VI. THE LISTENING ROOM

A lot of popular misconceptions exist concerning listening rooms, the proper placement of loudspeakers with respect to room boundaries (walls) and the overall best listening position within a room. Many an audiophile has fallen prey to such misconceptions and friendly (but poor) advice, only to end sadder but wiser by the experience. Indeed, a listening room with good acoustics is usually a blessing and a source of continuing enjoyment for any serious audiophile. By contrast, a listening room with poor acoustics can represent a real stress-inducing challenge with respect to mitigating its problems, requiring a combination of patience, understanding, ingenuity, resourcefulness and a lot of perspiration.

Therefore, it is important to understand the basics of how various aspects of a listening room interact with loudspeakers, and the factors that affect our perception of the total sound field and the realism of reproduced music at the listening position. (See section covering Loudspeaker Placement.)

To begin, imagine a room of arbitrary size with speakers at one end and a listener at the opposite end (see Fig. 1). In addition to the direct-path sound, the listener also hears sound energy reflected off the wall behind the speakers, the two side walls, the ceiling, the floor and the wall behind the listener. Each of these reflected-sounds arrives at the listeners ears with a time-delay based upon the path length traveled by the sound at a velocity of about 1130 feet per second (approximately 13.6 inches each 1/1000 of a second).

Depending upon the delay-time of the reflected sounds, and whether the original sound was largely of a continuous nature (organ note) or a transient (plucked string), the listener may perceive the combination of the direct and reflected sounds either as a shift in overall spectral-balance or as an "echo" that might be pleasant (adding ambiance) or distracting (degrading transient-details or intelligibility). The spectral-balance of the loudspeaker's direct-arrival sound is modified by the delayed reflected-sound as it combines with the direct-sound in a manner that creates what is called a "comb-filter" response. This is because the fixed-delay of the reflected-sound produces partial cancellations at those frequencies where it is out-of-phase and enhancements (peaks) at those frequencies where it is in-phase (see Fig. 2).

The ability of a person to detect the presence of an "echo" added to a sharp musical transient by a room reflection is related to what is called the "fusion-time" of the hearing process. This may vary from as little as 4 milliseconds (4/1,000 of a second) to as much as 20 milliseconds, depending upon the hearing acuity of the individual. Generally, if the listener hears the reflected sound within their "fusion-time", it will be perceived as an alteration in spectral balance. However, if its arrival exceeds the fusion-time, the listener is more likely to perceive it as an echo, especially if the sound is transient in nature. Either way, reflected sounds having a loudness nearly equal to the loudness of the direct sound are to be avoided. This is especially true if two or more reflected sounds arrive at the listeners ears at the same time. As explained below, this is a good reason for avoiding loudspeaker locations that result in back-wall reflections arriving at the listening position at the same time as those from the side-wall.

For example, it should be relatively easy to understand that a room in the shape of a cube would represent the worst possible listening condition because a sound radiated into the room would tend to be subject to reinforcement and cancellation at the same set of frequencies because of the similar path lengths of the reflected sounds. A square-shaped room (identical length and width) is the second worst shape.

It should also be obvious that certain room dimensions and locations for the loudspeakers and the listener within the room can be employed to mitigate the problem. Indeed, certain optimum ratios of length-to-width-to-height do exist and can yield outstanding results if the user has the luxury of constructing a new room for listening. However, if the dimensions of the room are less than optimum, at least it is possible to lessen the bad effects of troublesome reflections by carefully choosing locations for the loudspeakers and the primary listening position.

Another means for diminishing the effects of undesirable reflections is by covering reflective areas along walls, ceiling and floor with proper amounts of efficient sound absorbing and/or time/frequency dispersive materials.

Some of the important aspects and criteria regarding listening rooms and loudspeaker placement that should be understood and appreciated by the serious audiophile are:

1. An acoustically-dead, reflection-free room does not provide the best listening environment.

   A room devoid of acoustical reflections (referred to as being anechoic) usually does not sound "natural" because our sub-conscious "visual assessment" of the room conflicts with our aural assessment based upon what we hear. Thus, music reproduced within a truly reflection-free room would tend to sound good in total darkness but un-natural with the lights on (using recordings containing good hall ambiance). However, few rooms exhibit anechoic response below about 200 Hz, because of the inefficiency of most absorbing materials at lower frequencies, leaving typical "anechoic" rooms sounding somewhat bass-heavy.

