JOHN EARGLE

# Requirements for Studio Monitoring

*The monitor system and its control room environment remain an ongoing challenge to both studio designer and component manufacturer.*

For most of its half century, electrical recording has made do with inferior monitoring speakers and conditions. The early requirements were fairly simple; monitors were used to check signal continuity and detect possible interference levels from hum and other sources. Esthetic judgments were rarely made over these early systems.

The advent of tape recording in the post-war years brought greater artistic freedom, in terms of increased bandwidth and dynamic range, and the role of the monitor speaker changed dramatically. The technology which had been developed for motion picture sound provided the basis for monitor systems over which esthetic judgments could be made. A handful of manufacturers dominated the field; in the United States, the Altec 604 coaxial loudspeaker became the reference standard, while the Tannoy 15-inch dual-concentric loudspeaker played a similar role in Europe.

In the early sixties, the monitor designs of James B. Lansing Sound, Inc. began drawing attention, primarily through joint efforts with a major record company and its affiliates around the world. The company's technical traditions were firmly rooted in those of Western Electric as well as the design philosophies which originated on the west coast during the early years of sound motion pictures. This technology stressed efficiency and ruggedness as well as the use of compression drivers and their associated horns and acoustic lenses for high-frequency applications.

The most recent epoch in monitor system design dates from the early seventies. Professional design consultants are responsible for many studios today, and they have integrated their own monitor designs, constructed from standard componentry, into control room environments which stress uniform acoustical absorption and diffusion across the audio range.

## MONITOR SYSTEM REQUIREMENTS

In general, we can outline present day-requirements for the professional monitor system and its environment as follows:

1. Ruggedness. Monitor systems must be able to withstand considerable electrical abuse, unintentional or otherwise.
2. High output capability with low distortion. Monitor systems must be able to reproduce cleanly the sound pressure levels in the control room typical of pop-rock performances. The ready availability of high amplifier power has allowed a beneficial trade-off between system sensitivity and low-frequency bandwidth extension.
3. Accurate time domain response. No firm criteria exist for this yet, but it is surprising how accurate in this regard many present monitor designs are.
4. Reasonably flat energy response across the audio band. Whether wide or narrow, the horizontal dispersion angle should be maintained as evenly as possible.
5. Lateral symmetry in the control room, along with smooth boundary conditions and smooth absorption characteristics across the audio range.

## ANALYSIS OF TYPICAL SYSTEMS

It is curious that the high fidelity industry realized the advantages of three-way designs long before the designers of monitor systems did. Up to the early seventies, most monitors were two-way systems. In fact, for certain "close-

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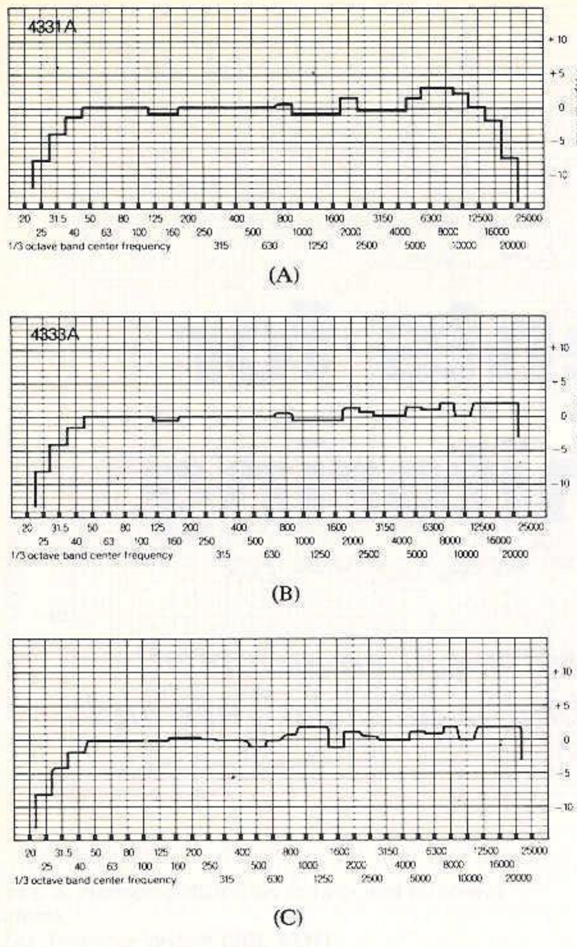


*Figure 1. Frequency response for three speaker systems.*
*(A) Two-way system (JBL 4331)*
*(B) Three-way system (JBL 4333)*
*(C) Four-Way system (JBL 4343)*

in" monitoring conditions, a two-way system may still be preferable to three- or four-way designs, because of the spatial integrity of high frequencies emanating from a single source.

