THE PA BIBLE

ADDITION NUMBER SIX
THE CON'·STANT DI·REC·TIV'I·TY WHITE HORN WHITE PAPER

In prior "PA Bible" material we dealt with sound system design and various supplements have gone more thoroughly into specific related areas. In this addition, we will take a look at the unique class of horns known as "constant directivity" horns. This addition is complete in itself, but you may want to use Addition Number 1 – which discusses basic horn types and their function – as background.

"CONSTANT DIRECTIVITY" DEFINED

One way to get a handle on the concept of "constant directivity" is to consider the common garden hose and the nozzle at the end of it. Let's start with "directivity." Water pressure corresponds to the driver which produces the sound output. The nozzle corresponds to the horn which spreads – or "directs" – the sound about the listening area. At some settings, the nozzle spreads the water over a wide angle. A horn designed to do the same thing with sound would be said to have "low directivity," since it spreads the sound over a wide area. The nozzle can be readjusted to direct the water over a very narrow angle. The analogous horn would be "high directivity." (The water also goes farther – an important point that we will expand upon later.)

Other phrases are often used to describe how a horn directs sound. Since a low-directivity horn spreads sound over a wide area, it is said to have a "wide coverage angle," a "wide dispersion angle," or a "wide beamwidth." Such a horn is also said to be a "short throw" horn, since the driver's sound output is spread over a wide angle and, therefore, isn't "thrown" very far. A horn with *high* directivity would be a "*long* throw" horn, with a *narrow* coverage angle, dispersion angle, and beamwidth.

Well, directivity was easy, but what about the "constant" part? With the nozzle, there's no problem; you adjust the nozzle to direct the water where you want it. Ignoring the local wind conditions, that's pretty constant. Unfortunately, nearly every horn fails to behave like the nozzle. At low frequencies the coverage angle is one thing, like 80 degrees. At high frequencies it's another thing (usually narrower). At mid frequencies it can be something else again. In other words, most horns are *variable* directivity, nonwithstanding the claims of the advertising department to the contrary. A few designs are much more special. They behave like our nice nozzle! They have essentially *constant* directivity – or coverage angle, dispersion angle, or beamwidth – over a wide frequency range. The concept of constant direcitivity is new, powerful, and unique. Don't forget it!

The dramatic coverage differences between a constant directivity horn and a radial horn of conventional design are summarized in a visual way in Figures 1, 2, and 3. Figure 1 shows the basic comparison. Figure 2 shows in a more technical and detailed way how the coverage angle of a conventional radial horn changes with frequency. The angle changes a *lot!* The maufacturer calls his horn 60° x 40° but that's true only at a few frequencies – otherwise, it varies from here to Newport, Tennessee. In contrast, the constant directivity horn has an essentially uniform coverage angle over a wide frequency range. Take a look at Figure 3.

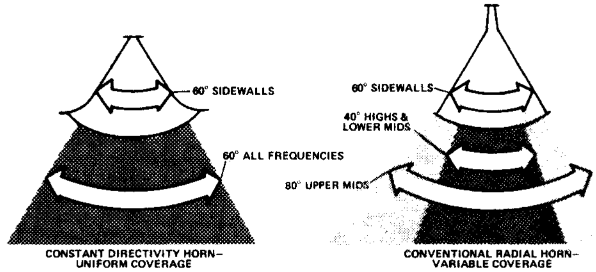

FIGURE 1 – Horizontal (Side-to-Side) Coverage Angle Comparison, Constant Directivity and Coventional Radial Horns