2. "Good speakers" tend to be more critical with respect to their location within the listening room.

   The effect of room reflections is usually much more pronounced with an accurate loudspeaker than with a loudspeaker whose curve of amplitude versus frequency already contains a number of peaks and valleys. When the peaks and valleys of the room response are superimposed on the response of an accurate loudspeaker, the degradation in response is much more evident than when the effect of the room is combined with the "jagged" response of the poor loudspeaker. This effect is especially evident as the location of an accurate loudspeaker is changed from one position to another within a room.

3. "Good speakers" can only provide their full potential for achieving an accurate soundstage at carefully-selected listening positions within a room.

   It is true that an accurate loudspeaker will usually provide a better and more believable sound-stage than a poorly designed or matched pair of loudspeakers, regardless of their location within a room. However, a loudspeaker with radiation lobes pointing everywhere may generate a diffuse soundstage that seems more stable, though imprecise, than that of an accurate loudspeaker whose imaging might appear to shift strongly as the listening position is varied. But properly positioned, usually symmetrically with respect to side-walls and the listening position, an accurate and well-matched pair of loudspeakers (like the SC-V) can provide an incredibly lifelike and stable soundstage that poorly-designed loudspeakers with a diffuse characteristic can never even approach.

4. <u>The height of the loudspeaker (its center) above the floor is important to achieving a life-like spectral-balance and ambiance.</u>

The hearing of most humans is reasonably acute with respect to discerning the relative height of a sound source above the floor. The hearing process basically uses two separate mechanisms in determining height:

1) the spectral shift of certain frequencies caused by interference between the direct sound from the source and the reflected sound off the floor and/or ceiling and,

2) the spectral-processing that takes place within the pinna or outer-ear.

The existence of this spectral shift and processing became quite apparent with the advent of home-video systems and their use of three front-channel loudspeakers. Many early home-video systems placed the two side-channel speakers with their center at ear height but with the center-channel speaker on the floor beneath the screen. But it was soon discovered that as someone walked across the movie stage while talking, the spectral-balance of their voice changed markedly as the sound source shifted from a side-channel speaker to the center-channel speaker. As a consequence, most high-quality home-video systems now configure all three front-channel speakers at the same height, near the floor. However, for an audiophile system, it is always best to locate the phase-center of both loudspeakers at "ear height" above the floor (about 35-40 inches when seated in a chair of average height). The phase-center of the SC-V is approximately 39" above floor level, corresponding to average ear height when seated.

5. <u>Floor coverings and ceiling texture are important considerations.</u>

The presence of the floor provides a substantial boost in low-end bass for loudspeakers with a woofer or sub-woofer located near the floor. This occurs because a "mirror-image" of the woofer appears in the floor, providing a near-doubling of the sound level. For this reason, it is important to cover the floor, when possible, with a heavy wool rug (preceded with a thick layer of wool underfelt). Natural sheep's wool has been found to be one of the best of all sound-absorbing materials.

This treatment of the floor will also improve the quality of the upper-bass and lower mid-range reproduction by reducing the level of these frequencies to one more consistent with that of higher frequencies where the relatively narrow vertical dispersion of most loudspeakers prevents much of the radiated power from bouncing off the floor, except at longer distances where the vertical angle becomes small.

The usually greater distance from the ceiling to the radiating portions of a speaker provides a longer path length to the listener than reflections from the floor, resulting in a perception similar to that of a reflection from a side-wall. In small rooms with a low ceiling, however, reflections from the ceiling can result in a harsh sound or an unpleasant alteration in spectral-balance.

Ample evidence exists for favoring a ceiling with reasonably large (at least 2" x 6"), rough-hewn beams running perpendicular to the path from the speaker to the listener. Such beams break up and disperse the sound energy in a way that is perceived to be pleasant to most listeners. As an alternative, commercially available dispersive panels can be placed at and near the principal reflection area on the ceiling, with a similar result.

