Chapter 2

The Environment

2.1 Why is the Environment Important?

When we refer to the environment, we are not talking about forests, swamps, rivers, or pollution. Rather, the environment is the collection of objects, conditions, and circumstances in which the sound system operates and with which the sound engineer must interact. The environment affects the final sound produced by the system, and thus what the audience hears. There are numerous aspects to the environment that affect the sound system, but we will limit our discussion to basic interactions with air temperature, humidity, and objects in the path of the sound.

2.2 Environmental Effects of Air on the Speed of Sound

The speed of sound changes when the physical attributes of the air through which it is traveling change. This change in speed can be quite dramatic. When using multiple speakers that are widely distributed around the audience area, it is common to use delay devices to align the sound from these speakers so that echoes are eliminated in the audience area. The change in the speed of sound could have a bearing on delay times when using multiple speakers.

The speed of sound is 331 m/s at 0 ºC. This speed will increase 0.6 m/s per ºC with increasing temperature. To a much lesser extent, the speed of sound will also increase with increasing humidity. Table 2-1 shows how the speed of sound varies with temperature and humidity. It is based on a formula in a paper[1] published by Owen Cramer in 1993. Interestingly, the speed of sound in air is not affected by changes in the air pressure.

	Relative Humidity (%)										
Temp ºC	**0**	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
0	331.5	331.5	331.5	331.6	331.6	331.6	331.6	331.7	331.7	331.7	331.8
10	337.5	337.5	337.6	337.7	337.7	337.8	337.9	337.9	338.0	338.1	338.1
20	343.4	343.5	343.6	343.7	343.9	344.0	344.1	344.3	344.4	344.5	344.6
30	349.2	349.4	349.6	349.9	350.1	350.3	350.6	350.8	351.0	351.3	351.5

Table 2-1 Changes in Speed of Sound with Temperature and Humidity

When people enter an enclosed space, both the temperature and the humidity of the air will rise. The degree to which these factors increase depends on the size of the audience and what they are doing, and obviously on the ability of the building's HVAC system to control the air quality of the space. A large, active crowd will generate more heat and humidity than a small, quiet group.

2.3 Reflection of Sound

Unless your speakers are floating outdoors in mid-air, there will always be some interaction of the sound waves with solid objects in the environment. As a technician, you must be concerned not only with the direct sound from the speakers, but also with reflected, absorbed, diffracted, and – to a lesser extent – transmitted sound that has interacted with objects in the environment.

When considering reflection of sound waves, the object of interest is usually large and flat, such as a wall, floor, or ceiling. When the sound source is close (less than 3 m) to the reflective surface, we consider that the wavefront is spherical. When the sound source is far (greater than 15 m) from the wall, the wavefront has expanded so much that it can be considered to be flat over small areas. In either case, the laws of reflection are the same. The waves will be reflected at an angle that is equal to the angle of incidence, even for spherical wavefronts. Therefore, for a spherical wavefront, the reflections themselves form a spherical wavefront. When the sound source is far from the reflecting surface, the reflected wavefront is also flat. This is shown in Figure 2-1.

