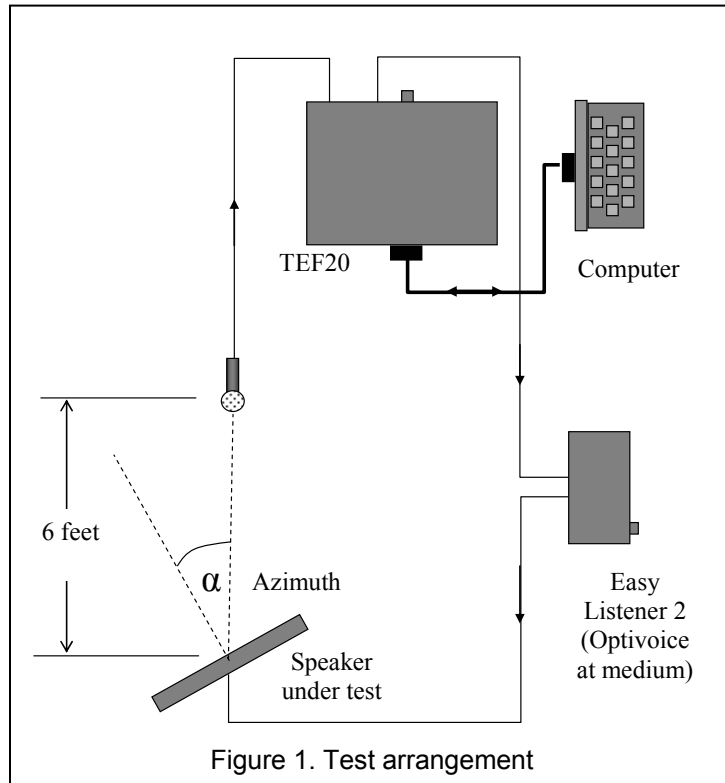


Evaluation of Lightspeed flat-panel loudspeaker SP007661  
Arthur Boothroyd  
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**1. Measurements and analyses**

The test arrangement is shown in Figure 1. Output was measured as a function of frequency using time-delay spectrometry. This technique makes it possible to eliminate room reflections and to obtain results that are equivalent to those obtained in an anechoic room. There is a trade-off, however between the temporal resolution needed to reject early reflections and the resulting frequency resolution. For the present analyses, the test tone was swept from 100 to 10000 Hz in 427 ms, and the time resolution was 2 ms, making it possible to attenuate reflections with a path length that exceeded the direct path by 2.26 feet or more. (With the test speaker some 5 feet below the ceiling and a test distance of 6 feet, the difference between the direct path and that of the first ceiling reflection would have been 5.7 feet).

The resulting frequency resolution was 500 HZ, which eliminates some of the fine detail of the spectrum-level frequency response and also invalidates measurements at 250 Hz or less. These conditions, however, provided an acceptable compromise between frequency resolution and reflection rejection.