6. <u>Live-End/Dead-End room treatment</u>

The concept of a "Live-End/Dead-End" listening room has been around for more than a decade and is generally attributed to the well-known Don Davis. Its success in improving the sound quality of most rooms is attested to by its longevity among knowledgeable audiophiles. Basically, it involves treating a section of the wall behind either the loudspeakers or the listening position with an efficient type of acoustical absorbing material to reduce what are often called "slap-echo" effects. Properly done, a fairly dramatic improvement in room acoustics can be achieved by eliminating these "ricochet" sounds, caused by sound reflecting back-and-forth between the two parallel walls. Research accomplished by DAL has shown that a 4 foot wide by 7 foot high sheet of 3 to 4 inch thick acoustical foam (now available in black or decorator colors) placed on the wall immediately behind the listener can often turn a problem-room into an audio pleasure-palace. By absorbing a large portion of the sound that would normally be reflected from the back wall, a "standing-wave" between the wall and the listener (alternate addition and cancellation between the direct and reflected wave components) is almost eliminated. Such standing-waves produce the peaks and valleys in frequency response that can destroy the quality of an otherwise excellent system.

7. <u>The location of doors, alcoves and windows within the room is often very important.</u>

Doors, alcoves and windows along the walls of a room can significantly alter the spectrum of the sound reflected from the wall area involved. Large glass windows, left uncovered, can be a source of harsh-sounding reflections worthy of being avoided.

8. <u>The angle subtended by the speakers from the listening position should exceed about 60 degrees (the distance from the listening position to each speaker should be less than the distance separating the speakers).</u>

With well-recorded music and highly-accurate loudspeakers (closely-matched as a pair), separation angles of as much as 100 degrees (or more) can be used without any degradation of the center-image for center-stage vocals or instruments. In fact, experience has shown that wide separations can be used to provide an even more realistic, accurate and stable soundstage than that achievable with closer spacing. In this regard, a pair of SC-Vs in a good listening room can easily rival the quality, wide soundstage and pin-point imaging of the best available stereo headphones.

9. <u>The symmetry of the listening room and the location of speakers within it are very important for best stereo imaging.</u>

   Accurate stereo imaging that remains stable throughout the audio spectrum requires that the listener "hear" reflected sound from both right and left directions with an equal time delay. This can only be achieved in a symmetrical room with the loudspeakers and the principal listening position located in a symmetrical configuration with respect to the side walls. <u>It is especially important that each of the two loudspeakers be located at exactly equal distances from the "primary" or "center" listening position if optimum imaging and a strong center-image is to be achieved.</u> This is because our hearing process evaluates and determines the location (direction of arrival) of a sound on the basis of the relative time-of-arrival and the relative amplitude of the sound as it is heard simultaneously by both ears.

   For truly optimal imaging, it is also best for the location of drapes, windows, etc. on both side walls to be arranged in a symmetrical manner.

10. <u>Loudspeakers should be located along a wall facing the shortest dimension of the room for most accurate reproduction of bass.</u>

    One of the longest-running myths in the audiophile industry that certainly needs to be set straight is that loudspeakers should always radiate along the longest dimension of the listening room.

    Fig. 3 illustrates the case with loudspeakers radiating along the longest axis of a rectangular room and the listener located some distance from the opposite-wall towards the center of the room. Simple acoustical analysis shows that this configuration yields a narrow soundstage and a lumpy bass-spectrum. This is because the sound reflected off the wall behind the listener creates a standing wave pattern that results in peaks and nulls in the low-bass response at the listening position. In addition, the entire end of the room behind the listener may actually behave as a resonant chamber with potentially deleterious consequences for reproduction of sound at the low-end of the spectrum.

    All of these potential problems can be avoided by simply rotating the room layout 90 degrees, such that the loudspeakers are located along the longest wall of the room with the listener seated adjacent to the opposite wall directly across from the center-point between the speakers. (Fig. 4 illustrates a typical room using this setup.) The listening position should be close enough to the back-wall (less than about one foot) to eliminate low-end standing waves between the wall and the listener.

    A thick sound-absorbing drape (preferably with a high percentage of sheep's wool) between the listener and the back-wall will further mitigate problems from developing at the low-end of the sound spectrum. (A low-cost alternative is to use a 3 to 4 inch thickness of sound-absorbing polyester foam, perhaps 4 X 6 feet, affixed to the wall behind an attractive drape, preferably one containing at least some natural wool (which will help absorb mid and high frequencies). This arrangement provides the most accurate spectral-balance, the smoothest and deepest bass, and the most natural imaging and soundstage.

