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System Intelligibility Estimates

• Long before a reinforcement system is on the drawing board, while it is still in the negotiating stage, the designer must have a clear idea of how well the system will work. The aim of any reinforcement system is to provide adequate intelligibility for the intended audience under all anticipated listening conditions.

Over the years, a number of methods have been developed for helping the designer estimate the effectiveness of the system while it is still in the conceptual stage. We hasten to underscore the term estimate, since these methods are only rough guides to what might be expected when the system is finally installed.

ARTICULATION TESTING

The final measure of a system's intelligibility is gained through a set of syllabic articulation tests. In this testing method, a talker reads from a random list of one-syllable words, and listeners at various points in the space write down the words as they hear them. An 85% score on these tests indicates that the system will provide overall speech intelligibility on the order of 97%, due to the contextual nature of speech. If the articulation score is 75%, then the listener will be able to understand approximately 94% of the words in normal speech context.

FACTORS DETERMINING SYSTEM INTELLIGIBILITY

The main factors in determining the effectiveness of speech transmission in a room are speech level, reverberation time, direct-to-reverberant ratio, background noise, and the presence of discrete interfering reflections. Unfortunately, there is no simple way to include all these factors into a method that will estimate the behavior of the system.

We have a number of models as useful tools, each which seems to work under certain circumstances. About a year and a half ago, we discussed, in a column dealing with sound fields, the Peutz method of estimating system intelligibility. The Peutz estimate, as we chose to employ it, considers the effects of reverberation time and the direct-to-reverberant ratio in the 1 to 2 kHz range as the determinant of system intelligibility performance. We also assumed that the effective noise level below peak speech levels was at least 25 to 30 dB.

The method is especially effective in auditoriums and houses of worship, where the background noise level can be kept fairly low. The method further assumes that there are no deleterious reflections and that the room reverberation pattern is fairly normal.

ESTIMATES IN NOISY ENVIRONMENTS: THE ARTICULATION INDEX

The question of what to do in noisy environments leads us to the Articulation Index (AI) of French and Steinberg[1]. Their work has been modified in later years by Kryter[2] and Smith[3].

In its simplified form, an AI estimate can be made by observing the peak speech levels relative to RMS noise levels in each of five octave bands: 250, 500, 1000, 2000, and 4000 Hz. These ratios are approximately weighted, and the weighted values are summed to give an Articulation Index.

FIGURE 1 shows the method by

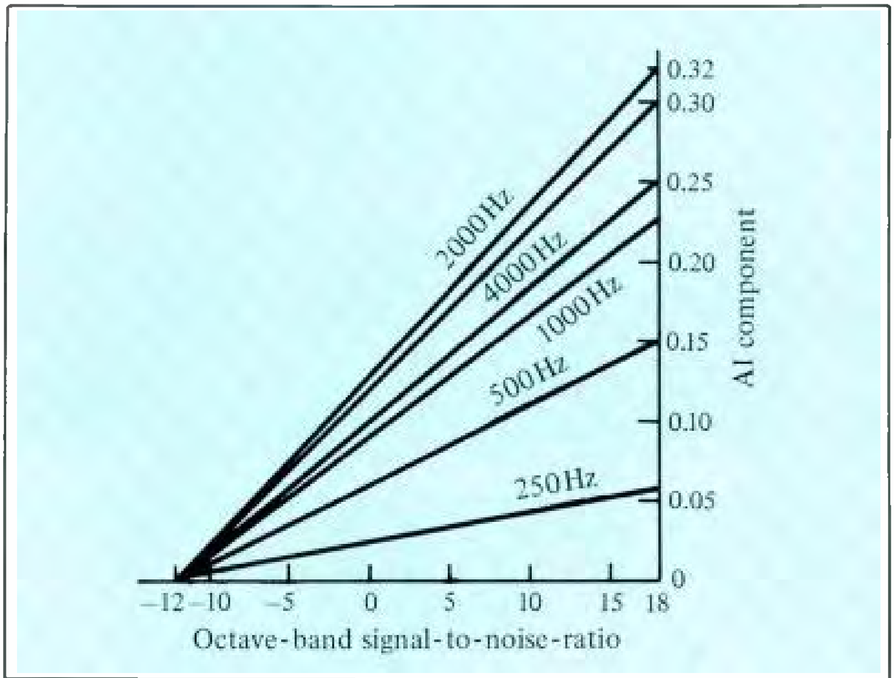

Figure 1. Calculation of Articulation Index (A1).

