HOME Theater

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Home Theater Acoustics

Volume Five

The ambience channel in a home theater system delivers a bandwidth-limited, mono signal to a pair of speakers which have been mounted above and to the side of the listener.

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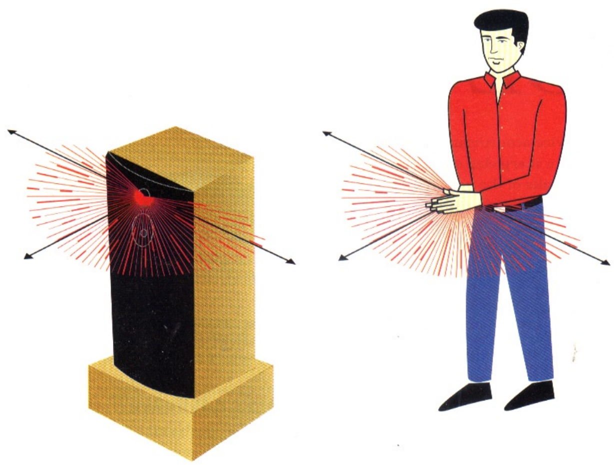
One of the first things the novice acoustician does upon entering a room is to deliver a sharp clap of the hands. This is followed by a grave shake of the head and comments about how bad the room sounds. Next comes a proposition to fix the room and the fee. The unsuspecting client then administers a sharp handclap, nods the head in agreement, and gives the guru a retainer. The only problem here is that these people are busy buying and selling modifications to the sound of their own handclap. We don't listen to a speaker while holding it in our hands, yet we can be tempted to consider acoustics based on the sound of our own handclap.

Home theater audio systems have an ambience channel. It usually delivers a bandwidth-limited (no bass), mono signal to a pair of speakers that have been mounted high on the wall and to the side of the listener. If you stand on a chair and clap your hands in the location of the ambience speaker, you will hear a very funny and undesirable sound effect. Is this really something we can hear? If so, do we want to listen to this sound effect or provide it to our clients? If not, there might be something we can do about flutter echo colorations.

THE ACOUSTIC CLAP TEST

On a practical basis, the only time that a self-administered and self-audited handclap is directly relevant to anything in audio is when the recording engineer is setting up mikes in a studio. Only in this special circumstance does the desired audio signal leave from and return to the same place. Listening to one's own handclap duplicates this round trip, acoustic process and thereby is a relevant test. If someone ever wants to know how a loudspeaker sounds to the listener, a different technique must be followed, one that mimics the actual speaker/listener acoustical path.

A handclap contains only high frequencies. For a loudspeaker, the high frequencies are directional, forward of the speaker box. To properly administer a handclap that mimics the high-frequency beaming pattern of a loudspeaker, the hands must meet at waist height while the clapper is facing the same direction that the speaker does. The body of the clapper blocks the expansion of the clap sound backwards. The listener is no longer in the clapper position; the listener is now seated in the listening position. This time, the handclap is cast forward from the speaker position



and is heard by the real listener. It is how the listener hears the speaker that counts and not so much how the speaker sounds to itself, at least in hi-fi playback settings.

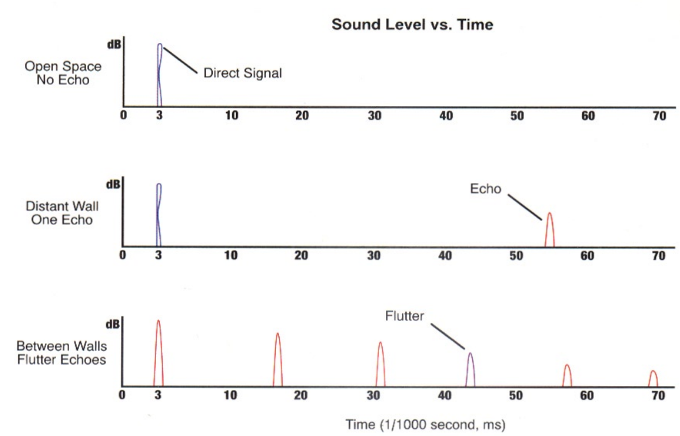
In order to properly evaluate the consequence on the listener of the strange sound we heard when standing on the chair and clapping our hands overhead and near the mounting position of the ambience speaker, we must repeat the test while a listener is seated in the listener's chair. True enough, in this case, the zing we hear when we clap is also heard by the listener. And so, is the sound we hear, good, bad, or inconsequential? Certainly this sound effect is distracting and that alone is enough to warrant its eradication. On the other hand, we want to retain an overhead liveliness so as to promote the ambience signal. We can't sacrifice the lively quality of the overhead space in the room, yet we must try to get rid of its distracting effect known as flutter echo.

