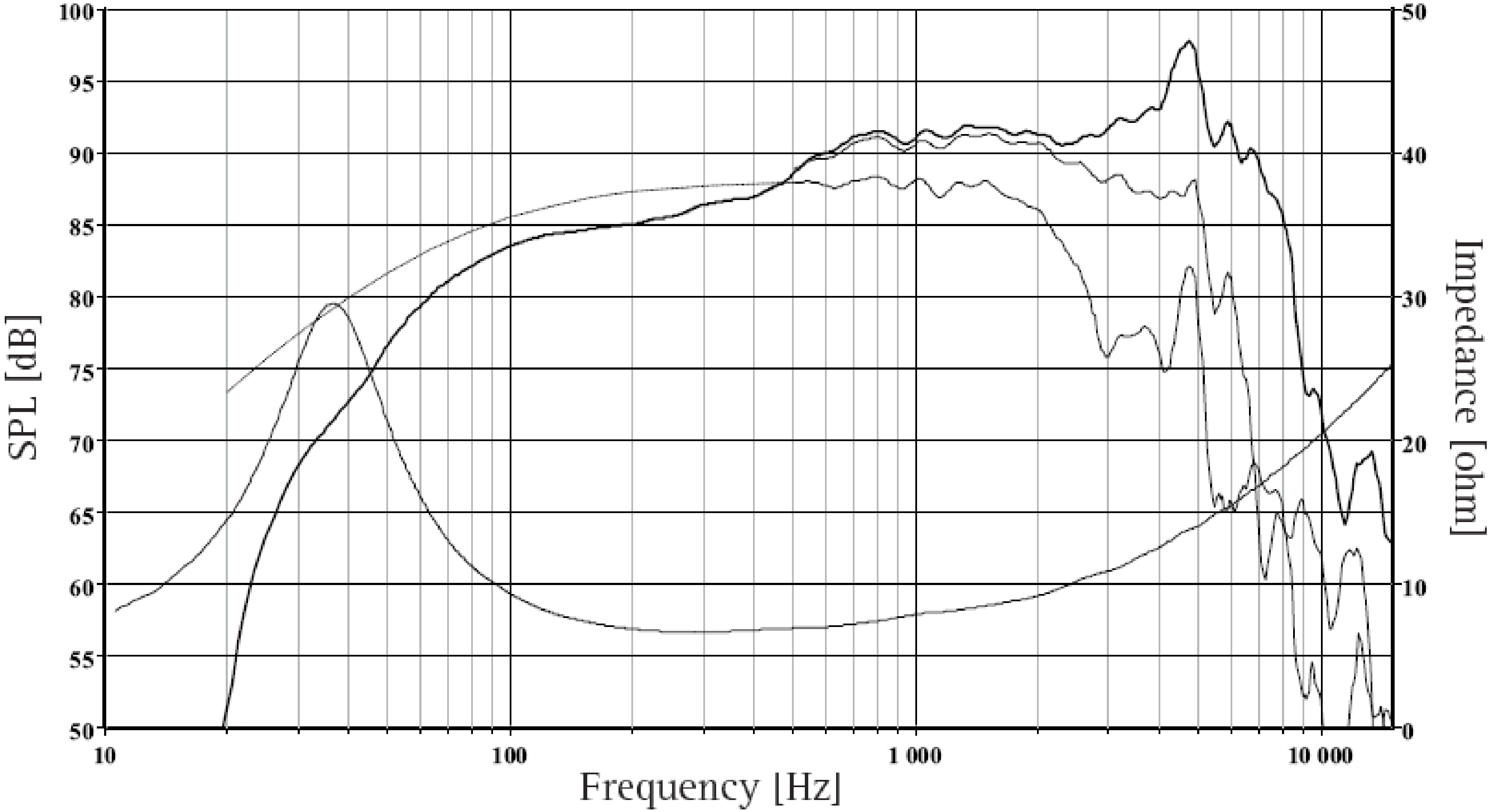
Elektroakustika

L12: Úvod do priestorovej akustiky

doc. Ing. Jozef Juhár, PhD.

http://voice.kemt.fei.tuke.sk

Prečo?



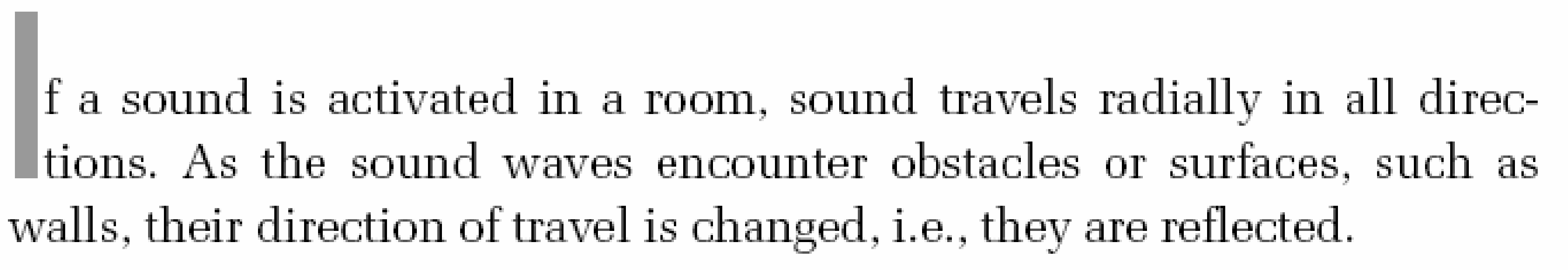
The frequency responses above show measured free field sound pressure in 0, 30, and 60 degrees angle using a 12L closed box. Input 2.83 VRMS, microphone distance 0.5m, normalized to SPL 1m.The dotted line is a calculated response in infinite baffle based on the parameters given for this specific driver. The impedance is measured in free air without baffle using a 2V sine signal.

