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Pro Sound Facts

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TRIPOLE TECHNOLOGY™ FOR LOW-FREQUENCY DIRECTIVITY

The Electro-Voice X-Array INSTALL™ series of loudspeakers systems was designed for permanent installations, performing arts applications, corporate sound reinforcement and "regional" touring applications. The product line initially consists of six products, some with multiple high-frequency directivity pattern options, as outlined in **Appendix 1.** (Contact Telex/EVI Audio for additional information.) The entire line features both mechanical and acoustical Ring-Mode Decoupling (RMD™), to produce high, level-independent vocal-range intelligibility and superior bandwidth fidelity. The X-Array INSTALL™ series utilizes EV's newly developed DH6 large-format compression driver, installed on rotatable high-frequency horns. The diaphragm material geometry and close diaphragm-to-phase-plug spacing of the DH6 are RMD™ techniques that contribute substantially to vocal intelligibility and sound quality.

Tripole Technology™

One of the most unique products in the Xi line is the **Xi-2153/64**. The Xi-2153 is a vertically oriented three-way system. The coaxial high-frequency horn/driver combination is asymmetrically placed within the mid-bass horn. This combination is augmented by two EVX-155 15-inch woofers—one located above the mid-bass horn and one located below. Each woofer is placed in a unique closed-volume/slot-loaded subenclosure. **This physical orientation of three sources, together with appropriate amplitude shading and filter combinations, produces vertical directivity control to below 125 Hz.**

Real Sonic Advantages

The sonic advantages of this combination are significant. Precisely controlled radiation patterns at low frequencies prevent reverberant energy in the 125- to 600-Hz range from degrading vocal fundamentals. The pattern control achieved by this three-source, single-enclosure "array" prevents the critical distance from moving "forward" (toward the source) as wavelengths become significant in size with respect to the radiating device, and pattern control is lost.[1] This is the case with conventional system designs.

The other primary advantage is that down to 125 Hz, acoustic output under the enclosure is a full 12 dB or more below on-axis levels. This results in greatly improved gain-before-feedback levels on stage. In conventional systems where "under enclosure" levels are comparable to on-axis levels, system intelligibility is even compromised at the source (microphone) because of poor loudspeaker directivity control and subsequent "spill over."

The **Xi-1153/64** is also available, featuring a single "woofer slot" located below the mid-bass/high-frequency section.[2] (The Xi-1153/64 is identical to the Xi-1183/64, but uses an EVX-155 15-inch woofer rather than the 1183's EVX-180B 18-inch woofer.) The Xi-1153 offers directivity advantages to below 300 Hz.

Note: In general, because Tripole Technology™ operates the woofers well into the lower midrange (to about 600 Hz) and in combination with the mid-bass device, the 15-inch versions are recommended for tripole operation. The 18-inch versions are more appropriate for conventional three-way operation (crossover without overlap at 160 Hz), and have more prodigious low-bass output.

How it Works

The basic operation of both the Xi-2153 and Xi-1153 systems, appropriately processed, employs the concept of *constructive interference* to produce the dramatic effects listed above. In the case of the Xi-2153 **(Figure 1)**, the basic operating principal can be understood by imagining three simple sources, all operating in phase. For the Xi-2153, source 1 is the top woofer slot, source 2 is the mid-bass horn mouth and source 3 is the bottom woofer slot. At the low-frequency end of the directivity-control range, only the two widely spaced woofer slots—sources 1 and 3—are used. At higher frequencies, where the two sources operating alone would produce undesired directivity results, source 2, the middle source, is appropriately introduced, shaping the desired directivity characteristics well into the midrange. (The coaxially mounted high-frequency driver should be ignored, since we are only dealing with pattern control below 600 Hz. Above 600 Hz, the mid-bass and high-frequency horn mouths are of sufficient size to produce good pattern control on their own.)

*It should be noted that 125- to 600-Hz system performance is controlled by maintaining the proper ratio of output levels and shading between the three sources. Once the levels have been established for proper polar control, any system equalization must occur **before** the crossover.* Low-frequency and lower mid-bass output ratios, if changed, will result in either pattern narrowing or widening, with subsequently uneven power response. The three vertically aligned "simple sources" are an extension of the common theoretical analysis of two simple sources in phase.

