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White Paper

JBL's LSR Principle, RMC™ (Room Mode Correction) and the Monitoring Environment

by John Eargle

Introduction and Background:

Although a loudspeaker may measure flat on-axis under anechoic conditions, what you hear at the mix position may be inaccurate. The room's boundaries, geometry, and surface treatment contribute significantly to the response you hear at the mix position, and as a result the balances and spectral content may be off-target. JBL's solution to this problem starts with an accurate loudspeaker system and incorporates the necessary equalization to correct the response at the mixer's position.

In all likelihood, the room in which you monitor your recording or mixing activities is reflective enough so that what you hear in the midrange at the mix position consists just about equally of direct sound and reflected sound (Augspurger, 1990). You may be unaware of the reflected sound component as such, but it is an essential element for comfortable and extended listening. If both direct and reflected sound fields are uniform and free from excessive peaks and dips, what you hear will convey an accurate impression of your mix. On the other hand, if your loudspeakers are flat on-axis – but the reflected sound field is not flat – what you hear will be aberrated.

Many loudspeakers are designed to deliver fairly flat on-axis response – but may at the same time have irregular off-axis response. This disparity between on- and off-axis response shows up in *power response* measurements of the system. Power response presents a picture of the relative output of the loudspeaker summed over all directions as compared with what the on-axis listener hears.

As far back as 1983, JBL first addressed this problem in the design of the 4400-series monitors which made use of the Bi-Radial® horn. This design philosophy is shown in Figure 1.

At *A* we show the on-axis and power response of a well-designed monitor. Both the room response (reflected sound field) and on-axis response (direct field) can be adjusted for optimum response simultaneously, as shown at *B*.

If the loudspeaker has smooth on-axis response but irregular power response, as shown at *C*, then any attempt to make the reverberant response uniform will result in irregular on-axis response – or vice-versa. This is shown at *D* (Smith, et al., 1983).

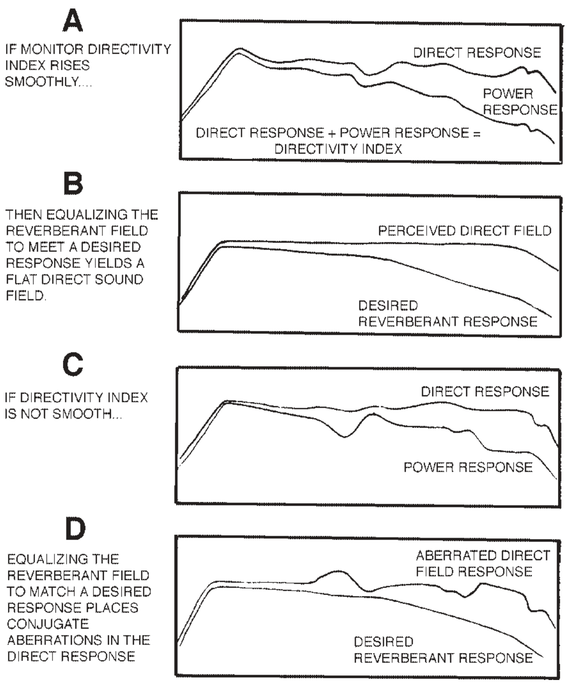


Figure 1. The effect of uniform on-axis response and uniform power response.

The LSR Principle:

More recently, the desire to extend the on- off-axis response matching to its highest degree has led to JBL's LSR, or *Linear Spatial Reference*, series of monitors. These systems make use of proper choice of crossover frequencies, dividing network adjustments, and specific baffle boundary details to ensure three very important performance features:

1. Flat on-axis frequency response.

2. Flat forward listening angle response (±30° horizontal; ±15° vertical).

3. Uniform, gradually diminishing power response with rising frequency.

The degree to which the LSR goals have been met can be summed up in the single composite graph shown in Figure 2. Here, we have plotted six response curves on the LSR6328P powered monitor:

1. Curves 1 and 2 show the forward only response components. Note that the averaged response over the forward listening angle is virtually the same as the on-axis response.