Šírenie zvuku v priestore

- odraz zvuku (refflection)
- ohyb zvuku (diffraction)
- lom zvuku (refraction)
- rozptyl zvuku (diffusion)
- pohlcovanie zvuku (absorption)

Odraz zvuku (reflection)

- …



If a sound is activated in a room, sound travels radially in all directions. As the sound waves encounter obstacles or surfaces, such as walls, their direction of travel is changed, i.e., they are reflected.

Odraz zvuku od rovinnej steny

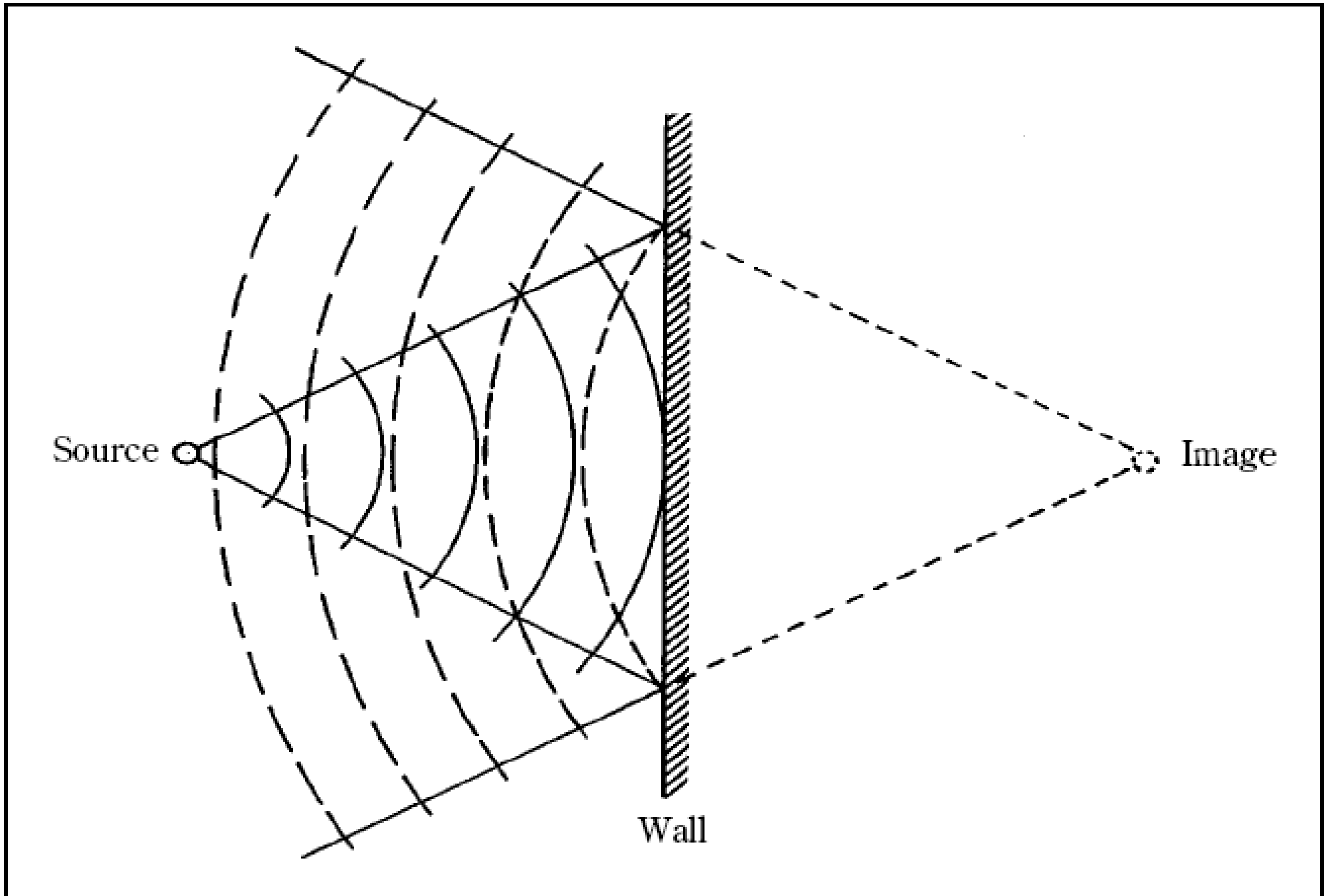
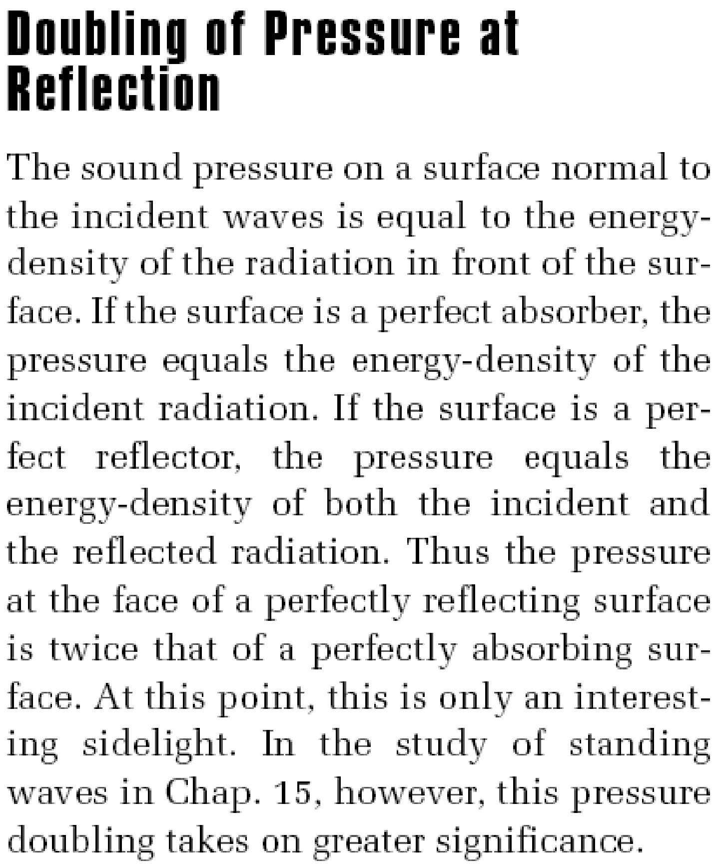