The chief drawbacks of two-way systems have to do with uneven energy response and a tendency for high-frequency distortion at high levels. A typical two-way system may have a 15-inch LF unit crossing over to a horn-loaded HF assembly in the region of 1 kHz to 1.5 kHz. In terms of energy response, the dispersion of the 15-inch LF unit narrows considerably as it approaches the 1 kHz range crossover point. The transition to the HF assembly once again broadens the dispersion angle, but beyond 10 kHz the response is apt to narrow again unless the design is an exemplary one.

In FIGURES 1 and 2, the frequency response and angular coverage of representative two-, three-, and four-way systems are compared. The frequency response plots were made using ⅓-octave pink noise signals, averaged over a 60 degree horizontal arc and a 30 degree vertical arc.

The JBL model 4331 is a typical two-way design. This system is an updated version of the model 4320, introduced in the early sixties. In the early seventies, the model 4333 added a UHF driver to the two-speaker array of the 4331.

From these figures, it will be readily seen that the additional UHF driver permits an extended high-frequency response, as well as an improvement in effective angular coverage. The same enclosure and baffle configuration is used for both the 4331 and 4333, and is shown in FIGURE 3.

FIGURE 4 shows details of the four-way model 4343, introduced in the mid 1970's. This system added a 10-inch lower mid-range cone element to the three-way configuration. As seen in FIGURE 2, the effect of the lower mid-range driver on angular coverage is apparent; it effectively broadens the system's coverage in the 500-1000 Hz octave.

While the 4331 is inherently symmetrical, the 4333 and 4343 provide for mirror imaging of all components through alternate component mounting as well as (in the case of the 4343) baffle rotation.

The effect of a separate UHF element in an array serves two purposes; dispersion at high frequencies is ensured (as is evident from the dispersion curves), and second harmonic distortion is reduced. FIGURE 5 shows the advantage of a three-way system over a two-way system as regards second harmonic distortion. In FIGURE 5(A) we see the on-axis high-frequency response of a two-way system with a nominal input level of one watt. The second harmonic distortion is shown raised in level by 20 dB for ease of comparison. Note that the level of the second harmonic component tends to rise with frequency and remain at a level about 35-40 dB below the fundamental. At FIGURE 5(B), we see the response of a three-way system under the same conditions. Here, the second harmonic distortion decreases as the UHF element comes into the picture. The same mechanism which causes harmonic distortion will of course cause intermodulation distortion well within the audio band on complex signals. The three-way system will therefore be less prone to IM effects than the two-way system.

## SPECIAL PURPOSE SYSTEMS

The three systems we have just discussed represent elaborations on the basic two-way theme, and should satisfy most normal monitor requirements. However, a "no holds barred" approach is sometimes required, in order to meet the demands of high-level rock monitoring. The JBL 4350 is a representative four-way design, making use of two LF drivers, and it is designed to be bi-amplified. Nominal specifications are:

| | LF Section | HF Section |
|---|---|---|
| Sensitivity | 93.5 dB/watt/metre | 93.5 dB/watt/metre |
| Power Handling | 200 watts | 100 watts |

*Figure 2. Angular coverage for three speaker systems.*
*(A) Two-way system (JBL 4331)*
*(B) Three-way system (JBL 4333)*
*(C) Four-way system (JBL 4343)*

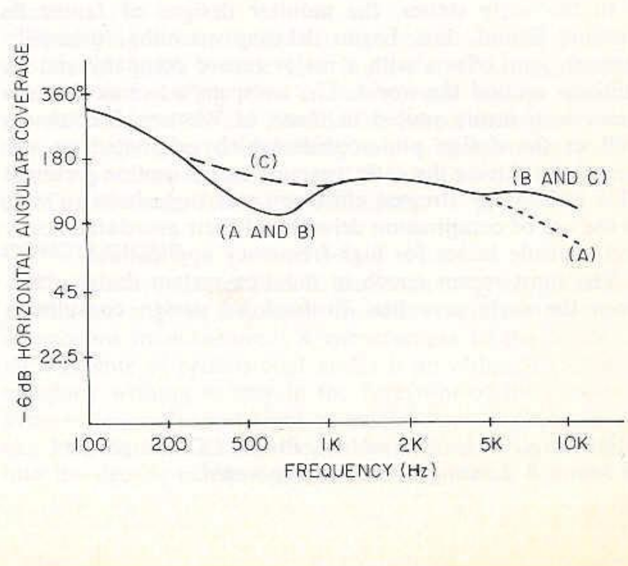

*Figure 3. A three-way enclosure system. Note the UHF driver to the left of the regular high-frequency system. (JBL 4333)*

*Figure 4. A four-way system. In the photo, the UHF driver is to the right of the high-frequency system.*

With these characteristics, the 4350 can easily produce levels in a normal environment of 110 dB at distances of 10 feet. The system is shown in Figure 6.

