more constant. Having the ability to model this aspect and to vary all array parameters should allow us to explore techniques for doing so.

Augspurger [6] models a 21-woofer line with raised-cosine weighting and shows an impressively smoothed far-field polar performance, but with nonconstant far-field beamwidth. In the context of auditorium coverage, constant beamwidth is important. A loudspeaker cluster or array hung above the proscenium may cover an audience spread over a vertical angle as large as 90°. For a loudspeaker intended for home listening the requirements are different. At a typical listening distance the difference between standing and sitting would cover at most 20°. The benefits of high power handling from multiple tweeters, and strong reduction of floor and ceiling reflections from much increased directivity, will remain, even if far-field directivity is not constant. In the home environment, the objective for a good line array is an even response over the likely *listening window*. For these reasons it was decided to evaluate some of these earlier techniques specifically in the near field.

The programs allow for applying weighting coefficients to each element. If a level-versus-tweeter scheme is found that provides good uniformity over a broad range of frequencies, it can easily be applied via resistive dividers within the crossover network.

Fig. 34 illustrates the vertical performance of a rectangularly weighted 16-element array from 3 m out. The curves show the response versus observer height for octave-spaced frequencies from 1 to 8 kHz. It is seriously flawed by the large swings in level for relatively minor changes in elevation. Specifically from 0 to 0.2 m above the centerline the response for 2 kHz drops about 3 dB while the 4-kHz response rises about 4 dB. If the response is equalized to be flat *on axis*, moving upward or downward 0.2 m will create a response deviation of 7 dB. Clearly the designer is forced to create a compromise equalization for some listener height. The customer must live with undesirable frequency response variations if he or she does not remain close to that height.

Fig. 35 shows the corresponding curves using a simple

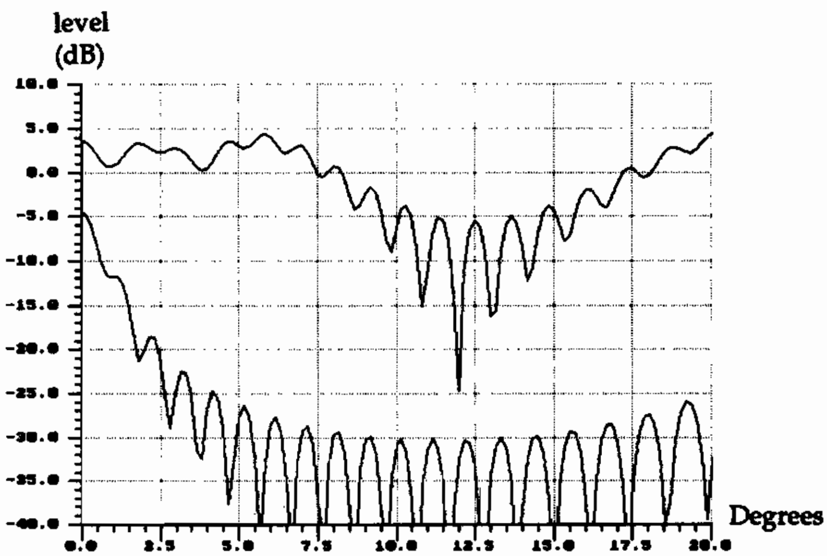

Fig. 32. Calculated "polar" curves of 23-element array 4 m out (top) and 32 m out, at 8 kHz.

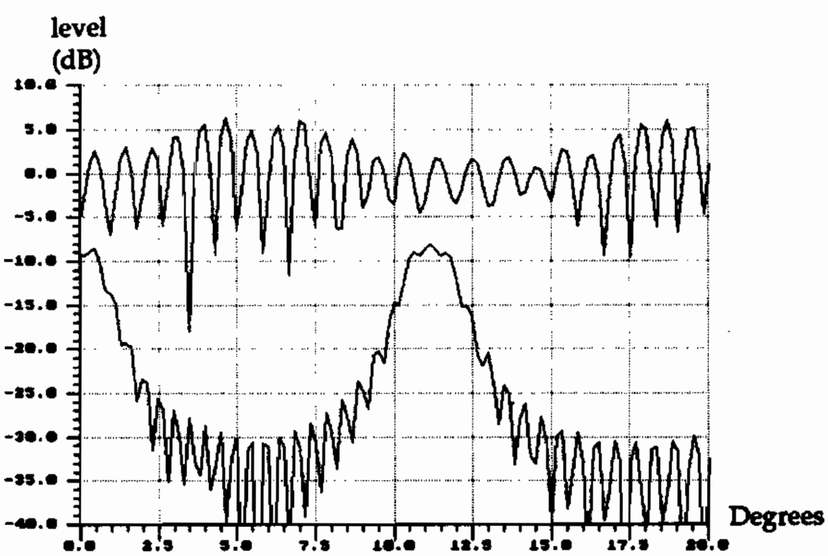

Fig. 33. Calculated "polar" curves of 23-element array 4 m out (top) and 32 m out, at 16 kHz.