FIGURE 10-1

Reflection of sound from a point source from a flat surface (incident sound, solid lines; reflected sound, broken lines). The reflected sound appears to be from a virtual image source.

Uhol odrazu versus uhol dopadu zvukového lúča



Doubling of Pressure at Reflection

The sound pressure on a surface normal to the incident waves is equal to the energy-density of the radiation in front of the surface. If the surface is a perfect absorber, the pressure equals the energy-density of the incident radiation. If the surface is a perfect reflector, the pressure equals the energy-density of both the incident and the reflected radiation. Thus the pressure at the face of a perfectly reflecting surface is twice that of a perfectly absorbing surface. At this point, this is only an interesting sidelight. In the study of standing waves in Chap. 15, however, this pressure doubling takes on greater significance.

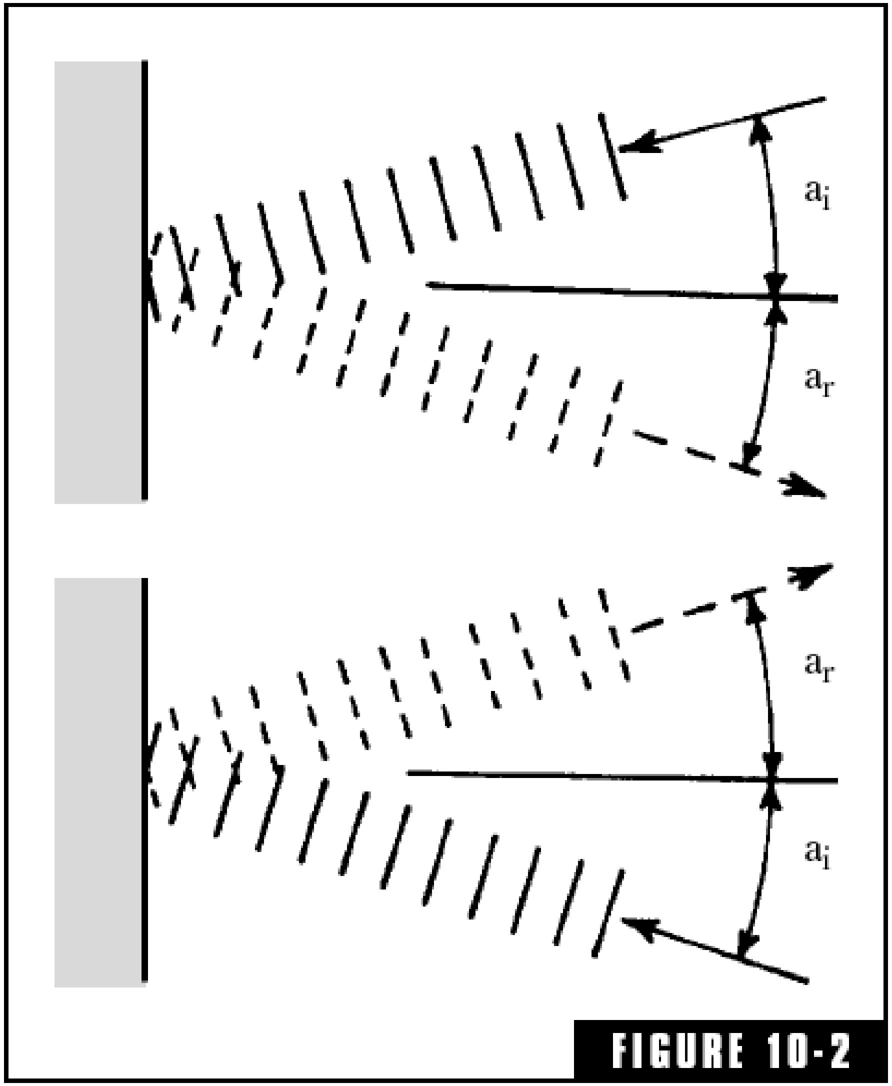


FIGURE 10-2

The angle of incidence, a_i, is equal to the angle of reflection, a_r.

Konvexná a konkávna plocha

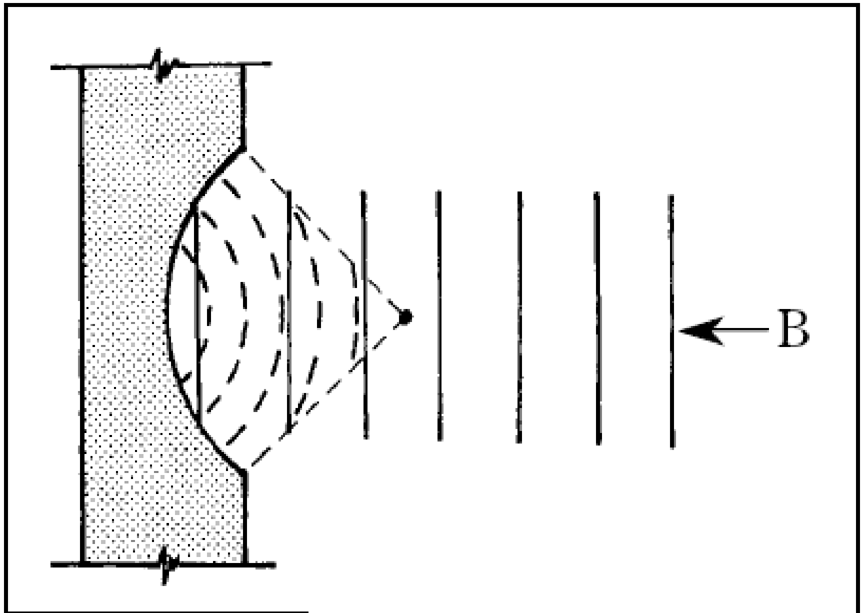


FIGURE 10-4

Plane sound waves impinging on a concave irregularity tend to be focussed if the size of the irregularity is large compared to the wavelength of the sound.

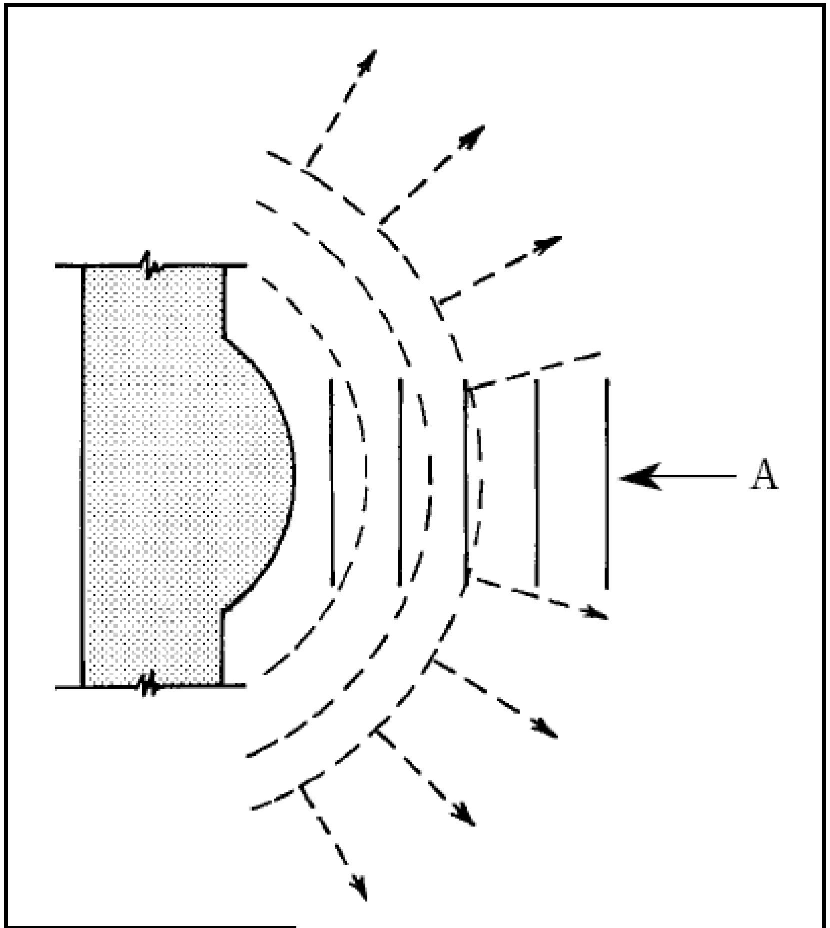


FIGURE 10-3

Plane sound waves impinging on a convex irregularity tend to be dispersed through a wide angle if the size of the irregularity is large compared to the wavelength of the sound.