11. It is usually best if the distance of a loudspeaker from the side-wall does not equal the distance to the back-wall.

If a loudspeaker is located equidistant from both the side and back walls, the distance being measured from the center of the front-surface to the relevant reflection point on the wall, a symmetrical cavity is formed. This may create enhancements of as much as 6 dB at some frequencies, resulting in a degradation of perceived sound quality, especially in the upper-bass and lower-mid ranges. Best overall response is usually obtained when the distance of the loudspeaker from the side-wall is either larger or smaller than the distance of the loudspeaker from the back-wall. This will prevent reinforcements of peaks and valleys from occurring at the same set of frequencies, thereby smoothing the overall frequency response of the system. For a typical room of average size, e.g. 8 feet high, 13 feet wide and 20 feet long and a listening distance of from 8 to 12 feet, a good starting point would be that depicted in Fig. 4, i.e. a distance between the loudspeakers and the back-wall of approximately 3 feet (36 inches) and a distance to the side walls of about 4 feet (48 Inches).

After listening for several minutes to a variety of music at these distances, either shorten or lengthen the distance to the back or the side walls by about 6 inches and determine whether or not the change made an improvement in the overall spectral balance. Patient experimentation with different distances will usually be necessary before the optimum distances to the back and side walls are discovered.

12. The resonant frequencies associated with the length, width and height of the listening room and the location of the loudspeakers within the room tend to dominate our perception of sound quality, especially at bass frequencies, and imply the existence of optimum ratios for room dimensions and the best location for loudspeakers within a room.

In reality, the loudspeaker and the listening room are components that interact with each other as members of the same system. In fact, it is usually the resonant frequency of the room that dominates the lowest frequency which an audiophile loudspeaker can reproduce. But that lowest frequency can vary substantially from one part of the room to another because of the standing-waves that are always present. These standing-waves set up a pattern of modes at each frequency above resonance, consisting of minimum and maximum levels of amplitude, much like hills and valleys are portrayed on a topographical map. And each dimension of the room (its length, width and height) produce standing-waves with corresponding resonant frequencies and modes (and their harmonics). Therefore, locating an "optimum" position for loudspeakers within a room requires first a definition of what optimum implies: maximum low-bass extension, smoothest overall bass response, widest stereo sound stage with best imaging, etc.? No one location in a room is likely to be capable of fulfilling all such definitions of optimum - a compromise is almost always necessary (See par. 10, above).

The lowest natural resonant frequency of a room is called its "fundamental resonance". The fundamental resonance occurs at that frequency for which the length (or longest dimension) of the room is equal to one-half of a wavelength. A half-wavelength, expressed in feet, is found by dividing 567 by the frequency in Hertz (based upon air at a temperature of 70 deg. F with average atmospheric pressure and humidity).

Conversely, since wavelength and frequency are inversely related, the fundamental resonance of a room (in Hertz) may be determined by dividing 567 by its length in feet. Thus, a room with a length of 20 feet has a fundamental resonance equal to 567/20, or approximately 28 Hz. If the room has a width of 13 feet, another resonance occurs at about 44 Hz. A ceiling height of 8 feet implies a third resonance at about 71 Hz. Harmonic resonances and anti-resonances occur at higher frequencies, being whole-number multiples of each of the fundamental frequencies.

At each fundamental bass resonance of a room, a maximum Sound Pressure Level (SPL) occurs near the center of the two walls perpendicular to the relevant dimension (length or width). Minimum SPL's, corresponding to each of these maximums, are located in the geometric center of the room. Therefore, the center of a room tends to be the poorest listening position if maximum, low-end bass is desired.

If a loudspeaker excites a given resonance mode within a room, the resulting "system" resonance (Fs) will occur at a frequency that is approximately equal to the square-root of the product of the relevant room resonance (Fr) and the loudspeaker resonance (Fl), i.e. $Fs = (Fr \times Fl)^{1/2}$.