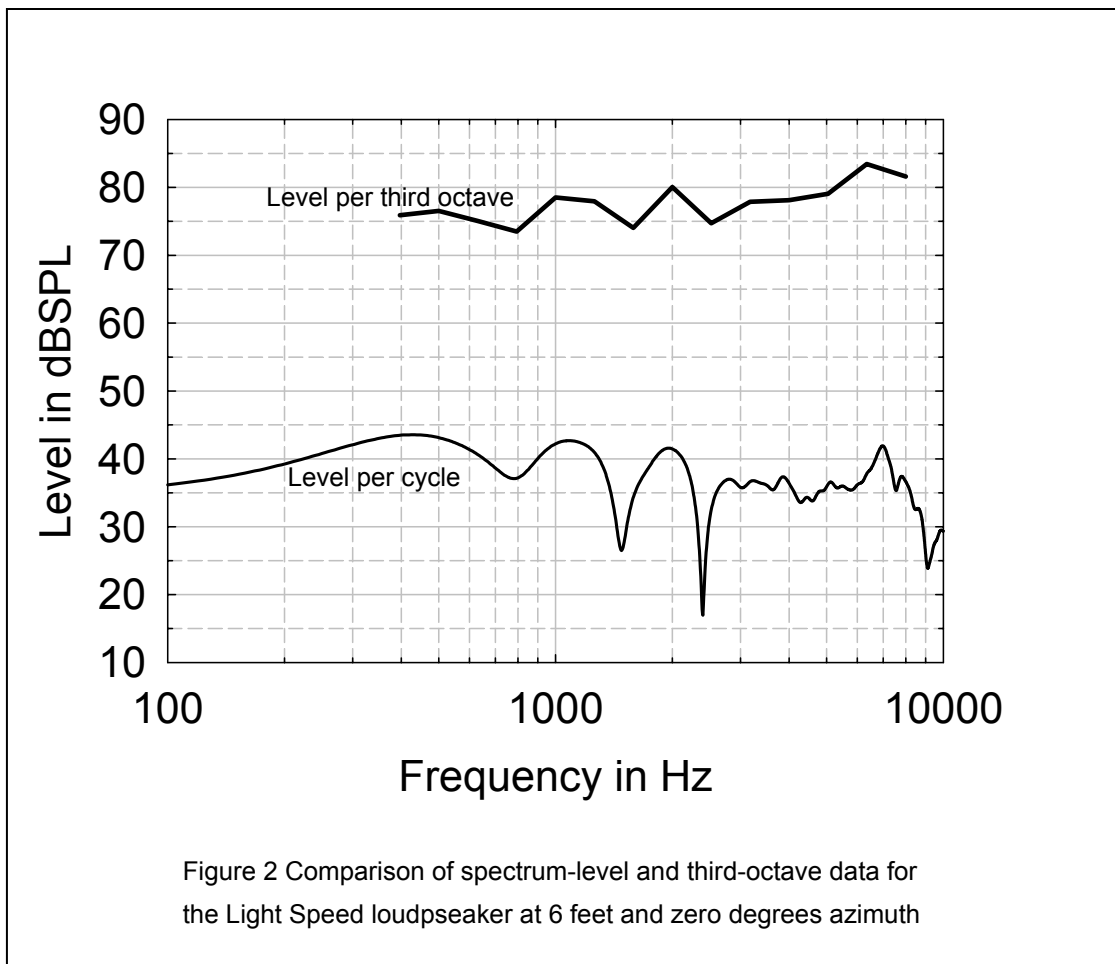


The resulting data on spectrum level vs. frequency were converted to third-octave levels by summing energy over one-third octave bands. For example:

$$L_{500} = 10 \cdot \log \sum (10^{s_i/10})$$

Where  $L_{500}$  is the third octave level at 500 Hz,  $s$  is spectrum level, and  $i$  goes from 445 to 561.