Parabolická plocha

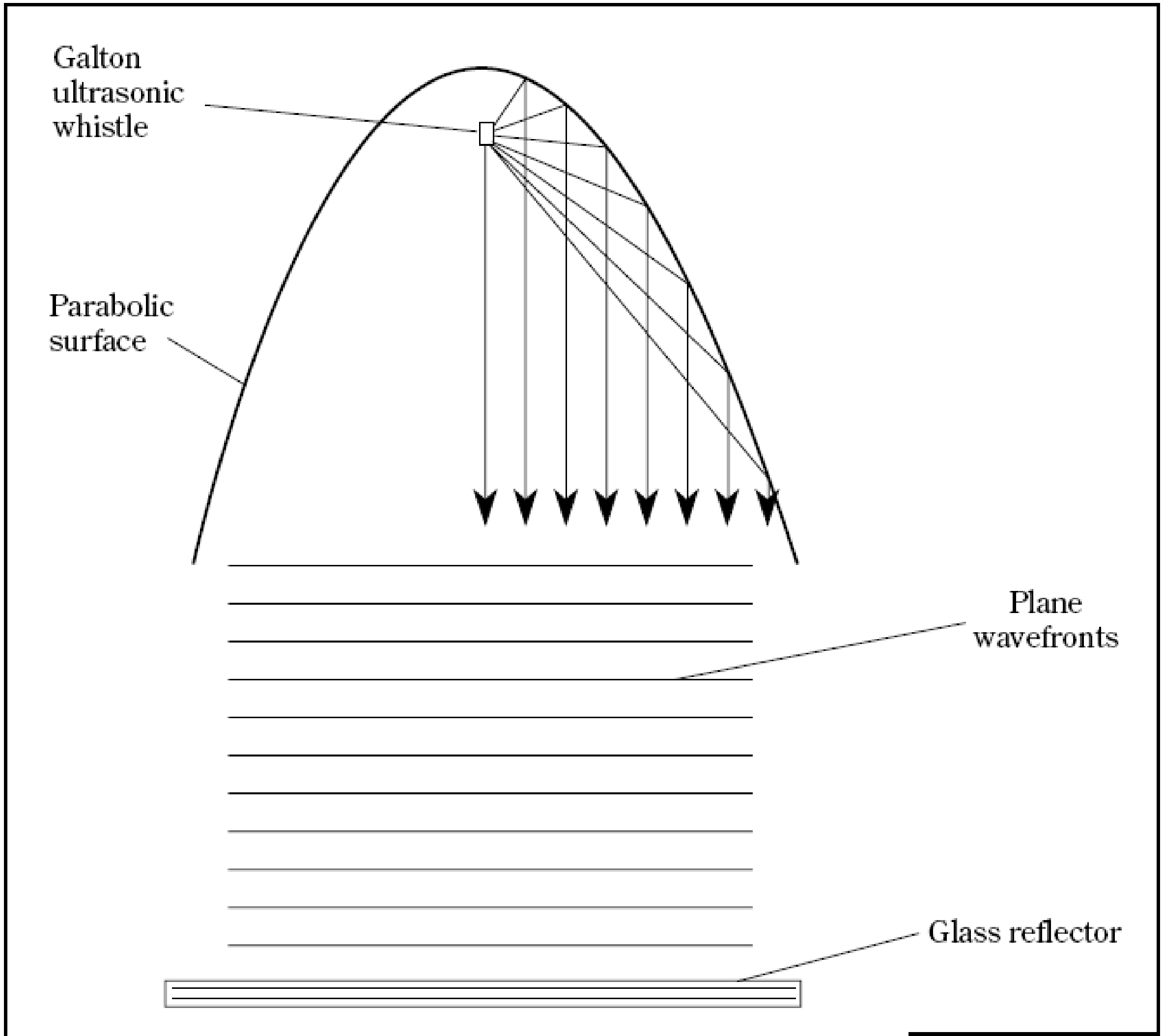


FIGURE 10-5

A parabolic surface can focus sound precisely at a focal point or, the converse, a sound source placed at the focal point can produce plane, parallel wavefronts. In this case, the source is an ultrasonic Galton Whistle blown by compressed air with the results shown in Figs. 10-6 and 10-7.