Figure 2 is a plot of the vertical and horizontal directivity of the mid-bass horn *without help from its "friends"*—the top and bottom 15's. This measurement, made in the Electro-Voice anechoic chamber, illustrates the vertical control, or lack thereof, below 500 Hz (the polar chart is at 500 Hz). It can be seen that this lack of control will provide audibly significant amounts of acoustic energy to reflect from floors, ceilings and walls, thus degrading the ratio of direct-to-reflected sound. Also, it should be remembered that this is a common occurrence when the wavelengths become long with regard to the dimensions of the horn mouth. **Figure 3** is the polar response of a single source at 250 Hz. **Figure 4** shows the effects of three sources oriented vertically at the same frequency (250 Hz). Notice the substantially improved vertical control. This plot was generated by EV's shareware, ArraySHOW™.[3] **Figure 5** is an actual polar plot of the Xi-2153/64 at 250 Hz. **Figure 6** is another polar of the Xi-2153, but now at 125 Hz. At 125 Hz, as is the case with the 250 Hz polar of **Figure 5**, all three sources are active in the 2153. This polar control as mentioned earlier is the result of both the physical configuration of the system and the amplitude and phase "shading" in the crossover/processor (in this case the Merlin ISP-100 is the loudspeaker management system; the EV Dx34A or Klark Teknik DN8000 processor may also be used). The amplitude shading, or device overlap, can be programmed to produce pattern control in a vertical plane from 125 Hz to 600 Hz. Below 125 Hz, the wavelengths become too long with respect to the driver's physical separation to provide any pattern control. **Figure 7** shows the configuration of the Xi-1153/64. Loaded with a single EVX-155 15-inch woofer, the Xi-1153 can also produce pattern control superior to that of the mid-bass horn mouth alone. In this case, there are two instead of three simple sources operating. As a result, the pattern control is well defined to below 300 Hz instead of 125 Hz. The smaller physical size of the Xi-1153, however, makes it ideal for many applications when space or unobstructed lines of sight are critical.

The product literature for the Xi-2153 refers to its physical configuration and mode of operation as "tripole configured," the term "tripole" being the extension of the term "dipole." "Dipole" would be used to refer to the Xi-1153 because of the two sources operating together. It should be mentioned, from a purely theoretical standpoint, that the term "acoustic doublet" is used to refer to two simple sources some distance apart.[4] Those sources are defined as a doublet when both are at equal strength and operating out of phase in the far field. Where the distances are much greater than the source dimensions, the acoustic pressure is referred to as "acoustic dipole radiation." In the case of the Xi-1153, both sources are in phase so the term dipole is technically incorrect, but used in the sense that it gives a good initial description of the two sources. (Maybe a better description would be a two-element line source, the Xi-2153 being a three-element line source). The term "tripole" is an outgrowth of the dipole misnomer.

Both the Xi-2153 and the Xi-1153 may be used with the newly developed Xi-1191 subwoofer. The **Xi-1191** has a single EVX-180B 18-inch woofer in a large internal enclosure volume optimally vented to maximize 30- to 50-Hz output. When used with the 2153 or the 1153, in order not to compromise their vertical directivity control, the maximum subwoofer-to-bass crossover frequency should be 80 Hz.

More detail on the basic physics a dipole is shown in Appendix 2.

Summary

Low-frequency directional control is an excellent approach for improved system fidelity and intelligibility. The Electro-Voice Xi-2153/64 and Xi-1153/64 systems, when used with the Xi-1191 subwoofer, will produce 30- to 20,000-Hz response with vertical control to below 125 Hz (125 Hz for the Xi-2153 and 300 Hz for the Xi-1153). When this level of pattern control is combined with the sonic benefits of Ring-Mode Decoupling (RMD™), these new EV systems will provide a very high level of flexibility and fidelity.

Appendix 1: EV X-Array INSTALL™ Line at Introduction

Model	Description
Xi-1122/85	12-inch two-way, 80° x 55°; 60-20,000 Hz, flying
Xi-1152/64	15-inch two-way, 60° x 40°; 50-20,000 Hz, flying
Xi-1152/94	15-inch two-way, 90° x 40°; 50-20,000 Hz, flying
Xi-1153/64[5]	15-inch three-way dipole, 60° x 40°; 40-20,000 Hz, flying
Xi-1183/64	18-inch three-way, 60° x 40°; 40-20,000 Hz, flying
Xi-1191	Single 18-inch true subwoofer; 32-160 Hz, flying or non flying
Xi-2153/64	Dual 15-inch three-way tripole; 40-20,000 Hz, flying
Xi-2183/64	Dual 18-inch three-way; 40-20,000 Hz, flying

Appendix 2: Basic Dipole Physics

Two sources vertically arrayed form a useful, horizontal "donut" of directivity when separated by a distance equal to one-half wavelength of the frequency of interest. For example, for control at 200 Hz, a separation of 34 inches is appropriate. For perfect point sources and exactly (and only at) one appropriate frequency, there is no radiation along the array physical axis, since the half-wavelength separation cancels array output in the direction of the array axis. The 34-in. half-wavelength dipole length, l_d, is determined as follows.

First, determine the wavelength for the frequency of interest, 200 Hz:

$$\lambda = 13{,}560/f,$$

where λ = wavelength in inches, 13,560 = the speed of sound in inches/sec and f = frequency in Hz. Thus,

$$\lambda_{200} = 13{,}560/200 = 67.8 \text{ inches.}$$

Then, the half-wavelength dipole length, l_d, = $\lambda_{200}/2$ = 34 inches.

At an octave below the half-wavelength frequency (100 Hz), the cancellation along the array axis is gone, but there is still a useful increase in directivity compared to that of a point source or many specific individual devices operating alone. There is also the opportunity of crossing over to a separate, larger dipole.