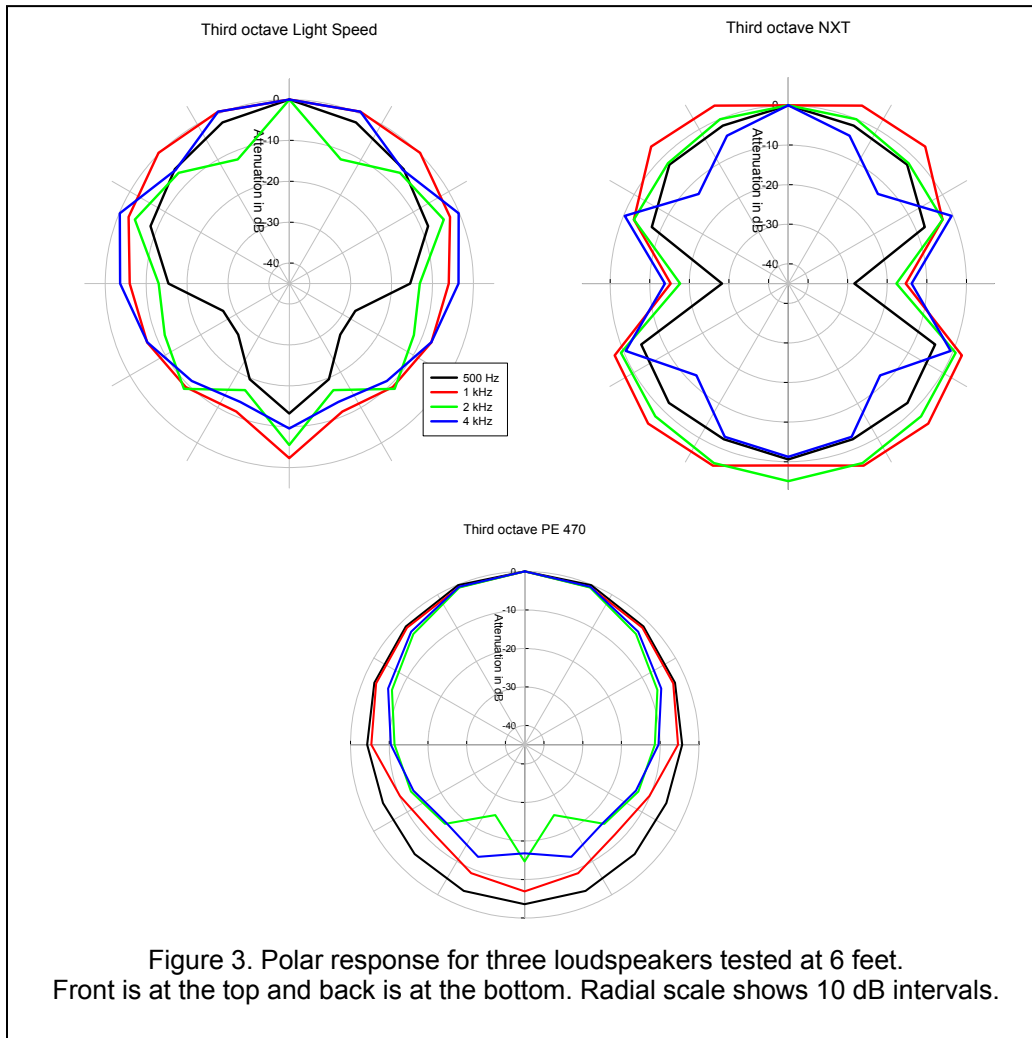
Figure 2 shows a comparison of spectrum-level and third-octave data. Note that the third-octave analysis hides a lot of the undesirable irregularities in the spectrum-level data and also adds a 3 dB per octave high-frequency emphasis. There are two reasons for this step, however. First, it avoids small irregularities in the spectrum being mistaken for the effects of distance and azimuth. Second, it more closely approximates the behavior of the human ear – which integrates energy over bands of equal logarithmic bandwidth.



## 2. Results

### i) Directional characteristics

The first panel in Figure 3 shows the third-octave output of the Light Speed loudspeaker at selected frequencies as a function of direction. Also shown for comparison are data for the NXT flat-panel loudspeaker and the Phonic Ear 470 loudspeaker. These data were obtained in the same testing session using identical set-up and test parameters.



It will be seen that the conventional Phonic Ear loudspeaker provides a more uniform frontal horizontal coverage than do either of the flat-panel speakers. Between -60 and +60 degrees, the maximum deviation from zero degree azimuth is about 6 or 7 dB for the PE 470, at 2 and 4 kHz. The other units show almost twice as much deviation. For the Light Speed, the deviation is at the frequency of 2 kHz – a critical frequency region for speech intelligibility. For the NXT, the deviation is at 4 kHz – which is somewhat less important but still significant. Note also that the Light Speed radiates more effectively in the forward than in the backwards direction – unlike the open-mounted NXT, which radiates well in both directions.

## ii) Frequency responses

Figure 4 shows third-octave output as a function of frequency for 4 angles in the forward direction. The top panel shows data for the Light Speed speaker, The other two panels show equivalent data for the other two speakers.

It will be seen that the conventional PE 470 has a frequency response that is both smoother and less dependent on azimuth than either of the flat-panel speakers. It is also clear that the problems of response irregularity and angle-dependence are greater for the Light Speed than for the NXT speaker.