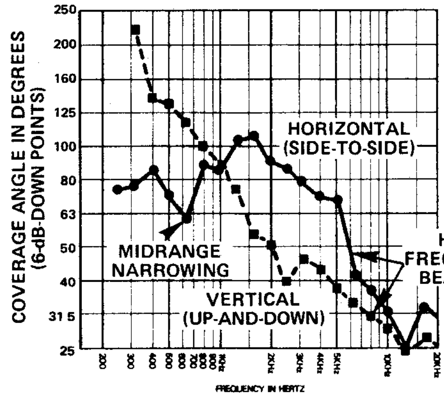

FIGURE 2 – Coverage Angle of a Conventional "60° x 40° Radial Horn

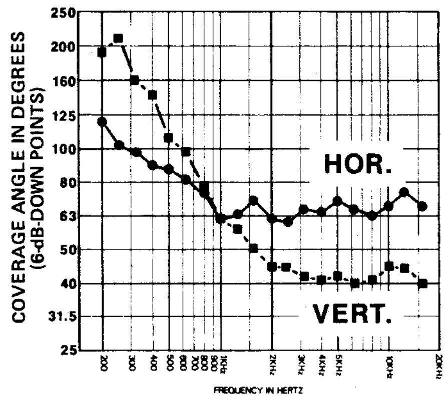

FIGURE 3 – Coverage Angle of 60° x 40° Constant Directivity Horn (E-V 6040A)

WHAT CONSTANT DIRECTIVITY HORNS DO FOR YOU

The advantages of constant directivity horns are fundamental:

1. **Constant directivity horns give a well defined zone of coverage that you can count on.** Every one in the audience within that zone will hear the full range and brilliance of the program. Dead spots and bright spots can be eliminated once and for all. This feature alone is very powerful.

2. **You can use fewer constant directivity horns.** No longer will you need to overlap conventional horns in an attempt to get uniform coverage at high frequencies. That saves money and van space. And you will have eliminated the "interference" which occurs when two or more horns are serving the same portion of the audience. The interference produces large dips and peaks in the direct field frequency response, which "dulls" the sound quality and tends to negate the very coverage you're aiming for.

WHAT MAKES A CONSTANT DIRECTIVITY HORN?

From twenty feet away all horns look alike. They are small where the driver gets attached and bigger at the other end. But if you put your glasses on you'll see that constant directivity horns look different. To make it easier to get specific, consider our HR6040A constant directivity horn which has a coverage angle of 60 degrees in the horizontal (left-to-right) direction and 40 degrees in the vertical (up-and-down) direction. Each special characteristic eliminates one of the problem areas of conventional variable directivity horn designs:

1. **A constant directivity horn is fed by a small opening.** This opening is usually, but not always, near the driver. The small opening assures that high-frequency sounds coming from the driver will be spread wide enough to fill, and be controlled by, the main section of the horn. Simply put, the laws of physics dictate that a *large* opening at the entrance to the main horn section *cannot* spread the highs to fill the main section. The problem is related to the principle of why the tweeters in you hi-fi speakers are much smaller than the midrange and woofer parts. For a look at a typical small feed section in a constant directivity horn, see Figure 4.

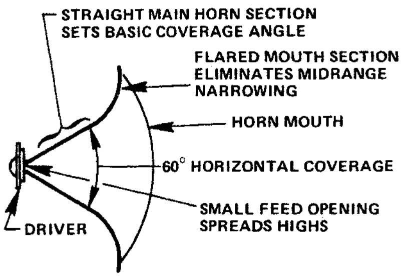

FIGURE 4 – Top Section View of Constant Directivity Horn (E-V HR6040A)

Most conventional horns have a long tapered "throat" that has a rather large opening by the time it reaches the main section of the horn. This means that the highest frequencies are *not* spread enough to be controlled by the main section and tend, instead, to beam straight ahead (the higher the frequency, the more straight ahead). See Figure 5 for a horn whose large throat opening cannot spread the highs.