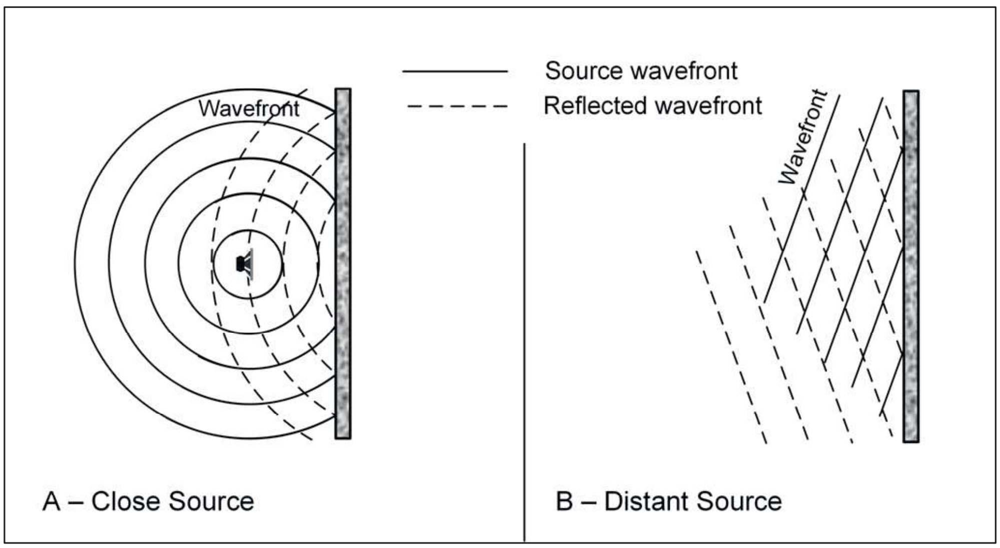

Figure 2-1 Sound Wave Reflection

Clearly, a surface that reflects a lot of sound is one that does not absorb a lot of sound. These surfaces tend to be hard, rigid, and not porous. Examples are glass panes, tiled floors, painted wood panels and painted walls

In a live venue, strong reflections can cause problems with feedback and echo. Rooms that have very reflective surfaces are said to be 'live' and may pose problems with reverberation. Sound engineers therefore need to be aware of these issues and take the appropriate steps when aiming loud speakers and microphones to best use the reflective properties of the venue to their advantage. We will discuss approaches to such problems in Chapter 11.

2.4 Diffusion of Sound

When reflection occurs from a hard flat surface such that the sound energy in a small area is all propagated in the same direction (as in a ray of light reflecting off of a mirror), this is called

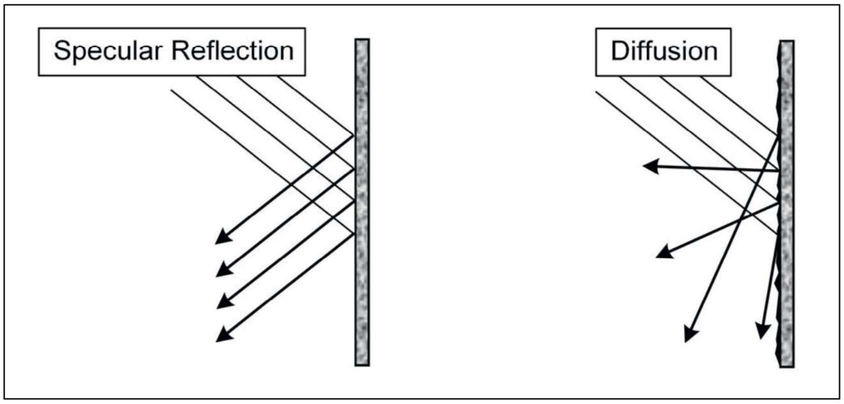

Figure 2-2 Reflection and Diffusion

specular reflection. This is shown in the left hand side of Figure 2-2. Specular reflection may exacerbate certain problems, such as feedback, in certain situations.

When reflection occurs from a rough or irregular surface such that the sound energy in a small area is propagated in many directions, as shown in the right hand side of Figure 2-2, this is called diffuse reflection or simply diffusion. Because the sound energy is spread over a larger area, the harsh directional qualities associated with specular reflection are reduced. Diffusion therefore has the effect of 'taking the edge off' the sound in a room and adds to the sense of spaciousness.

2.5 Reverberation

Whenever there is reflection of sound waves in an enclosed area (even partially enclosed) there will be reverberation. Consider a listener in a room with a speaker emitting sounds. The first sound heard by the listener is the direct sound, which takes the shortest path from the source. This sound is heard at a higher intensity than any single reflection. The listener will next hear sounds reflected from various surfaces. Figure 2-3 graphically shows this situation. The more times the sound is reflected, the less the intensity will be when it arrives at the listener. The intensity decays exponentially.