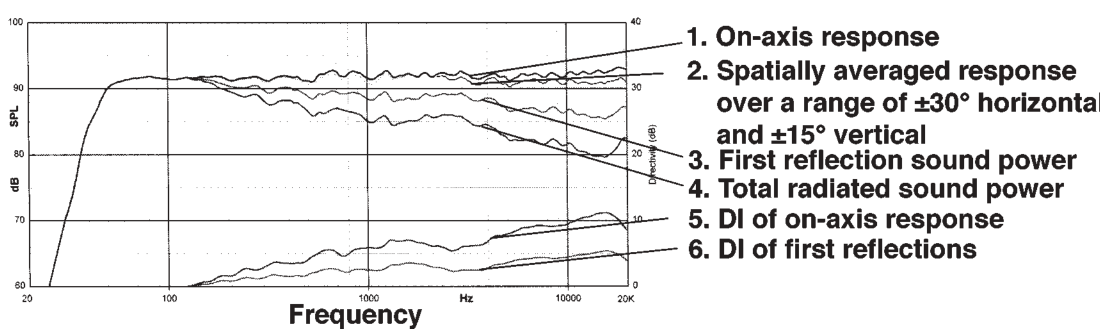


Figure 2. Response data for JBL LSR6328P monitor system.

2. Curves 3 and 4 show the radiated power (power response) of the system, based on both first reflections and on total radiated power.

3. Curves 5 and 6 are derived by subtracting the radiated power curves from the on-axis curve, giving an overview of the system's DI (directivity index).

Figure 3 shows the same family of response curves for a competitive monitor which has not been designed according to these principles. Specifically, the power response (Curves 3 and 4) show significant peaks and dips in the upper midrange, which indicate that there will be an uneven reflected sound field in the room.

paying for is symmetry of design, bass traps, and a high degree of acoustical isolation, all of which may require extensive structural alterations. The control room will also likely have large flush mounted monitors. A room in your home on the other hand will have none of these improvements, and there are two low frequency problems that you will have to address by non-structural means. One of these has to do with reflected images of loudspeakers which are located close to walls, and the other has to do with standing waves in the room. We will now discuss these problems in detail.

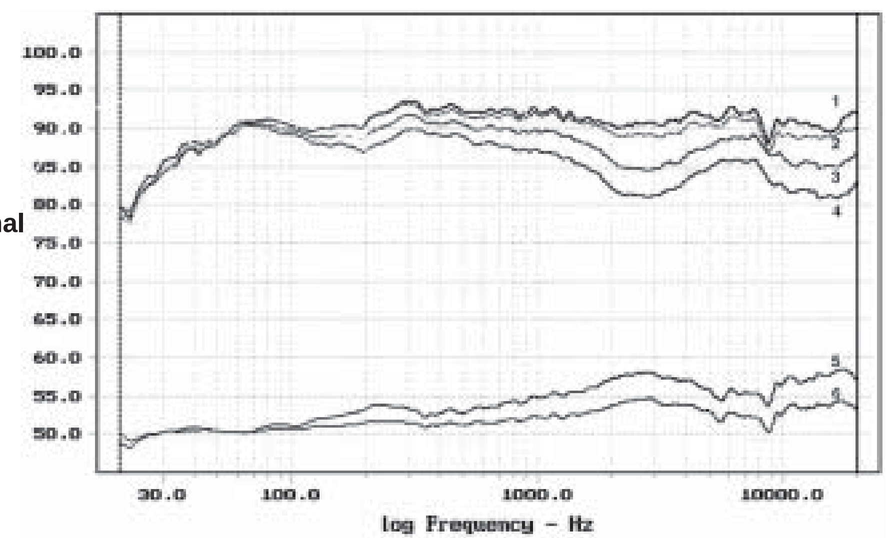


Figure 3. Response data for a sub-optimal system.

Low Frequency Problems:

Many audio operations are set up in what we can call "ordinary" rooms. A spare bedroom is often the choice for a home workspace, and if it has carpeting, drapery, bookshelves, and a few other pieces of furniture, it may actually be better than you think it is. When you spend a fortune on a control room, what you are largely

Boundary Compensation:

JBL's new powered LSR-series products incorporate a set of equalizers which will enable you to make certain low frequency (LF) adjustments to your system. The first of these is *Boundary Compensation*.