frequency-independent (resistive network) weighting technique. The weighting was arrived at empirically and is roughly of a raised-cosine nature. The 16 elements are divided into four groups: the top two elements along with the bottom two are the first group. The adjacent two just below the top and the two just above the bottom are the second group. The next two down from the top and the two up from the bottom, are the third group. The remaining four elements in the center are the final group. From the ends to the middle, the groups are driven with coefficient strengths of 0.32, 0.7, 0.9, and 1.0. As Fig. 35 shows, the variation of level versus height is greatly reduced. The family of curves tapers off gently with increasing observation height. Only a hint of the 2- and 4-kHz trends remains. Equalization on axis will still hold well over a broad range of listener heights.

Performance is also improved versus listening distance, as shown in Figs. 36 and 37. In these curves the frequency is held at 4 kHz and the observation distance varies from 1 m to 16 m out, with the distance doubling for each curve. For the unweighted case Fig. 36 shows significant variation versus height for all observation distances. With the weighting scheme applied (Fig. 37) the variation is smoothed considerably, both for changes in vertical listening position and for distance out. This weighting scheme was applied to a 16-tweeter array in the model XRT 24 loudspeaker.

5 CONCLUSIONS

Both near-field and far-field performances of line arrays were explored. A thorough explanation of all observed phenomena for line arrays was illustrated. The interrelation between the Fourier transform and the far-field polar response was explored. This understanding allowed the manipulation of an array's polar responses via element level tapering.

It was shown that for long arrays used in a home setting the performance was very much dominated by near-field considerations. Instead of concentrating on a complete polar curve, improvements to the forward

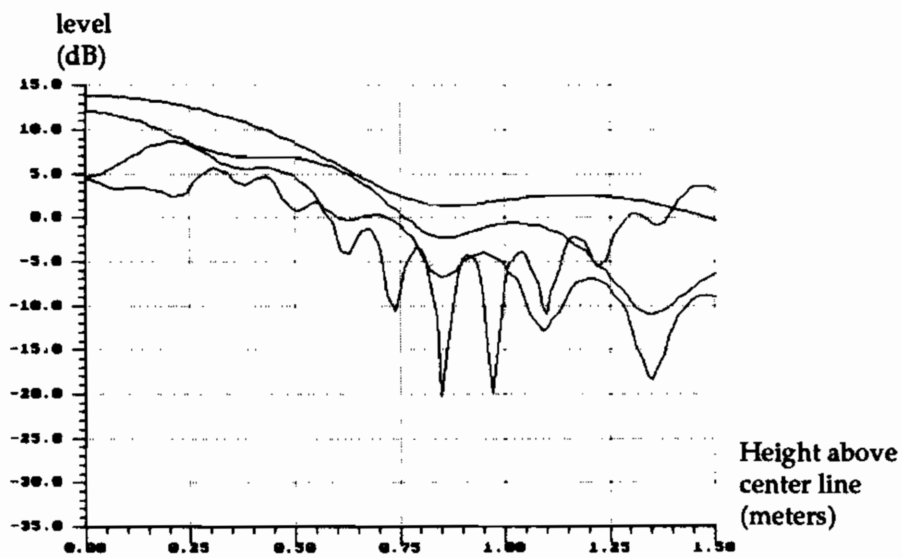

Fig. 34. Level versus observation height of 16-element *unweighted* array from 1 kHz (top curve) to 8 kHz.

