3. Surround Sound Monitoring In The Professional Mixing Environment

This section addresses the various issues concerning monitoring for surround sound mixing. To some degree, the recommendations provided here are application-specific; that is, the requirements for music mixing can vary greatly from that of film mixing. In fact, some recommendations are even genre-specific: for example, speaker positioning for pop music mixing, where the surround monitors are typically treated as "equal partners," often carrying key musical elements, differs significantly from that of classical music, where the rear speakers generally are used only for room ambience. Nonetheless, there are certain recommended practices that should be adhered to in most if not all circumstances.

Room design is discussed in section 3.1. Recommendations are made regarding dimensions, acoustic treatment, and minimum ambient noise requirements.

Of course, a key element in any professional mixing environment is an accurate monitoring system, one which is free of distortion and coloration. Definitions of popular speaker types used in surround mixing, with recommendations for their use, are provided in section 3.2.

Also, because the aim of a successful surround mix is to achieve a balance between envelopment and localization (see section 2.1), the placement of the monitors is an equally critical issue. Comprehensive recommendations for speaker positioning is provided in section 3.3.

It is important to remember that most consumers do not listen to surround sound on state-of-the-art monitoring. Surround mixes should therefore be referenced on systems that approximate the typical home theater experience and the effect of bass management (utilized by most consumer systems) should also be checked. Section 3.4 addresses bass management in detail.

Once positioned, the speakers in a surround mixing environment must be calibrated correctly. Recommended reference listening level is described in section 3.5 and the recommended procedure for speaker calibration is given in section 3.6.

Finally, the formulas for compensatory delay, when required, are given in section 3.7.

3.1 Room Design and Acoustic Treatment

From experience gained thus far, it seems that the average listener adapts over time to asymmetrical (both left-right as well as front-back) speaker positions. The goal of creating the best average presentation across the main speakers in a surround sound environment can best be attained by having more diffusion in the mixing environment rather than less. A neutral, as opposed to absorptive, monitoring room is optimum.

To as great a degree as possible, early reflections should be suppressed. Because the rooms that home theaters are typically installed in have no identifiable pattern of early reflections, significant early reflections in the professional mixing environment will be misleading. Appropriate amounts of low-frequency absorption should be deployed at least on the ceiling and on two of the four walls.

In addition, there should be as much diffusion as a budget will allow. From simply deploying everyday furniture and artifacts (shelves and bookcases, marble statuettes of one's significant other, etc.) to full-on quadratic residue diffusers, increasing diffusion helps flatten the spectral response of a room.

To summarize: the more uniform (diffuse) the ambience in the professional mixing environment, the more site-independent the resultant mixes will be.

3.1.1 Dimensions

No two room dimensions should be equal. Preferably, all three dimensions should vary by well-known ratios such that the low-frequency nodes generated in the three axes of a rectangular model are spread uniformly throughout the low three to four octaves. The ceiling height ideally should be greater than 11 feet.

3.1.2 Background Noise

Background noise with all equipment powered on should optimally not exceed 25dB SPL A-weighted.

3.2 Monitoring Recommendations

This section contains recommendations for speaker type. In all circumstances, appropriate amplification with sufficient headroom before clipping (at the recommended listening level; see section 3.5) is an absolute requirement. Self-powered mid-field monitors often provide the best solution for surround monitoring; in addition to the convenience factor, they can be easily moved and repositioned if necessary (see section 3.3). They also come with matching amplification and obviate the need for speaker cabling.

3.2.1 Full Range vs. Satellite

For the purposes of this document, "full range" speakers are defined as those which are capable of reproducing frequencies of at least 18kHz or higher at the high end, and 40Hz or lower at the low end. Surround mixing should always be done on identical full range speakers of the same brand and model, plus a subwoofer.

"Satellite" speakers are typically found in consumer home theater systems. They are much smaller in size than full range speakers, and have a very limited low end response, relying instead on a subwoofer to deliver bass frequencies. Surround mixes should be checked on a satellite speaker system, preferably one that emulates a typical consumer home theater environment. (See section 2.3)

All speakers must be correctly calibrated so that they are not only equally matched in level, but so that their crossover frequencies are aligned to that of the subwoofer being used in order to ensure a flat frequency response. This is important whether bass management is being used or not. Of course, as with stereo mixing, it is critical that all speakers be wired in phase. See section 3.6 for detailed instructions on how to correctly calibrate all surround monitors, including the subwoofer.