JBL's LSR full-range systems are designed to have flat LF response when

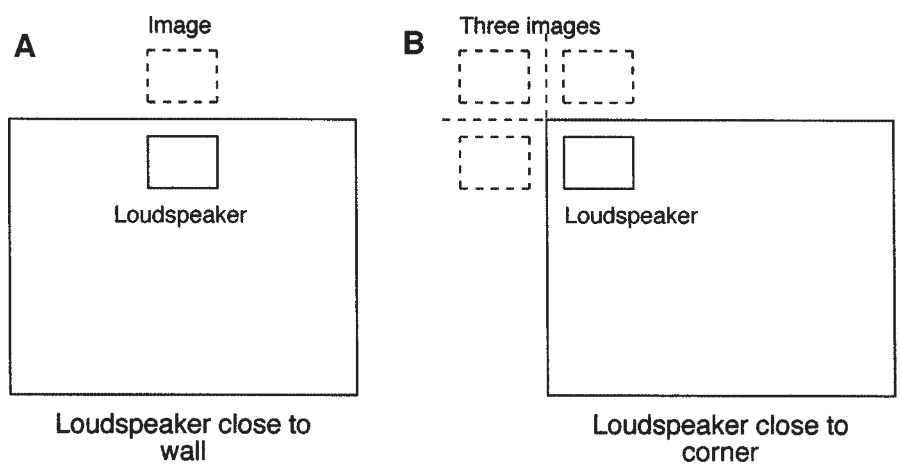


Figure 4. Loudspeaker boundary conditions. Against a wall (A); in a corner (B).

they are mounted on conventional loudspeaker stands that are normally placed 2 feet or more from the walls. When the systems are placed within about 10 inches of a wall, the situation will be as shown in Figure 4. At *A*, the system is fairly close to a single wall, and the reflected image of the loudspeaker will increase the loudspeaker's LF loading, resulting in an increase in output below about 200 Hz. The degree of LF boost will be approximately 1.5 to 3 dB, depending on the actual distance from the wall. Under these conditions, you would want to *decrease* the amount of LF feed to the system by adjusting a set of DIP switches on the rear panel of the LSR6328P. The models LSR25P and LSR6312SP also have boundary compensating equalization tailored to their normal mounting alternatives.

Figure 4B shows the effect of positioning the loudspeaker in a corner. Generally, we don't recommend this, but if you are working in a very small space, such positioning may be necessary. In this case the maximum amount of LF cut (4.5 dB) may be applied. In any event, you will be able to observe the effects of these degrees of LF cut as you get further into the equalization process.

Figure 5 shows the range of the boundary compensation equalizer in the LSR6328P. Each step is 1.5 dB, providing a maximum reduction of 4.5 dB below about 200 Hz.

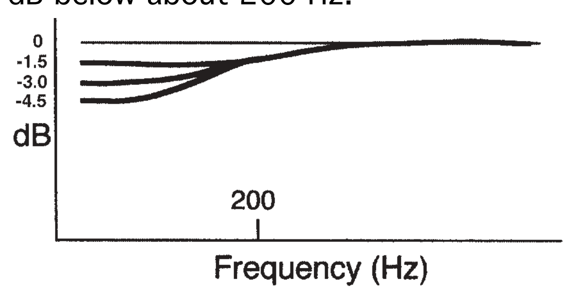


Figure 5. Boundary compensation curves.

Room Modes and RMC (Room Mode Correction):

Room modes are resonances that exist between two or more boundaries of a room. In a rectangular room, the most common of these are the so-*called axial modes*, which take place between opposite walls and between the floor and ceiling. Figure 6 shows a side section view of a typical workspace, and the panel just below that figure shows the sound pressure distribution for the first-order axial mode along the front-back dimension of the room. The bottom panel shows the modal pressured distribution for the second-order axial mode, which is an octave higher than the first.

Let's assume that the front-back distance in this space is 20 feet. The frequency of an axial mode is given by the following equation:

$$f = (c/2)(n/l)$$

where f is the frequency (Hz), c is the speed of sound (1130 feet/second), n is an integer value (1, 2, 3, etc.), and l is the length of the room in feet. Solving this for the first-order mode (n = 1) gives:

$$f = (1130/2)(1/20) = 28.3 \text{ Hz}$$

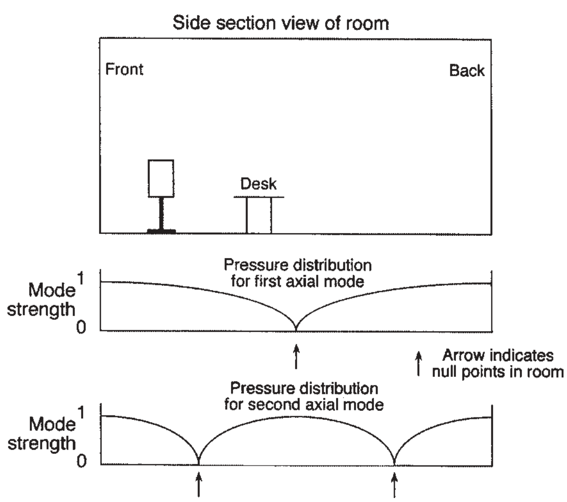


Figure 6. Axial modes in a rectangular space.

