YAMAHA

VXL SERIES

Benefits of Line Arrays with More-Compact Speaker Units

1. Introduction

We have developed a new VXL series of column-type line array speakers in order to further expand Yamaha's lineup of speakers for commercial installations—which currently includes the VXS surface-mount series and VXC ceiling-mount series—and to also cater for a wider range of applications.
While the market for this type of line-array speaker is already crowded, many current models focus primarily on sound reinforcement of speech at the expense of music playback, and products providing a better-quality sound are in demand.
Given their distinctive sleek appearance, column-type arrays are often the first choice for designers looking to make sound-reinforcement solutions as invisible as possible and perfectly matched to the venue, and still the market continues to call for even slimmer products that offer a higher degree of freedom in architectural design.
That said, efforts to improve sound quality in more streamlined arrays tend to be hampered by the smaller overall unit volume and other mechanical limitations.
In developing the new VXL series, we sought to address this problem and the above-mentioned needs of the market by simultaneously providing excellent acoustic performance and a high degree of freedom in venue design. The key facets of this development concept are as follows.

① Slim design delivering high quality sound while also catering for music playback
High fidelity units in a super-sleek form provide for crystal clear sound-reinforcement of speech as well as high-quality playback of music.

② Flexibility to accommodate the requirements of a wide range of installations
Different models from the VXL lineup can be linked in order to optimize sound pressure and coverage area, to select vertical dispersion, and so forth.

③ Full range of accessories providing for a wide variety of installation
In order to support all kinds of installation environments and specifications, the lineup also features an assortment of different brackets, speaker transformers for high-impedance systems, and many other optional extras.

Three of the most important features of the acoustic performance of the VXL series are described below.

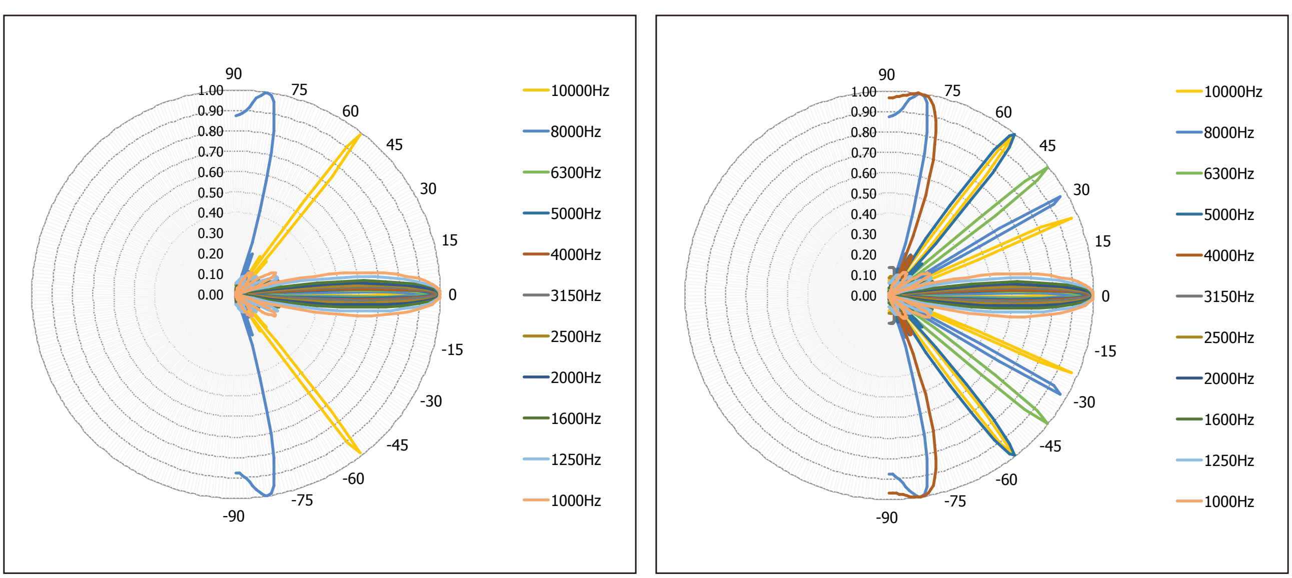
Photograph 1: Exterior view of the VXL series

