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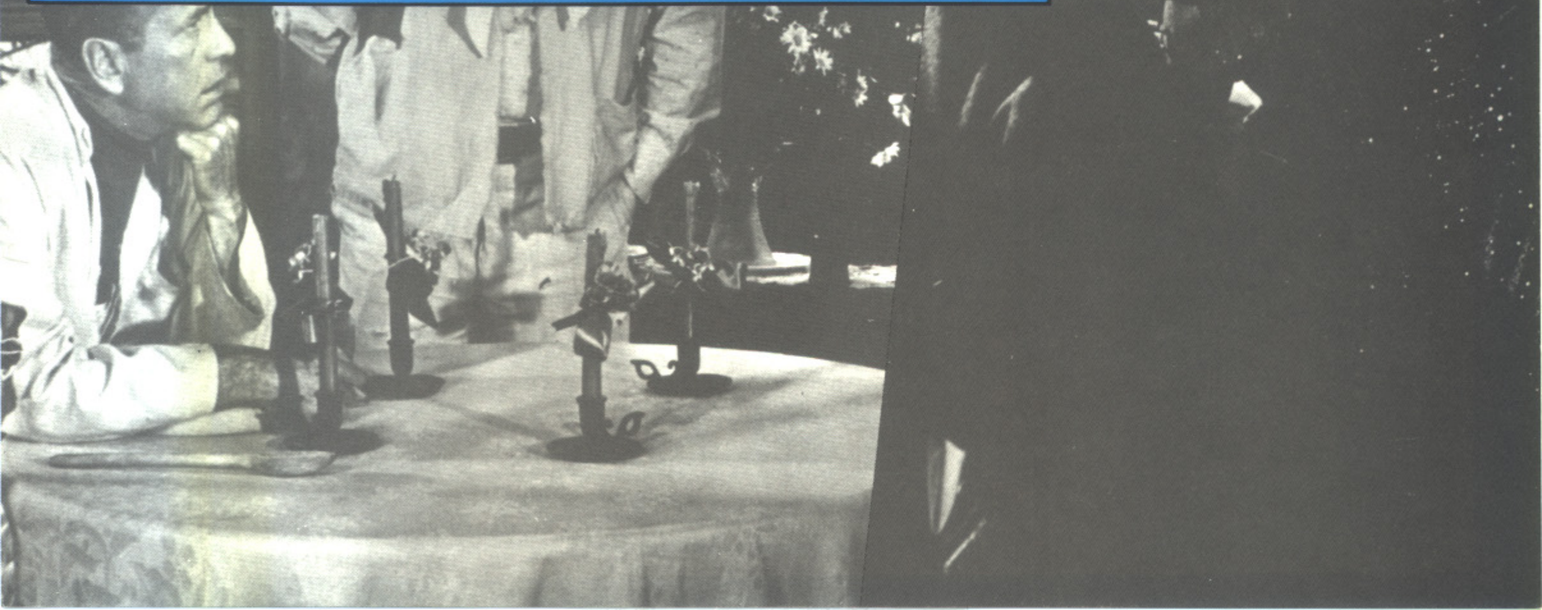


ANDREW T. MARTIN

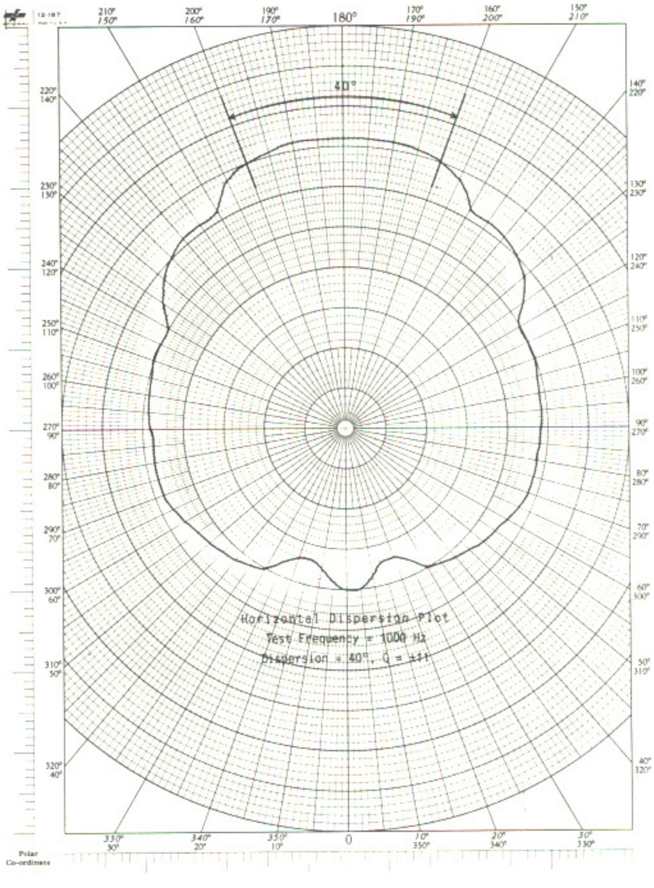
Sound Source Dispersion and Directivity Factor

Some of the most commonly overlooked aspects of sound reinforcement are also the most basic, and, as with the majority of subjects, the most basic are usually of the highest importance. An excellent case in point is the significance of sound source dispersion and directivity factor.