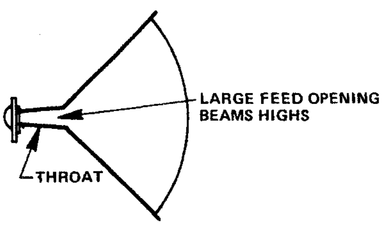

FIGURE 5 – Top Section of Conventional Radial Horn

2. **A constant directivity horn has straight sidewalls over a major portion of its length in both the horizontal and vertical planes.** These straight sections are basically responsible for establishing the horn's constant directivity over a wide frequency range. The particular coverage angle of the horn corresponds (nicely) to the angle between the two straight sides. Refer to Figure 4. The curved vertical section of a traditional exponential radial horn *cannot*, by definition, have constant directivity. However, there are many horns made this way and one is shown in Figure 6.

FIGURE 6 – Side Section of Conventional Radial Horn

3. **Constant directivity horns have an addtional wide-flare section near their mouth openings.** This flare is shown in Figure 4. The additional flare eliminates the substantial narrowing of midrange coverage angle that occurs in all horns of conventional design (refer back to Figure 2).

4. **Constant directivity horns are usually bigger than conventional horns.** This is for a good reason, not just because bigger looks impressive. To maintain constant directivity down to the typical crossover frequency (like 500 or 800 Hz), the mouth of the horn needs to be larger than has been customary in the past. A conventional 90° x 40° radial horn designed to load a driver down to 500 Hz might be, say, 8 inches high. On the other hand, the E-V HR9040A, which maintains its rated directivity over a wide frequency range, is about 17-½ inches high.

A DRIVER ON A CONSTANT DIRECTIVITY HORN NEEDS EQUALIZATION

The Newman Criteria for Drivers

We have seen that a constant directivity horn takes the output of the driver and spreads it around the room evenly. Great! But this stellar performance reveals an interesting and fundamental performance characteristic of *all* compression drivers that is not well known. If the output of the driver *itself* is isolated – unmodified by any particular horn to which it might be attached – it has anything but the "flat" response we've all been taught is good. An excellent real-world compression driver will convert about 30% of the amplifier's output into acoustic output up to about 3000 Hz. (In more technical terms, we would say that the driver's "midband efficiency" can be about 30%.) Above 3000 Hz, output falls at about 6 dB per octave. This curve shape is shown in Figure 7. Note that at 15,000 Hz, output is about 15 dB down. This corresponds to a mere 1% efficiency, similar to that of an inexpensive cone tweeter! We call the line shown in Figure 7 the "Newman Criteria," after our Chief Loudspeaker Engineer, Ray Newman, who postulated the criteria in the course of his driver development work. The Newman Criteria is an excellent standard against which to compare any compression driver or tweeter.

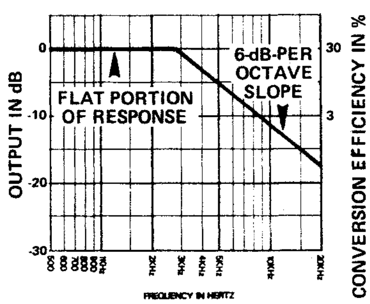

FIGURE 7 – "Newman Criteria" Total Output Reference Standard for Compression Drivers (No Horn)

The rolloff inherent in the Newman Criteria results because of the practical problems involved in making the mass of the moving parts (diaphragm and voice coil) any lower and/or the strength of the magnetic motor (magnet and related steel parts) any stronger. Really good drivers meet the Newman Criteria line over a substantial portion of the frequency range, occasionally exceeding it in certain parts of the range by a small margin. Unusual materials (such as beryllium diaphragms) can provide modest increases in high-frequency output but the resultant performance still basically follows the Newman Criteria. This situation is sometimes missed by enthusiastic advertising departments who find it convenient to confuse the output of the driver *itself* with the output as modified by a non-constant directivity horn. Other driver designs get "more highs" by a substantial (and typically unmentioned) sacrifice of midrange efficiency. Most vocal energy is in the midrange and – all other things being equal – a driver with low midband efficiency will have increased amplifier power requirements, a higher probability of blowout, and a reduced maximum sound pressure level capability. The output of a typical high-quality, wide-range driver with high midband efficiency is shown in Figure 8. The Newman Criteria is displayed for comparison.