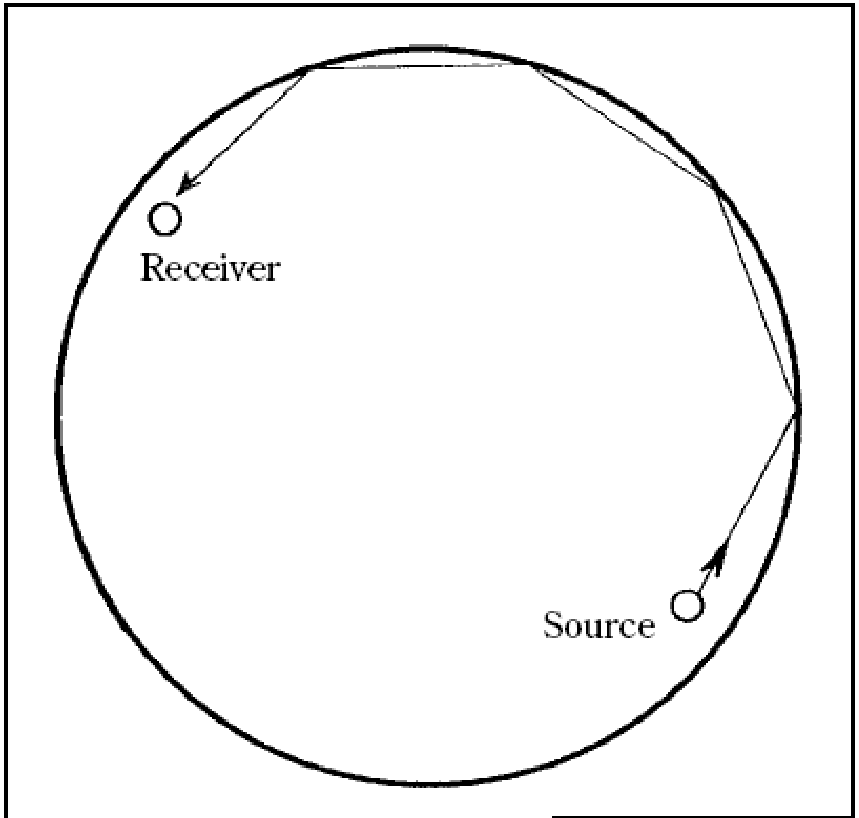


FIGURE 10-8

Graphic explanation of the "Whispering Gallery" of St. Paul's Cathedral, London. A whisper directed tangentially to the cylinderical surface is readily heard by the receiver on the far side of the room.