3.2.2 Direct Radiator vs. Dipole Speakers

Most loudspeakers designed for professional applications are of the direct radiator variety, where the speaker cone fires in one direction only. This type of design provides the smoothest frequency response as well as the best localization qualities — it is easy to perceive exactly where the sound is coming from.

Despite the fact that most theatrical installations use direct radiator speakers (albeit in arrays — see section 2.4), some consumer home theater systems employ dipole speakers in an effort to emulate the wash of sound that occurs in a large room such as a cinema. Dipole speakers radiate signal in opposite directions at the same time, at equal energy but with opposite polarity. Thus, they can provide better envelopment than direct radiator speakers, but with very poor localization. Also, due to their construction, dipole speakers have limited bass response (unless they are quite large) and so generally require the addition of a subwoofer, making them fall into the category of "satellite" speakers. (See section 3.2.1)

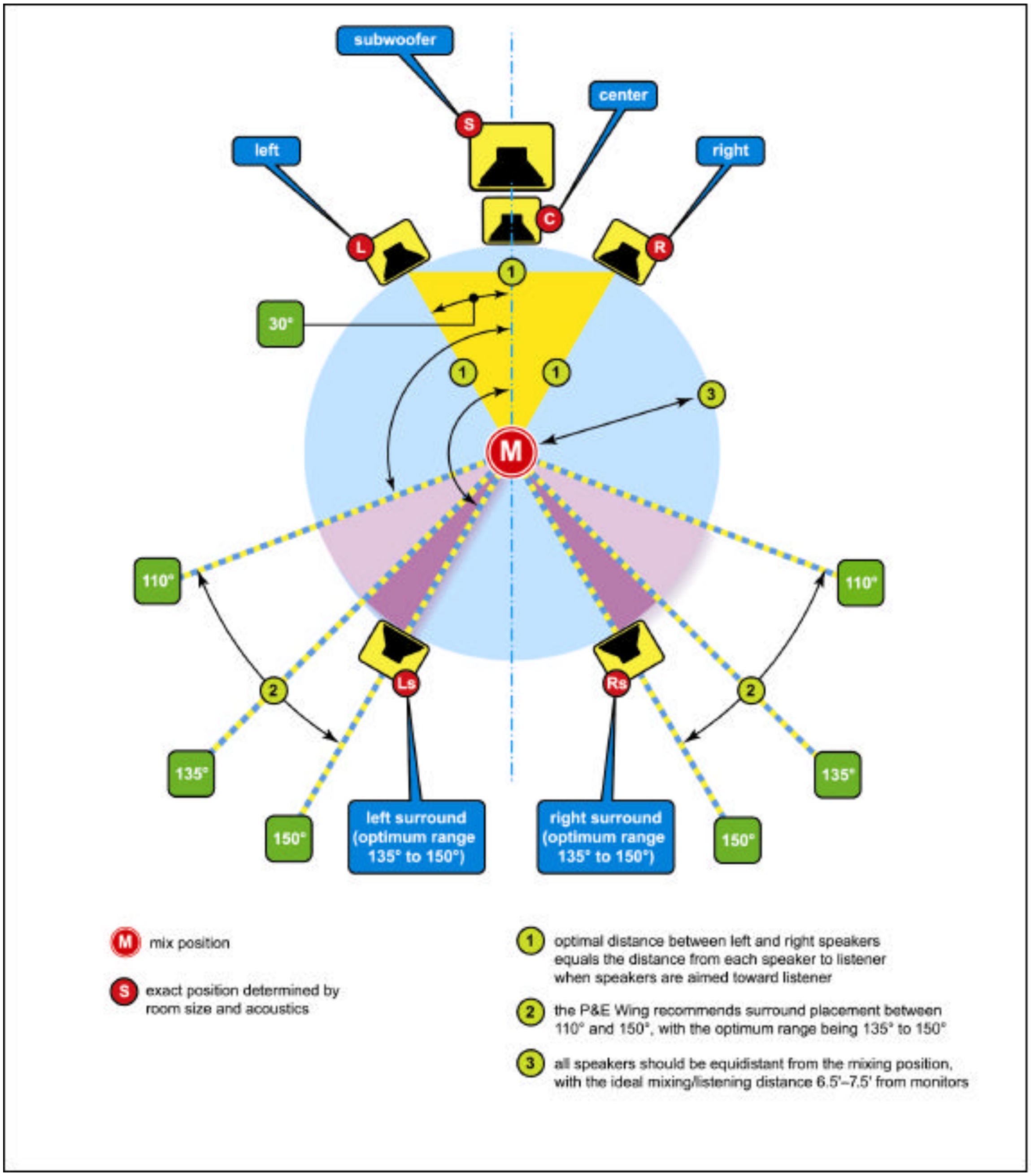
Only direct radiator speakers should be used for music surround sound mixing. Because of their dependence upon reflective surfaces and the phase anomalies inherent in their design, dipole speakers will produce inaccurate results when placed in an acoustically tuned professional mixing environment. However, it may be helpful to check a surround mix on a consumer system equipped with dipole speakers, provided the system is physically located in a room that simulates a typical home theater listening environment. (See section 2.3)