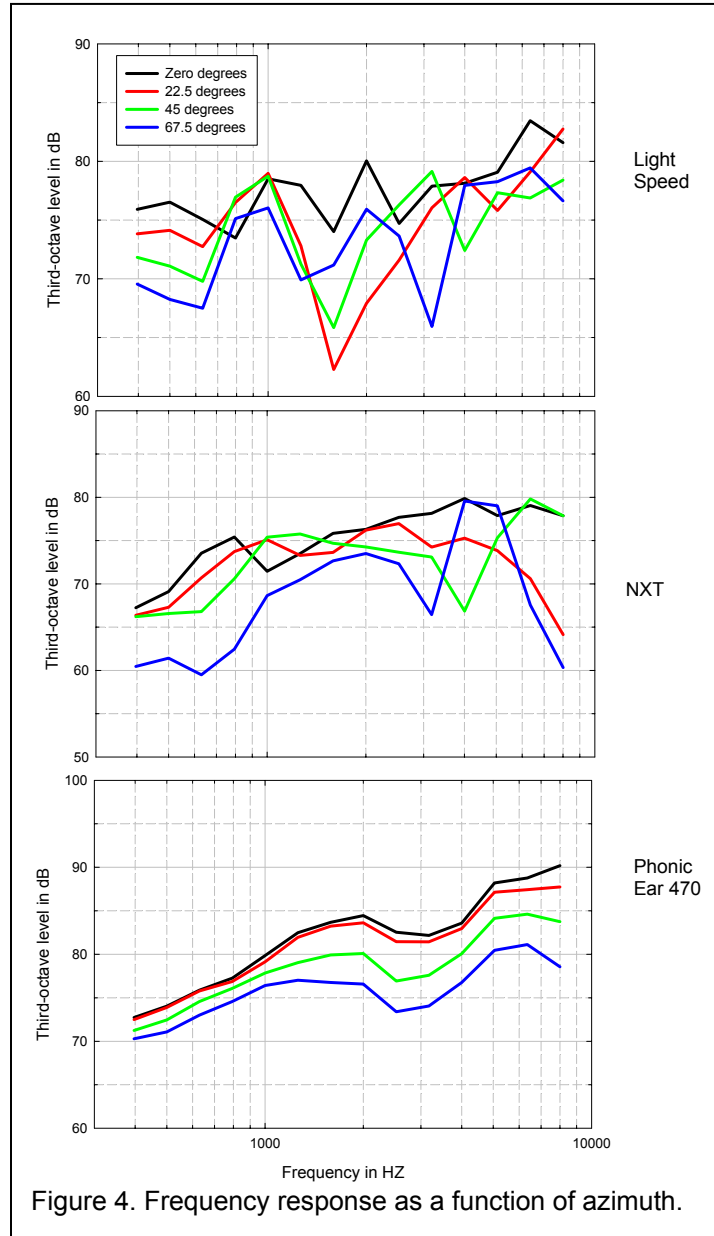
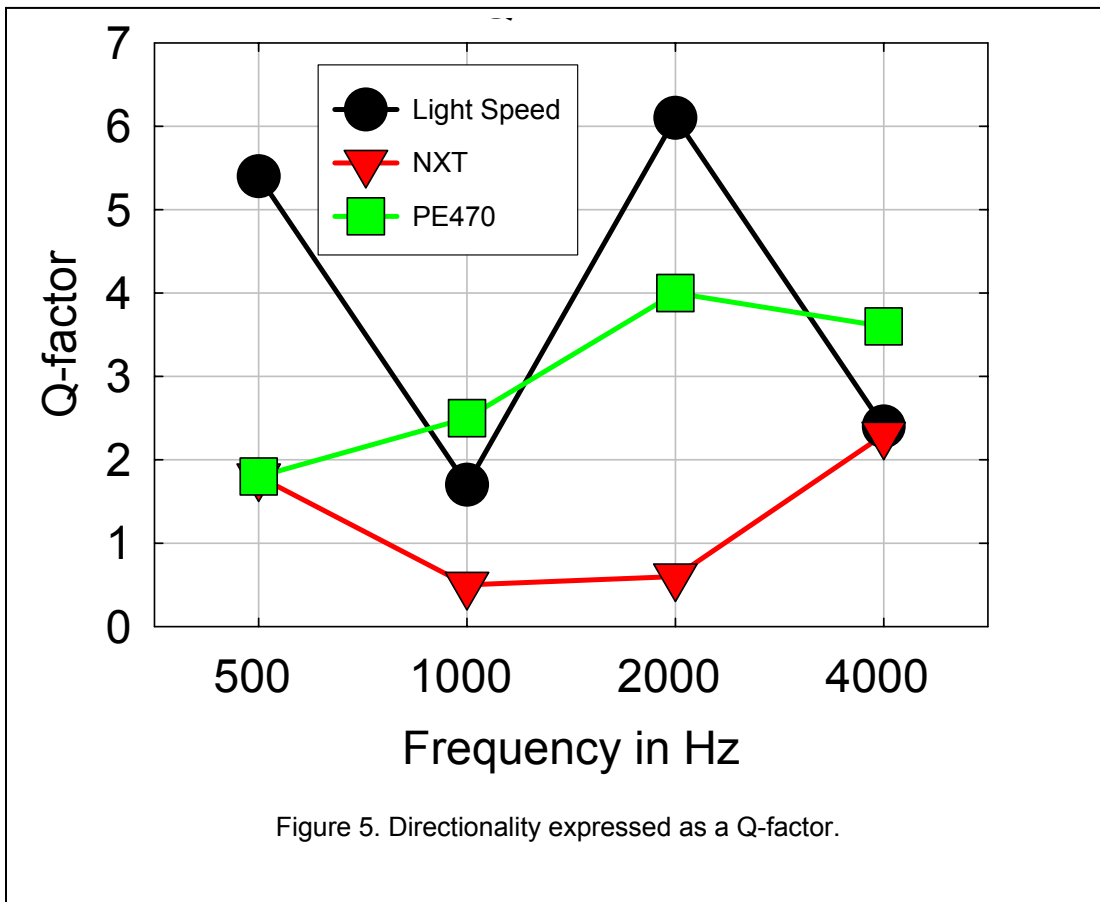