which the weighting is obtained. Along the X-axis, we enter the octave band signal-to-noise ratio, and along the Y-axis we read the corresponding AI component for that band. Since it is usually easier to measure average levels of long-term speech, these are the values to be entered in the graph. Generally, we assume that average speech levels in each band are some 12 dB lower than their peak levels.

Suppose that we measure average speech levels and RMS noise spectra as given in FIGURE 2. Then, we simply enter the level differences between them and read the corre-

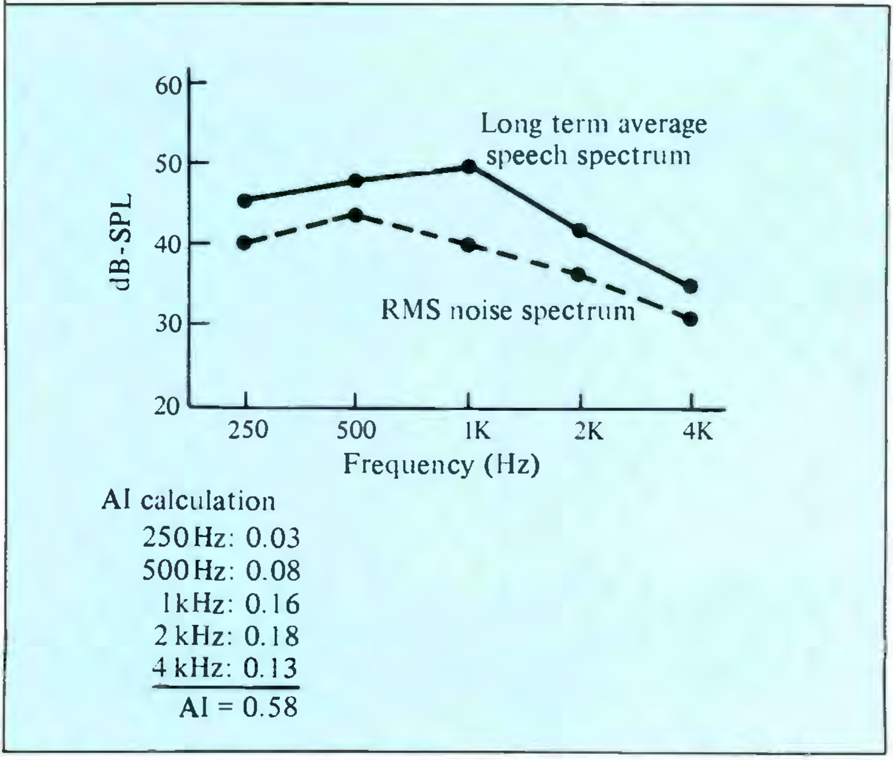

Figure 2. Sample speech and noise spectrum.