FLUTTER ECHO/FLUTTER TONES

Before we try to solve our problems, let's spend some time learning about it. When we administer a handclap test while located between a pair of uncluttered and parallel walls, we hear a flutter echo. It has a "zing" sound. The flutter echo actually does sound like a tone. The frequency of the tone depends upon the timing of the flutter. A flutter echo is how we hear what really is a rapid sequence of noise pulses. When we clap our hands in the outdoors, we simply hear the single, sharp pulse of noise we call the clap sound. If we clap our hands while standing some distance away, yet facing a wall or building, we will hear a single rapport of the clap, its echo. Then, if we relocate and stand between a pair of more nearby and parallel walls, that single pulse reflects back and forth rapidly between the parallel walls and we hear what we call a flutter echo.

If the walls are far apart, some 60 feet or more, we actually hear the flutter sequence of the echo reflections. But if the walls are closer together, the distinct detail of the staccato seems to disappear, but only to be replaced by a new sound, one of tonal quality. If the walls are far apart, say 60 feet, we hear the slap back at a rate of 1130/60 or 17 times a second and it sounds like the tap-tap-tap of a true flutter echo. However, if the walls are closer, say 20 feet apart, we will hear that slap back pulse of sound at a rate of 1130/20 or 57 times per second. When we, the human listeners, hear a click or noise pulsed at 57 times a second, our ears/brains are tricked into perceiving a buzz-like tone of 57 Hz. And so, the flutter echo we hear when the walls are farther apart becomes a zing-sounding flutter tone when the walls are closer together.

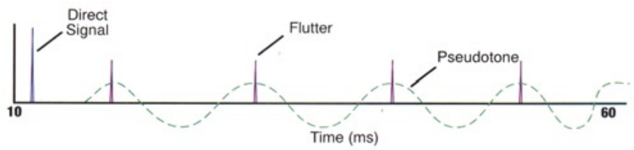
In hi-fi, home theater, and even most recording studios, the parallel wall surfaces are within the range of 15 to 30 feet apart. That means we don't hear flutter echoes but do hear the flutter tones. Flutter tones are sounds that have a low-frequency character, but they are not to be confused with room modes, which also are low frequency in nature. The control of the low frequency flutter tones, as we will soon see, is accomplished with high-frequency type diffusion or absorption. Of course, control of the low frequency of room modes is accomplished only by means of larger-sized bass traps, usually best located in the corners.



HAND CLAP ECHOES

FLUTTER TONES

The low-frequency flutter tone is a pseudotone - a trick on our hearing system played by the rapid staccato of high-frequency noise pulses. Sometimes a careful listener can become confused as to how a seemingly low-frequency sound can be eliminated by the introduction of a paper thin reflector or fabric, especially when common sense leads us to expect that only those large-sized bass traps