- …

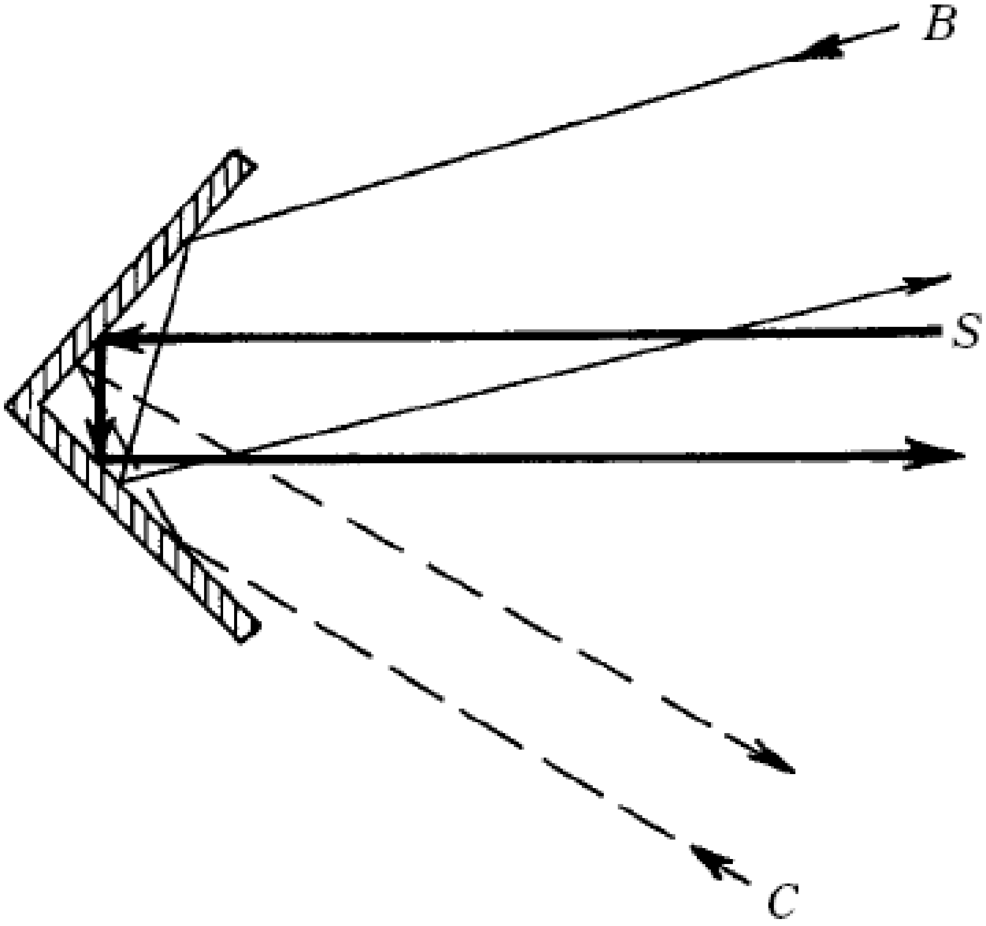
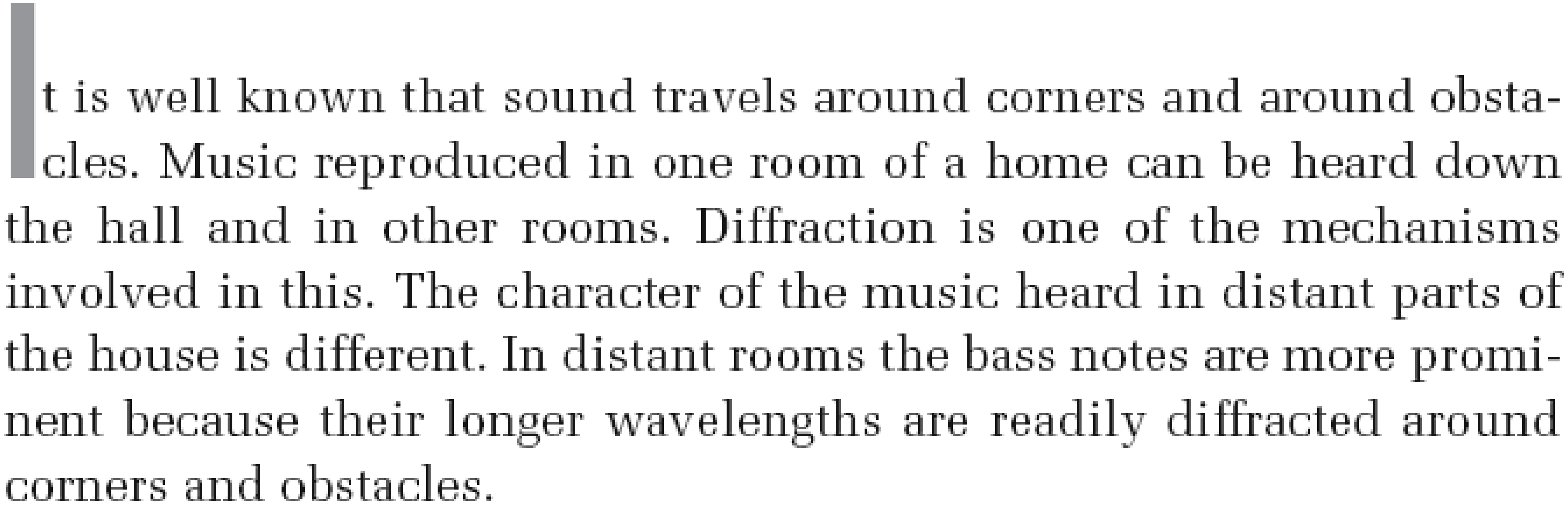


FIGURE 10-9

The corner reflector has the property of reflecting sound back toward the source from any direction.

Difrakcia (ohyb) zvukového vlnenia



It is well known that sound travels around corners and around obstacles. Music reproduced in one room of a home can be heard down the hall and in other rooms. Diffraction is one of the mechanisms involved in this. The character of the music heard in distant parts of the house is different. In distant rooms the bass notes are more prominent because their longer wavelengths are readily diffracted around corners and obstacles.

Difrakcia zvuku vo veľkom a malom otvore (v porovnaní s vlnovou dĺžkou)