At an octave above the half-wavelength frequency (400 Hz), there is a narrow forward lobe and a major lobe of equal output above and below the array axis. This suggests that the useful frequency range of the dipole radiator is restricted to something less than an octave above the half-wavelength frequency, perhaps something like two-thirds of an octave above, or, in this example, 315 Hz.

An interesting possible improvement to the situation noted in the above paragraph is to employ a tripole radiator, with the same overall array dimension, at twice the dipole half-wavelength frequency. This would be equivalent to being at a crossover frequency from the dipole to a centrally located MB horn at twice the dipole half-wavelength frequency. **Note:** for this technique to be successful, appropriate amplitude shading is required.

ArraySHOW™ software, available at no charge from Telex/EVI Audio, makes it easy to see how the ideas described above work.

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1. "Critical distance" is that distance from the loudspeaker where its direct sound (responsible for intelligibility) and the reverberant field set up by reflective room surfaces (counter to intelligibility) are equal in level. Beyond critical distance, the direct sound (and intelligibility) continues to decrease with increasing distance from the loudspeaker. Eventually, the direct sound is sufficiently below the reverberant field to result in very poor intelligibility. The critical distance decreases as speaker directivity decreases (coverage angle increases).
2. Available summer 1998.
3. Contact the Customer Service Department, Telex/EVI Audio, Buchanan, Michigan, for a copy.
4. The acoustic doublet and other related arrays are well treated in Leo L. Beranek, *Acoustics* (McGraw-Hill, New York, 1954), pp. 93-101.
5. Available summer 1998.

Figure 1 -
Front View of Xi-2153/64 Tripole and Xi-2183/64, Showing the Three Sources Used in Tripole Technology™ Operation of the Xi-2153/64

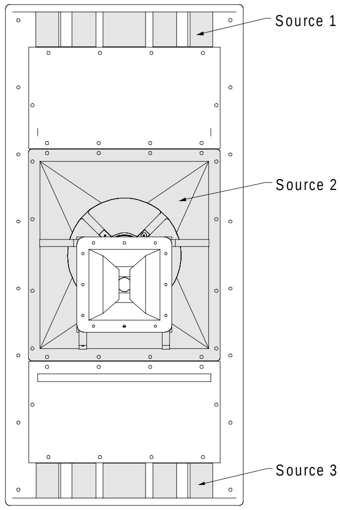


Figure 2 -
500-Hz Horizontal and Vertical Polars of the Xi-2153/64 Mid-Bass Horn Alone without Help from the Flanking Woofers (one-third octave)

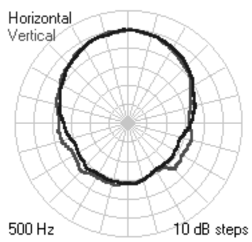


Figure 3 -
250-Hz Horizontal and Vertical Polars of the Xi-2153/64 Mid-Bass Horn Alone without Help from the Flanking Woofers (one-third octave)

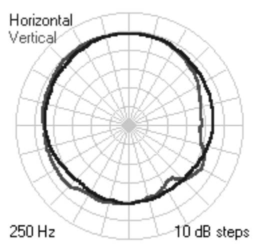


Figure 4 -
250-Hz Horizontal and Vertical Polars of the Xi-2153/64 with All Three Sources Operating (one-third octave, predicted by ArraySHOW™)

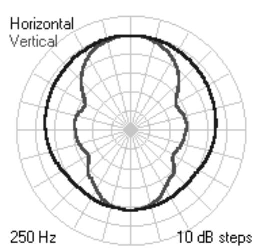


Figure 5 -
250-Hz Horizontal and Vertical Polars of the Xi-2153/64 with All Three Sources Operating (one-third octave, actual anechoic measurement)

________ Vertical
_ _ _ _ Horizontal

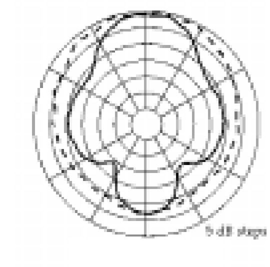


Figure 6 -
125-Hz Horizontal and Vertical Polars of the Xi-2153/64 with All Three Sources Operating (one-third octave, actual anechoic measurement)

________ Vertical
_ _ _ _ Horizontal

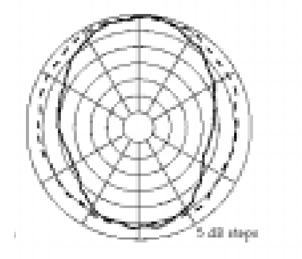
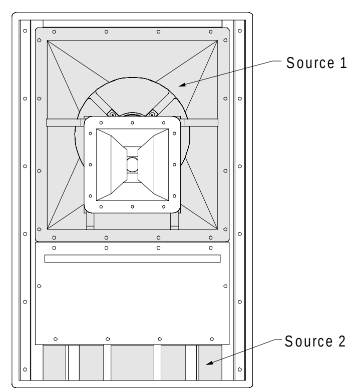


Figure 7 -
Front View of Xi-1153/64 and Xi-1183/64 Three-Way Dipoles, Showing the Two Sources Used in Dipole Operation of the Xi-2153/64



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