For many broadcast and semi-pro recording applications, fairly straight-forward two- and three-way direct radiator systems are more than adequate as monitor speakers. These are generally bookshelf systems, and as such are limited in power handling capability when compared with their big brothers in the compression driver class. Typical sensitivity and power ratings for such systems are listed below.

| Number of Elements | Sensitivity | Power Rating (steady State) | JBL Model |
|---|---|---|---|
| 2 | 88 dB/watt/metre | 15 watts | 4301 |
| 3 | 91 dB/watt/metre | 40 watts | 4311 |
| 3 | 89 dB/watt/metre | 40 watts | 4313 |
| 4 | 89 dB/watt/metre | 60 watts | 4315 |

## TIME DOMAIN ACCURACY

We have heard much in the last two years of the importance of time and phase accuracy in high fidelity speaker designs. These concerns, if they are important at all, should have relevance in the monitor area as well. Writing in the *Journal of the Acoustical Society of America,* Blauert and Laws established criteria for non-audibility of delay effects, in the paper, "Group Delay Distortion in Electroacoustical Systems," vol. 63, no. 5, May, 1978.

While it is true that a number of consumer high-fidelity systems exceed the Blauert and Laws criteria, it may be argued that this level of performance is really not necessary.

It is surprising how well behaved the modest three-way monitor systems are in their time domain response; they are better in this regard than the larger designs with compression drivers. This may be seen in FIGURE 7, where the time domain response of the 4313 is compared with its big brother—the 4333. The displacement due to the midrange horn structures account for these differences, as opposed to a typical three-way direct radiator system with the acoustic centers of its elements located on the plane.

In computing the group delay characteristics of the models 4313 and 4333 shown in FIGURE 7, the phase response was first measured using a time delay adjusted to the acoustic path length between the system and the microphone. The slope of the phase response with respect to frequency was then measured graphically. This slope ($d\O/d\omega$) represents the group delay characteristic of the system.

## THE MONITORING ENVIRONMENT

The professional studio designers we referred to earlier have not only designed their own monitor systems but have established criteria for studio and control room acoustics as well. A handful of these design consultants have been very successful and have established impressive "track records," designing rooms in which absorption is evenly distributed and further, is uniformly calculated as a function of frequency.

Often, the monitor enclosures are flush-mounted into the environment; this ensures that uneven response from diffraction effects due to sharp boundary discontinuities will be minimized.

Another characteristic of a well-designed control room is the avoidance of uneven bass response through the use of selective absorption. Such "bass traps" effectively damp out low-frequency resonances due to the normal mode or eigentone structure characteristic of the room.

Finally, a canting inward of the monitors, along with the use of wide-dispersion HF devices, will ensure that smooth response will be maintained over a relatively large space, enabling both engineer and producer to hear equally well.

## MONITOR EQUALIZATION

Monitor system equalization has become an accepted practice in professional control room design. If the monitor componentry has been properly specified at the outset, and if the acoustical design is proper, then the amount of equalization required for smoothly-tailored response at the operator's position may be quite small.

Typically, one-third-octave, minimum-phase, band-rejection equalizer designs are used, and these are now available from many manufacturers. After some years of field experience in monitor equalization, most practitioners of the art are pretty much in agreement on the following:

1. The last equalization is the best. This rule is almost self-fulfilling if due attention has been paid to monitor "hardware and horse power" as well as acoustical matters.