Sounds that arrive at the listener within the first 80 ms of the direct sound add to the perceived loudness of the sound and are called early reflections. These sounds are directionally well defined and correlated to the room geometry.

Sounds that arrive at the listener after 100 ms of the direct sound add to the persistence of the sound. That is, they cause the sound to be heard even after the source has stopped transmitting the sound. The rate of arrival of these reflections is much higher than that of the early reflections and it increases very rapidly. Additionally, the direction of these reflections appears more random. These reflections are called late reflections, diffuse reverberation, or simply reverberation. Reverberation gives the listener a sense of size and spaciousness of the enclosure.

Rooms with too little reverberation sound dead and sterile. Rooms with too much reverberation cause the sound to become muddy and difficult to understand, as new sounds blend into the reflections of the old sounds. The reverberation time of a room is a well defined concept, being equal to the time it takes for the sound level to decay to 60 dB below the initial SPL of the direct sound. The reverberation time of a room depends on the type of walls, ceiling, and floor treatment, as well as the volume of the space. There is no hard and fast rule for optimal reverberation

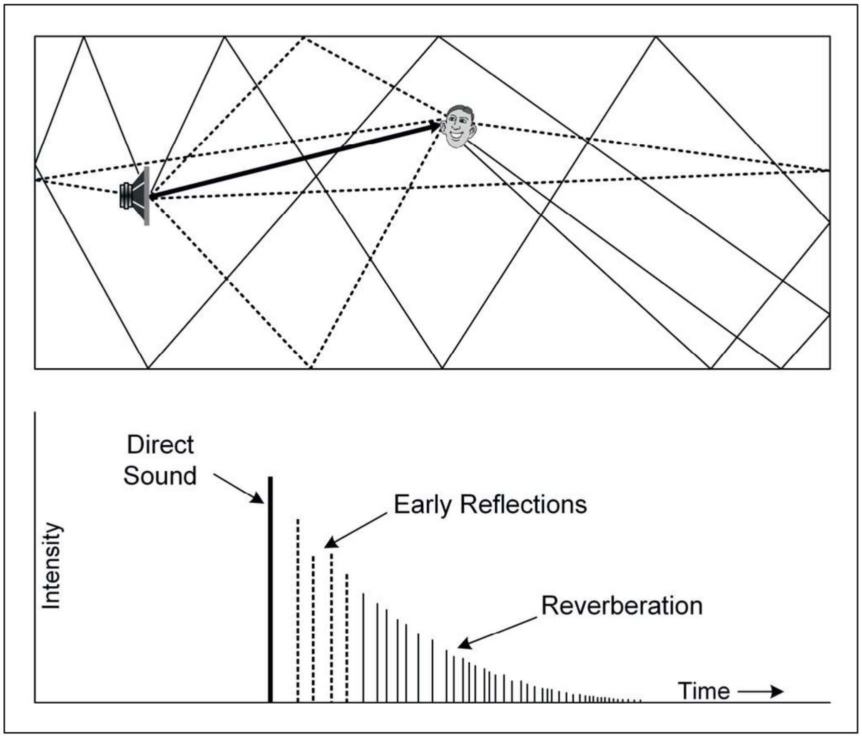

Figure 2-3 Reverberation

times, but generally, speech requires shorter reverberation time than music. Concert halls have a reverberation time of about 1.5 to 2 seconds. Church music can tolerate longer times than pop music which has short attacks and quick rhythms. A reverberation time of about 0.5 to 1.5 seconds seems like a reasonable compromise.

2.6 Absorption of Sound by Objects

If a sound wave can penetrate into an object, then some or all of the sound will be absorbed by that object. The best absorbers are ones that are composed of solid material with some air spaces interspersed. Absorption occurs because the energy carried by the wave, which was previously used to displace only air molecules, is now being used to displace the molecules of the object. It takes more energy to displace the molecules of the object than of air. That is why denser materials absorb more sound than less dense ones. High frequency sounds, which must displace molecules more times per second, are absorbed more than low frequency sounds. The energy that is absorbed from the sound wave is transformed into a very small amount of heat in the object. This is shown in Figure 2-4. Whatever sound is not absorbed (or reflected) is transmitted through the object.