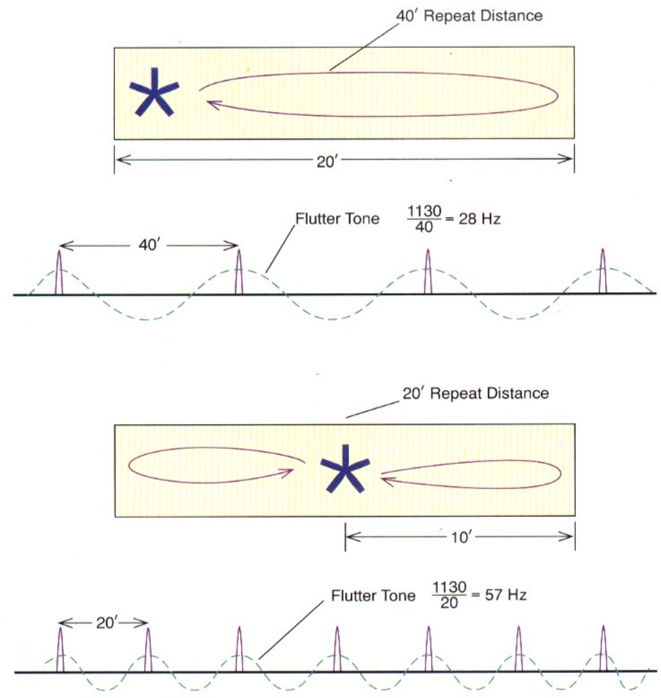
should have been needed. In order to eliminate the detection of a flutter echo pseudotone, we need only to break up the flutter echo process. It takes very little scattering or absorption of high-frequency sounds to break up the flutter echo sequence, and thereby eliminate the accompanying impression of the low-frequency sounds of the flutter tone.

Audio parlor tricks, such as making bass reverberation disappear with nothing more than a carefully placed scrap of paper, are accomplished with the magician's classic technique, a distraction of words and slight of hand. Only this time, we say that to create the illusion, the hand must be moving faster than the ear. Actually, the clue to the trick will be found in the presentation. The guru claps the hands and says to listen to the low-toned overhang. If you spectral analyze the energy content of a handclap, you will find no energy below 400 Hz, yet the handclap generates the perception of typically a 50 Hz sound. It's a great trick. Practice it and amaze your friends with your superpowers. You could even start up your own business, selling little tinfoil "bass traps" and you'll probably even get away with it, for awhile.

FLUTTER TONE SCIENCE

If we stand at the end of a long, narrow room such as a hallway and clap, we will hear the flutter echo as it returns to us each round trip. If the hall is 20 feet in length, the flutter echo returns after every 40 feet of travel. The time for the round trip is controlled by the speed of sound. In this example, the sound of the clap makes a round trip some 1130/40 or 28 times a second, which sounds like the note of 28 Hz, a half octave below the lowest note of the piano keyboard. However, if we stand in the middle of the room and clap, we hear a different flutter tone. In this situation, part of the clap sound travels towards each end wall. Being in the middle means that each end wall is only ten feet away. Both sounds return to us after only 20 feet of travel. They pass by and head off towards the opposite wall, only to return to us after another 20 feet of travel. This situation produces a flutter tone of 1130/20 or 57 Hz, a full octave above the basic flutter tone of the hall.

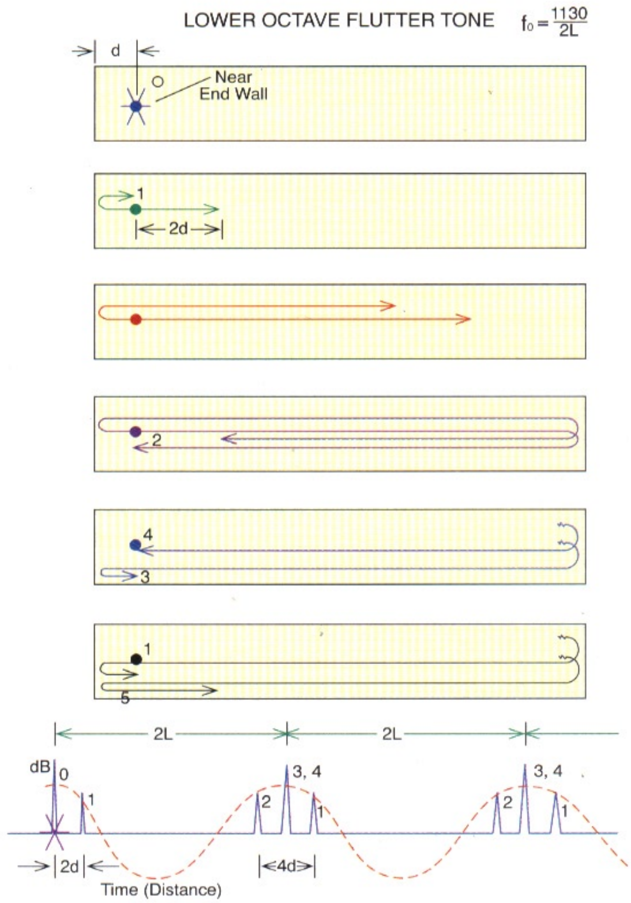
If we were really doing this experiment, we would quickly find that we must stand to the side of the hall so as to let the two end walls have a clear view of each other. If we stand in the center of the hall, the flutter is quickly damped out because of the absorption of our body. In this position, with our back to the side wall, sound travels away from the clap equally in both directions, up the hall and down the hall. When we stand at the midpoint of the hall and clap, the two wave fronts race towards the two end walls, reach them and reflect back to soon pass by the clapper at the