If a sound system is to be designed properly, these two concepts must be known and understood by the sound system designer. Yet, in the past, many designers have not been well versed with the effects that dispersion and directivity factor have on all sound systems. They have been unaware that these two factors can be utilized to extend the overall system's efficiency, increase intelligibility, and diminish unwanted room reflections. They have been unaware that misuse of sound source dispersion and directivity factor will in almost all instances cause a sizeable reduction in the performance of the sound system. It is for this reason this paper is dedicated to introducing the sound system designer to these concepts, and try to communicate the magnitude of these concepts clearly and without a tremendous amount of technical terminology. The following fictional narrative has been constructed to be helpful in understanding the importance of sound source dispersion and directivity factor.

Super Neeto Sound Company was in the process of installing a sound reinforcement system in a medium-sized church with a balcony. They had decided to try to uniformly cover the entire audience with sound from a central loudspeaker cluster mounted from the ceiling of the room directly over the minister's podium. Since the system was meant only to reproduce speech, a frequency response of 250 Hz to 5000 Hz would be totally acceptable. With this in mind, the company carefully chose the proper high frequency compression drivers and low frequency loudspeaker enclosures that would adequately generate the desired frequency response; and then picked out the horns that the compression drivers would be mounted on before being installed in the suspended loudspeaker cluster. Super Neeto Sound had decided to install three of the same 90 degree horizontal dispersion by 60 degree vertical dispersion horns with identical compression drivers on each. The directivity factor of the horns was 6. They mounted the horns in a contiguous vertical array with each horn mouth aligned precisely flush with the next, and with the high frequency compression drivers in synchronization. To complement the horns they decided to install two 15-inch vent loaded woofer cabinets which would be mounted directly underneath the horns. The suspended loudspeaker cluster was then constructed and hoisted into place: the top horn was aimed at the center of the balcony seating section,

Figure 1.



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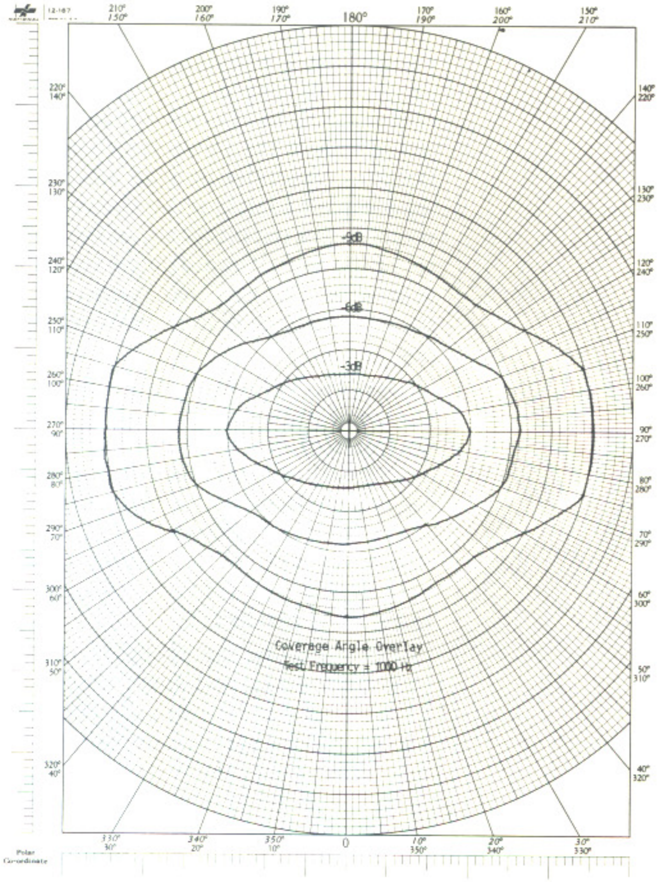

Figure 2.

and the bottom two horns and the woofers were aimed directly at the center of the floor seating section.

After the sound system had been connected with the power amplification and the various signal processing and program mixing equipment, the designer began what is always the final performance test: he began to listen to the system he had worked so hard to manufacture. As he walked around the church, he noticed that in many locations he could not understand what the speaker on the intelligibility test tapes was saying. He also noticed that the sound pressure level in the front and at the center of the seating areas were drastically higher than at the rear and the edges of the audience seating areas. The designer also found that the fidelity of the sound system was appreciably worse in the balcony than on the floor level. In desperation, the designer began to modify the equalization he had previously adjusted so precisely in the hopes of improving the fidelity of the sound system, but it was to no avail, the sound system could not be corrected with equalization.