Figure 4. Frequency response as a function of azimuth.

### iii) Q-Factors

Figure 5 shows the Q-factors derived from the data of Figure 3. Q is, essentially, a ratio of the energy radiated in the forward direction (zero degrees azimuth) to the energy averaged over all directions. The higher the number, the greater the directionality. Loudspeakers with low values of Q generate more reverberant energy in relation to the direct sound. This reduces the critical distance – that is the distance beyond which a listener receives mainly reflected sound. It also reduces the difference between the helpful reflections and the destructive late reflections. In general, low values of Q are fine for rooms that have short reverberation times (less than 0.4 seconds) but high Q values are needed for rooms with longer reverberation times (greater than 0.7 seconds). Because of the importance of the higher speech frequencies to speech intelligibility, one should probably look at an average of 1000, 2000, and 4000 Hz. These averages are 3.4, 1.1, and 3.4 for the Light Speed, NXT, and PE470 speakers, respectively. At first sight, it would seem that the Light Speed and PE 470 speakers are equivalent, but the disparity between Q at 1000 and 2000 Hz seen for the Light Speed is a liability. In a reverberant space, the reverberant energy created by the low Q-value at 1000 Hz could interfere with the lower reverberant energy at 2000 Hz because of upward spread of masking.

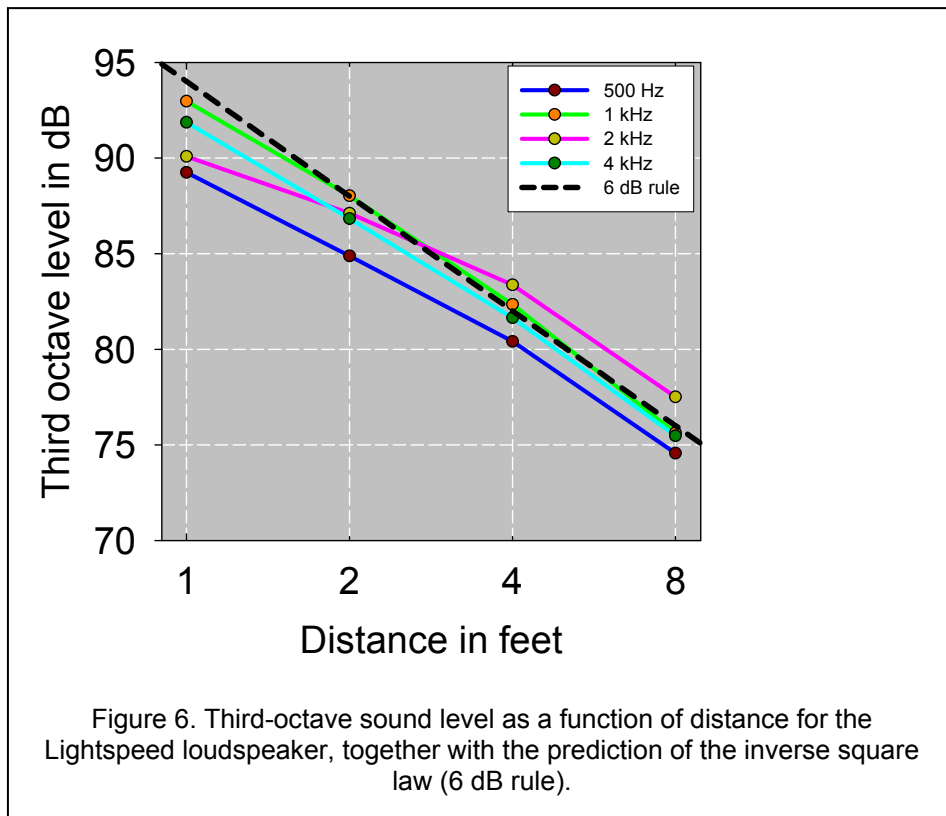


#### iv) Effect of distance

One claim of the designers of flat-panel loudspeakers is that level falls less with increasing distance than is predicted by the inverse square law – (inverse square law predicts a 6 dB drop in level for every doubling of distance from a point source). Of course, a loudspeaker is not a point source. Both theory and practice, however, show that, as long as the distance is greater than the size of the source, the law applies pretty well. One would, therefore predict that, at the kinds of distances involved in classroom listening, any departures from the inverse square law would be negligible. In other words, there is no reason to expect that the Lightspeed speaker can “throw” the direct (non-reflected) sound further than a conventional loudspeaker.

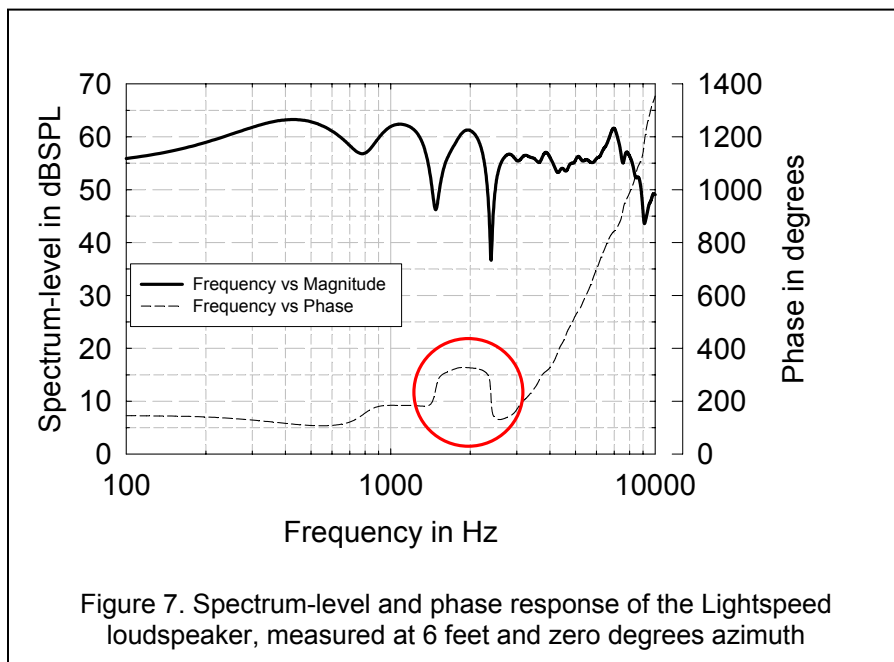
Figure 6 shows measured third-octave levels, as a function of distance, at octave frequencies from 500 to 4000 Hz. It will be seen that there are some departures from the 6 dB rule for distances below 4 feet. After 4 feet, however, the inverse square law fits the data very closely. In other words, there is no basis for the claim that level falls more slowly with distance than is the case with other loudspeakers – at least for the kinds of distances involved in classroom listening. The laws of Physics are not being violated.