By making the ratios of the room's height, width and length equal to multiples of one-third (1/3) of an octave, e.g. $1 : 2^{2/3}$, it is possible to arrive at an overall room response, at least at bass-frequencies, that is relatively smooth and audibly un-objectionable. Assuming that the height (H) of the room is made equal to one (1), the ratios (multipliers) for the width and length of several types of rooms, along with their fundamental resonances (for H = 8 feet), are as follows:

	- - - - - Ratio - - - - -			Resonances in Hertz for H = 8 ft.		
Type of room	Height	Width	Length	f3	f2	f1
Small	1	1.26	1.59	71	56	45
Average	1	1.59	2.52	71	45	28
Long	1	1.59	3.18	71	45	22
Large	1	2.52	3.18	71	28	22

From the above table, it may be seen that an "average room", with a ceiling height of 8 feet, would have a width of approximately 13 feet and a length of about 20 feet, would exhibit fundamental resonances at 71 Hz., 45 Hz., and 28 Hz.

Exciting the f1 and f2 fundamental resonance modes to their full amplitude requires that the source of the sound (loudspeaker) be located at the center of the wall facing the relevant room dimension. Moving the sound source from this center position toward the corner of the room will usually alter the frequency of resonance and excite the second room resonance mode.

(The corners of a room at the ends of the longest wall usually represent the best location for sub-woofers.)

If, in the "average room" described above, the listening position is located against a long wall (20 feet) at its center (10 feet from each end) and the loudspeakers are located along the opposite long wall, about 3 feet from the back-wall and 4 feet from the side-walls, the angle subtended from the listener is about 65 degrees and the listening distance to each loudspeaker is about 11 feet (see par. 10 above and Fig. 4). This arrangement of loudspeakers and the listening position within an "average room" represents a good starting point.

These dimensions and ratios are suggestions only, based upon the experience of many researchers in the field of acoustics. They are meant to serve as a practical guide, for no guarantee can be given that they are optimum for all situations, all types of loudspeakers and/or all possible locations of loudspeakers within the room.