FLUTTER TONE FREQUENCIES

same time. These two pulses, having arrived at the same time, are heard as one loud pulse. Positions non-reversed, the two pulses race for the opposite far walk, and again repeat the course. For this position, the double-strength pulses are heard every time they make half of a full round trip of the hall.

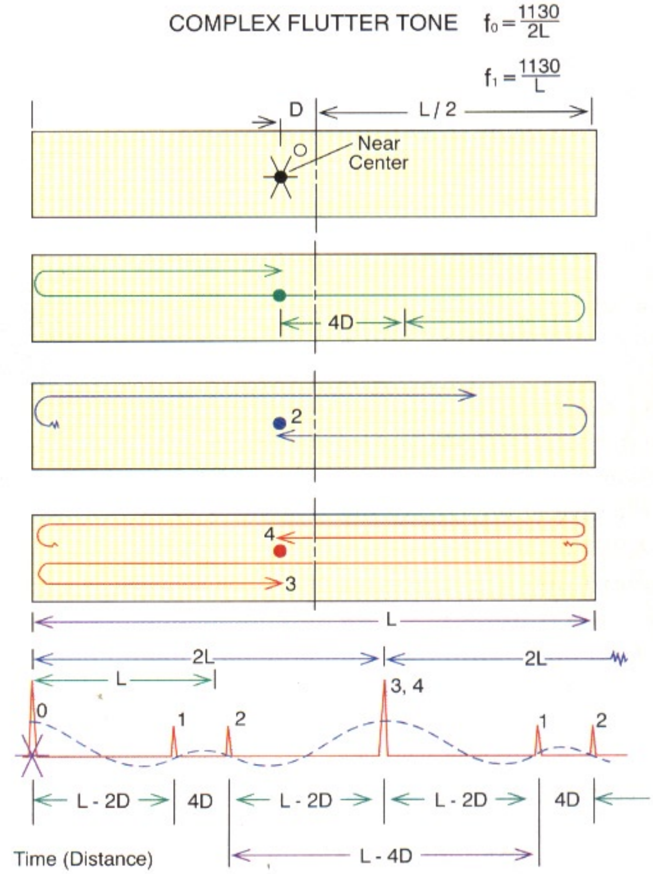
Another important position to stand at is the end of the hall. We already know the flutter echo occurs at half the rate as when we stood in the middle of the hall. But let's look at the pulse timing detail. Again, two pulses expand from the clapper's position, one heads toward the far end wall and the other toward the near end wall. The first reflection, off the near end wall, hits us after an overall travel of only three or four feet. It races by and follows the other pulse down the hall, lagging by six to eight feet. They both hit the far end wall and return towards the clapper's position. The leading pulse flashes by and on to hit the nearby end wall. By the time it again hits the clapper, the lagging pulse also hits the clapper. This creates the effect of a single-hitting, double-strength pulse. Then the lagging pulse moves past and towards the nearby end wall. It reflects and, after a bit, again passes by while heading for the far end wall. In the meantime, the leading pulse had already long left the scene, heading again for the far end wall and a repeat of the cycle.



What we have here is a triple pulse event whose timing is that of a full round trip in the hall. The three pulses are so close together that they sound as if they were one pulse. This combining effect is well known in pro and high-end audio. It is called the Haas effect, after the scientist who did a lot of work in this area of hearing. What he found is that when high-frequency reflections, such as those in the handclap arrive within ten to 15 ms (thousandths of a second), they fuse together and sound as one.

