THE PA BIBLE

ADDITION NUMBER SEVENTEEN
WHAT IS MANIFOLD TECHNOLOGY™?

Manifold Technology™* is the blending of the output of several loudspeaker elements. This combined sound source acts as a larger, more powerful loudspeaker. It can project sound directly into an area or be used to power a horn.

The far reaching significance of this simply stated concept became the subject of numerous discussions and experiments at Electro-Voice. This gestation period began in 1983 and resulted in the introduction of the first completely manifolded product, the MT-4, in 1986. Electro-Voice is proud to be the first to recognize the potential inherent in Manifold Technology™ and to offer the first product featuring this concept. We would like to share our knowledge and enthusiasm with you through this PA Bible addition.

MANIFOLD TECHNOLOGY™ BENEFITS: MORE FROM LESS

Simply stated, Manifold Technology™ is a way of obtaining more acoustic output from a smaller, lighter, better performing and less expensive package. This is done by avoiding unnecessary duplication of certain parts of a loudspeaker system. As an example, the horn portion of a horn loudspeaker system can be fed by a number of horn drivers instead of stacking several horn-plus-driver assemblies together. The saving of space and weight is immediately obvious. What is not so obvious are the performance improvements that result as well. The useful characteristics of Manifold Technology™ can be summarized in five ways.

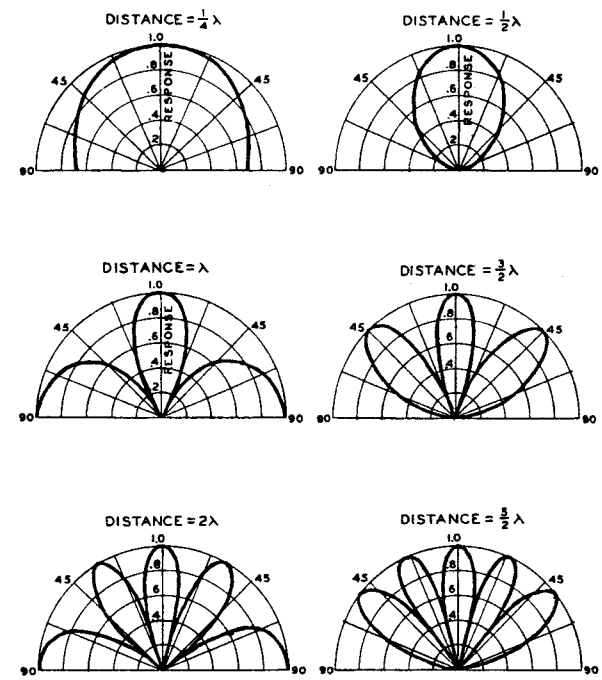
1. At low frequencies (below approximately 200 Hz) the outputs of a number of woofers can be effectively coupled to act as one very large loudspeaker. This maximizes acoustic output and minimizes the cone movement (excursion) needed at high output levels. Additionally, the variable air mass loading of the manifold chamber (see Ref. 1 for a detailed description) results in an enclosure size that is smaller than usual for a given level of performance. (Performance is meant to indicate the amount of usable acoustic output available over a frequency range.)
2. At higher frequencies the number of directivity-controlling structures (typically horns) in front of the loudspeakers or drivers can be minimized. This results in less bulk, lower weight, lower cost and the elimination of interference patterns caused by several sound sources operating at the same time.
3. Driver redundancy is provided. Sound will not be totally lost if some manifolded loudspeakers should fail.
4. The required total piston area needed for a given level of performance is subdivided into smaller sizes that don't "break up" (cease to act as a unified sound source) as readily.
5. Manifolding permits the fabrication of large voice coil circumferences for a given piston size. This has favorable thermal implications because of the increased coil surface area. More area results in reduced coil temperature. (Example: Four two-inch-diameter driver diaphragms with the expected two-inch-diameter voice coils, when taken together, act as a single four-inch diaphragm which has — as if by magic — an *eight*-inch coil diameter.)