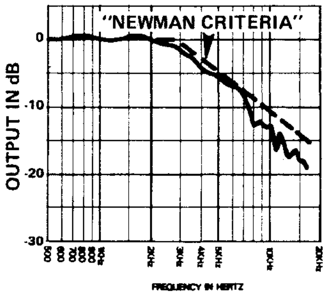

FIGURE 8 – Total Output of Typical Wide-Range Compression Driver (No Horn)

Horns Affect Driver Output

Now, let's get back to the horn. Figure 9 shows the response of the driver in Figure 8 mounted on a constant directivity horn (E-V HR9040A). Notice how closely the response matches the driver output shown in Figure 8. This makes sense because the horn, being constant directivity, spreads driver output over the same basic coverage zone over a wide frequency range. But the response curve certainly doesn't look too nice! No highs! You would probably say, "my brand X driver gives a nice flat frequency response curve a lot better than that." And you could be right. But you would have it on a horn (*not* constant directivity) like the one in Figure 2; and maybe the driver would be one of the low midband efficiency types to give the effect of more highs. The horn's collapsing high-frequency coverage angle makes the frequency response of the driver and horn *combination* look flat on the axis (in front) of the horn.

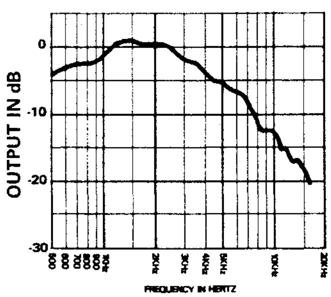

FIGURE 9 – Response Typical Wide-Range Driver on Constant Directivity Horn (E-V DH1506/ HR9040A)

Pick up that garden hose again. Of course, water flow doesn't have a frequency (high and low) like sound does, but it's fun to stretch the analogy a bit. Let's say a big high-pressure pump corresponds to the lower frequencies. We'll set the nozzle for a wide angle. Because we have lots of pressure we can adjust the nozzle for a wide angle of spray and still get the water as far as we want it to go. Now, let higher frequencies correspond to a low-pressure pump. If we leave the nozzle at the same spray angle, our water won't reach the flower bed any more. What to do? The only way to get the water to reach the flowers is to readjust the water for a narrow angle. Unfortunately, that gets water to the flowers but only to *some* of them! That's the plight of the old-fashioned variable directivity horn. It gets its nice flat response on axis only by depriving the listeners at the side of all those nice highs.

Utopia by Equalization!

The solution is to get a bigger pump for those high frequencies and put it on a constant directivity nozzle. Back in the real world of horns and drivers, that means putting the driver on a constant directivity horn and applying the appropriate *equalization* to get the flat response you want and need. "Equalization," you say. "That's a dirty word." What you need to understand is that the variable *coverage* of a conventional horn (which can be quite irregular) cannot be changed. It's fixed by the (hard) geometry of the horn. But the *response* of a driver on a constant directivity horn can be changed by appropriate equalization, easily. Read the last three sentences again and grab the concept before you go on!

By boosting or equalizing the high frequencies, a flat response can be obtained *and* at all angles of the stated coverage of the constant directivity horn. Then you'll have the open, transparent, super-clear sound you maybe thought you couldn't get from a horn. The effect of equalization on frequency response is shown in Figure 10.

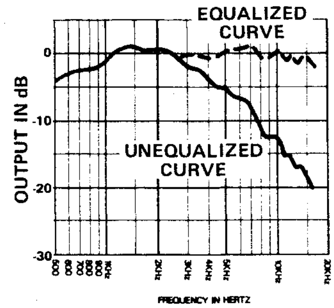

FIGURE 10 – Equalized and Unequalized Response of Wide-Range Driver on Constant Directivity Horn (E-V DH1506/ HR9040A)

Since the demand placed on a driver at high frequencies is not great compared to midrange and low frequencies (see "PA Bible" Addition Number 2, "Power Handling"), the boost required will not damage the driver or require excessive power from the amplifier in any practical situation. The Electro-Voice XEQ series of crossover/ equalizers has been specially designed to provide the proper boost to complement each of the seven E-V constant directivity horns. This leaves equalizers free to be used for enhancement or room tuning as desired (see "PA Bible" Addition Number 4, "Understanding Equalization and the Various Types of Equalizers").