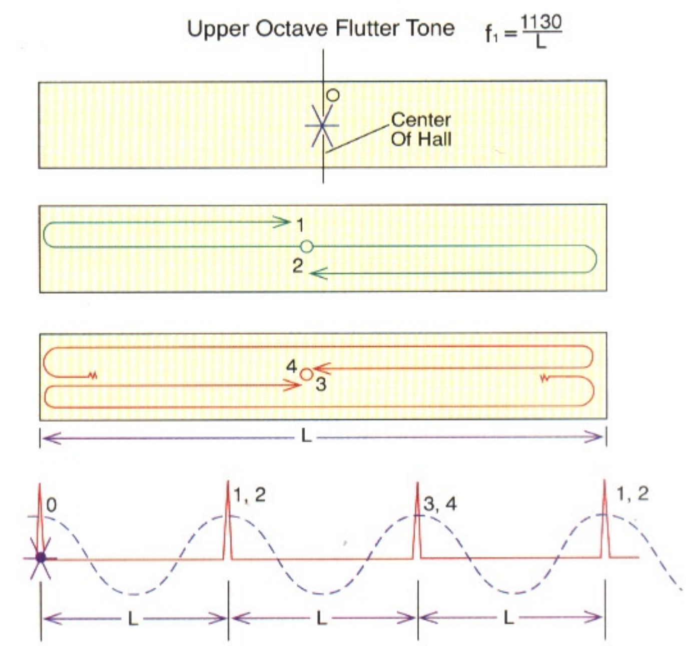
Next, we take a few steps down the hall and repeat the handclap test, listening for any changes in the sound of the flutter tone. If we moved five feet off the end wall, the two pulses would be 20 feet apart and heard as separate pulses because they arrived outside the sound fusion time period. However, the same sequence of events still occurs. The only difference is the separation of the two distinct and small pulses. In the middle position, double-strength pulse effect still occurs. As we change positions along the length of the hall, we change the timing of the discrete echoes that make up the flutter tone. We also find that as we approach the middle of the hall, the two single echoes get far away from the double pulse and closer to each other. When they are within about six feet of each other, the fusion effects begin and the two pulses start sounding as if they were one and the upper octave flutter tone is heard. Get just a few feet off dead center of the hall and the upper octave disappears and the lower flutter tone begins to reappear.

The timing of the two separated pulses is what accounts for the changing of the character of the flutter tone. As we move closer to either of the end walls, the timing between the two separate pulses gets closer together, sandwiching the double-strength pulse until the end wall is reached and

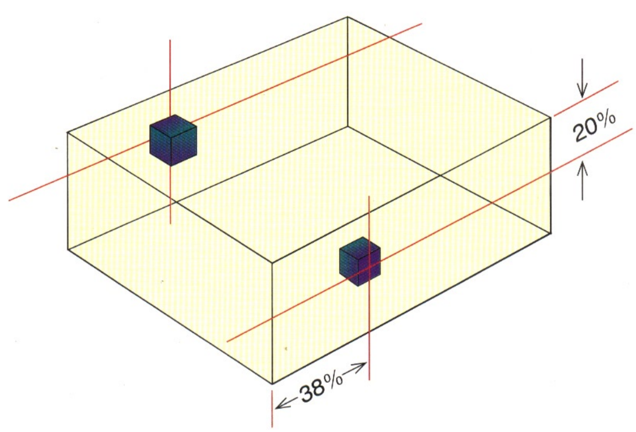


they are essentially all on top of each other. As we move closer to the center of the hall, the timing between the two separate pulses again gets smaller. This time, they do not sandwich and are as far as possible from the double-strength pulse. Finally, at the center, the time between them goes to zero, creating a second, double-strength pulse.

All the pulses contain energy, the same amount of energy. Whenever they return to the clapping position, together they combine into a stronger, double-strength pulse. Even more, when they arrive at the clapper's position within six feet of each other, they still combine into a single, double-strength pulse. When a clap originates within three feet of an end wall, all of the pulses arrive at effectively the same time and the result is heard as a four-times stronger, low frequency flutter tone. Then again, if the clapper is within three feet of the middle of the hall, the separated pulses arrive close enough together to combine and double up in strength. Either of these extreme conditions is about as easy to detect.