Every material has an absorption coefficient which tells how effective the material is in absorbing sounds. The absorption coefficient is the percentage of incident sound energy that is absorbed. For example, if 20% of the sound falling on the material is absorbed, then the material has an absorption coefficient of 0.2. If the material absorbed all of the incident sound energy, it would have an absorption coefficient of 1. For a given material, absorption coefficients are usually published for the frequencies 125 Hz, 250 Hz, 500 Hz, 1 kHz, 2 kHz, and 4 kHz. Occasionally, you may see the absorption of a specific absorber published in sabins, the unit of sound absorption (after Wallace C. Sabine, a Harvard University professor c1900). For example, one square

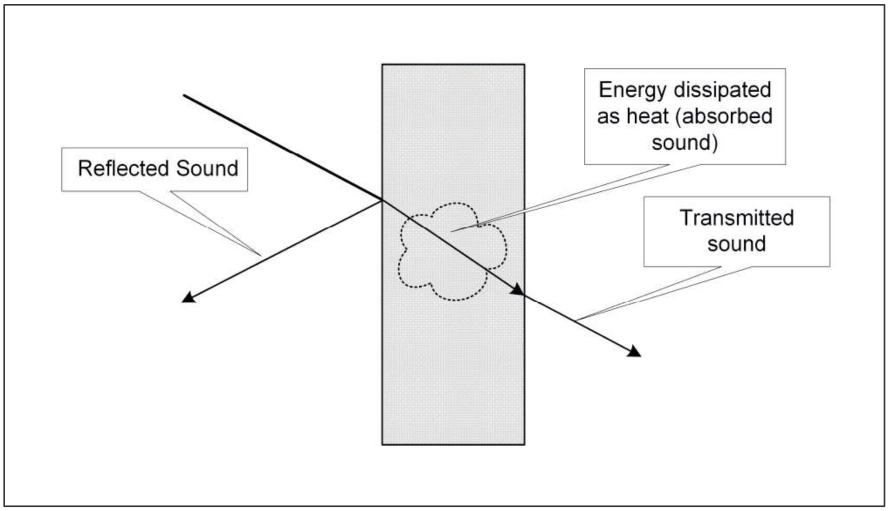

Figure 2-4 Sound Absorption

meter of a material having an absorption coefficient of 0.2 gives 0.2 metric sabins of absorption. To get the total absorption of an object in sabins, simply multiply the surface area of the object by its absorption coefficient.

One of the things that the sound engineer needs to be aware of is sound absorption by people. Most times when the sound check is performed in a venue, the space is mostly empty – the audience has not yet arrived. After the show starts, though, the venue will be filled with efficient high frequency absorbers, i.e. people. The amount of sound absorbed by the audience depends on how they are dressed, whether they are sitting or standing, and the spacing between them. What this means to the engineer is that things will sound different after the audience arrives than during the sound check, and small EQ adjustments will have to be made to restore the overall tonal balance of the system.