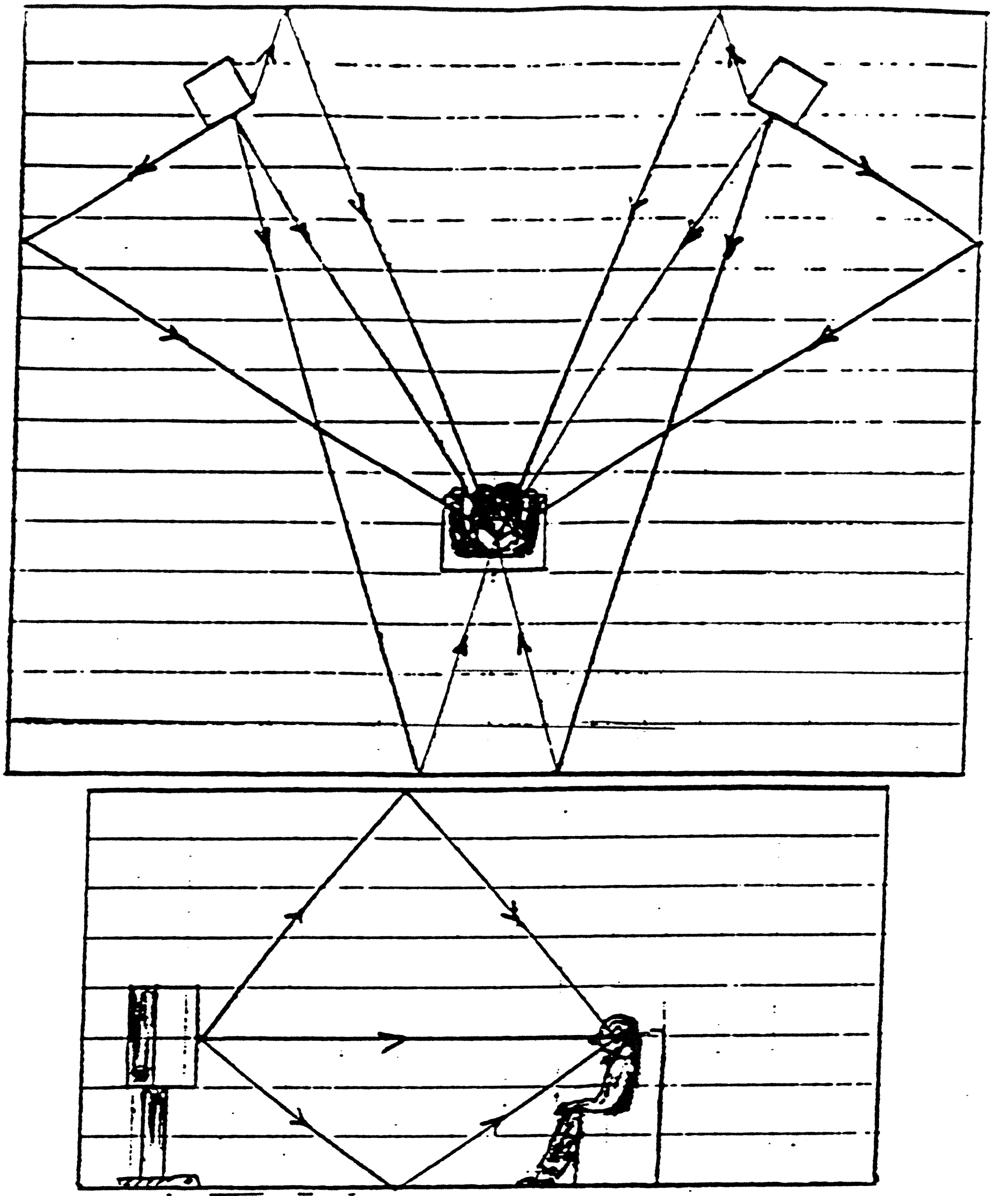

FIGURE 1

Typical room showing primary (1st-order) reflection modes.

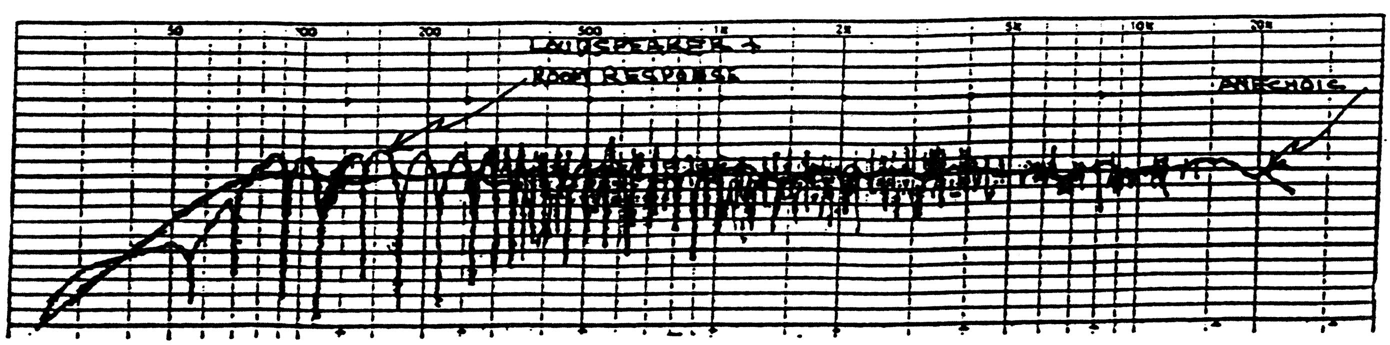

FIGURE 2

Typical plots of amplitude vs. frequency for a loudspeaker showing both anechoic and room responses.