2. Three key features of VXL audio performance

Key feature ①
Small speaker units

More than anything else in developing the line-array speakers of the VXL series, we were resolute in our selection of smaller speaker units in order to optimize the distinguishing acoustic performance of the line array—namely, narrower vertical dispersion combined with wider horizontal dispersion—for the typical frequency range of speech.
Based on an inventive redesign of the 1.5-inch subminiature full-range driver originally developed for the VXS1ML ultra-compact surface mount speaker, the VXL speaker units combine a large voice coil with a neodymium magnet. Thanks to this, they can deliver distortion-free sound over a broad band of playback frequencies, with wide 170° horizontal and vertical dispersion.
Line-array speakers actively utilize phase cancellation of the output of speaker units that are arranged close to one another in a linear pattern, in order to project the combined sound in a cylindrical pattern. This characteristic feature allows dispersion in the vertical plane to be controlled, but the degree to which this is possible depends on the distance between the speaker units and the overall length of the array.
The three arrays of the VXL series—namely, the VXL1-8, the VXL1-16, and the VXL1-24—have respectively 8, 16, and 24 closely vertically packed speaker units, and the distance between the units is roughly 43 mm.
We can better understand the relationship between unit separation distances and directionality in line-array speakers by looking at some simple math.
Figure 1 compares the directionality of a pair of line-array speakers that have the same overall length but a different unit separation—(a) shows the frequency-specific directionality for a separation distance of 43 mm, as in the VXL series; (b) shows the same for 86 mm, double this distance. The strong propagations of sound seen at directions other than directly in front of the array are known as grating lobes, and in practical terms, they represent certain frequencies being projected strongly from the array in a direction other than the one being targeted. The result of this phenomenon is impaired clarity due to undesirable reflections and an inconsistent distribution of sound pressure. Unit separation distance determines the frequencies at which grating lobes occur and their corresponding distances. For example, where D is the separation distance and λ is the wavelength, the effect of the grating lobes diminishes in the range of frequencies for which D/ λ < 1, in other words, where the wavelength is larger than the unit separation distance.
In contrast to grating lobes occurring at 4 kHz and higher in case (b), which has a large unit separation distance, there is a shift toward the high end of the spectrum in case (b), with these lobes occurring only at 8 kHz and higher. We can confirm, therefore, that the use of smaller units, which in turn allows for smaller unit separation, reduces the effect of grating lobes on the principal speech frequencies.

Figure 1: Typical calculation results for directionality of line-array speakers

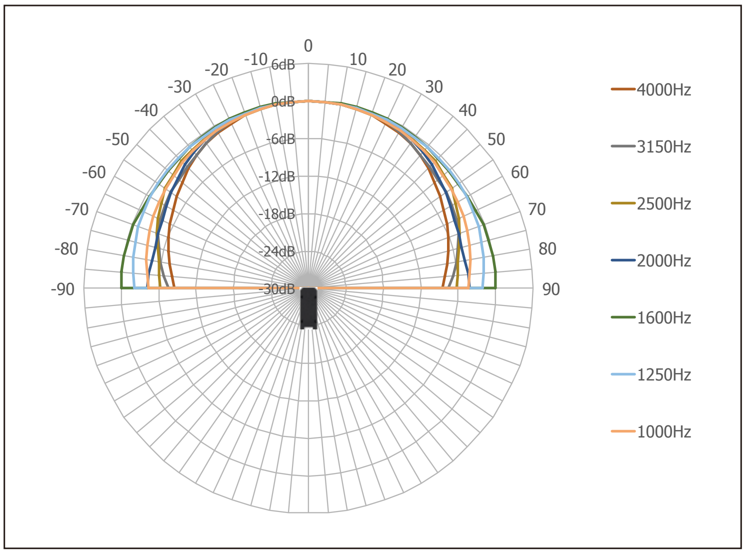


Case (a): 43-mm spacing between speaker units

Case (b): 86-mm spacing between speaker units

Turning our attention now to the horizontal plane, Figure 2 shows the wide dispersion* of 170° that can be achieved with small speaker units. Thanks to this, it is possible to reduce the number of arrays needed to provide coverage for the entire listening area, leading to fewer areas of interference, eliminating undesirable reverberation, and achieving clearer sound reinforcement of speech overall. (*: Average for 1 to 4 kHz)