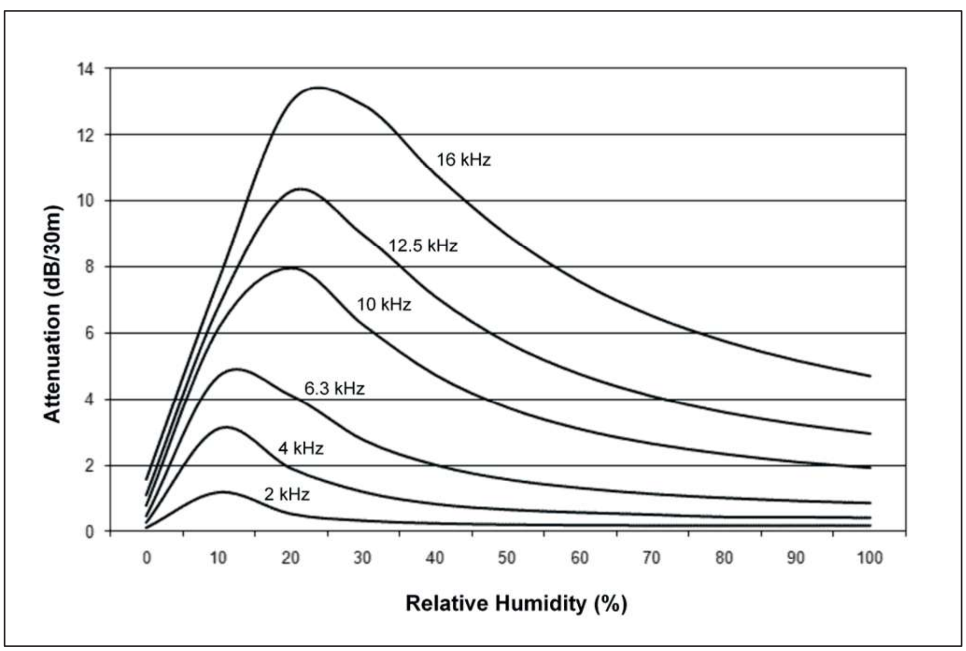

Figure 2-5 Sound Absorption in Air at 20ºC

2.7 Absorption of Sound by Air

Within a certain range of relative humidity, from about 5% to 50%, damp air will absorb sound better than dry air. The critical range is between 15% and 40%. This is also the most common range encountered.

Figure 2-5 is derived from data published by Bohn in 1988.[2] As can be seen from this figure, at 12.5 kHz, a change in relative humidity from 10% to 20% results in an increase in absorption of almost 4 dB per 30 m (100 ft). This could significantly alter the sonic quality of direct sounds in large auditoria and the quality of reflected sounds in smaller spaces. Note that in poorly climate controlled enclosed spaces, the relative humidity will rise as people fill the space.

Look again at Figure 2-5 and notice that the high frequencies are absorbed much more that the low. The absorption of high frequencies will result in lack of sparkle or zip for the members of the audience sitting farther away from the sound source.

2.8 Diffraction of Sound

Diffraction is the change in direction of travel of the sound waves caused by the interaction with an object, where the waves bend around the object. This should not be confused with reflection or refraction. In Figure 2-6(A), we can see that when the object is smaller than or equal to the wavelength of the sound, the wavefront will simply bend around the object. When the object is larger than the wavelength of the sound, as in Figure 2-6(B), a shadow zone develops behind the object. This again is one of the reasons why low frequency sounds travel farther than high frequency sounds. The long wavelength sounds simply bend around obstacles, while short wavelength high frequency sounds get dissipated in the shadow zone. Recall from Table 1-1 that the length of a 4 kHz wave is already much less than 10 cm, so it does not take very large objects to start affecting the high frequency waves in the sound.