3.3 Speaker Placement Recommendations

The goal of monitoring is, of course, to provide the engineer with as much accuracy as is possible. Much of this is down to the quality of the speakers and amplification being used, but in the world of surround sound, speaker positioning is an equally critical element. Moving speakers by just a few inches in distance or rotating them by just a few degrees in direction can cause a significant change in imaging, in frequency response, in envelopment / localization characteristics, or in some combination of all three.

That said, there are often physical conditions (such as room size or dimension) beyond the control of the engineer that dictate speaker placement in the professional mixing environment, and there is certainly no way to control how a consumer listening to surround sound situates *their* speakers. For these reasons, there is no intrinsically "correct" way to position speakers for surround sound production. Instead, it is our intention to provide a range of acceptable options, with a discussion of the applications best suited by each approach.

3.3.1 Main Speaker Placement



Recommended 5.1 surround sound speaker placement

The illustration above indicates the range of recommendations for speaker placement. As shown, all five main speakers in a 5.1 configuration should be positioned along the circumference of an imaginary circle at whose center is the mixing position (sometimes called the "sweet spot").
In order to avoid phase cancellation and comb filtering problems, it is absolutely

critical that the signal coming from all five main speakers arrive at the mixing position at the same time. This is best accomplished by having all five speakers equidistant from the mixing position. If this cannot be achieved because of the physical layout of the room, disparity in arrival time can be corrected with the use of delay. (See section 3.7.)

The optimum distance from the mix position is between 6.5 and 7.5 feet, depending upon the particular monitors being used and the size of the room.

In a 5.1 configuration, the "front wall" consists of the left, center, and right speakers (L, C, R). The center speaker should be directly facing the center of the mix position, with the left and right speakers toed inwards, with their axes oriented towards the mixing position. The L and R speakers should be angled by approximately 30°. This configuration is not only suitable for surround mixing but also offers compatibility with stereo monitoring and works well for many home theater systems, where the L and R speakers are not far from the video screen. Some surround mixing engineers prefer to work with a steeper angle (up to 45°) between the L and R speakers, while shallower angles (such as the 21° typically used in cinemas) can be useful for checking mixes destined for theatrical exhibition spaces. (See section 2.4.) If for some reason the L and R speakers cannot be toed in along a semi-circular arc and thus create a "flat" front wall, delay can be added to the center speaker in order to compensate for its earlier arrival time. (See section 3.7)

All three speakers in the front wall should be at the same height — optimally at ear height of the mixing engineer, or approximately four feet off the ground. The three front speakers should not be placed on the console meter bridge. If a video monitor is present, it should be raised or lowered (or positioned off to one side) as necessary, rather than moving the center speaker. The "rear wall" of surround speakers (Ls, Rs) should be at the same height as the front wall. Some surround mixing engineers prefer to raise the rear wall speakers slightly higher than the front wall, angled downward and directed to the mix position.

As shown in the speaker placement illustration on the previous page, the Ls and Rs speakers should also be toed inwards, with their axes oriented towards the mixing position. The acceptable range of angles for the rear speakers is 110° to 150° relative to the center of the mix position. This range of position options reflects the need to facilitate various mixing practices and thus the respective use of the surround speakers. Recent analysis of current practices shows a consistent relationship between the content in the surround channels and the accompanying surround speaker placement. This relationship can be best described as the *mix perspective*. A mix perspective where the listener perceives himself or herself as being “in the audience” often places only room ambience or effects information in the surround speakers. In this case, the wash of sound created when the surround speakers are placed more to the side, at angles of approximately 110°, may be preferable. Conversely, many popular music mixes utilize an “in the band” perspective in which the listener appears to be part of the ensemble and featured performers are placed in the rear surround channels as well as the front channels. These kinds of mixes benefit from the improved rear phantom imaging achieved by placing the surround speakers further back behind the listener, angled in at 135° - 150°. In most cases, this will yield the most satisfying music listening experience while still providing home theater aficionados with an excellent cinematic experience.