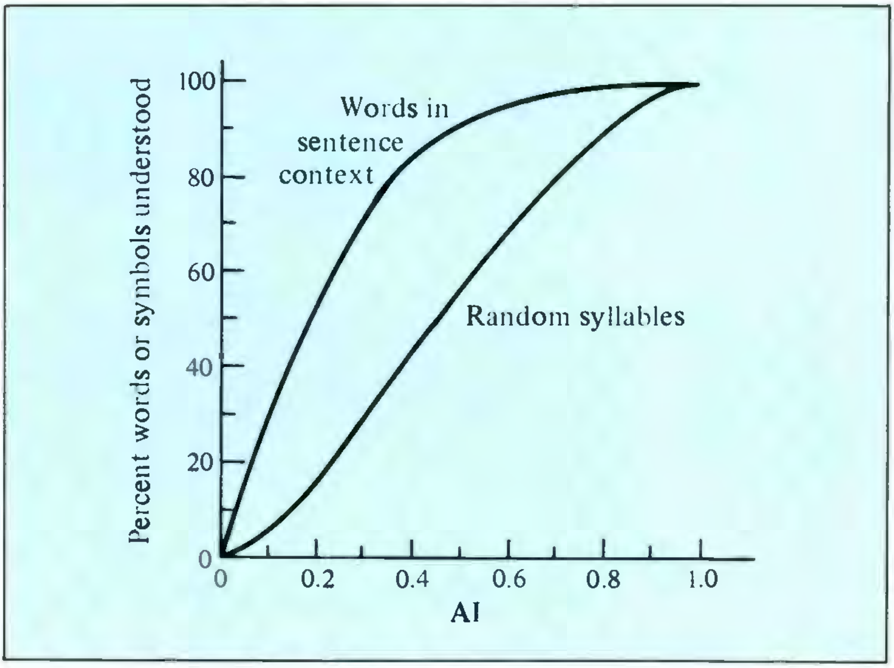

Figure 3. Comparison of AI and syllabic tests.

sponding AI component values from FIGURE 1, as indicated.

Note that the total AI is 0.58. As a measure of performance, we refer to the graph of FIGURE 3. Here, we observe that the AI value of 0.58 corresponds roughly to an accuracy well up in the 90% range for syllables in normal speech context. For random syllables, the accuracy would be around 70%.

There is a vast body of data relating AI estimates to actual measurements, and the agreement is quite good. The AI method is especially useful in public spaces, such as office areas and transportation terminals, where background noise can be significant.

ESTIMATES IN THE PRESENCE OF REVERBERATION

The adaptability of the AI method to spaces having both noise and excessive reverberation is not well established. While reverberation times less than, say, 1.5 seconds, probably have little deleterious effect on system intelligibility, longer reverberation times will certainly affect the intelligibility.

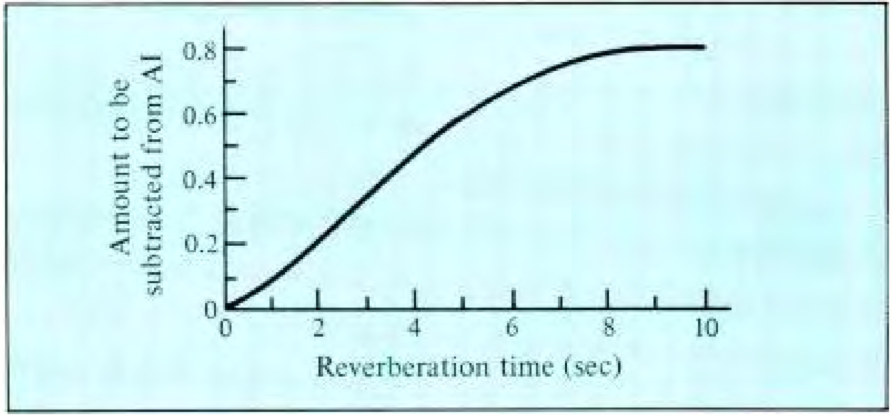

Figure 4. AI derating as a function of reverberation (Kryter).

Kryter suggests simply derating the AI value by the amount given by the graph of FIGURE 4. However, this is not recommended. Smith and others suggest that excessive reverberation be considered as additional noise to be summed, on a power basis, with the fixed noise spectrum in each octave band. In this manner, a reasonable AI estimate can be made for a sound system in a large space which is both noisy and reverberant. ■

References

1. French, N. R. and Steinberg, J. C., "Factors Governing the Intelligibility of Speech Sounds," J. Acoustical Society of America, Volume 19 (1947).

2. Kryter, K. D., "Methods for the Calculation and Use of the Articulation Index," J. Acoustical Society of America, Volume 34 (1962).

3. Smith, H. G., "Acoustic Design Considerations of Speech Intelligibility," J. Audio Engineering Society, Volume 29 (1981).