A STUDY OF HOW LOUDSPEAKER HIGH FREQUENCY DIRECTIVITY AFFECTS SPEECH INTELLIGIBILITY

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1 INTRODUCTION:

Modern construction techniques have allowed architects to design and erect venues offering huge volumes and hosting capacities. This is not good news for the PA system designer as his two worst enemies are room reverberation and public noise. Since PA systems are now used for evacuation messages, communications as well as promotional announcements, the quest for good speech intelligibility is now more challenging than ever. The PA system needs to perform better in noisier and more reverberant spaces.
In the following presentation, we will explain the importance of the PA system's high frequency performance and dispersion in its ability to deliver good speech intelligibility.

2 WHY SO HIGH? WHY SO LOUD?

The straightforward idea behind speech diffusion would be to achieve a linear playback performance in which you do not alter the original speech spectrum. However, as you can see on the following diagrams, the playback for good speech intelligibility requires a different tonal balance, which is in fact the opposite of the average speech spectrum, with a strong stress on upper midrange and high frequencies. This boost in high frequencies gets even more important in reverberant and noisy spaces.

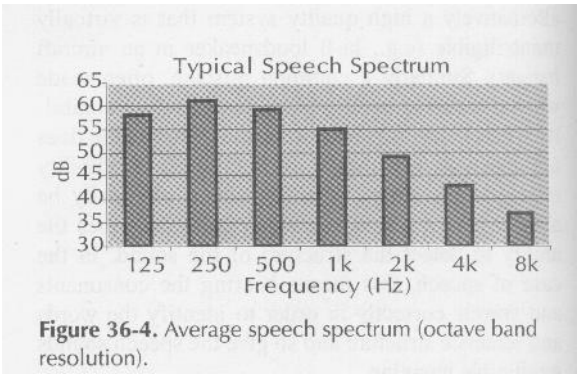


Figure 36-4. Average speech spectrum (octave band resolution).

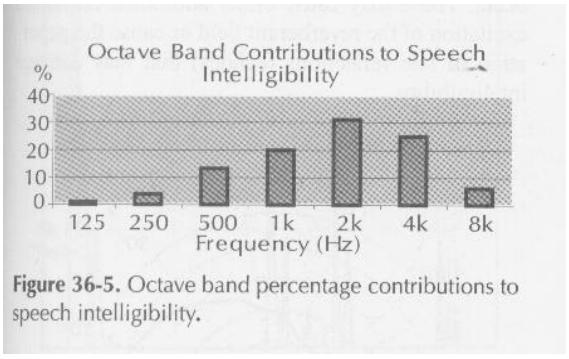
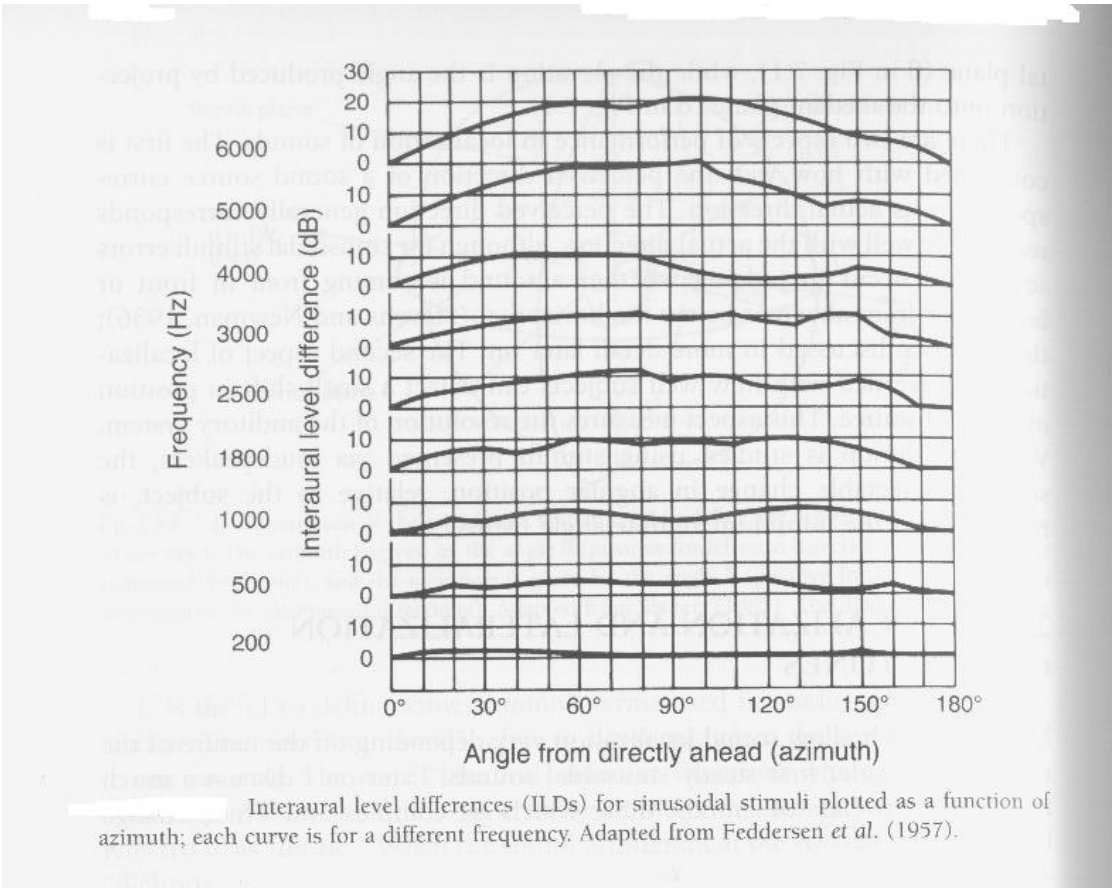