**Electro-Voice has chosen this proprietary term to describe the physical process taking place.*

The increased output from a given volume of space that manifolding provides, leads to smaller loudspeaker system size for a desired level of loudness. It can also mean the ability to achieve greater output when system size or weight must be restricted.

INHERENT ENGINEERING PROBLEMS

The main problem lies in combining effectively the output from several loudspeakers or horn drivers. If the various outputs are not blended "in phase" there will be partial or complete cancellation of their outputs. The exact nature of these cancellations will depend upon the geometry of the various loudspeakers, the frequency involved and the position of the listener. A simple example of this phenomenon is shown in Figure 1, showing two sound sources displaced in space by a distance expressed in wavelengths. The resulting peaks and dips that occur at various listening positions are sometimes referred to as a comb filter effect.



Directional characteristics of two equal sound sources moving in phase as a function of their separation distance in wavelengths. The polar graph depicts the sound pressure level, at a fixed distance, as a function of angle. The direction corresponding to the angle 0° is perpendicular to the line joining the two sources (after Olsen, Ref. 4).

FIGURE 1

In the example of Figure 1, the cancellation process which causes the lobing takes place in the air in front of the two loudspeakers within the listening space. It would seem attractive to combine the two sources of Figure 1 into a single radiating device to avoid the anomalies shown. This is what Manifold Technology™ successfully achieves. However, the problems associated with combining a number of acoustic sources is difficult at high frequencies. This is primarily because:

1. It is hard to put acoustic sources close together in terms of the wavelengths involved. This is especially difficult at high frequencies where the wavelength can vary between a few inches to less than inch.
2. It is hard for sound waves to negotiate sharp bends without some cancellation occurring. This is particularly true when the dimensions of the bend are comparable to or larger than the wavelength of the sound.

The "yardstick" or critical unit of measurement that is used to help explain and categorize acoustic phenomena is the wavelength. Wavelength is related to frequency by the expression $\lambda = \frac{c}{f}$ where λ denotes wavelength, c is the velocity of sound (approximately 1130 feet per second) and f is frequency. Similar yardsticks occur in the evaluation of light and electromagnetic phenomena.

Sound wavelengths can vary from 69 feet (16.35 Hz) down to 0.68 inches (20,000 Hz). In order to have the outputs of several acoustic sources blend well, they must be spaced less than 0.5 wavelength apart at the highest frequency they are required to produce.

A crude but useful analogy can be seen by dropping two pebbles into water. (The wavelength or distance between the wave crests will usually be of the order of an inch in this case.) If the two pebbles are dropped close together they will act as one larger pebble. That is, the wavelets will go outwards from the drop point as well defined circles. However, if the pebbles are simultaneously dropped with a spacing of an inch or more between them, the situation will become more chaotic. There will be two distinct sources of wavelets which will tend to interfere with each other. So it is with sound waves.

At lower frequencies the wavelengths are relatively long. At 200 Hz the wavelength is 5.65 feet, at 100 Hz it is 11.3 feet and so on. At these frequencies it is possible to place a number of loudspeakers close together and have the centers between them be substantially less than a half wavelength apart. Their output act as one large speaker, without the spacing-induced interferences of Figure 1.

However, as frequencies increase, the combining problems increase as well. In many high frequency transducers there will be a directivity-controlling structure, such as a horn, in front of the loudspeaker (which in this case is often referred to as a horn driver or compression driver) so that the outputs of the combined units can be directed to the listener. Here the loudspeakers or drivers would be combined at the small end or "throat" or the horn.* At the lower frequencies mentioned above, directional control is difficult to accomplish due to size considerations. This is because the frontal dimensions of an *effective* directivity control structure needs to be roughly comparable to that of the wavelength being radiated. (At 50 Hz, for instance, these dimensions would approach 20 feet.)