Another commonly used technique is to slightly offset the convergence angles of the front left and right speakers relative to the rear left and right speakers so as to create a wider "sweet spot." This typically involves aiming the front left and right speakers so they converge centrally one foot *behind* the mix position, and aiming the rear speakers so they converge centrally one foot in *front of* the mix position. A laser pointer, or the more low-tech approach of using two identical length pieces of string, can be useful in creating such a setup.

It is worth noting that the ITU (International Telecommunications Union) has recommended that the rear speakers be positioned more to the side of the listener, angled between 100° and 120°. (See section 1.) This recommendation, which was originally developed for television broadcast and not for music, represents a compromise between envelopment, which is strongest at 90°, and rear phantom imaging, which improves as the rear speakers are moved further back and are angled in more steeply. Although this practice has been adopted by many surround professionals in the film and broadcast industries, it may not be suitable for music applications where the rear speakers are used to carry vital musical information and not just ambience or effects. Speaker placement, therefore, need not be restricted to the ITU recommendation alone: at the engineer’s discretion, more extreme rear speaker anglings (at up to 150°) are acceptable, depending upon the program content being mixed.

3.3.2 Subwoofer Placement

The optimum location for the subwoofer in a surround sound system depends almost entirely upon the room dimensions and design, as well as the physical layout of other equipment in the room. The key to its successful placement is that its location not be apparent. If the listener is able to perceive the direction that the low frequencies are coming from, that is a sure sign that the subwoofer is not positioned correctly.

That said, <u>it is our recommendation that the subwoofer be positioned in front of</u>

the mixing position, between the left and right speakers. The reason for this is that bass-heavy elements such as bass guitar and kick drum are most often placed in one or more of the front wall speakers. Positioning the subwoofer off to the side or behind the mix position therefore compromises imaging and can contribute to phase smearing.

There are two basic techniques for identifying the optimum position for a subwoofer. One is to listen at the mixing position while an assistant physically moves the subwoofer around the room while signal with significant low-frequency content is being played. (If program material with sufficient low-frequency content is not available, an 80 or 100Hz sine wave, or band-limited pink noise, low pass filtered at 80 or 100Hz, can be substituted.) The second technique involves temporarily placing the subwoofer itself at the mixing position while the *listener* moves around the room — much easier on the back! Then simply re-position the subwoofer to the spot in the room (optimally along a boundary wall in front of the mix position, between the left and right speakers) that yields the strongest and smoothest bass response. Measurements taken by a trained acoustician can also aid in identifying the best position for the subwoofer in a particular room.

When positioning a subwoofer, beware of standing waves! This is most likely to occur if the subwoofer is placed in a symmetrical location, such as directly under the center speaker. Shifting it slightly off to the side can often reduce or remove standing waves and yield better sonic results.

Phase correlation with the main speakers is also an important consideration. If the subwoofer itself provides a phase switch, experiment with different settings. Alternatively, try rotating the subwoofer in 90° increments until the smoothest bass response is heard. (See section 3.6.)

In some rooms, particularly larger ones, more even bass dispersion and improved imaging can be achieved by adding a second subwoofer. Be sure not to position the two subwoofers so that they are firing directly across from one another, or phase anomalies will result.

Remember that by its very design, the subwoofer is band-limited and carries only low frequencies. As its crossover frequency rises, the ability to localize its position increases. It is therefore recommended that any low-pass filter internal to the subwoofer should be set no higher than 120Hz. This is distinct from the bass management crossover point, which is typically set at 80Hz (see Section 3.4).

3.4 Bass Management

The term *bass management* refers to the redirection of low frequencies from the main channels to the subwoofer, so that it reproduces all the low frequencies in a surround mix, including the dedicated ".1" LFE channel (see section 1.3). Because most consumer home theater systems use satellite speakers instead of full range speakers, their amplifiers almost inevitably employ crossover networks for this purpose. Therefore, <u>surround mixes should always be checked on a bass-managed satellite speaker system</u>.