On the positive side, however, the tendency for level to fall by more than 6 dB for every halving of distance below 4 feet should offer some advantage in terms of the onset of acoustic feedback when the microphone is brought close to the loudspeaker.

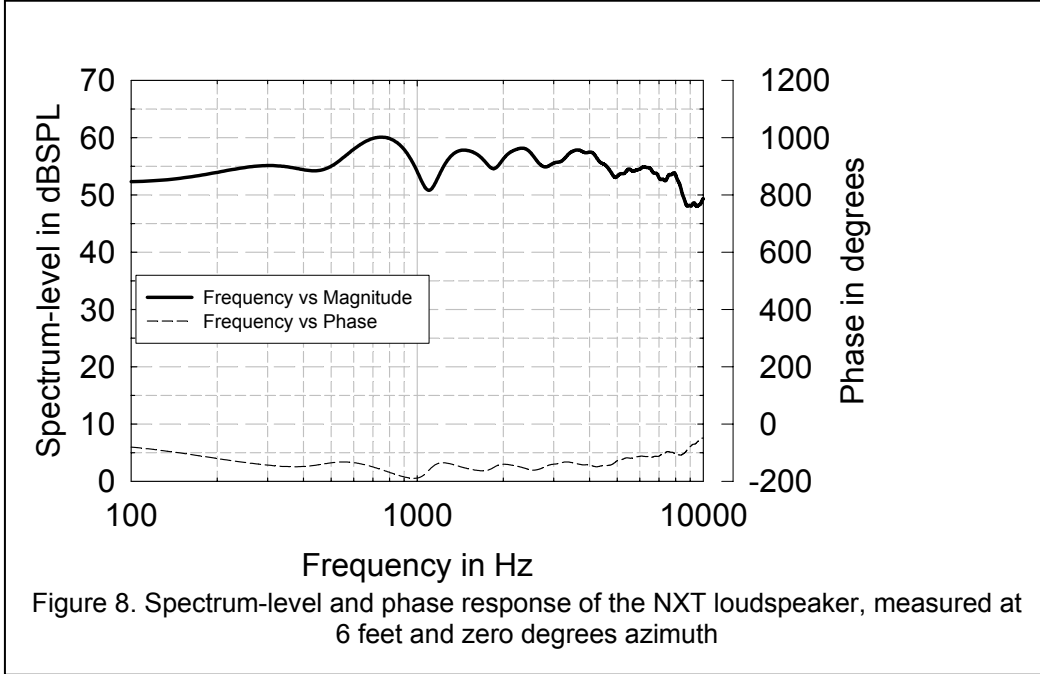


**v) Phase and interference effects.**

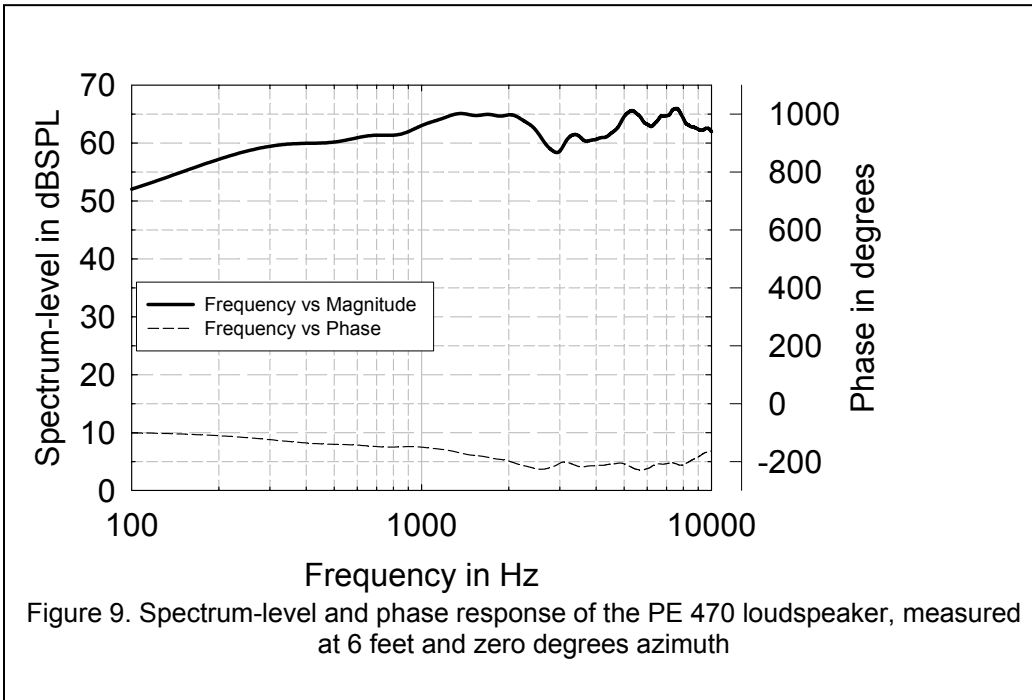
The concept behind the NXT and Lightspeed loudspeakers is that a driver mounted on a flat, semi-rigid surface will create traveling waves across that surface. These waves involve “bending” of the surface (unlike sound waves in the air which involve compression and rarefaction). When these waves reach the surface edge, they will be reflected, causing patterns of interference. By using more than one driver, the designers hope to mix the resulting patterns to create a random pattern of vibration across the surface – rather like the pattern of vibration observed on the surface of a swimming pool when it is in use. Unfortunately, they are only partially successful. At certain frequencies, the surface adopts a resonant pattern of vibration with standing waves in which regions of maximum vibration are separated by regions without vibration. It is as though the surface becomes a set of discrete cone loudspeakers. At a point which is equidistant from two of the regions of maximum vibration, the level will be enhanced if the vibrations are in phase – and they will cancel each other if the vibrations are out of phase. The effect will be to create peaks and nulls in the measured response of the loudspeaker – and the frequencies of these peaks and nulls will change with azimuth. This effect is seen very clearly for the Lightspeed speaker in Figure 2. It accounts for the drop in response at 2 kHz at 22.5 degrees in azimuth Figure 3. And it also accounts for the dramatic changes in frequency response with angle seen in Figure 4. The effect is less apparent, but still present, for the NXT speaker. For further illustration, Figure 7 shows the spectrum-level response of the Lightspeed loudspeaker at zero degrees azimuth, together with the phase response. Note the 180 degree phase change between the two nulls at 1400 and 2300 Hz. This observation supports the conclusion that the irregularities in the response are the result of shifting standing wave patterns.



