The Line Radiator

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The line radiator provides limited vertical distribution of sound thus reducing acoustical feedback in theatres and other places where live performances are addressed to a live audience. The result is enhanced realism.

Sound reenforcement, particularly where speakers and microphones are used in close proximity, presents a difficult problem for the sound engineer. The purpose of this article is to convey information obtained from research and development of a new concept in public-address speakers designed specifically to reduce the feedback problem as well as to provide the realism of a live source.

The prime purpose of a sound system is, of course, to provide those in the audience with the illusion that no such system exists—that all sound they hear is reaching them direct from its original source.

Providing this illusion can be difficult and costly. However, new techniques discovered during the development of the line radiator loudspeakers can greatly simplify the most difficult problems and provide fine quality sound coverage at a modest cost. Further, these small, compact loudspeakers ease mounting problems for any installation.

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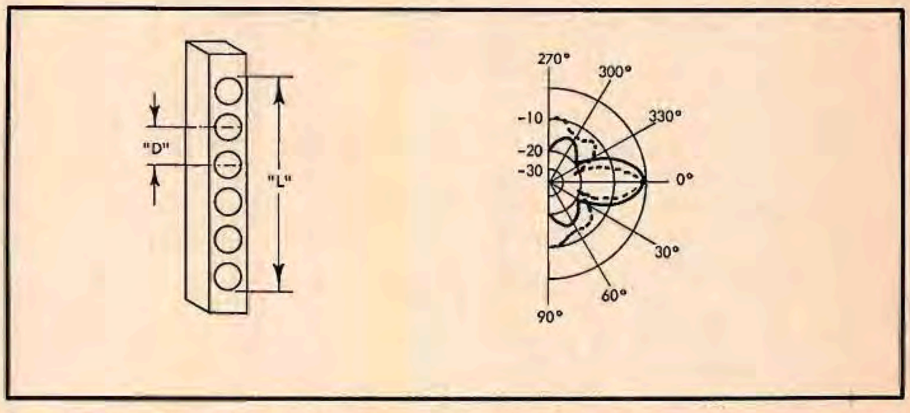

Fig. 2. Geometry of column loudspeaker: (A) "D" = distance between speakers, "L" = effective column length; (B) Vertical polar distribution with dotted line curve indicating result of increasing "D".

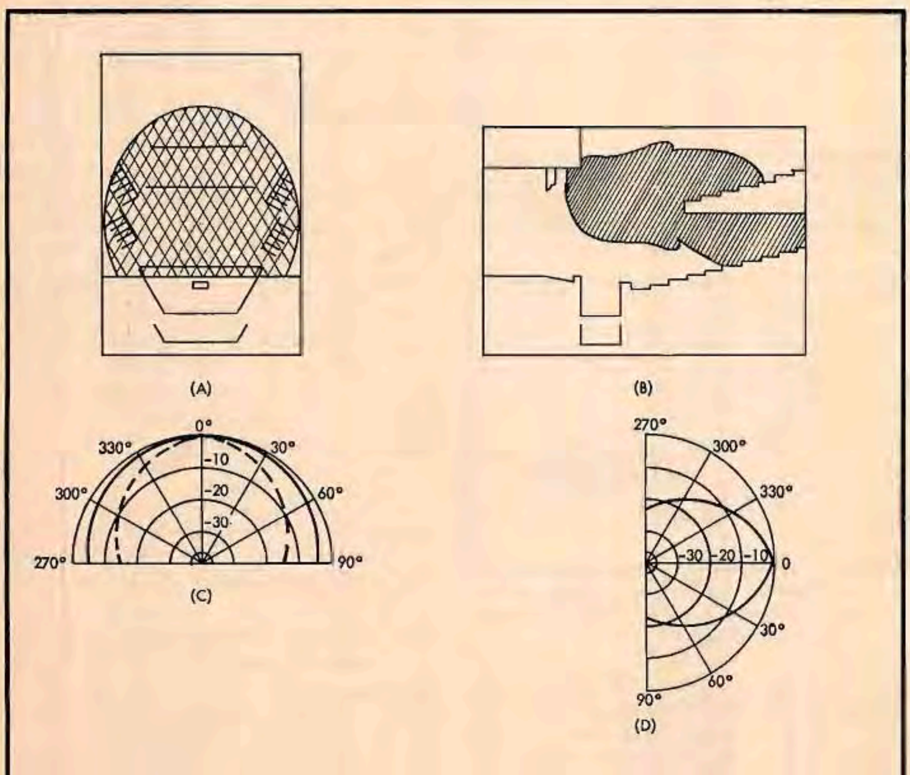

Fig. 1. Sound distribution of column loudspeakers in typical theatre: (A) Floor plan with dark area indicating horizontal coverage at 5000 cps; (B) Elevation with dark area indicating vertical coverage; (C) Horizontal polar distribution (——500 cps, ------5000 cps); (D) Vertical polar distribution (——500 cps, ------1500 cps).