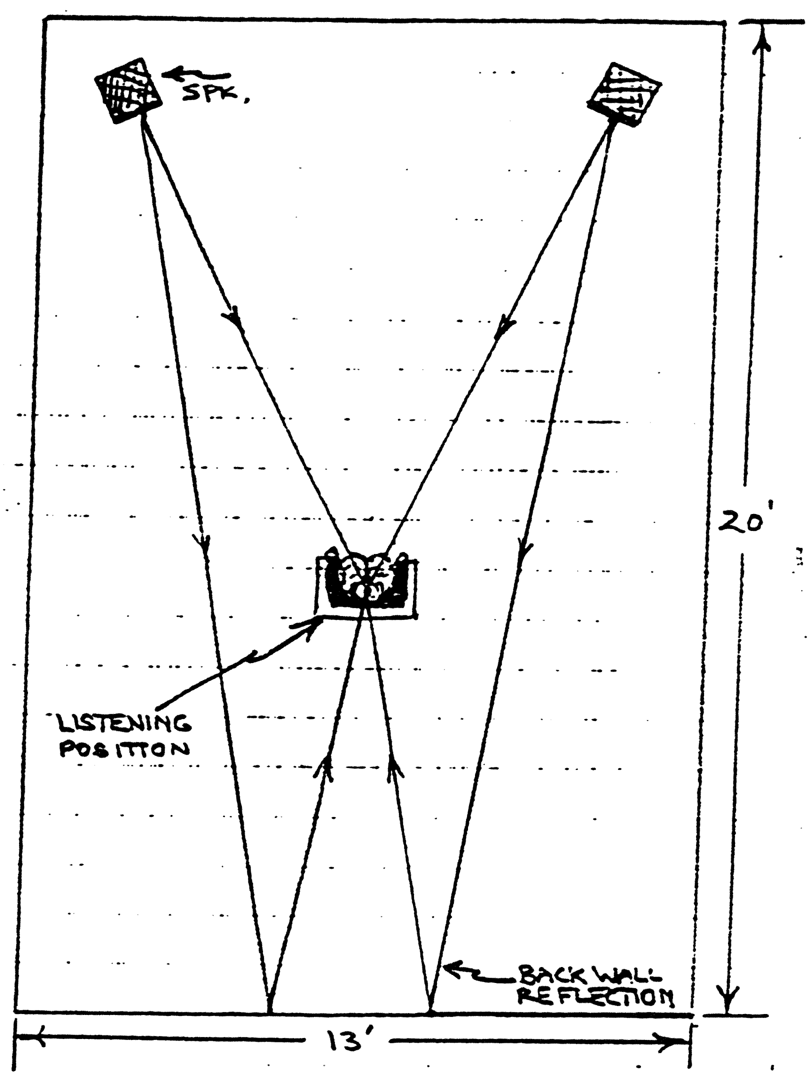

FIGURE 3

Loudspeakers "firing" along the length of a 20' x 13' room, showing reflections off of back-wall which produce large peaks and nulls in the response at bass frequencies.