Figure 36-5. Octave band percentage contributions to speech intelligibility.

Reaching proper speech intelligibility in difficult conditions is also about getting some help from specific skills of the hearing apparatus. It has the ability to focus on critical messages by localizing the sound source in the space. Binaural localization is phase dependent in the lower part of the audio spectrum but becomes level dependent in its highest. Localization gets better as frequency increases. In large spaces, low frequency phase perception is very poor especially since more than 2 loudspeakers are usually active at one time. Only directly radiated high frequency information will allow the listener to locate the sound source.



Interaural level differences (ILDs) for sinusoidal stimuli plotted as a function of azimuth; each curve is for a different frequency. Adapted from Feddersen *et al.* (1957).

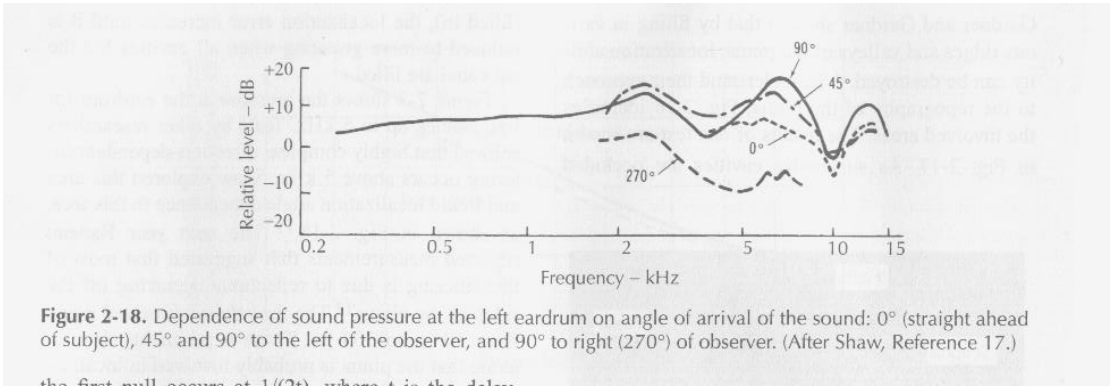


Figure 2-18. Dependence of sound pressure at the left eardrum on angle of arrival of the sound: 0° (straight ahead of subject), 45° and 90° to the left of the observer, and 90° to right (270°) of observer. (After Shaw, Reference 17.)