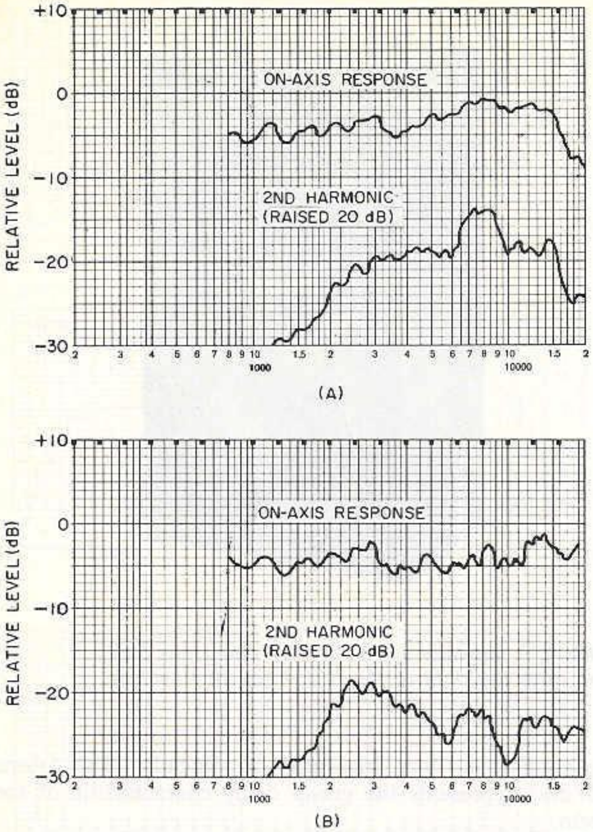


*Figure 5. Harmonic distortion in two- and three-way systems.*
*(A) Two-way system (JBL 4331)*
*(B) Three-way system (JBL 4333)*

2. Where the room design is laterally symmetrical, it is apparent that the same equalization curves should apply to both left and right monitor channels. This is highly desirable, as it guarantees that stereophonic imaging—a function of the first arrival sound at the listener—will be precise and unambiguous.

Preferred equalization contours will vary according to tastes and traditions. In general, an adequate monitor in a properly designed control room can be equalized for flat response in the prime listening area out to 15 kHz. More usually, the response is held flat out to about 7 or 8 kHz and allowed to roll off 3 dB/octave above that point.

*Figure 6. The "no-holds barred" approach. A four-way system with two low-frequency drivers. (JBL 4350)*

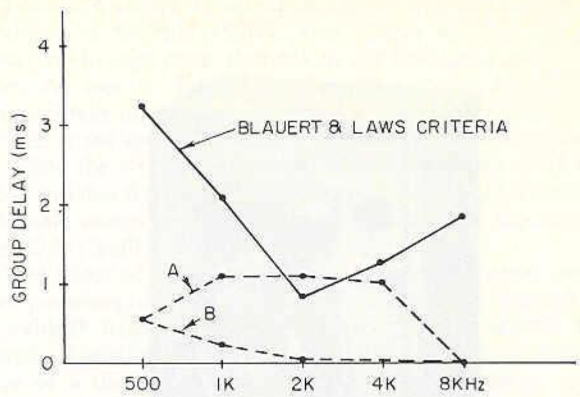


*Figure 7. The Blauert and Laws criteria for non-audibility of delay effects.*
*(A) Time domain response for a professional three-way system (JBL 4333).*
*(B) Time domain response for a bookshelf three-way system (JBL 4313).*

## BI-AMPLIFICATION

The chief benefit of bi-amplification is the reduction in intermodulation distortion which it affords. Low-frequency power demands (and they are invariably greater than the high-frequency demands) may drive even a large amplifier into clipping, and the products of the clipping will show up as distortion through the HF portion of the system. With bi-amplification, both LF and HF portions of the system have their respective amplifiers, with the frequency-dividing action taking place before their inputs. Therefore, there is no possibility of intermodulation taking place between LF and HF parts of the monitor system.

An additional, but more subtle, advantage of bi-amping results from the elimination of lossy inductances in the LF portion of a conventional dividing network, and the result may be a significantly better amplifier damping factor, as seen by the LF transducer.

One should *never* skimp on power allotments in a bi-amped system. Even though it can easily be shown that bi-amping can provide a two-to-one power advantage over a standard system on certain kinds of program material, this will not be true in the general case. In any event, amplifier power is cheap these days, and there is absolutely no reason in a well-engineered system not to use rated power—with an additional 6 dB of head room for good measure. Many bi-amplified systems are equalized as well, and this is only one more reason to power the system adequately.

Bi-amping is sometimes hard to implement, and the user is often left to his own devices. It should not be undertaken without first asking the manufacturer's advice. Larger monitor systems should provide for proper component access through external switching and additional terminals. Many manufacturers, including JBL, also provide electronic dividing networks for use in bi-amping.

## CONCLUSIONS

The monitor system and its environmental requirements remain an ongoing challenge to both studio designer and component manufacturer. Responsiveness to the needs of all segments of professional audio is an obligation of any company wishing to stay in the forefront of the industry. Progress over the last eight years has been rapid, and we can look forward to significant developments as we move into the decade of the eighties. ■