Figure 2: Directionality in the horizontal plane

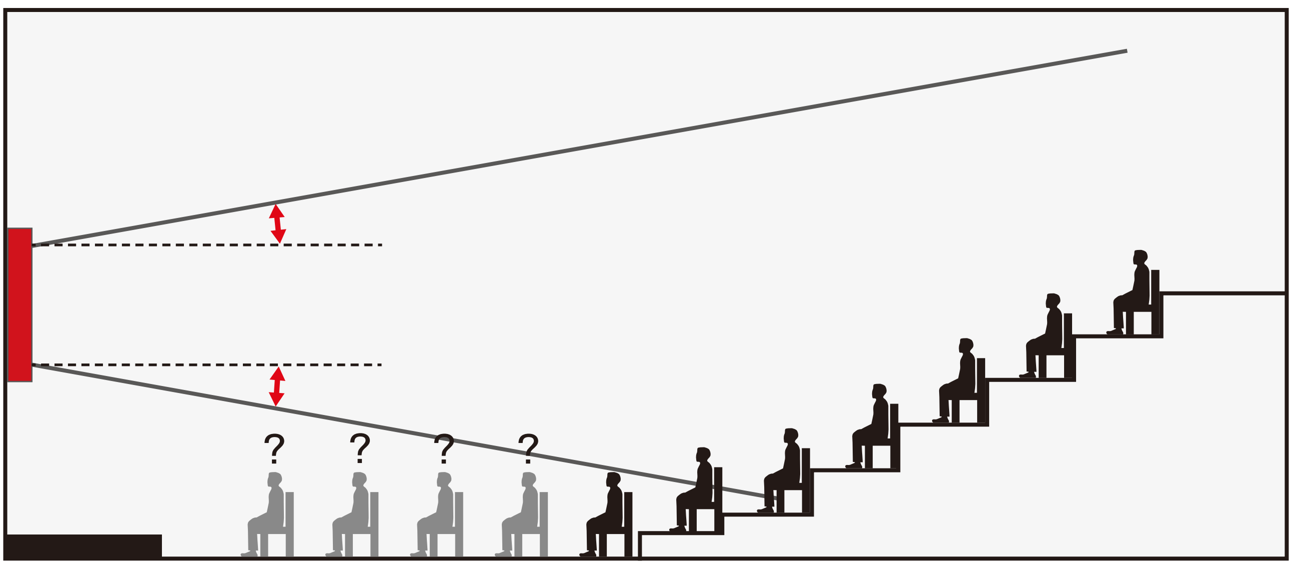


Key feature ②
Greater control of functional downward dispersion

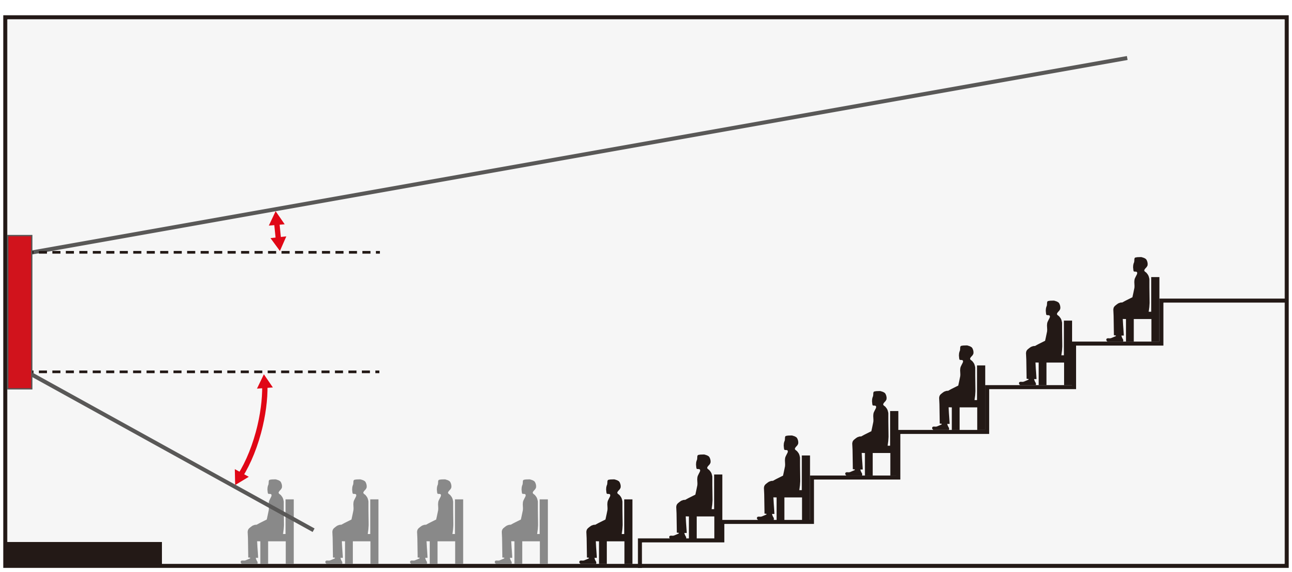
Given that line-array speakers leverage the characteristics of the line source to limit the spread of amplified sound in the vertical plane, installing these speakers relatively high off the ground can exclude the front-of-house from the coverage area, reducing volume and clarity. Typical remedies are the installation of separate subwoofers for this zone or using arrays with a J-shaped curve to increase downward dispersion. Meanwhile, certain types of line-array speakers offer variable angles of vertical dispersion, but this mostly affects both upward and downward directions together, not just downward dispersion. Clarity thus suffers as a result of undesirable reflections from the roof surface. Alternatively, in cases where dispersion is increased more than necessary, sound pressure will drop and the amplified sound will not travel as far.

In contrast, the VXL series efficiently reinforces sound only for the required coverage area, and using a switch on the rear panel, it is possible to expand the angle of dispersion in just the downward direction. Expansion of this dispersion angle is controlled by means of a passive delay on the output from the bottom units, and as shown in Figure 3, this means that the effective downward angle can be expanded to 10° for the VXL24 and 15° for the VXL16, without the need for any change in the shape of the array.