Creating a surround sound mix without bass management is sometimes referred to as mixing "direct to sub." <u>Bass management is not required for full range speakers and may in fact significantly change the overall sound when switched in, so it is an option that may be employed during surround mixing at the discretion of the engineer</u>. However, it is worth noting that many studio monitors, including some termed "full range," are not flat to the bottom octaves and will not reproduce sounds heard through bass-managed home systems. Bass management therefore allows the detection of unwanted low frequency information such as rumble which may otherwise be inaudible in the studio — but which the consumer may well hear in his or her home theater environment! It also allows the surround mixer to check the interaction between the LFE channel and redirected low frequencies from the main channels. Potential phase cancellation or phase smearing problems in the consumer system can thus be avoided.

Accurate calibration of both the main speakers and subwoofer is an absolute requirement for proper bass management. (See section 3.6) This will ensure a seamless transition between the high frequencies being radiated by the main speakers and the low frequencies being output by the sub. <u>We recommend setting a bass management crossover frequency of 80Hz</u>. This is not only the frequency most commonly used by consumer home theater systems, but its use also significantly reduces localization of the subwoofer and therefore adds flexibility in terms of its placement (see section 3.3.2).

It is worth noting that some consumer home theater systems offer a variety of bass management options. Some allow only the low frequency information from selected main channels (instead of all of them) to be redirected to the subwoofer. Other bass management options allow for playback through systems that contain no subwoofer at all, redirecting the LFE content to the front left and right speakers instead. It is worth checking the effect of each of these processes on a mix in progress in order to ensure a satisfactory result even when these kinds of options are engaged.

3.5 Reference Listening Level

The recommended reference listening level for surround sound production is in the range of 79 to 85dB C-weighted. However, it is important to check mixes at varying levels, from very soft (as low as 40dB) to quite loud (not to exceed 92dB, however, and only for short periods of time).

3.6 Speaker Calibration Procedure

Along with physical placement, correct speaker calibration is the single most important factor in ensuring an accurate monitoring environment. The tools required for calibrating a surround sound speaker system are much the same as those required for a stereo system: a source for pink noise and/or tones, and a Real Time Analyzer (RTA) or Sound Pressure Level (SPL) meter, with a reasonable quality omnidirectional condenser microphone. RTA metering is the preferred method for calibrating a surround sound speaker system because an SPL meter will yield a less accurate result since only the peak of one band is measured. If an SPL meter is used, set it to C-weighting on the slow scale.
It is also helpful to have a number of well-recorded commercial surround sound releases on hand to play back in order to do final “tweaking” by ear.

In addition to console oscillators and onboard pink noise generators, there are a number of surround sound calibration tapes and CDs available which can be very helpful in calibrating speakers. These range from professional releases (such as those available from MLSSA, Tomlinson Holman, and Dolby) to numerous consumer DVDs and CDs. The key is to have access to both full bandwidth and band limited pink noise (low-pass filtered at 80 - 120Hz) and a sine wave at the subwoofer crossover frequency (80Hz in most instances).

The need for precise speaker calibration should be obvious: Only if the system plays back accurately can it be used to produce surround sound mixes which will translate well in other listening environments. The converse is also true: If the speaker system used for mixing is not correctly calibrated, there is a greater likelihood that the resulting surround mixes will *only* sound good in the studio in which they were mixed, and nowhere else.

After making sure that the signal path from the console is in proper electrical phase to all speakers (a near-certainty if using powered monitors and correct balanced wiring), the first, and perhaps most important calibration is the acoustic phase alignment of the subwoofer(s) at its crossover point (again, 80Hz in most instances); incorrect alignment will cause a drop in the frequency response of the entire system at the crossover point. Some subwoofers have built-in phase matching controls which allow adjustment in precise 90° steps.
Following is the recommended procedure for subwoofer phase alignment: (Note

that this procedure assumes that all main speakers in the system are full range and not satellite.)

1. Route a sine wave at the crossover frequency (generally 80Hz) at a moderate listening level to the left front and right front speakers and to the subwoofer.

2. Using an RTA or SPL meter, note the signal level at the mix position.

3. If the subwoofer provides phase controls, toggle the switches, noting the signal level at the mix position each time. Leave the switch at the position which yields the maximum signal level.

4. If the subwoofer does not provide phase controls, simply rotate it by hand at 90° increments until the signal level at the mix position is highest.