At high frequencies the two conditions noted earlier make effective manifolding much more difficult. Being more specific, the size of the acoustic source can be as much as one to two wavelengths in diameter. An eight-inch source (representative of a 10-inch loudspeaker) is about 1.2 wavelengths across at 2000 Hz. In addition, especially in the case of compression drivers, the magnetic system that drives the diaphragm can be considerably larger than the diaphragm itself. A compression driver with a one-inch opening can have an outer diameter of four to six inches. These conditions make it difficult to crowd the acoustic sources close together (less than a half wavelength) so they will act together as a unified whole.

As a result, manifolding at high frequencies requires that the output of the various acoustic sources be channeled along passages that culminate effectively at the back of the horn. Invariably, this acoustic "plumbing" must be bent to permit the drivers to physically clear one another. This brings into play the second condition previously noted involving the difficulty of sound waves negotiating bends. Unfortunately, bent acoustic plumbing often alters the wavefront coming from the drivers so that effective blending does not take place. This situation is additionally compliciated as the number of manifolded drivers increases due to the increased complexity of the plumbing. Four drivers are more complicated than two, and eight drivers would be harder yet.

**A horn will be assumed in this discussion for sake of convenience However, it should be noted that it is possible to have directivity control structures that are not horns In a horn driver the acoustic source that would be manifolded is the hole in the driver casing This is often referred to as the throat size*

SOME SOLUTIONS

At low frequencies the usual system choices are either a horn or a vented direct radiator. Horns are sometimes selected because of their high-efficiency characteristics. It is not widely known that direct radiator systems can have efficiencies comparable to horns when multiple loudspeakers are used. Additionally, vented forms of direct radiators are more efficient users of space than horns [Ref. 1]. This translates into the vented format system having the smallest box size for a given level of performance. Since Manifold Technology™ in general offers maximum performance from minimum space, vented direct radiators fit nicely into the spirit of "more from less."

At higher frequencies the logical desire to control the directivity of acoustic output coupled with the availability of many fine horn drivers, makes horn transducers very attractive. Horns needed to cover the range above 200 to 300 Hz are relatively small compared to their low frequency counterparts, making them a desirable choice for reproducing all higher frequencies.

The problems inherent in creating high-frequency manifolds were mentioned earlier. They involve being able to pack the acoustic sources of the drivers close together and providing acoustic plumbing which does not permit destructive interference. Such interference can occur within the manifold or where the manifold exits into the throat of the horn.

The problems in manifold design usually lie at the top end of the range of frequencies they are required to reproduce. At these frequencies the wavelength is often becoming equal to or smaller than manifold dimensions. Here the technique of "geometric optics" (ray tracing) is starting to become a valid method of evaluating performance. Figure 2 illustrates a situation that can occur in a simple "Y" type of manifold. Here, rays that pass directly through the manifold passages can interfere with rays that reflect off sidewalls due to the differences in path length. A way of dealing with this kind of problem is to turn it into an advantage through a different design technique. Figure 3 shows a configuration in which most of the rays reflect off a suitably shaped wedge. In this case, all rays have equal path lengths and, therefore, do not interfere with each other when they assemble together at the throat of the horn.