Figure 3: Effective dispersion angle in vertical plane



(a) Fixed coverage area



(b) Control over coverage-area expansion

Key feature ③
Mixing models for scalability

In order to support a wide variety of diverse installations, the VXL series features three different array models—the VXL1-8, VXL1-16, and VXL1-24—each containing a different number of speaker units. Furthermore, complete arrays can also be combined and linked both horizontally and vertically for even greater scalability and flexibility in adjusting sound pressure and coverage area, in order to suit all kinds of installation environments and applications.

Vertical linking

By virtue of their behavior as a line source, line-array speakers boast less dispersion of sound in the vertical plane and smaller attenuation of volume over distance; however, this advantage is not without limit. Beyond a certain distance, for example, the sound begins to disperse upwards and downwards in a manner reminiscent of a point source, resulting in a greater degree of attenuation. The distance over which the advantage is maintained is known as the effective distance, and it is expressed as shown in Equation 1 below.

$$CD = \frac{(L^2 \times f)}{700}$$

where CD = Effective distance (m)

L = Length of the line array (m)

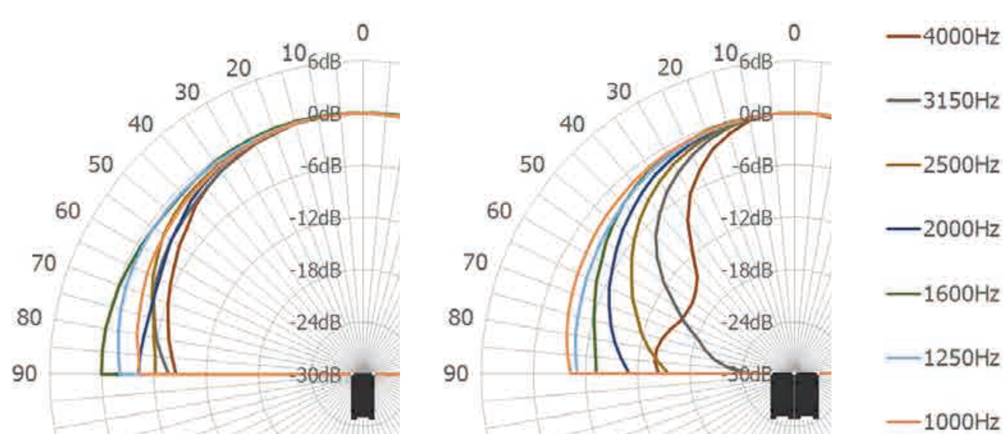
f = Frequency (Hz)