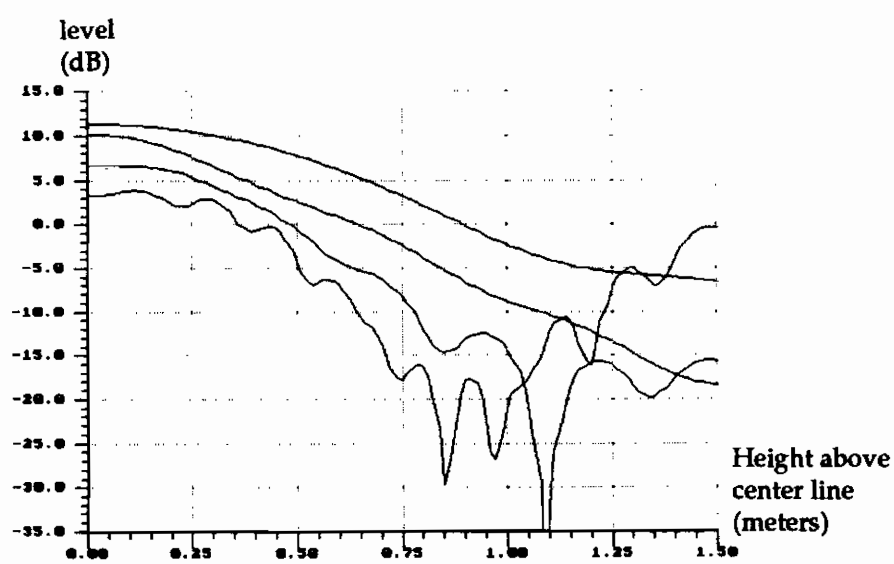

Fig. 35. Level versus observation height of 16-element *weighted-coefficient* array from 1 kHz (top curve) to 8 kHz.

beam of the array would best benefit the user. At typical listening distances, level tapering schemes were found to be useful in giving much improved response smoothness for any listening height.

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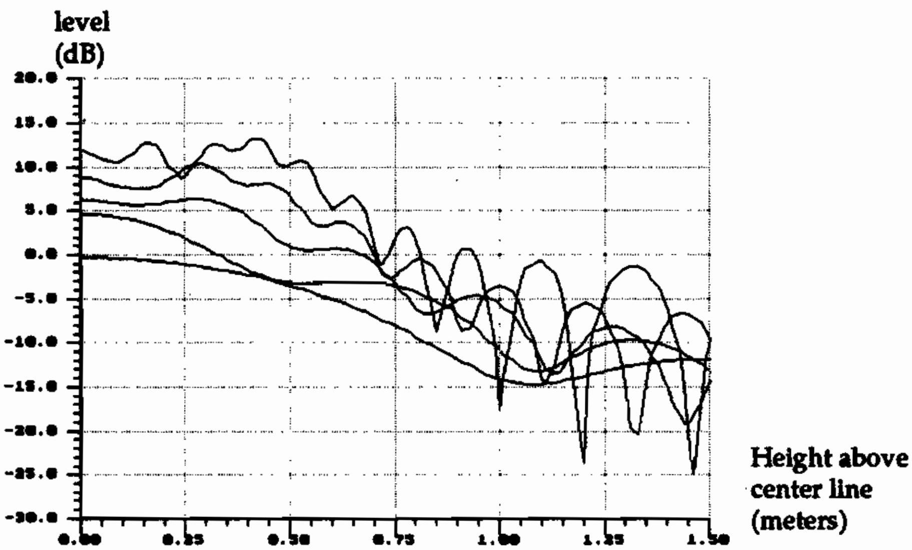

Fig. 36. Level versus observation height of 16-element *unweighted* array at 4 kHz. Sweep taken from 1 m out (top curve) to 16 m out.

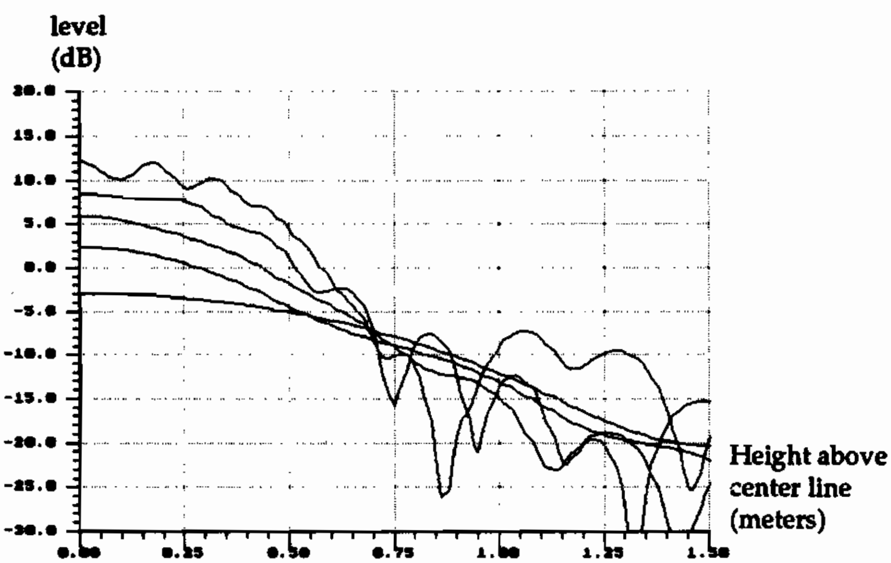

Fig. 37. Level versus observation height of 16-element *weighted-coefficient* array at 4 kHz. Sweep taken from 1 m out (top curve) to 16 m out.

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