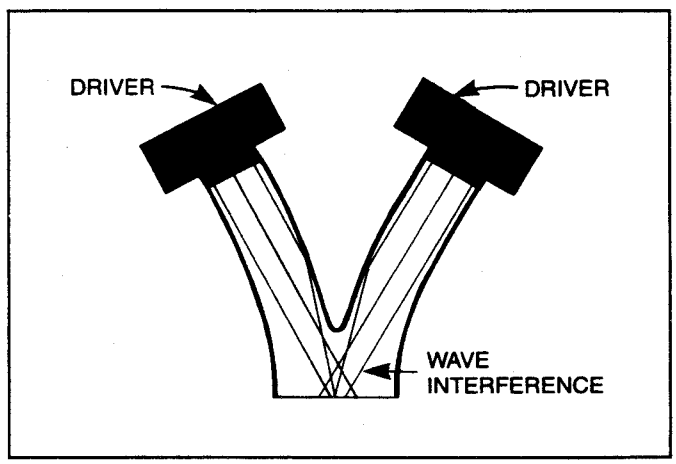


FIGURE 2
"Y" Manifold Showing Ray Interferences

It is possible to use this technique or a variation of it to combine the outputs of either cone loudspeakers used as horn drivers or actual compression drivers. In the former instance, it may be necessary to provide a suitable phasing plug in front of the cone to shape and phase-correct the wavefront that enters the manifold. The result is a compact manifold that can effectively blend together

the outputs of several drivers. Although the illustrations show two driver situations, it is possible to extend the technique to greater numbers of drivers.

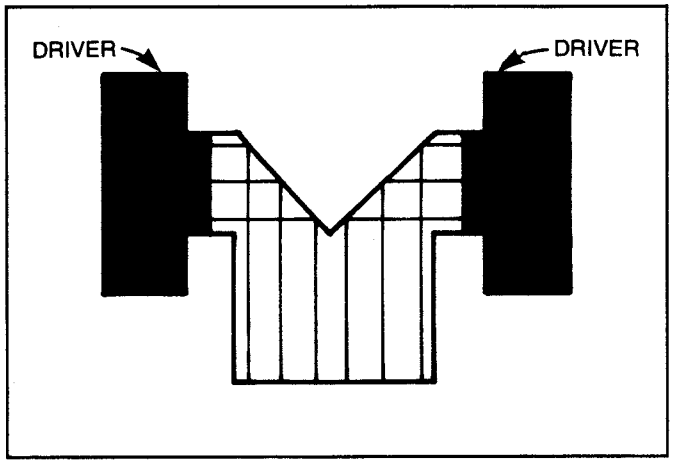


FIGURE 3
Wedge Type Reflective Manifold Showing Rays Coherently Reflected

SOME SPECIFIC REALIZATIONS

When the outputs of two drivers are combined effectively, the result is a doubling in output power. The subjective effect is quite audible and useful in many applications, but it is not dramatic. This is because hearing is not a linear process. A doubling of output is not heard as a doubling in loudness. If four drivers are combined, the result is very noticeable and begins to approach a doubling in perceived loudness. Four-driver manifolds were, therefore, chosen as a suitable upward step in the design of the first system to fully employ Manifold Technology™, the EV MT-4 [Ref. 2 & 3]. In this system the extreme bass is reproduced by transducers in their own separate enclosure and higher frequencies (160 to 20,000 Hz) are reproduced by three high-input-power horns. The critical decade range from 160 to 1600 Hz is handled by four ten-inch loudspeakers with specialized loading plugs feeding a manifold much like that shown in Figure 3. (The second set of drivers can be pictured as being below the first in this figure.) The throat of the wood horn connected to this manifold is a slot suitably proportioned to accept the geometry of the manifold. The upper part of this middle range (1600 to 8000 Hz) is reproduced by a small horn with mouth dimensions about the size of this sheet of paper fed through a circular two-inch opening. The manifold attached to this horn is a variation of that shown in Figure 3. It is shaped to blend the outputs of four horn drivers into a standard two-inch opening. The manifold is shown in Figure 4. The extreme top end (8000 to 20,000 Hz) is provided by four specialized tweeter drivers feeding an identical manifold/horn combination.

Low frequencies (40 to 160 Hz) are reproduced by a vented system with four 18-inch cone loudspeakers manifolded into a rectangular chamber. The loudspeakers are in reverse position to provide additional volume to the interior of the box and to put the heat producing part of the loudspeaker on the outside. This section (the MTL-4) takes advantage of variable air mass loading [Ref. 3] to provide an unusually compact box for the four 18-inch units. Figure 5 shows the entire system. The manifolding employed in each of the four sections is unique and the subject of several patents.