This calculation shows, for example, that the effective distance of a single VXL1-24 (array length = 1.1 m approx.) is 3.3 m, and that for a pair of vertically linked VXL1-24s (2.3 m approx.) is 15.0 m.
In other words, linking boosts the effective length of line-array speakers by a factor of five, thereby ensuring clearer and more even sound reinforcement of speech in bigger venues or over longer distances.

Horizontal linking

Thanks to the use of small speaker units, the VXL series can deliver sound over an extremely wide dispersion angle of 170° in the horizontal plane, however there are situations where a narrower angle better suits the installation environment. In a situation where, for example, feedback is extremely difficult to control due to the installation of line-array speakers at the back of the stage, the horizontal dispersion angle can be reduced in order to minimize the amount of output going back into the microphones, thereby providing for more stable sound reinforcement.
The VXL series makes it possible to reduce the horizontal dispersion angle by positioning two linked arrays beside one another. Figure 4 compares the frequency-specific directionality of two horizontally-linked VXL arrays to a single array setup. With this type of configuration, the default dispersion angle of 170° can be tightened to approximately 120°. And because the two horizontally-linked arrays are driven in phase, the total sound pressure can also be boosted by 6 dB. What's more, the ultra slim VXL design ensures that installation of two horizontally-linked arrays does not detract from their sleek overall appearance.

Figure 4: Horizontal directionality of two linked arrays



(a) Single array

(b) Two linked arrays

3. Conclusion

As described above, our aim in developing the VXL series was to solve many of the problems faced in sound reinforcement with a lineup of column-type line-array speakers that deliver a clearer amplified sound, provide for high-quality music playback, are perfectly matched to a wide range of building architectures and interiors, and thereby, allow for a higher degree of freedom in the design of sound spaces.

This concept has been successfully brought to life thanks to the knowledge, skill, and production expertise cultivated at Yamaha over a history spanning more than 130 years, as well as an uncompromising approach—even to the finest detail—in terms of the materials used for our high-fidelity units and cabinets, the physical designs of these components, overall sound quality, and acoustic performance.

Together with our highly-popular VXS surface-mount speakers and VXC ceiling-mount speakers, these line-array speakers make it possible to design systems in a more flexible way to cater for a wide range of aesthetics and applications, thereby helping to create better, more enjoyable event venues.

References

[1] M. Ureda, Line Arrays: Theory and Applications, AES Convention Paper 5304 Presented at the 110th AES Convention, Amsterdam, May12-15, 2001.

