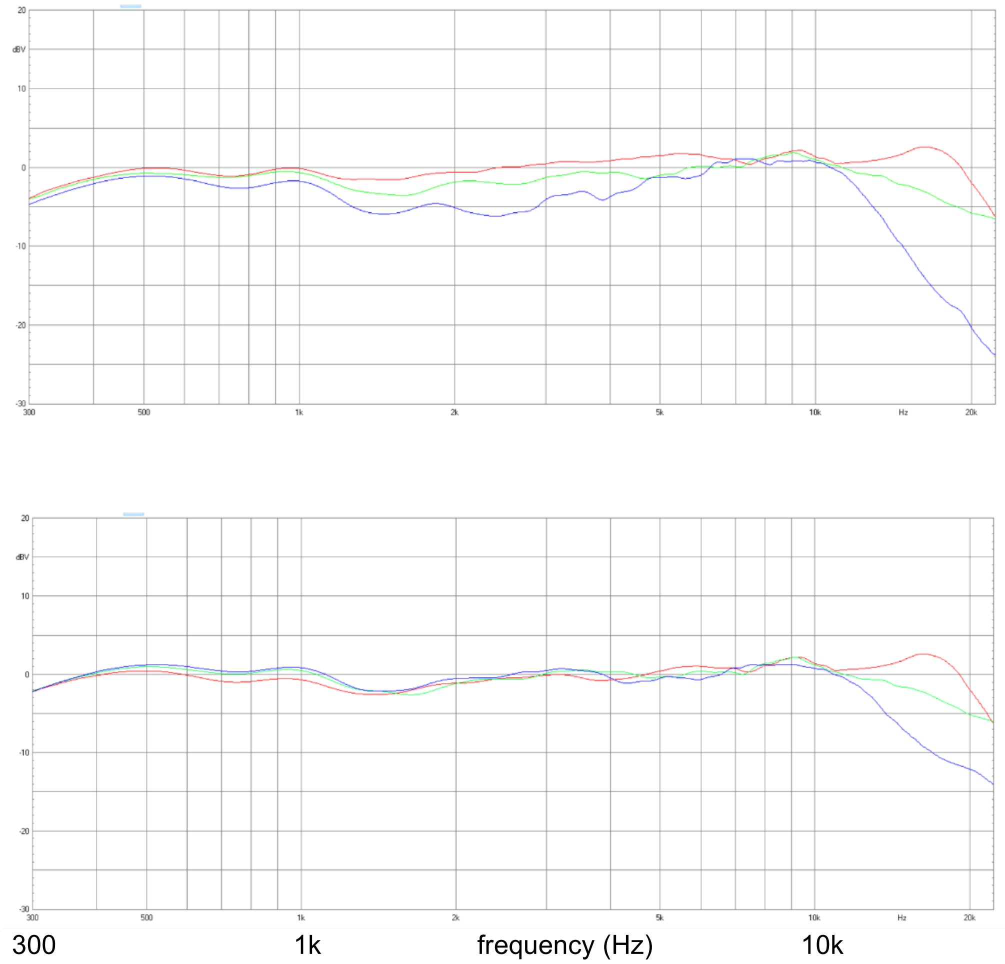

Figure 6 (b) and (c). System frequency response on-axis (red), and at 30 (green) and 60 (blue) degrees horizontally off-axis. Upper graph (b) - side units on – standard wide mode, lower graph (c) – side units on – super-wide mode. (Vertical scale 5dB/div).

5 FURTHER DEVELOPMENTS

5.1 Extension into 3-dimensions

For each of the midrange and high-frequency bands, a third driver can be placed on the top surface of the cabinet, with its level and bandwidth adjusted in a similar way as for the side mounted unit, to broaden the dispersion in the vertical plane as well as the horizontal. This has been investigated in simulations.

5.2 3-Element tweeter array

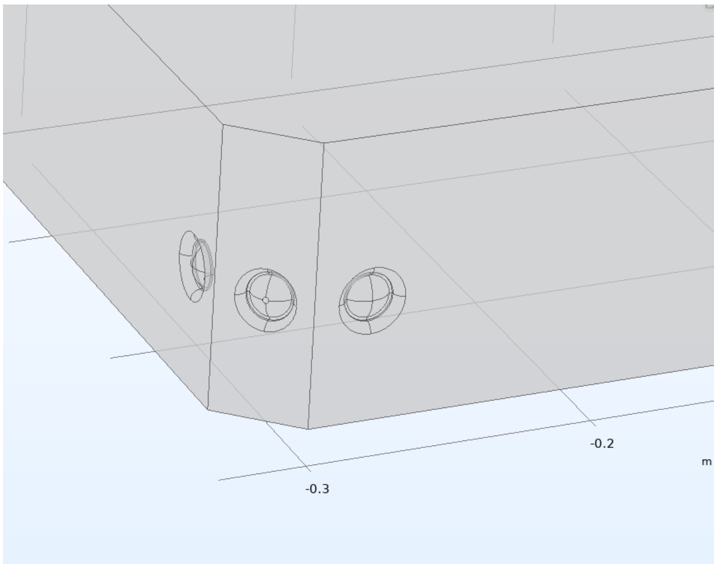

Figure 7. The 3-element array of 15mm tweeters aligned at 0, 45 and 90 degrees.