The next step is to set the reference level for the main speakers. We recommend a nominal reference level of 79 - 85dB SPL (see section 3.5). The important thing here is not so much the actual SPL chosen, but that all five main speakers are set to that same chosen level. Following is the recommended procedure for reference level adjustment for the main speakers: (for purposes of illustration, a reference level of 85dB is assumed)

1. Turn off all speakers and subs except the front left speaker.

2. Place the calibration microphone at the center of the mix circle, at ear height, facing directly towards the center speaker. If an RTA is being used for measurement, set it to read 85dB. If an SPL meter is being used for measurement, set it to C-weighting on the slow scale, and then set it to read 85dB.

3. Route pink noise at 0 vu to the front left speaker and raise the speaker's amplifier level until all bands of the RTA (or the SPL meter) read 85dB.

4. Continue by routing pink noise to each remaining speaker in turn (front right, then center, then rear left, then rear right), adjusting their amplifier levels so that the RTA or SPL meter reads 85dB for each. In each instance, leave the calibration microphone at the same fixed position as in step #2 above.

Some professionals instead suggest pointing the calibration microphone towards the phantom center when measuring the rear speakers. Others recommend pointing it at 90° left and 270° right when calibrating the rear speakers. Though these techniques will yield slightly different results, the fundamentals remain the same.

The final step is to set the level of each subwoofer relative to that of the main speakers. Common practice is to calibrate the subwoofer approximately 4dB above the reference level of the main speakers. This procedure differs somewhat depending upon whether the subwoofer is receiving the LFE channel only or whether bass management is being utilized to route signal to it from some or all of the main channels.

<u>The recommended subwoofer calibration procedure when no bass management is being used is as follows</u>:

1. Turn off all five main speakers.

2. Route band-limited pink noise (low-pass filtered at 80 - 120Hz) at 0 vu via the LFE channel bus to the subwoofer and raise its amplifier level until the RTA or SPL meter reads +4 dB over the selected reference level (i.e. 89dB if the selected reference level for the main speakers is 85dB).

3. Turn on the front left and right speakers.

4. Route full frequency pink noise at 0 vu to the front left and right speakers as well as to the sub. Adjust the subwoofer amplifier so that the gain boost when adding the subs to the mix does not exceed 4 - 6db, as measured by the RTA or SPL meter.

<u>The recommended subwoofer calibration procedure when bass management *is* being used is as follows</u>:

1. Route band-limited pink noise (low-pass filtered at 80 – 120Hz) at -10 vu via the LFE channel bus to the subwoofer. (The 10dB of attenuation compensates for approximately 10dB of "in-band gain" in the LFE channel as compared with a main channel.)

   Note: "In-band gain" refers to the fact that the level in each 1/3-octave band within the frequency range of the subwoofer is 10dB above the level in each 1/3 octave band in each of the main channels, averaged across the main frequency range. This does not mean that the LFE channel is 10dB higher in SPL than the main channels, however, due to the broader bandwidth (and correspondingly greater energy) in the main channels.

2. At the same time, route band-limited pink noise (low-pass filtered at

80 - 120Hz) at 0 vu via a single bus that is sending signal to the subwoofer via the bass management circuitry.

3. Raise the amplifier level of the subwoofer until all bands of the RTA (or the SPL meter) read at the selected reference level.

Note that, following this calibration procedure, the subwoofer level may need to be adjusted up or down by a dB or two to compensate for heavy bass trapping (or lack thereof) in the room. The best way to do this is to listen critically to some commercially recorded surround sound music while seated at the mix position. Some subwoofers have DIP switches that allow their level to be adjusted in fine increments of plus or minus 1 or 2dB.

Also note that, following speaker calibration, the overall gain of the system is mathematically up to 12db louder, excluding the sub (i.e., a reference level of 85db for each individual speaker actually sums to 97db at the mix position with all five main speakers driven).

3.7 Use of Delay

As noted in section 3.3.1, delay may be used to compensate for non-coincident (differing) arrival times if it is not possible to place all five main speakers equidistant from the mix position, or if it is not possible to angle them correctly (for instance, if there is a "flat" front wall, with the L, C, and R speakers in a straight line).

The following formula should be applied: For each foot of distance disparity, add .88 milliseconds of delay. (For each meter of distance disparity, add 2.94 milliseconds of delay). For example, if the rear speakers are two feet further away from the mix position than the front speakers, the signal going to the front speakers should be delayed by 1.76 milliseconds. In the case of a "flat" front wall, delay should be added to the center speaker.

It is important to note that the use of delay is not recommended unless absolutely necessary. It provides a far less satisfactory solution than actually positioning and angling speakers correctly!