For comparison, Figure 8 shows equivalent data for the NXT speaker. Note that both the response and the phase spectrum are relatively smooth, suggesting greater success in the achieving the goal of a random vibration pattern. There is still some evidence of comb filtering, however.



Finally, Figure 9 shows equivalent data for the Phonic Ear 470 speaker.



### 3. Summary

There is little in these data to recommend the Light Speed loudspeaker:

- i) There are peaks and nulls in the frequency response that can be attributed to standing wave patterns in the vibrating panel.
- ii) There is no evidence that it provides more uniform coverage at different listening angles than does the conventional PE 470 loudspeaker. In fact, at relatively small angles, there is evidence of significant attenuation at frequencies of importance to speech perception.
- iii) Overall directionality, as measured by the Q-factor is similar to that of the more conventional speaker, but the dramatic variations of Q with frequency are a cause for concern.
- iv) There is no evidence that the Light Speed speaker can project, or “throw” sound further than conventional loudspeakers. At a distance of 4 feet or more, the inverse square law applies for this speaker just as it does for conventional speakers.

The negative effects will be most important for those students who are reasonably close to the loudspeaker (within about 6 feet – depending on the reverberation time and size of the room) and are listening, mainly, to direct sound that has not been reflected from the rooms boundaries. For students who are listening in the reverberant field, the peaks and nulls in the responses at various angles will overlap to produce a fairly smooth response and the negative consequences should be less apparent.

If the goal is to generate high-fidelity amplification for as many listeners as possible, then a high-quality conventional speaker such as the PE 470 is the better choice. If, however, a customer is attracted by the aesthetics of a wall-mounted flat-panel speaker, the loss of sound quality is probably not overly serious. It would be better, however, to use a higher quality flat-panel unit that more effectively realizes the intended behavior of these devices.