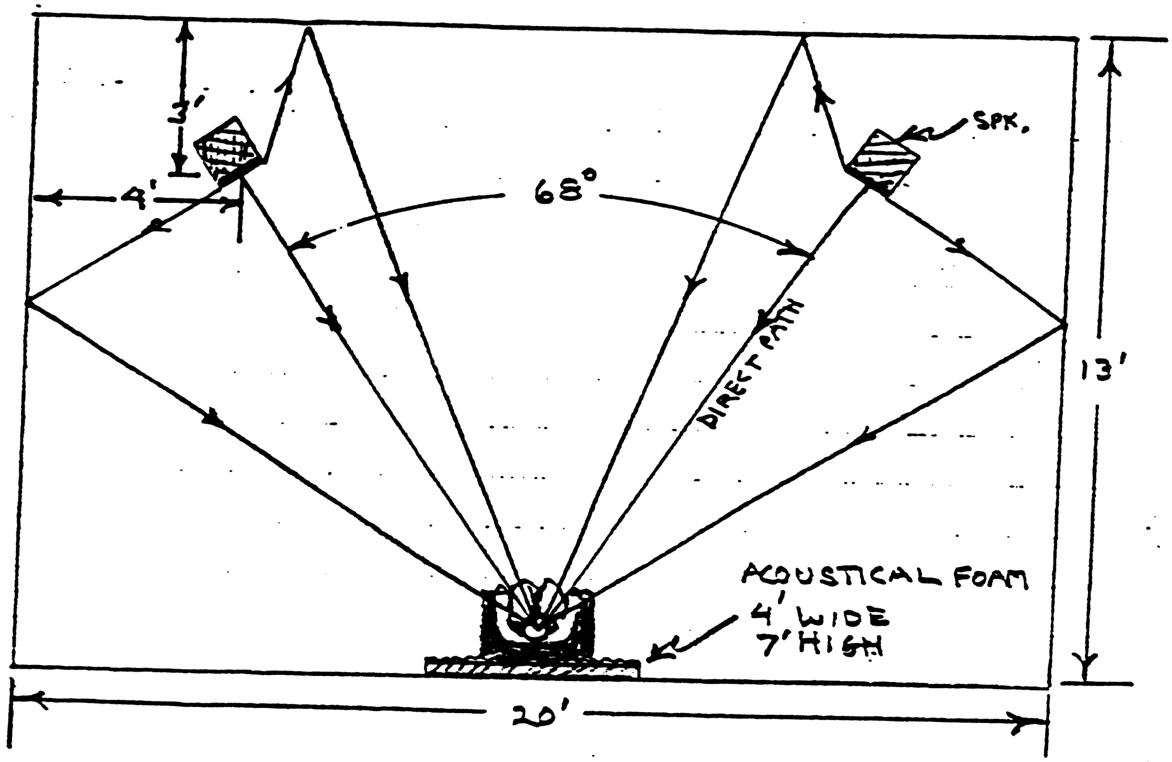

FIGURE 4

A good "starting-point" arrangement of loudspeakers and the listening position in a typically good room.

VIII. CARING FOR YOUR LOUDSPEAKERS

POWER HANDLING AND BURNOUT

It is generally accepted by today's audiophiles that fuses and other protective devices can be a source of audible distortion. As such, DAL has elected not to use such devices.

However, SC-V's sound very "clean" at high sound levels (SPL), with little evidence of the distortion produced by most other loudspeakers as a warning of potential "burn-out".

Therefore, it is very important that extreme caution be exercised to prevent exceeding the maximum "peak" design limit of the SC-V, which is about 250 watts (115 dB SPL) on short-duration musical transients (less than 10 mS in length). This peak rating corresponds to about 25 watts of average music or pink-noise power, which is equivalent to an average SPL level of about 105 dB (all SPL 's being referenced to a distance of 1 meter on-axis). However, since many of today's best power-amps are only rated for 250 watts output (and may produce distortion products well beyond that level which can nearly instantly damage your loudspeakers), it is best not to risk such situations. In the event of driver failure, the DAL Limited Warranty will be voided if any sign of a "burned" voice-coil is evident.

KEEPING YOUR LOUDSPEAKERS LOOKING LIKE NEW

Only select-grade, solid wood or natural wood veneers have been used to manufacture your loudspeakers. To protect their surface, a very hard and durable catalyzed finish has been applied to those models with a natural wood finish. Models with a black finish were either painted with a quality lacquer or hand-rubbed with a black stain.

The only care normally required to retain the original appearance of your loudspeakers is an occasional dusting or light rubbing with a soft, clean, dry cloth.

If the surface of your loudspeaker should inadvertently become stained, do not use a solvent of any kind without first experimenting with its use on an area of limited size where possible damage will not be visible (bottom of enclosure). Since some solvents are slow acting, it might be wise to test any "stain removing compound" for a period of at least an hour before using it on a visible affected area.

VII. COMPARING LOUDSPEAKERS

When comparing loudspeakers, plan to listen for periods exceeding one hour. This amount of time is needed for several reasons:

1. It is necessary to become "acclimated" to the acoustics of the listening room. Normally, fifteen to twenty minutes are required for our hearing processes to adjust to the reverberation and standing-wave properties that are unique to each room.

2. If the listener is unfamiliar with the amplifier, pre-amp, CD player, etc., time may be required to adjust to any unique qualities they might have before judging the speakers.

3. Time may also be needed to adjust to the quality and properties of the source material, CD's, LP's, etc., if the listener has not previously become familiar with them.

4. Once the above are accomplished, another thirty to forty minutes should be dedicated to getting past what the industry refers to as the "pizzazz" element of some loudspeakers. It was discovered many years ago that a large segment of the public could be initially seduced by loudspeakers designed with a prominent rise in the bass-response at about 80 Hz (kick-drum frequency), a modest rise in the response centered in the voice-range (to convey an artificial sensation of depth on vocals) and a third peak covering from about 7 to 12 kHz for accentuating snare and cymbal sounds. However, after comparing a loudspeaker with pizzazz-response to a loudspeaker with flat-response for about 30 minutes, the average listener will prefer the smooth, natural sound of the latter.

5. Last, but not least, it may be necessary to interchange the location of the speakers to rule out one position within the room being better than another. It may even prove desirable to try different locations within the room for both the speakers (as well as the listening location) in order to resolve which effects can be attributed to the loudspeakers and which to the room.

Listen to a wide variety of music and recording labels so as to reduce the possibility of recording flaws or unusual techniques that might bias the comparison.