When the two separated pulses are not close to the doubled-up pulse, the lower flutter tone is quieter, less noticeable to detect and that is good. Also, when the separated pulses are not combined due to a midpoint clap position, the upper octave flutter tone is not heard. That is also good. Clearly, we now know that the most non-stimulating position for flutter tone generation will be more than four feet away from either end wall and a few feet off the center of the room. By experimenting, additional information is developed. Anywhere in the end third of the room seems to strongly stimulate the lower flutter tone. The third waypoint seems to stimulate the third octave, along



AMBIENCE SPEAKER POSITION

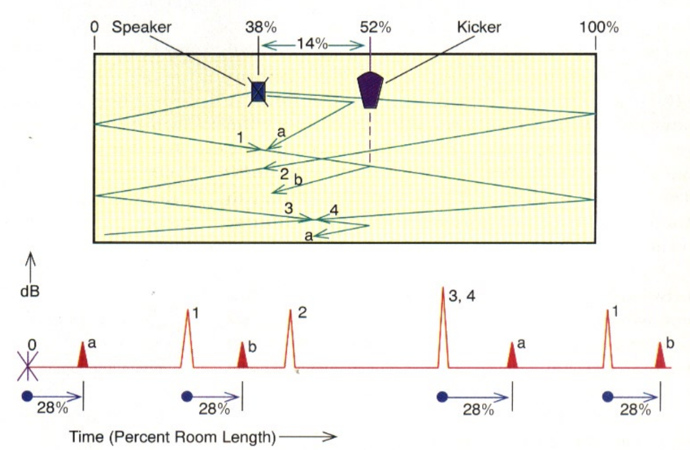
with the fundamental flutter tone. The middle of the room really generates the second octave flutter tone within a foot or two of the center point.

Using our 20-foot room as an example, the ambience speaker ought to be located ahead of the 1/3 point, but two to three feet off the center. That puts it at about seven to eight feet off either end of the room, probably the rear wall for home theater. As a general rule, the ambience speaker can be placed 38 percent of the room length off the back of the room. This position will ensure that minimal flutter tone coloration is introduced into the room. This section has been intended to be a baseline guide for the anti-flutter tone positioning of the surround speakers. To this, we next add some enhancement devices to both increase the presence of the ambience signal and to continue to reduce the telltale presence of flutter tones in the home theater setup.

DIFFUSION OF FLUTTER

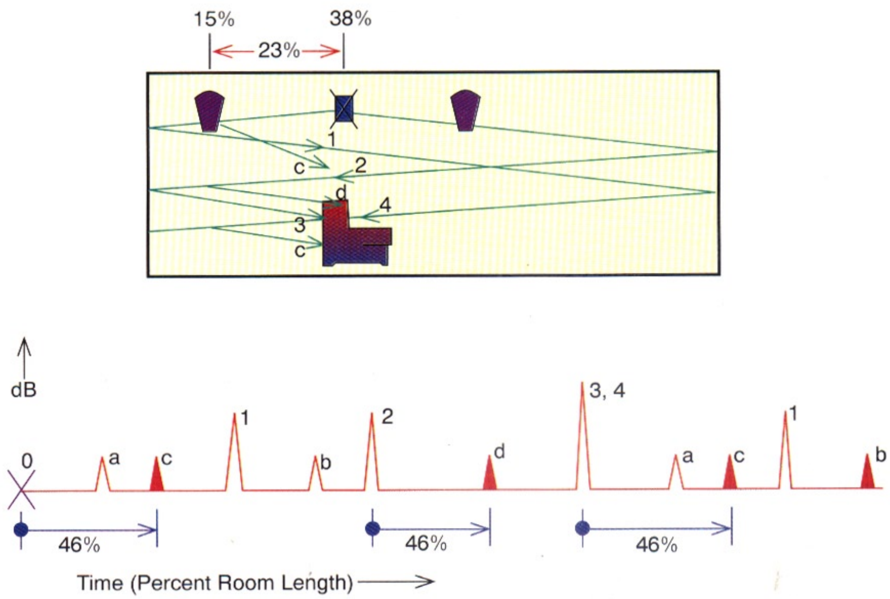
In addition to positioning the speaker to weakly stimulate the distracting flutter tones, another element of acoustics can be brought into the battle and put to good use. Diffusers are devices or surfaces that scatter sound. The home theater ambience speakers are located high on the sidewalls and directed to illuminate the upper outside areas of the front and back walls. The first idea about scattering sound tends to be directed to these areas. Why not add a curved or otherwise irregular surface to these areas of direct illumination?