DO CONSTANT DIRECTIVITY HORNS REQUIRE ANY OTHER SPECIAL EQUIPMENT?

What you will need besides the appropriate equalization depends entirely on your existing setup. If you are currently using a component system consisting of low-frequency (bass) enclosures, high-frequency horns, and a graphic equalizer (octave, half octave, or one-third octave), you probably have all the equipment you will need, including that required for horn-driver equalization. If you currently have an integrated speaker system (all speakers in a single enclosure), you will need some additional equipment. If you are designing a system for the first time, the recommendations in the "Basic Approach to System Design" section of the "PA Bible" will be of help.

The basic requirements for a two-way component sound system are shown in Figure 11. The low-level active crossover can be one of the E-V XEQ series, which also provides the high-frequency boost required, or a conventional unit which only provides the basic crossover function. If a conventional crossover is used, a graphic equalizer (such as the E-V/TAPCO C-201, 2202, and 2200) will be necessary to provide the proper high-frequency boost. (The engineering data sheet covering the E-V RC series of encased horns – which includes the DH1506 driver – shows recommended settings.) Even if the E-V XEQ crossover/ equalizer is used, a graphic equalizer is still useful for enhancement and room tuning as discussed in Addition Number 4 of the "PA Bible."

Driver-to-horn mounting arrangements vary. All Electro-Voice HR series constant directivity horns will accept most 1.3" diameter throat bolt-on drivers (including the E-V

DH1012). Using the ADH-1 adaptor allows most bolt-on drivers with 1" throats and all screw-on drivers with 1-3/8"-18 mounting threads (including the E-V DH1506) to be mated to the HR horns without any performance degradation. Some drivers have 2" throats and can only be mounted on horns or adaptors specifically designed for this largest throat size.

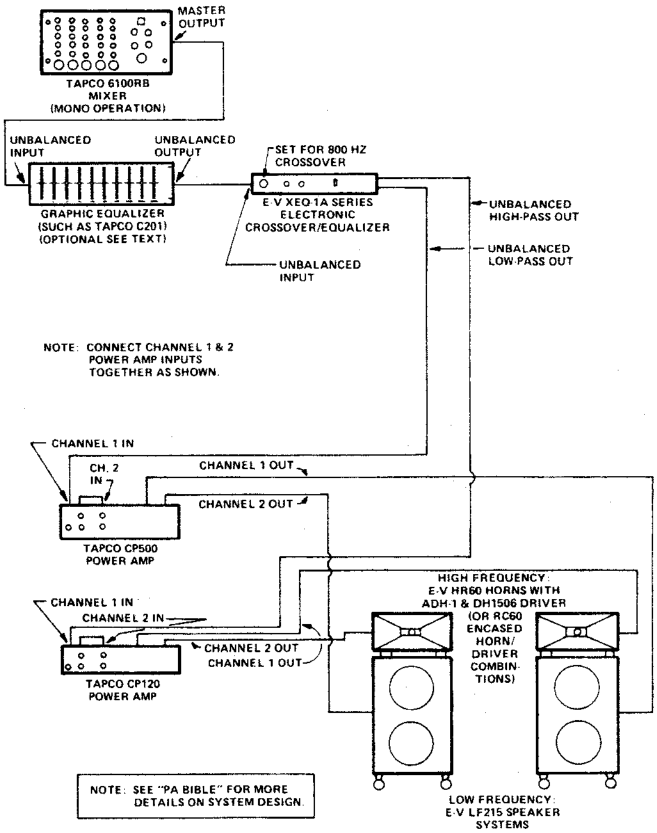

FIGURE 11 – Block Diagram of Typical Two-Way Component System

WHY ARE THERE A NUMBER OF DIFFERENT CONSTANT-DIRECTIVITY HORNS?