The information presented below is the result of over one year of research, both in the laboratory and in field testing to confirm the theory which evolved as work proceeded.

Acoustic Feedback

Acoustic feedback is a major problem
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when performers are working at great distances from the microphones. Poor acoustic properties in large rooms such as theatres, amphitheatres, gymnasiums, and churches are among the many conditions that cause or add to acoustical feedback. By a brief discussion of existing installations, we will illustrate the reasons behind the development of these new loudspeakers.

One of the most common methods of installation is to strategically locate a number of cone or horn-type loudspeakers throughout the area to be covered. There are several disadvantages to this type of installation. Sound which is projected from the ceiling or from the side walls causes fatigue and is distracting because the eyes focus on one point while the ears attempt to focus on another. In large areas time delay causes phase distortion and becomes a problem which

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is difficult to correct. Installations in which the microphones are required to pick up voices at distances of ten or fifteen feet completely rule out this speaker arrangement.

A second common type of installation utilizes horn-type loudspeakers with wide-range response, placed in the vicinity of the stage, platform, or pulpit. The loudspeaker widely used in this type of installation is the multicellular horn which is usually located in the proscenium arch. The greatest advantage of this arrangement is the effect of realism. This is an important point, for nothing is more pleasing than attending a theatre where all the sound appears to come from the actual source of the sound. The great disadvantage, however, is that acoustic feedback between speaker and microphone limits working distance to the microphone. Because of this, satisfactory coverage of a stage is often limited or impossible.

The acoustic properties of the room are also a controlling factor. Where acoustics are poor, the combination of reflected and direct sound will cause feedback. With the use of directional microphones, feedback can be controlled. However, where microphone working distance is ten feet or more, this arrangement will not be satisfactory.

The third type of speaker system which is relatively new in this country but which has been used widely in Europe for many years, is known as the columnar loudspeaker. This loudspeaker assembly consists of a number of cone type loudspeakers stacked vertically, one above the other, in a long narrow cabinet. In fact, some column installations exist where a cabinet is not used, and the loudspeakers are oriented somewhat as the stripes on a barber pole. This is required to obtain wider spread of the high frequencies. Because such installations are both unique and of questionable value, we will limit our discussion able value, we will limit our discussion to speakers stacked vertically in a cabinet and facing in one direction.

The characteristics that make columns advantageous are efficiency that approaches that of a horn loudspeaker, enhanced horizontal distribution, and narrow vertical distribution. (About 30 deg. is normal.) Vertical distribution will vary with column length; the longer the column, the more narrow the vertical distribution. However, this can be overdone, and the speaker tends to become too directional to provide full audience coverage.

Columnar speakers properly installed near the source of sound, at the stage or pulpit, provide the advantage of realism. The quality of the reproduced sound can be far superior to that of public-address loudspeakers of approximately the same size and cost.

The inherent disadvantage of the column is the presence of lobes in the vertical plane of distribution caused by characteristics of the column itself. This is a major cause of acoustic feedback.

Before discussing these loudspeakers further, we shall briefly review the polar distribution patterns involved. (A) and (B) in *Fig.* 1 illustrates a typical floor plan and elevation of a theatre. (C) and (D) in *Fig.* 1 are the polar patterns of horizontal and vertical distribution of a typical column loudspeaker. Zero db is the reference level determined by the sensitivity rating of the loudspeaker. This information is extremely important to the sound system engineer.

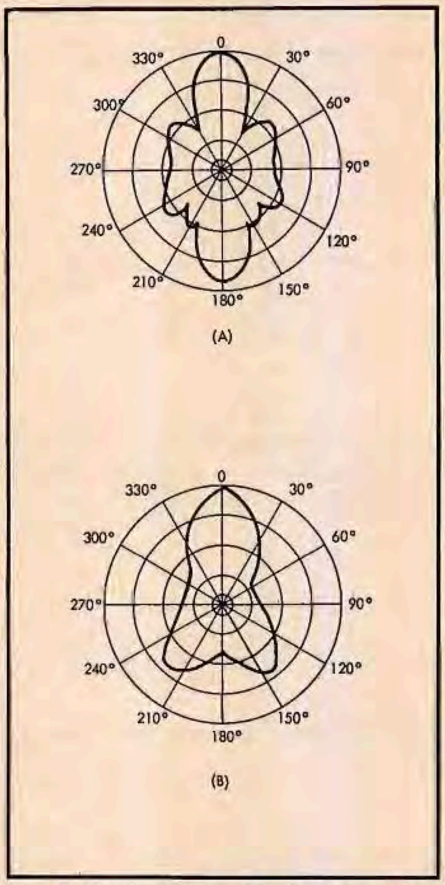

Fig. 3. Vertical polar distribution at frequencies above 4 wavelengths of: (A) Typical column speaker; (B) Straight line radiator.