Unbeknownst to Super Neeto Sound Company's designer was the significance of sound source dispersion and directivity factor. It may be helpful at this time to explain these two concepts in further depth.

Sound source dispersion, also known as coverage angle, is easily understood by viewing either polar charts or 3-D plots of the acoustic output of the sound source at a specified frequency. Usually the 6 dB down points are used to designate the dispersion angles in degrees, as shown in *Figure 1.* This measurement is made for both the horizontal axis and the vertical axis. With this information the designer is able to choose the sound source which will cover the audience maximally, but reduce the reflections of the sound source energy in the room to a minimum; thereby increasing the intelligibility of the program significantly. To further aid the designer, many manufacturers publish coverage angle overlays which outline the dispersion characteristics of the sound source as they would affect the audience area, as seen in *Figure 2.* There are now many price effective computer software programs which will simulate the dispersion of a sound source in a computer-generated replica of the environment the loudspeaker is to be installed in.

Directivity factor, also known as Q, is the ratio of the sound pressure squared, at a specific distance and fixed direction, to the mean squared sound pressure level at the same distance; then averaged over all directions from the sound source. Therefore, the directivity factor of a sound source is not an average measurement, but rather an average of all the individual Q measurements. Hence, an omnidirectional sound source would have a $Q=1$, and a hemispherical sound source would have a $Q=2$, and so on. What this means in practicality is that a sound source with a $Q=1$ would be half as directive as a sound source with a $Q=2$, and a sound source with a $Q=4$ would be twice as directive as the sound source with a $Q=2$. As seen in *Figure 3,* it is apparent that an increasing Q is directly proportionate to increasing sound source power, as long as the input power to the sound source remains the same. This is due to the horn's ability to take the acoustic energy of the sound source and tighten the dispersive pattern, thereby creating a more directive and concentrated output. As a result, utilizing higher Q loudspeakers make more efficient sound systems if the higher Q sound source conforms with the dispersion requirements of the system. But use extreme caution when installing high Q devices, for if they are not installed properly the adversity of the sound system can be as extreme as the profit. Additionally, not all manufacturers include the directivity factor measurement (Q) in their specifications sheet, but most will supply the information if it is requested.

So, applying the two concepts of sound source dispersion and directivity factor to Super Neeto Sound Company's installation, it is clear that some modifications need to take place.

Firstly, the balcony seating section would require a horn with a 70 degree by 40 degree dispersion and a Q of about 9. This sound source would considerably cut down the unwanted room reflections, and also increase the efficiency of the balcony horn and compression driver combination. In addition to changing the horn, its center axis should be aimed toward the seats in the center-rear of the balcony. By doing this, the sound pressure will remain more constant for the entire balcony audience due to the inverse square law; see appendix 1-0.

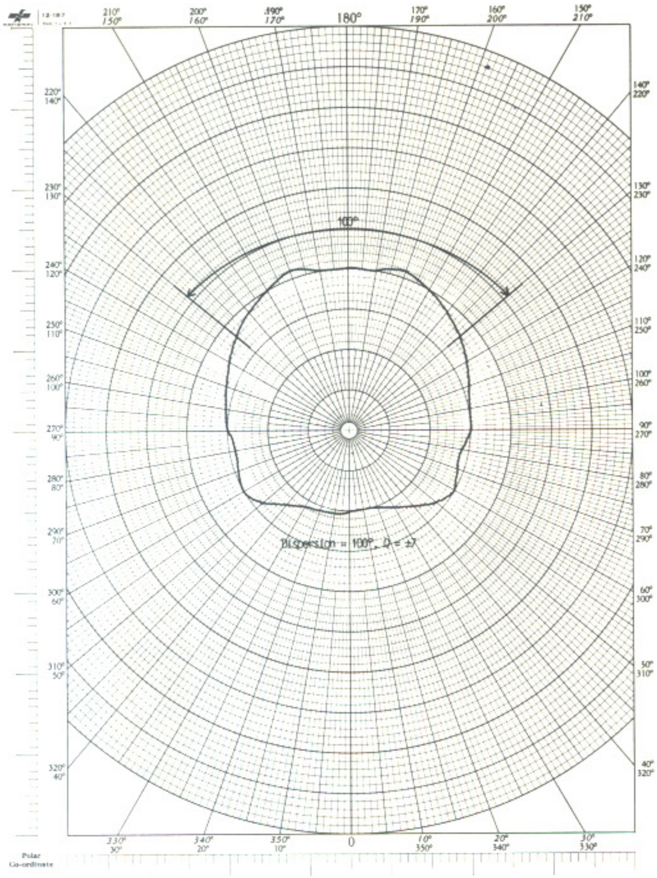

Figure 3A.