Coverage Angle

All-in-one PA speakers have what ever coverage angle they have, in the hopes that the specific performance is adequate for a relatively broad range of applications. When you step up to separate PA components, you can deal more accurately with the different physical situations you are likely to encounter. In the "PA Bible" we presented some typical examples and decided which horns would properly cover the listening area. Because listening areas vary in size and configuration, so should the speaker coverage angles. Constant directivity horns are usually available in three standard coverage patterns: 90° x 40°, 60° x 40°, and 40° x 20°. At least one other available constant directivity horn has 120° x 40° coverage. These coverage patterns provide a useful range to select from for most applications. Determining the proper coverage is the first step in deciding which constant directivity horn will do the job.

The second step is to know if long-throw horns will be required. Reviewing the section on "Room Reverberation Swamps Your Voice" from the "PA Bible" will be helpful here. In highly reverberant rooms, low-directivity, wide-angle horns (like 90° x 40° or 120° x 40°) will not provide enough "direct" sound (that which comes right from the horn and has not been reflected by one or more of the room surfaces) for listening positions past the approximate mid-point of the room. Sound past this point is likely to be mostly "reverberant" (reflected by one or more of the room surfaces) and, therefore, unintelligible. The solution is to get more direct sound in the back of the room (without blasting the high-paying seats in the front of the room) by aiming a high-directivity, narrow-angle horn (such as the E-V HR40 or HR4020A 40° x 20°) at the back.

In most clubs of small-to-medium size, under normal conditions, one type of constant directivity horn will satisfy your requirements. A 90° x 40° or 60° x 40° horn can usually do an effective job for these environments.

Minimum Crossover Frequency

The different constant directivity horns available "load" their associated drivers down to various "mimimum crossover frequencies," typically 500 or 800 Hz. For example, the "large" E-V HR4020A 40° x 20° loads down to 300 Hz. The other "large" HR's (HR6040A and HR9040A) load down to 400 Hz. The "small" HR's (HR40, HR60, HR90, and HR120) load down to 500 Hz. Each HR may be used down to its stated limit, as long as the driver itself can sustain full rated power down to that frequency. (For example, the E-V DH1012 can sustain full rated power down to 400 Hz; the DH1506 sustains full power down to 800 Hz.)

Minimum Frequency for Coverage Angle Control

At some low frequency, chosen by the horn designer, all constant directivity horns lose their coverage control and the coverage angle begins to widen. (Figure 3 shows this phenomenon.) Horns with larger mouth sizes maintain their rated coverage angle to lower frequencies. Horns which maintain coverage to low crossover frequencies (like 500 Hz) are very large, say 30" x 30" at the mouth. Often, compromises in maintaining the rated coverage angles are desirable, due to practical size and cost considerations. For example, compare the "large" E-V HR9040A (approximately 18" x 39" x 22" hwd) to the "small" E-V HR90 (11" x 24" x 14" hwd), both nominal 90° x 40° horns. Both horns are wide enough to maintain horizontal (side-to-side) coverage down to 500 Hz and below. The smaller vertical dimension of the HR90, however, limits its strict vertical (up-and-down) control to about 2000 Hz, versus the larger HR9040A's 1000 Hz. It is also good to keep in mind that complex multi-way speaker arrays which use high crossover frequencies (say, 1500 Hz and above) can use a relatively small constant directivity horn. For example, the large HR9040A provides no performance advantage over the small HR90 if crossed over in the 1000/2000-Hz range.

SPECIAL NOTE TO THE READER

The E-V "PA Bible" and this addition have been prepared to help you solve your PA problems. Let us know if you have any other areas in mind for us to tackle.

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