If we apply a signal at this frequency to the loudspeaker and walk the room from front to back, we will hear the LF signal very loudly at the two ends of the room, and we will find that it diminishes considerably in level as we approach the null region in the middle of the room.

Assume for a moment that you placed your work desk right at the null point. As you moved your head back and forth, even slightly, in the null region, you would hear the 28.3 Hz signal rise and fall in level – not a good effect! You will normally want to locate your listening position clearly out of the null region.

But let's consider that you were constrained, for whatever reason, to sit directly in the null. As you continued searching out room modes you would soon run into the first-order axial side-to-side mode and the second-order front-back axial mode.

Modes are plentiful, and even more complex modes exist between multiple room surfaces. But in the normal course of setting up a room the lowest axial mode in the longest room dimension will be the one you will want to identify and equalize.

How Does the RMC Equalization Process Work?

We have gone to great lengths to simplify the process of identifying modes and equalizing them. All the measurement gear that you'll need is contained in the RMC kit that accompanies the model LSR6312SP. The kit of course can be used to calibrate and adjust all of your LSR systems that have RMC capability. The analysis kit consists of the following items:

1. Test CD, with noise bands for level reference and one-tenth octave warble tones for making frequency response measurements.

2. A hand-held sound level meter.

3. Chart paper for entering your measurements.

4. A template for measuring the width (Q) of the response peak.

5. A small tool for making equalizer settings on the electronics.

6. A comparator switch for making quick A-B comparisons with and without RMC.

A quick overview of the measurement process is shown in Figure 7. Using the test CD, a nominal reference level is chosen. You then play the sequence of one-tenth octave warble tones and manually enter the values on a piece of chart paper.

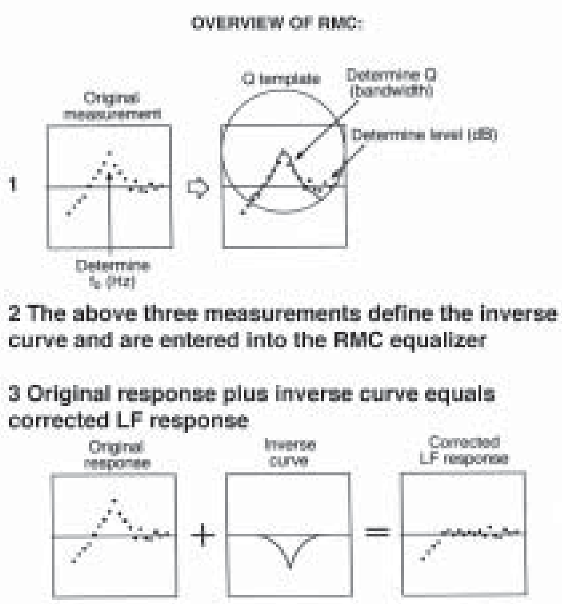


Figure 7. Overview of the RMC process.

Once this has been done, the width template is placed over the plotted curve and adjusted so that you get a good fit between the curve and the markers on the template. You then note the width value and the height of the curve in dB.

You now have the three parametric values: *frequency, width,* and *level*. These are each entered into the equalizer on the back of the LSR electronics via detented potentiometers. The data you have entered provides an inverse curve to the one that you measured, and the net acoustical response of the system will be flat over the affected portion of the frequency range.

At this point you can engage the equalizer and listen. Or, you can use the comparator switch box and make before-after comparisons throughout the listening space. You may even wish to fine tune the system purely by ear.