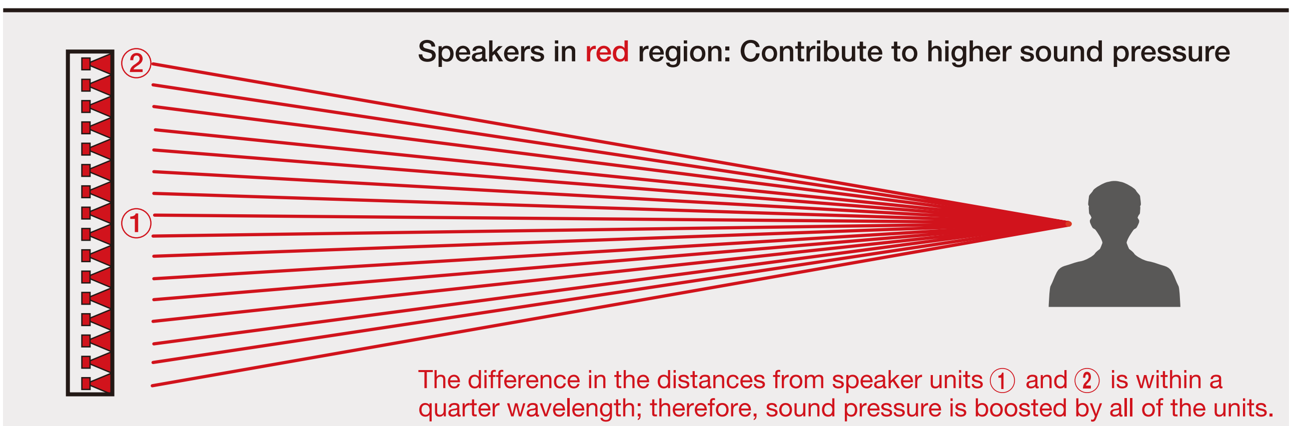
Appendix

Why is feedback less likely to occur with line-array speakers?

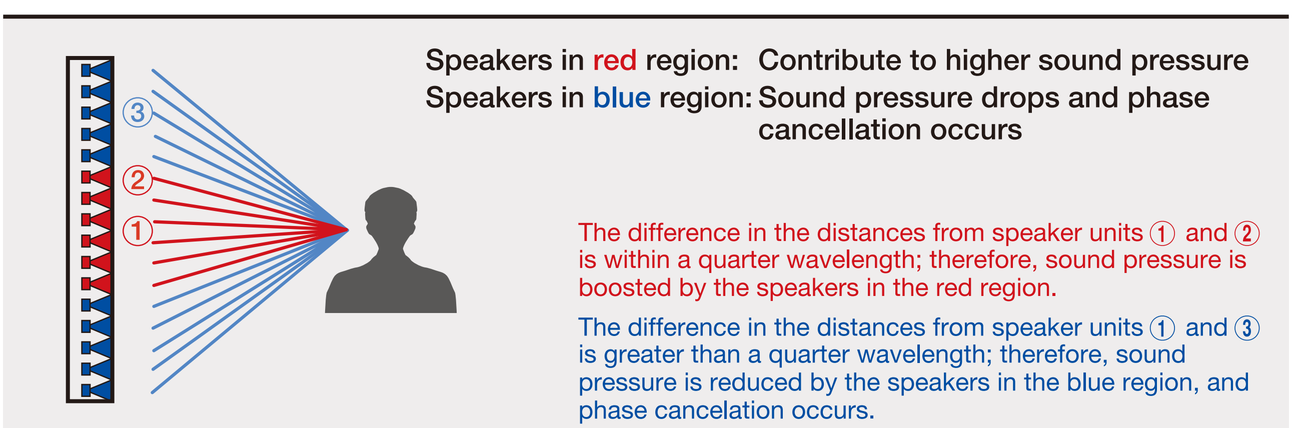
Line-array speakers are commonly said to be less prone to audio feedback than point-source speakers, and the reason can be attributed to the coupling mechanism used with the individual speaker units, and the way in which volume attenuates over distance.

Line-array speakers capitalize on the increase in sound pressure achieved as a result of coupling together scattered sound from multiple speaker units so that they operate as a line source. Generally speaking, a boost in sound pressure is produced by those speaker units for which the difference between corresponding straight-line distances for each speaker to the listening point is within a quarter wavelength. However, units for which the difference in corresponding distances is greater have the opposite effect, and phase cancellation occurs when the difference approaches half a wavelength.

At listening points separated from the array by at least a certain distance and where the distance differences are within a quarter wavelength, all of the speaker units contribute to higher sound pressure. In contrast, the relative difference in distances from the central and end units becomes greater when the listening point is relatively close to the array, thereby limiting the number of units that can contribute to higher sound pressure and reducing the combined sound energy.