As it is, we can hear the flutter tone that comes from the ambience speaker because its multiple reflecting wave front not only shuttles back and forth between the front



FLUTTER WITH FORWARD KICKER

and back walls, but the wave front expands while doing so. What we hear is the expanding edge of the flutter echo circuit. Now if we add diffusion to the end walls, we will certainly reduce the time that the flutter tone is sustained because the diffusers are redirecting some of the flutter energy away from the flutter circuit at each reflection. This redirected energy is not absorbed but scattered more fully into the room. That means that the listener is getting an even stronger flutter tone signal than before. Not only does the listener hear the expanding edge of the flutter echo, but now additionally hears the scattered sound off the diffuser. Ironic as it seems, adding diffusers to the end walls is a trade-off treatment with mixed results. The flutter tone



FLUTTER WITH KICKER ADDED

becomes louder but shorter-lived. It is a change, but is it an improvement? Better, worse, or merely different, this now is something for you to decide for yourself.

Let's look at another technique. The flutter echo runs back and forth along the length of the room, hugging the upper sidewall/ceiling corner. Sound-scattering devices can be placed along the upper sidewalls of the room. Again, sound is depleted from the flutter echo circuit. As energy from the flutter echo is redirected into the room, the flutter echo lifetime is reduced. However, this time the scattering takes place between the end wall reflections and not in lumped reflections off the end walls.

These deflectors can be slightly angled down so as to not only kick the reflection to the side, but also downwards. After all, the listener is nearer the floor than the ceiling. Such deflectors are sometimes called ambience kickers in the professional world of recording studios. Another aspect in the setup of these kickers is their spacing. Just as the regular timing of end wall reflections manifests itself to us as a flutter tone, regular timing of reflections off the deflectors can also create a flutter tone. Additionally, we don't want to place the deflectors so that their signal arrives at the same time as any of the regular flutter echo signals. In such a case, the work accomplished would be minimally different from that by diffusers on the end walls.

Clearly, we won't want the deflector to be located the same distance towards the front of the room as the distance the ambience speaker is to the rear wall. This would give the same timing to both reflections being received at the listener's position. The side scattering deflector has to either be in front of or behind this position. Since the ambience speaker is located about 38 percent off the back wall, the ambience kicker should avoid the location of 76 percent off the rear wall. As a first guess, we could locate it almost halfway between, about 52 percent off the rear wall. This produces two new reflections spaced out between the timing of the end wall reflections. The strength of these reflections will be similar to the end wall reflections because of the longer distances involved.

Another deflector could be placed about halfway between the ambience speaker and the rear wall. This one will produce a reflection that arrives somewhat before the rear wall reflection and helps to fill in that big time gap. How many other such ambience kickers can be installed is not so easily predicted. The side fill they produce and its value to the listener belong, in a large degree, to the listener's taste and judgment.

The sonic impact produced by upper sidewall diffusers is quite different on two levels. First, the scattering reflections are distributed all around the listener rather than coming from just in front of and behind the listener. This more diffuse "source" of the ambience signal seems to promise to be more supportive and involving for the surround sound effect. Second, is the relief provided due to multiple reflections that crop up in between the end wall reflections? These intermediate reflections spoil the perception of the otherwise clear and distinct end wall reflections. The result is that distributed, upper sidewall deflectors produce a signal that masks out the flutter tone. The result is a lively, diffuse, and colorless ambience signal.

CONCLUSION

Over the last two sections, the dipole ambience speaker has been shown to best be placed about 38 percent of the room length off the back wall, and 20 percent of the room height down from the ceiling. Located directly above it there needs to be a bass trap good through 100 Hz. Along the upper sidewalls there should be distributed a set of ambience kickers. Attend to these details and the ambience speakers can safely play into your. room without inducing coloration or distracting distortions. Only then can the true shading and hue of the signal on the ambience sound track be heard. ❑