Two Typical Examples Using LSR6328P Systems:

Figure 8 shows before and after measurements in a space where two peaks were evident in the system's response (upper panel). The lower peak was the one that was compensated for. It is at 31 Hz and is 7 dB above the established baseline. Using the width template we arrived at a width value of 25%. Entering these values into the parametric equalizer we arrived at the adjusted response shown in the lower panel. You will note that the equalized LF response between 28 and 105 Hz is uniform within a range of ±2.5 dB. The secondary peak at 47 Hz was due to the first order side-to-side mode in the listening room.

Figure 9 (upper panel) shows response with a peak at 41 Hz and a dip 57 Hz. The dip is caused by a

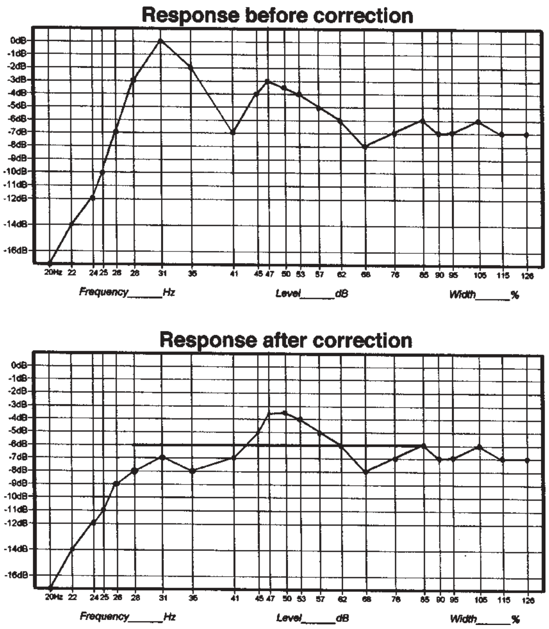


Figure 8. Before-after comparison#1.

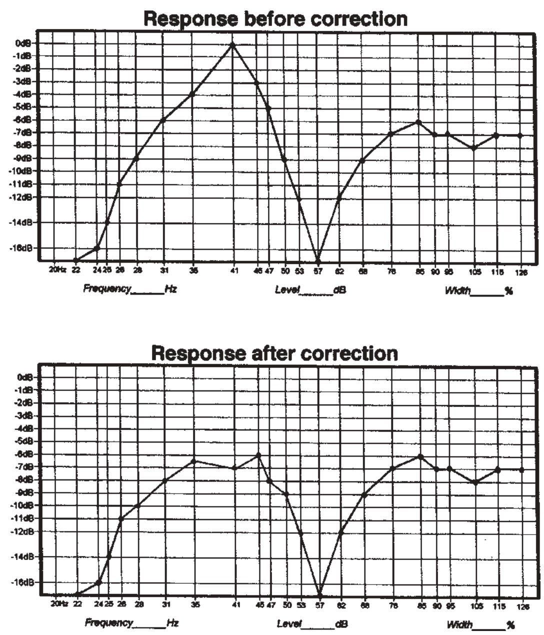


Figure 9. Before-after comparison #2.

floor reflection and cannot be compensated for with any kind of equalization. Such dips can usually be alleviated somewhat by making slight adjustments in the positions of the loudspeakers and the listening locations. Normally, these dips are of little consequence because they are almost always compensated for by the response of the subwoofer. The lower panel of Figure 9 shows the overall response after the 41 Hz peak has been reduced by about 7 dB.

A Comparison Between RMC and One-third Octave Equalization:

One-third octave EQ is felt by many engineers to be a cure-all for loudspeaker-room problems, but this is not generally the case. The composite curve in Figure 10A shows the before and after MLSSA high resolution response of a subwoofer exhibiting a sharp response peak at about 45 Hz. Note that RMC has reduced the peak about 14 dB. The effect this has on the transient response of the system is shown at *B*, where it is clear that the ringing has been heavily damped (Toole, 2000).

If we had used one-third octave analysis and equalization to solve this problem, our analyzer would have presented us with the data shown in Figure 11A. There is no indication of either the sharp 45 Hz peak or the dip at 70 Hz. In fact, the curve as it exists doesn’t look all that bad. Using one-third octave filtering, we now EQ the system to flatten it by about 13 dB, as shown at *B*, and it looks even better.

Now, let’s go back and remeasure the system with MLSSA, as shown in Figure 12. The data at *A* shows that the sharp peak is still present, and the ringing, although somewhat lower in level, has not been damped out at all.