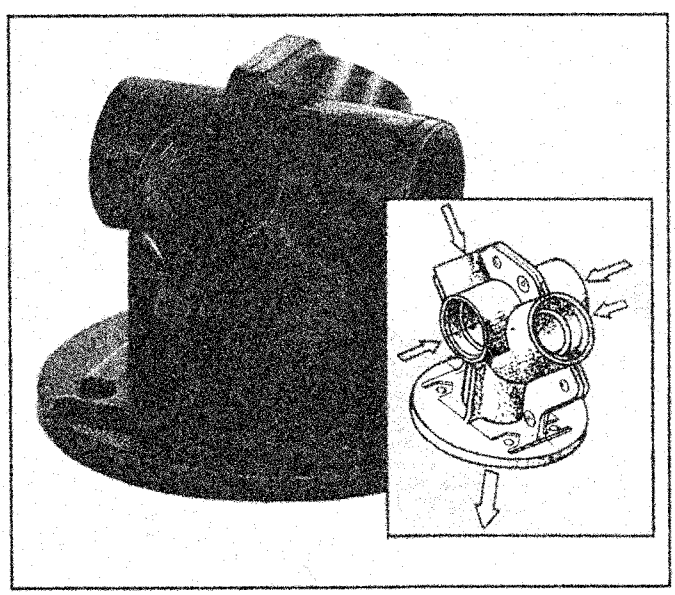


FIGURE 4
A Four-Driver Manifold for Use on Horns Having Two-Inch Throats
(the accompanying sketch shows additional detail)

WHERE DOES THIS ALL LEAD?

Manifold Technology™ is such a fundamentally sound idea that there is little question about it finding increasing usage in the future. The concept is valuable whenever larger amounts of undistorted output are needed from relatively small packages. Recall that higher output does not necessarily mean louder. It more typically translates into achieving a desired loudness level at the listener's ears with the least amount of equipment. The concept is bound to eventually find its place alongside other acoustic milestones such as vented systems and constant directivity. It has the hallmark of a fundamentally correct concept waiting to be fully employed.

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3. D. Carlson and D. Gunness, "Loudspeaker Manifolds for High-Level Concert Sound Reinforcement," presented at the 81st Convention of the Audio Engineering Society (Nov. 12-16, 1986).
4. H.F. Olson, *Acoustical Engineering* (Van Nostrand, New York, 1960) p. 35.

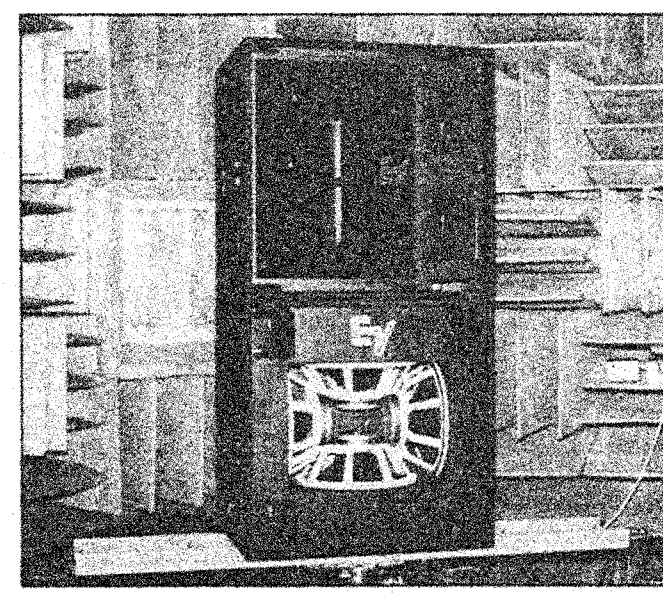

FIGURE 5
The MT-4 2-Box, 4-Way Concert Sound Reinforcement System. The MTH-4 High-Frequency Box is on Top with the MTL-4 Low-Frequency Box on the Bottom

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