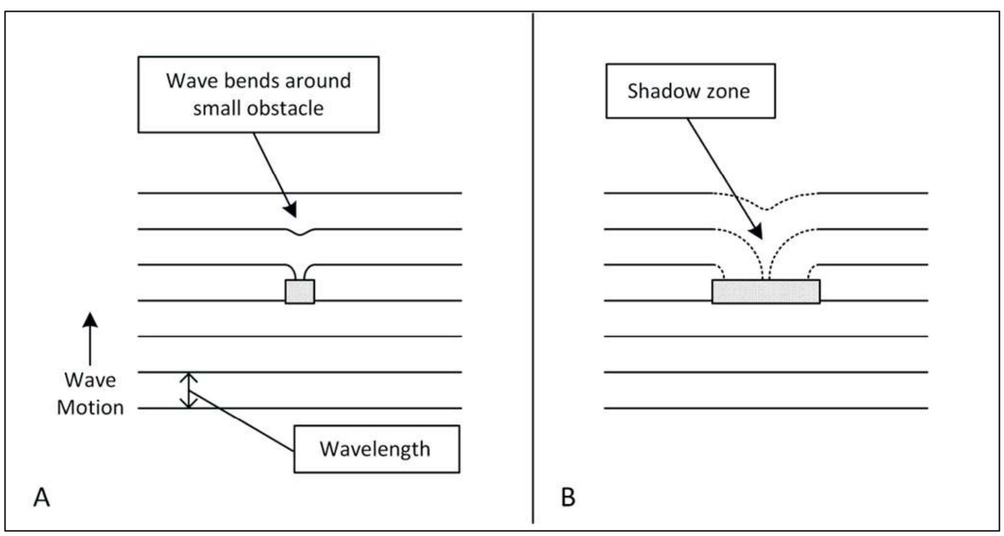

Figure 2-6 Interaction with Small and Large Objects

When the object is larger than the wavelength of the sound, its edge becomes a new point source for the sound. This is shown in Figure 2-7. That is why a small (relative to the wavelength) opening in a wall acts a point source of the sound striking the wall from the opposite side.

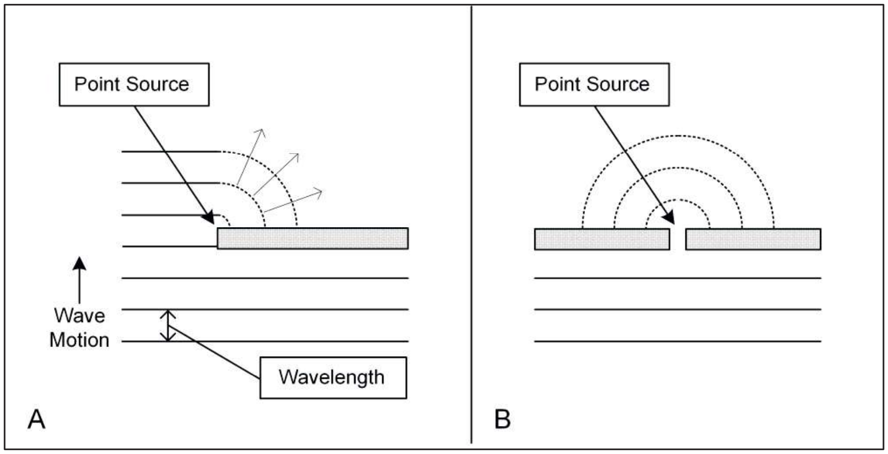

Figure 2-7 Diffraction Point Sources

2.9 Work with the Environment

As we have seen, there are many things that can dramatically alter the sound as it travels from our loudspeakers to the members of the audience. Even the bodies in the audience itself will affect the way the sound is perceived. Understanding how the various elements of the environment affect the sound allows the engineer to apply reasoned and considered adjustments to the sound system, working with the environment rather than blindly fighting it, and removes much of the guesswork when trying to shape the quality of the audio to achieve the end goal of intelligible, pleasing sound.

Review Questions

1. How do changes to the temperature of the air affect the speed of sound travelling through it?
2. How do changes to the humidity of the air affect the speed of sound travelling through it?
3. Consider two rooms: a hall with hardwood floor and bare paneled walls, and a hall with carpeted floor and draped walls. Which room is likely to cause problems with feedback? Why?
4. Explain what is meant by diffusion of sound.
5. What are early reflections?
6. What is sound reverberation?
7. How does reverberation affect the intelligibility of sound in a room?
8. What effect does the audience have on the quality of the perceived sound in the listening space and why?
9. Discuss how the level of relative humidity of the air affects the absorption of sound waves traveling through the air?
10. What are the minimum dimensions of an object that will just create a shadow zone for a 2 kHz sound wave?
11. What happens to the sound energy that is absorbed by an object?
12. An absorption panel has dimensions of 2 m x 1.5 m and has an absorption coefficient of 0.25. What is its total absorption in metric sabins?
13. What kind of surface would you expect to be good at diffusing sound waves?
14. What is the difference between diffusion and diffraction of sound?