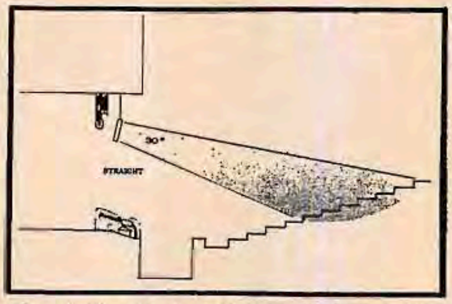

Fig. 4. Theatre installation of line radiator with microphone in low intensity area.

Examination of (C) in *Fig.* 1 reveals that at a frequency of 5000 cps, the angle of coverage is much smaller than at 500 cps. The energy at 90 and 270 deg. is 5 db lower at 500 cps and 15 db lower at 5000 cps in reference to the energy directly in front of the loudspeaker. This fact is contrary to much published information on column loudspeakers, but it is easily proved in the laboratory or on an actual installation. This point is extremely important; a columnar loudspeaker does not have low intensity areas at 90 or 270 deg. in its horizontal plane of distribution *at any frequency*.

The polar distribution in the vertical plane [(D) *Fig.* 1] is completely different from that of other loudspeakers since the output tends to beam. This is caused by the characteristics of loudspeakers mounted in a line.[1] The curves shown in *Fig.* 1 through 6 are not theoretical, but are those actually measured in an anechoic sound chamber in the Electro-Voice laboratory.

Extensive research into the action of columnar speakers disclosed the two characteristics most important to proper design which are the length of the line and the distance of separation between the speakers. As D increases, (A) *Fig.* 2, a point is reached where the column ceases to act as a line source and becomes a series of point sources. This introduces lobes at 90 and 270 deg. with intensities almost equal to that at 0 deg. [See (B) *Fig.* 2.] The horizontal distribution pattern is essentially unchanged.

Since the main purpose of these systems is to suppress feedback, investigations were made to determine the maximum distance possible between speakers which would allow them to operate as a line source in the desired frequency range. The information gained in this research made possible the development of a series of improved columnar speakers which operate as a true line source.

The line source has one undesirable characteristic which must be eliminated to make it best serve our purpose. When to make it best serve our purpose. When the length of the line source is four wavelengths or more compared to the frequency reproduced, lobes again become a problem as shown in (A) of *Fig.* 3.

To eliminate these lobes, a filter[2] was designed to roll off the output of groups of speakers at the extremities of the column at predetermined frequencies, which effectively shortens the length of the line source. In essence, the speaker has an acoustical length that varies inversely with frequency.

The advantage of this design is shown in (B) of *Fig.* 3. In this example the line source is one wavelength long at 230 cps. The line is four wavelengths long at 920 cps. (Wavelength is inversely

[1] Wolff & Malter, *IRE Journal*, 1930; p. 209.

[2] Electro-Voice Patents Pending

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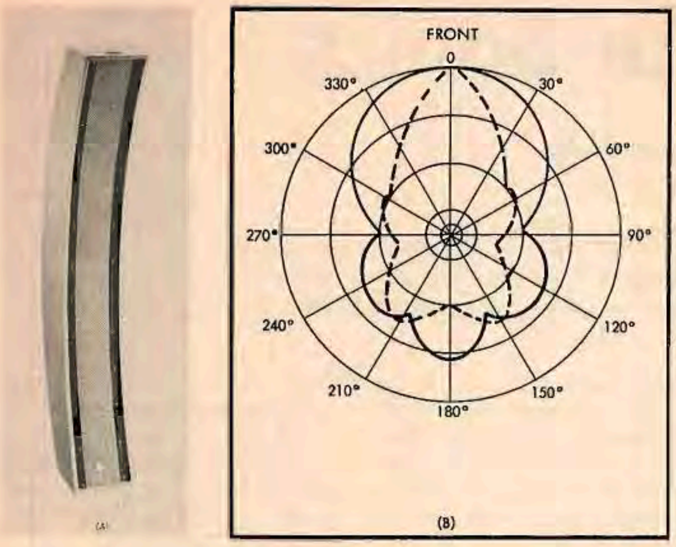

Fig. 5. (A) Electro-Voice curved line radiator; (B) Vertical polar distribution of curved line radiator (——) as compared to straight line radiator (------).

proportional to frequency.) The filter is designed to cut off half the speakers at the frequency corresponding to four wavelengths of the line. The line now appears two wavelengths long at this frequency, and the vertical distribution pattern will become essentially a two wavelength pattern.