Various research on hearing aids have shown that sound source localization is critical in speech perception over noise or random sounds. We can therefore assume that high frequency audibility will improve a PA system's speech intelligibility especially in noisy and reverberant spaces.

In order to be heard, these high frequencies need to be properly balanced over the rest of the spectrum. Because signal to noise ration is a primary element in an intelligible audio system, certain venues with high background noise will require high SPL announcements. One of the non-helping feature of human hearing is the combination of frequency masking and equal loudness contours. As SPL increases, low frequency sensitivity of a given individual will increase and this information will start masking the high frequencies we have found earlier on to be so helpful for speech perception and localization! This is why a PA system should offer perfect high frequency playback with proper headroom to overcome high frequency masking effects.

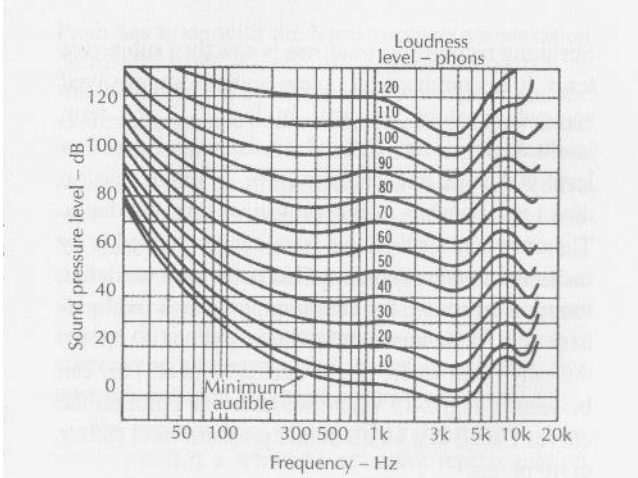


Figure 2-12. Equal loudness contours for pure tones in a frontal sound field for humans of average hearing acuity determined by Robinson and Dadson. The loudness levels in phons correspond to the sound pressure levels at 1000 Hz. (ISO Recommendation 226)

3 WHY SO WIDE?

If high frequencies are important to the listener at a given spot, they are important over the whole coverage area. PA loudspeakers should offer a high frequency dispersion wide enough to allow a constant frequency response in the venue free of dead spots that would create un-intelligible sound zones. A constant frequency response will also allow the PA engineer to properly equalise the system for speech intelligibility optimization.

This high frequency dispersion should be wide but regular as well. It goes without saying that a loudspeaker offering a good dispersion at a given frequency and half this dispersion an octave above would not provide the benefits we are looking for here. The fact is that a constant directivity loudspeaker will limit tonal balance differences between direct and reflected sound. An unbalance between the direct and reflected sound's frequency content will make the system impossible to equalise, generating a systematic boost of lower frequencies that will increase the masking effects we talked about earlier on, as well as reverberation level.
This unbalance will also force the PA engineer in using drastic equalisation or level changes to try to achieve acceptable intelligibility in some areas. These drastic measures are very likely to make the system unstable if an open microphone is brought in the venue.
Another consequence of a good high frequency dispersion is the reduction of the number of loudspeakers. This reduction offer several benefits:

- Increase level differences between 2 sound sources which will help with the binaural localization effect described before
- Reduce the total acoustic power which will help reducing the reverberation level
- Reduce installation and cabling costs. The saving can be re-invested in higher quality loudspeakers with proper high frequency dispersion!

4 CONCLUSION:

It looks like high frequency performance and coverage should be carefully thought through while designing a PA system. Poor high frequency level and distribution will systematically limit the system's speech intelligibility when exposed to noise and long reverberation time.
It is disappointing to note that a lot of PA systems are still designed with the "good old telephone bandwidth" as a guideline. This industry habit is certainly not suitable for today's PA systems challenges. It would be great to see more budget allocated to loudspeakers in distributed systems as most of the specified ones are not able to reach a desirable level of high frequency playback or dispersion.

5 REFERENCES:

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