It is obvious that one-third octave equalization is of no use in damping out sharp response peaks. It is also a fact that experienced control room designers do not normally use one-third octave equalization for these purposes; they rely instead on bass traps and other acoustical damping to remove such response peaks.

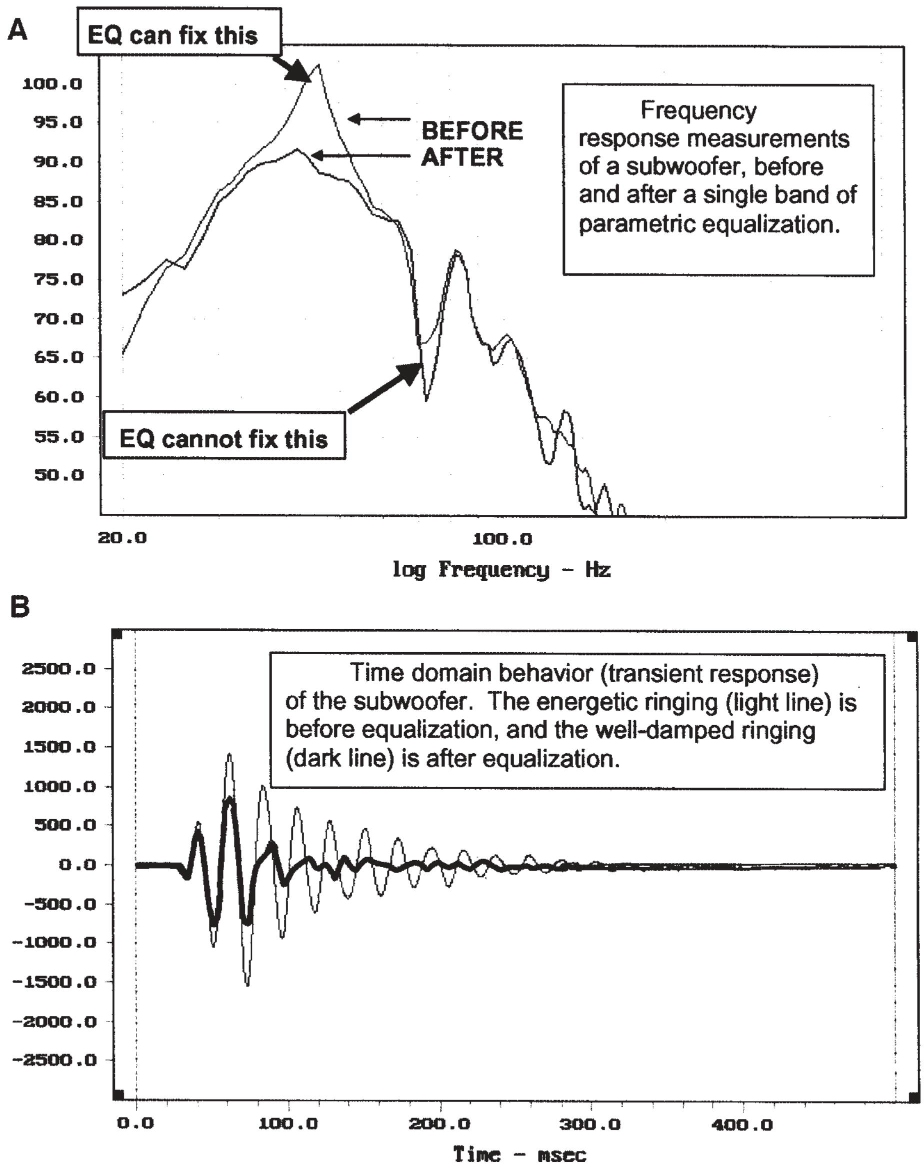
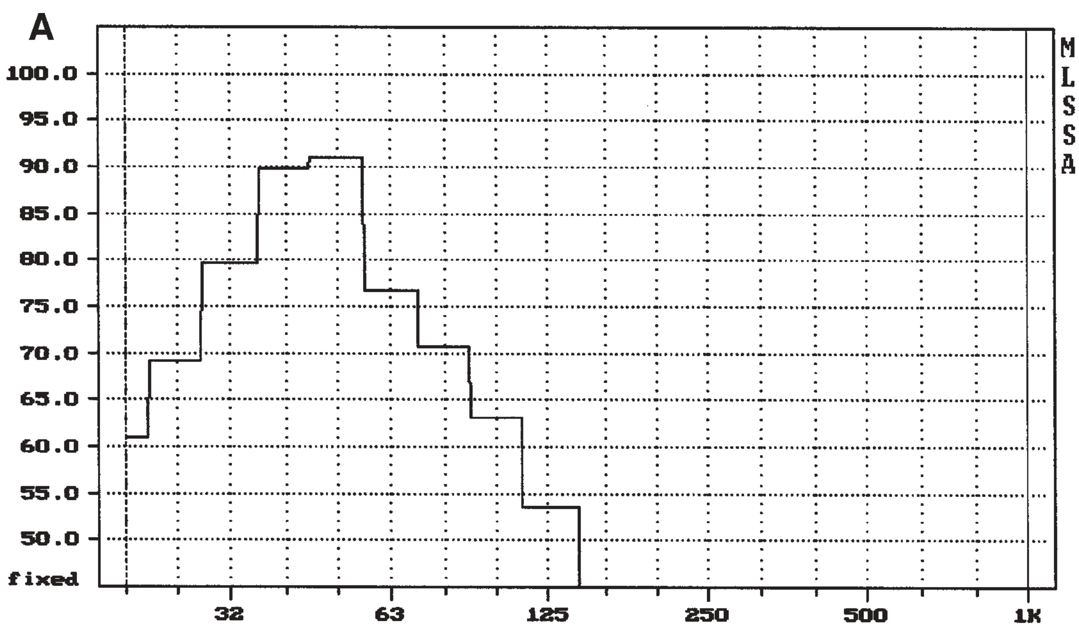