In conjunction with suppressing the lobes, an area of low intensity occurs at 90 and 270 deg. This is a great advantage, since the microphones will normally be placed in this area, and feedback caused by direct sound is substantially reduced. This allows more satisfactory coverage of the area in which the loudspeaker is used.

The correct installation of a system utilizing straight line loudspeakers and microphones in close proximity is shown in *Fig.* 4. This was determined both by theory and practical installations made in theatres, churches, gymnasiums and auditoriums. One particular test was made to compare a line radiator with and without a filter. The loudspeaker was mounted as shown in *Fig.* 4 and the line radiator was placed at twenty feet above the microphone. The filter in the line radiator was switched in and out of the circuit. Levels were adjusted to a point just under the feedback threshold and a person standing fifteen feet from the microphone spoke at a conversational level. The output obtained with filter was noticeably greater. This conclusively confirmed the laboratory findings.

Previously, it was stated that narrow vertical distribution could be a disadvantage. This was found to be true of one particular theatre used for field test work. Four straight line radiators were needed for adequate coverage. Two were directed under the balcony and two into the balcony. As can be seen, straight line radiators must be mounted low, and they do have the disadvantage of losing sound level because of absorption by the audience. This reduces available level in the extreme rear of the room involved.

Since the verticle distribution of sound provided by the straight line radiator (or a conventional columnar speaker) is quite restricted, more than one column will be required to cover a large theatre, church or any long room. This is brought about both from the standpoint of power requirements and the fact that the speaker assemblies must be positioned at various angles to adequately cover the audience. These problems can be greately reduced through the use of a curved line radiator.

The Curved Line Radiation

The curved line radiator[3] was developed to simplify sound installation and increase realism of the performance. One loudspeaker if this type will replace two or more straight line radiators, yet maintain the advantages mentioned above. Maintenance of the low intensity area in the vertical pattern of the straight line radiator is the principal factor in the control of acoustic feedback. This characteristic is maintained even though the vertical angle of coverage is increased. To accomplish this, the line radiator was formed into a concave curve as shown in (A) of *Fig.* 5.

In this configuration, the radius of the curvature is critical as is the distance between the speakers within the line. Polar distribution in the horizontal plane is essentially the same as the straight line radiator. The polar distribution in the vertical plane, however, is quite different as shown in (B) of *Fig.* 5. The angle of spread is at least twice that of the straight line. Sound intensity at 90 and 270 deg. is still quite low when compared to intensities within the angle of distribution. An even more important characteristic is that the lobe characteristic of the conventional columnar speaker is entirely eliminated.

The advantage of the curved line radiator can be seen in *Fig.* 6. Its placement is now higher than that permitted by the straight-line type. When mounting in this manner, two factors become important: (1) The distance from the speaker to the microphone is increased. This added distance along with low vertical intensity becomes more effective in controlling feedback. (2) The added height directs the sound to the entire audience without loss due to absorbtion.

Tests made in one large theatre resulted in placement of two curved-line radiators on the proscenium arch. The center of the loudspeakers, directed at the first balcony, covered the entire theatre with excellent sound reenforcement. Two curved-line radiators were used in place of the four straight line radiators. Five microphones were used in the footlights of the stage. Stage coverage was excellent to its full depth, a distance of 30 feet from the microphones. With the arrangement shown in *Fig.* 6, every seat was the "best seat in the house."

Conclusion

The "line radiator" is a sophisticated and improved sound column which is an invaluable tool for the sound technician which will provide excellent sound if the following points are kept in mind during installation:

1. To obtain the best possible performance from the system, the microphone(s) must be located in low intensity areas of the line radiator polar distribution pattern.
2. The straight-line and curved-line units must be mounted differently to obtain maximum coverage.
3. Movement of the line source vertically causes little change in direction of sound, while a small horizontal movement is very noticeable.
4. The polar distribution of line radiators tends to beam the sound vertically, but have side coverage horizontally. They are not "dead" off the sides and must *not* be mounted in the same horizontal plane as the microphone.

If these points are followed, installations which have given borderline results and those which have been considered impossible may now give excellent results with a minimum of cost, time, and labor. Æ

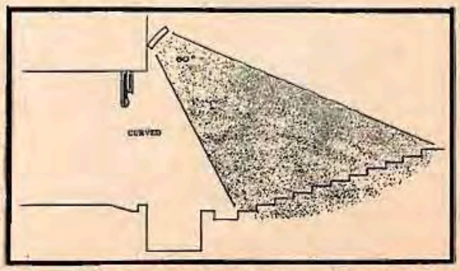

Fig. 6. Vertical distribution of curved line radiator in theatre.

[3] Electro-Voice Patents Pending

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