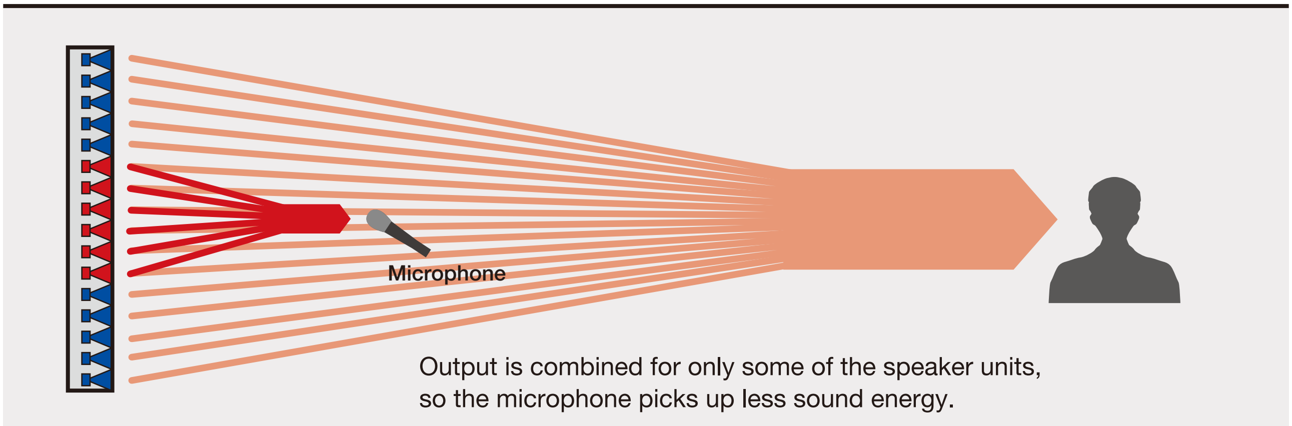


(a) Listener is relatively far away from the array

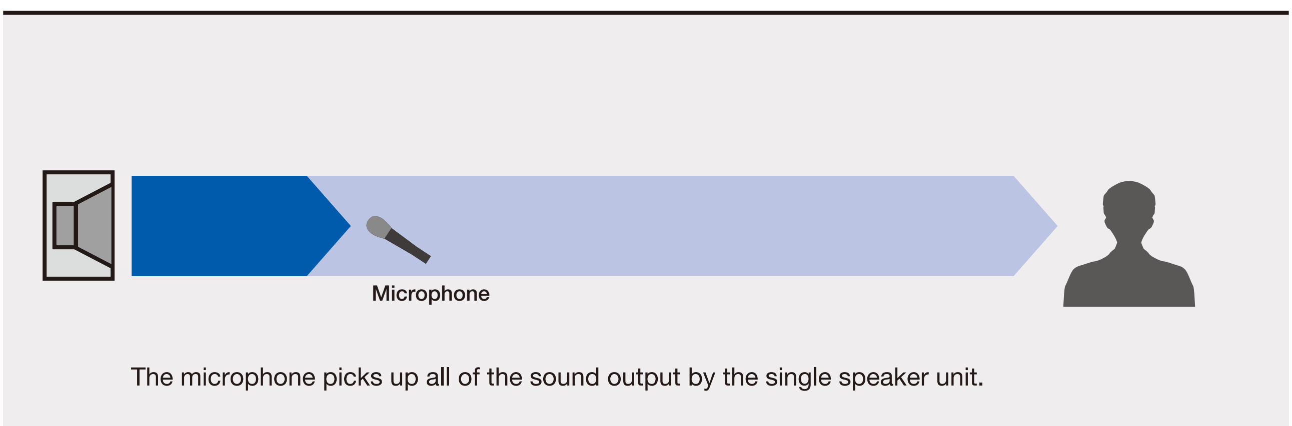


(b) Listener is relatively close to the array

In order to better understand the conditions affecting the sound energy picked up by a microphone located near a speaker, let's take a look at both a line-array speaker and a point-source speaker, assuming that the distances to the listening point and the sound-pressure level at that point are identical for each.
In the case of the line array speaker, the coupling mechanism described above ensures that the microphone picks up the combined output only from those speaker units for which the distance difference is within a quarter wavelength, whereas all of the sound output by the point-source speaker will be picked up by the microphone. In other words, the sound energy picked up by the microphone will be smaller in the case of the line array, so feedback is less likely to occur.