Figure 10. MLSSA measurements of a typical RMC equalization. Frequency response (A); time domain response (B).



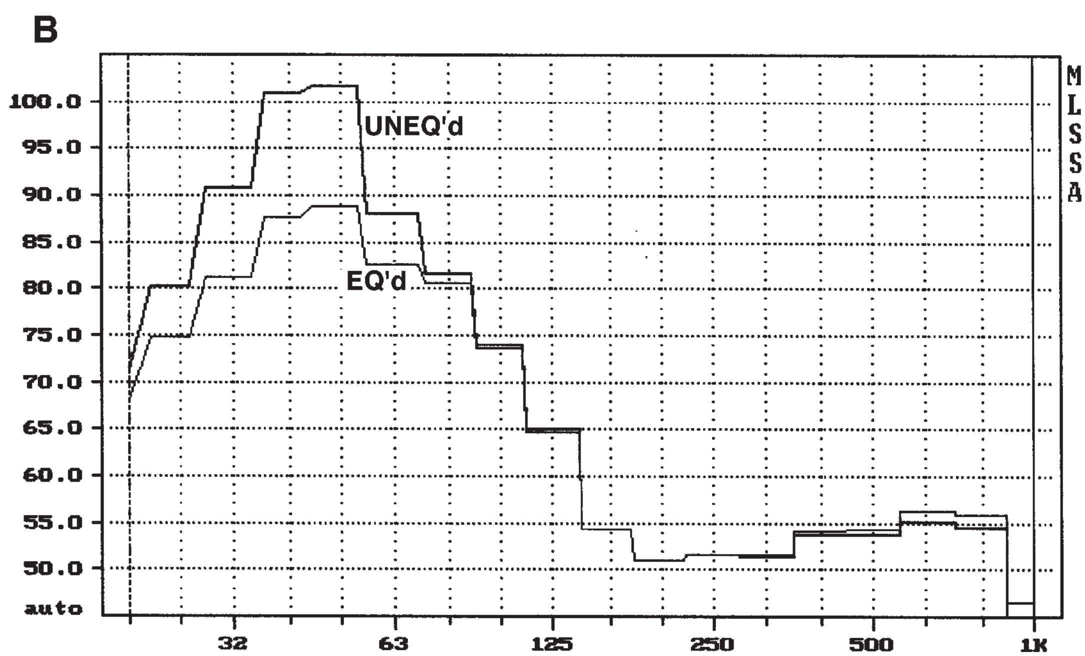


Figure 11. Same setup as before, but viewed with one-third octave analyzer (A); equalized with one-third octave equalization (B).