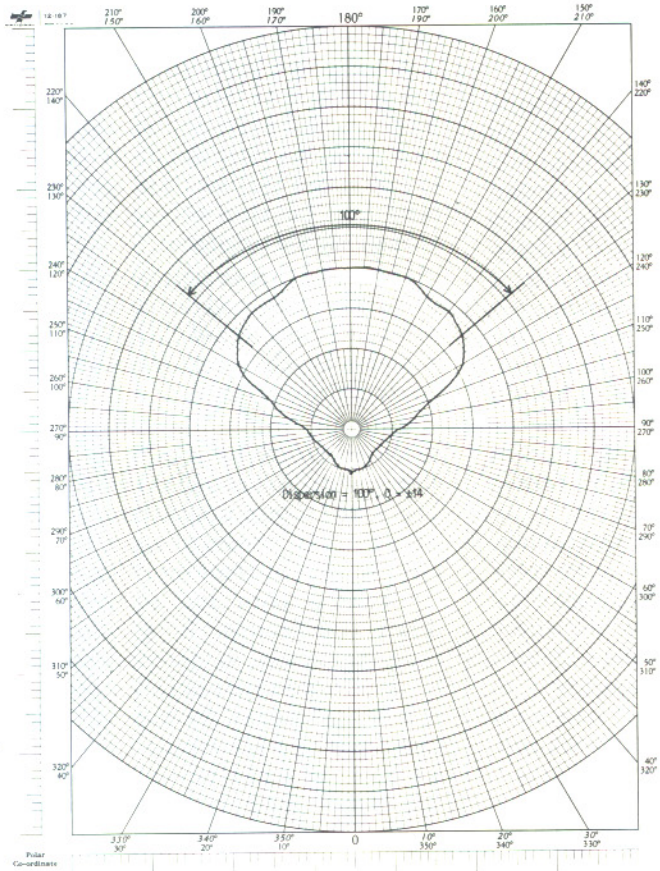

Figure 3B.

Secondly, the floor seating section would require only one of the existing 90 degree by 60 degree, Q = 6, horn and compression driver combinations. This would reduce the unwanted room reflections tremendously while maintaining adequate sound pressure level in the room. Again, the center axis of the horn should be aimed toward the center-rear section of the audience, once more taking advantage of the inverse square law.

Lastly, the two 15-inch woofers should be aimed in the direction of the floor seating horn. It is not necessary to aim additional woofers at the balcony seating section because the dispersion of lower frequency devices is inherently very wide and will sufficiently cover both the balcony and floor seating sections; see appendix 1-1.

After reviewing the effects of sound source dispersion and directivity factor it is obvious that they are an imperative part of sound reinforcement system design. When these two concepts are applied correctly by the sound system designer the benefits are immense. For the sound contractor the cost of the sound reinforcement system will be reduced thereby giving the contractor a larger profit margin and a lower bid. For the client, an installation that meets or exceeds all performance specifications is achieved at a reduced cost which will result in satisfaction and future referrals to the contractor. Sound source dispersion and directivity factor are not to be taken lightly.

APPENDIX 1-0

Inverse square law rate of level change.

This law describes the geometric expansion of sound from a sound source. The change in level for a spherical expansion from a point sound source is approximately 6 dB for each doubling of the distance. However, the reverberant field indoors is relatively constant, and therefore must be taken into consideration.

loss in dB-SPL at the measurement point,

where: $r = 10\log\left[\frac{Q}{4\pi r^2} + \frac{4}{R}\right]$

r is the distance to the measurement point

Q is the directivity factor of the sound source
R is the room constant

Example:

$$\text{loss }(4') = 10\log\left[\frac{6}{4\pi(4)^2}\ \frac{4}{1000}\right] = -14.71\text{ dB}$$

$$\text{loss }(40') = 10\log\left[\frac{6}{4\pi(40)^2}\ \frac{4}{1000}\right] = -23.67\text{ dB}$$

The difference is 23.67 - 14.71 = 8.96 dB-SPL

Outdoors, the formula for the inverse square law is as follows:

loss in dB-SPL at the measurement point, $r = 20\log\frac{r}{r_1}$

where:
r is the distance to the measurement point
r_1 is the measured reference distance

APPENDIX 1-1

Low frequency dispersion control.

At lower frequencies sound is dispersed in a very wide pattern. This is because the cone of the transducer is small in comparison to the wavelength of the low frequencies being reproduced. The approximate wavelength of a frequency in feet can be achieved by using this simple formula:

$$\text{wavelength} = \frac{1130'}{\text{frequency}}$$

example:

$$\text{wavelength of 250 Hz} = \frac{1130'}{250\text{ Hz}} = 4.52'$$

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