One of the possible alternative arrangements to the 2-element array shown above is depicted in Figure x. Three 15mm tweeters are arranged at 0, 45 and 90 degrees with the front and side units at 45mm from the virtual cabinet corner. Here, the centre (45degree) unit is the dominant one, with the front and side units supporting its output. The input signals to the front and side units are that of the front unit with the following adjustments - front: Gain -4dB, LPF B1/2300Hz, HPF B1/1150Hz; side: Gain -8dB, LPF B1/2300Hz.

Figure 8 (a) and (b) show the simulated acoustic output at 1m distance, from on-axis(red) to 120 degrees horizontally off-axis(green) in 15degree intervals with the outer units off (a) and on (b).

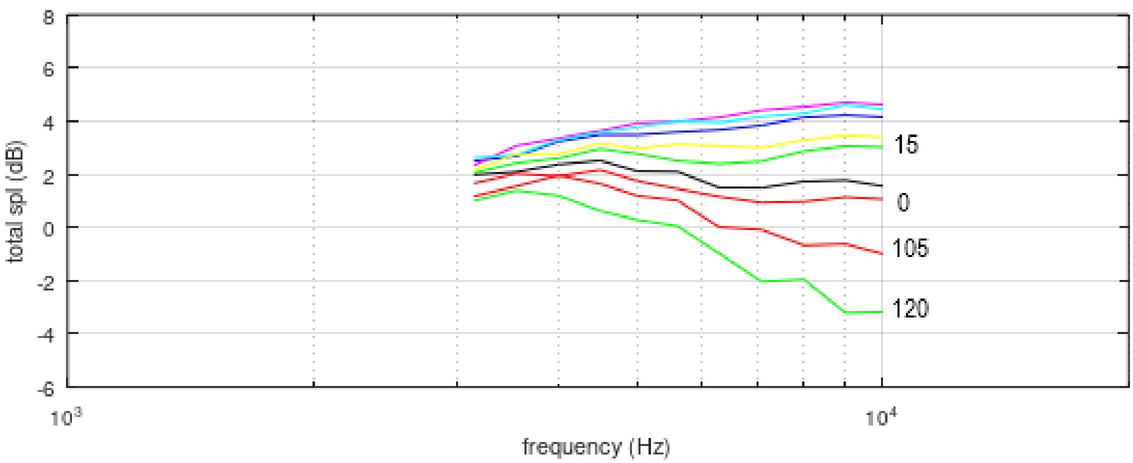

Figure 8 (a). Acoustic output of the 3-element tweeter array: outer units off. Red=on-axis, green=15deg, blue=30, magenta=45, cyan=60, yellow=75, black=90, red=105, green=120deg.

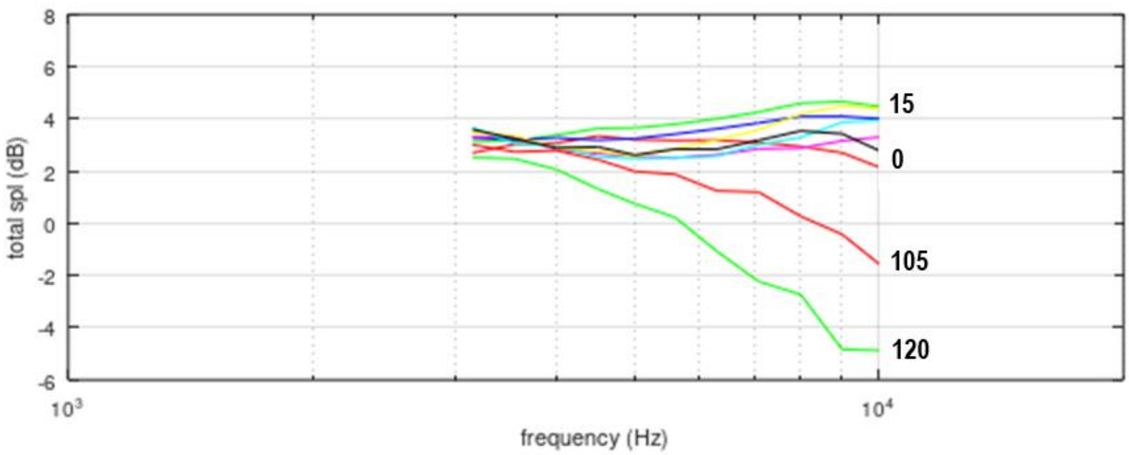

Figure 8 (b). Acoustic output of the 3-element tweeter array: outer units on. Red=on-axis, green=15deg, blue=30, magenta=45, cyan=60, yellow=75, black=90, red=105, green=120deg.

With the outer units on the acoustic output from on-axis to 90 degrees horizontally off axis is maintained within a 2dB amplitude range up to 10kHz, and there is no lobing at the extreme off-axis angles.

6 CONCLUSIONS

The current interest in single-box stereo speakers presents some challenges to the designer due to the obvious physical restrictions of the single box format, particularly if there is a requirement for a spacious room-filling sound. However, there are acoustical methods that lend themselves well to this sort of requirement, as described above, and help to correct for these limitations and provide customers with the convenience of the single box format together with a natural, spacious sound.

7 ACKNOWLEDGEMENTS

The speaker system described in this paper is the Cambridge Audio Evo One. The measurements shown are valid up to the pre-production stage and, at the time of writing, the production system contains just the ‘standard-wide’ mode.

8 REFERENCES

1. Current systems in the single-box speaker system category include the Naim Muso 2, Sonus Faber Omnia, Ruark 410 and Cambridge Audio Evo One (the subject of this paper).
2. K. Kessler and A. Watson. KEF – 50 years of innovation in sound. GP Acoustics International Ltd, 124-125. Comments by M. Gough on the design of the KEF Concord III.