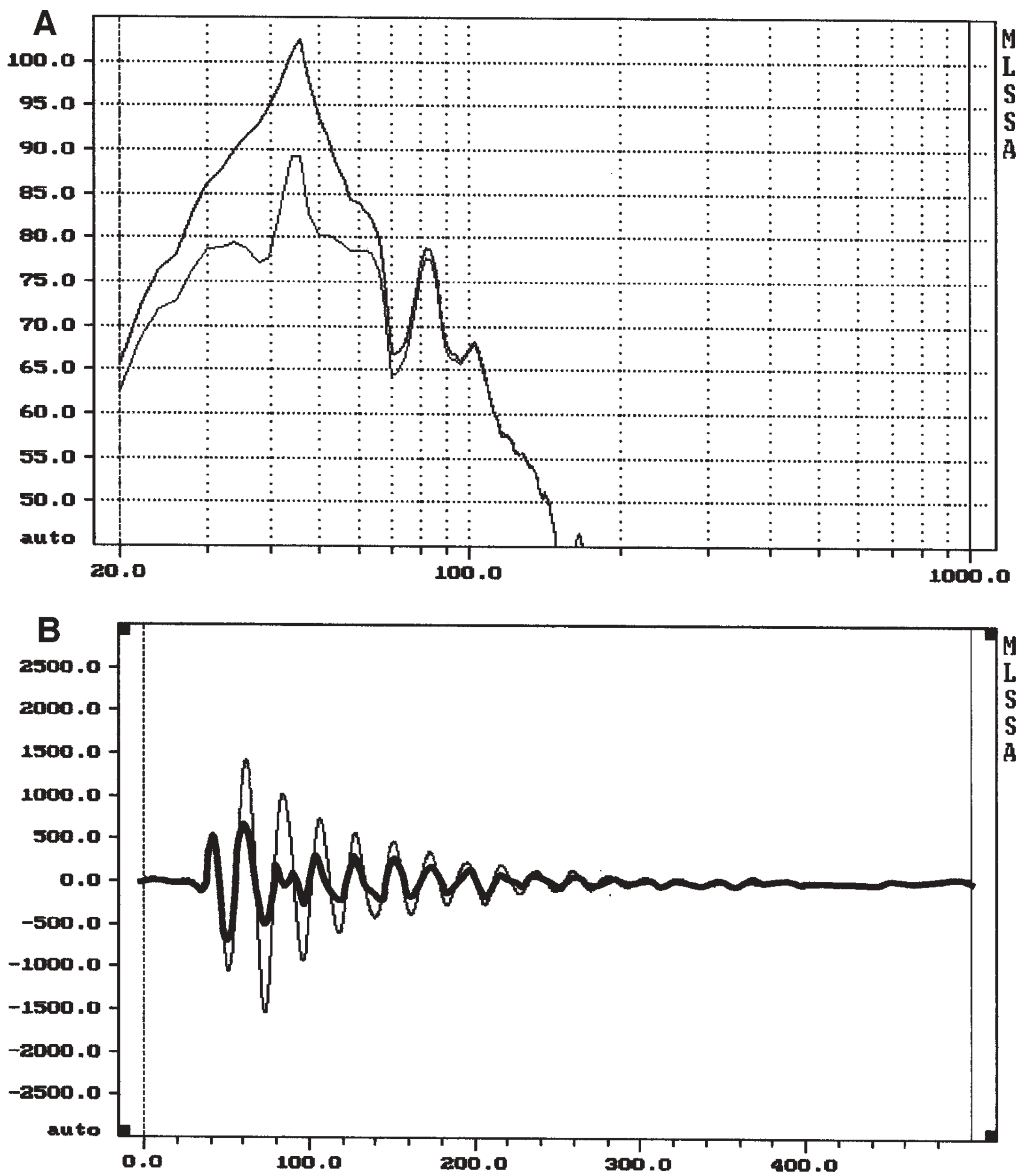


Figure 12. One-third octave equalization viewed with MLSSA (A); time domain response (B).

Conclusions:

RMC is a simple and effective way to ensure smooth LF response in monitoring spaces that do not have extensive LF acoustical treatment or bass traps. Its application is intuitively simple and straightforward – and after you have adjusted any upper bass peaks due to room modes you may be surprised how low in frequency your recordings actually extend.

You can mix and match systems with and without RMC very easily, For example, the LSR6312SP subwoofer can be used with the LSR25P, LSR6332, or any other passive full-range system you choose.

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