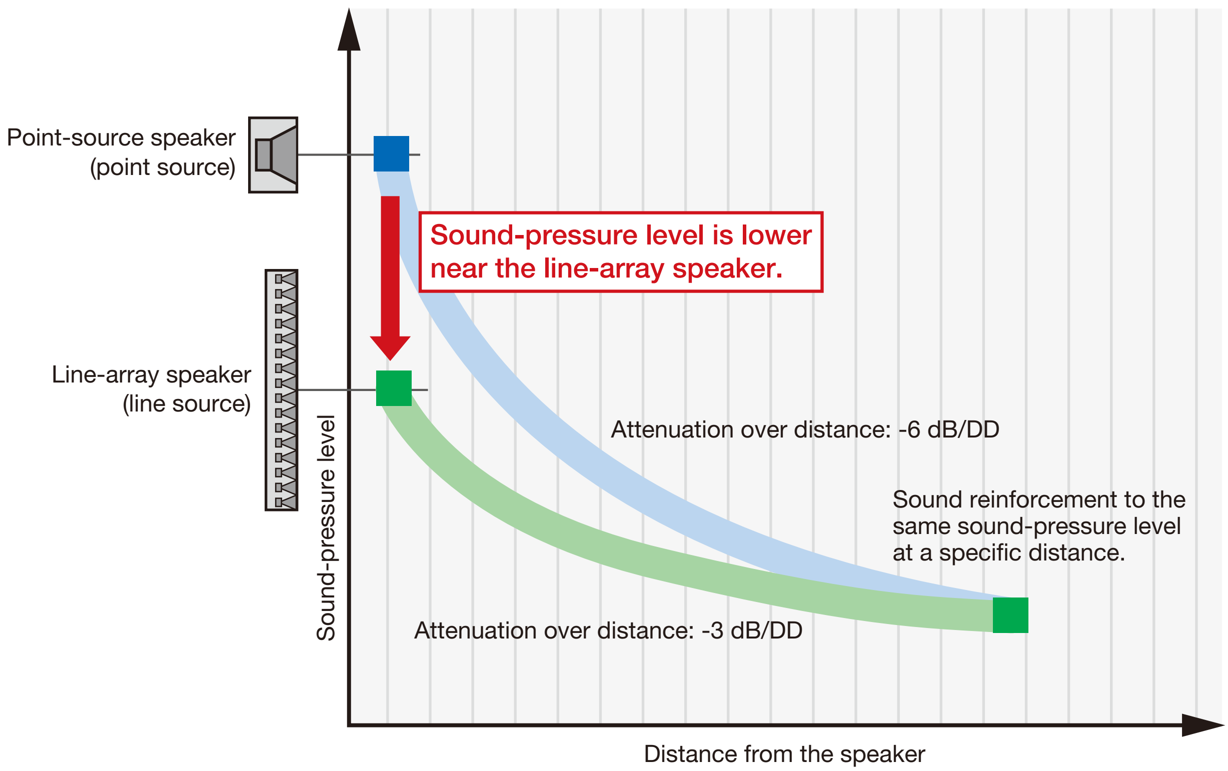


(a) Line-array speaker



(b) Point-source speaker

Another reason given for line-array speakers being less prone to feedback is the fact that the per-unit output is smaller than with point-array speakers, meaning that a microphone positioned nearby picks up less sound energy. Furthermore, whereas sound pressure decreases by 6 dB for each doubling of distance in the case of point-source speakers, this is only 3 dB for line arrays. The amount of radiant sound energy that needs to be output is also lower by the same amount, so the sound-pressure level close to the speakers is lower and volume is affected less by location.



As we have seen, the line array speaker delivers less sound energy directly into a microphone located nearby because of the way in which the individual speaker units are partially coupled together, and also—thanks to reduced attenuation of volume over distance—because the total sound pressure immediately surrounding the array is lower.

Therefore, if a microphone is placed in front of a line-array speaker and a point-source speaker both producing the same sound-pressure level at a specific listening point, the likelihood of feedback will be less with the line array speaker, allowing for more reliable and predictable sound reinforcement than with a point-source speaker.