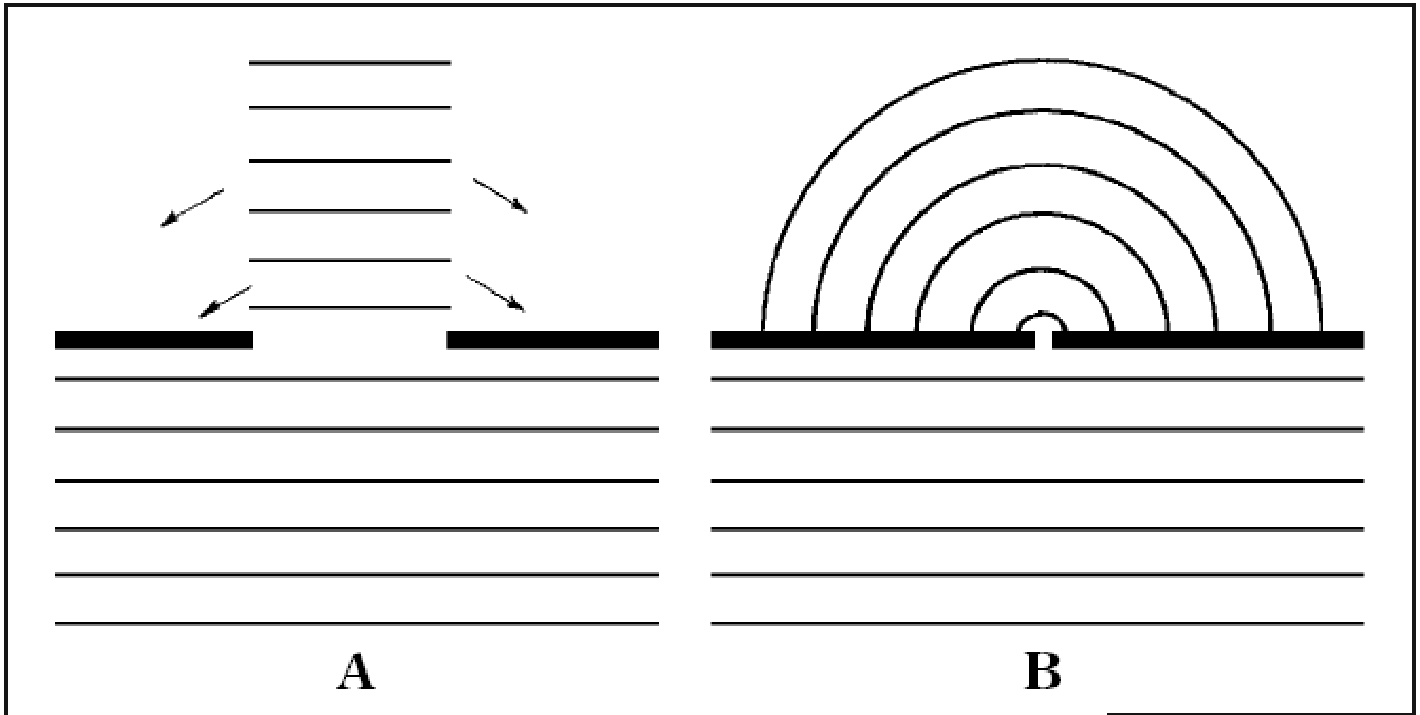


FIGURE 11-2

(A) An aperature large in terms of wavelength of sound allows wavefronts to go through with little disturbance. These wavefronts act as lines of new sources radiating sound energy into the shadow zone. (B) If the aperature is small compared to the wavelength of the sound, the small wavefronts which do penetrate the hole act almost as point sources, radiating a hemispherical field of sound into the shadow zone.

Difrakcia zvuku okolo prekážky

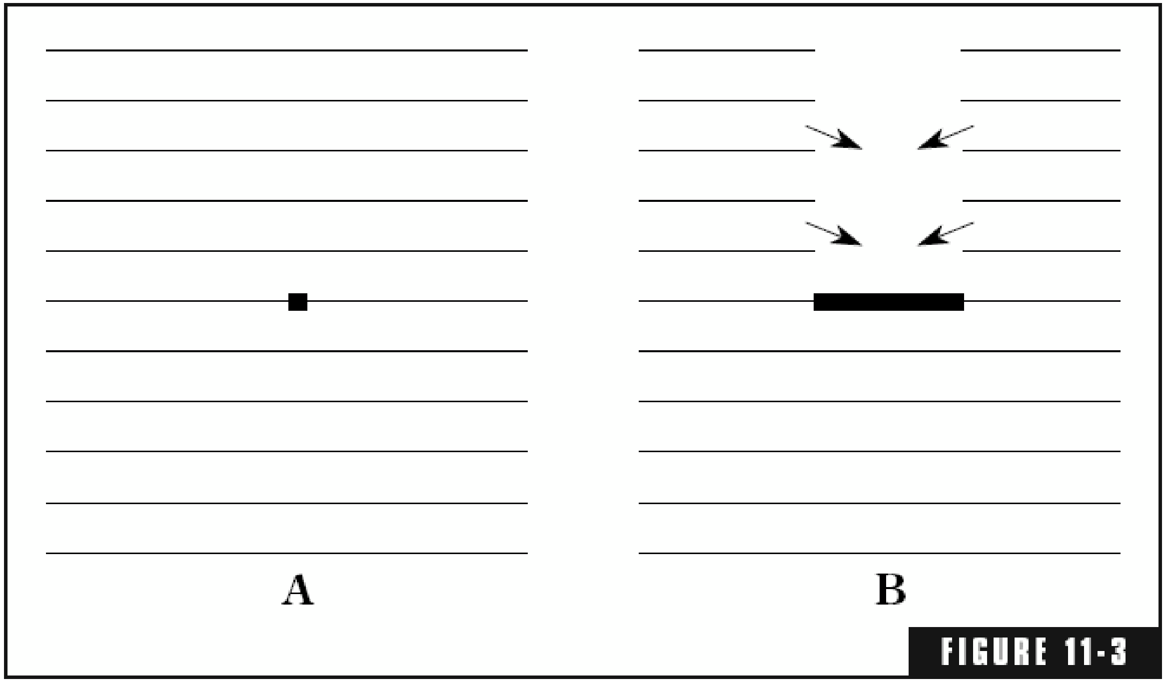


FIGURE 11-3

(A) An obstacle very much smaller than the wavelength of sound allows the wavefronts to pass essentially undisturbed. (B) An obstacle large compared to the wavelength of sound casts a shadow that tends to be irradiated from sources on the wavefronts of sound that go past the obstacle.

Zvuková bariéra

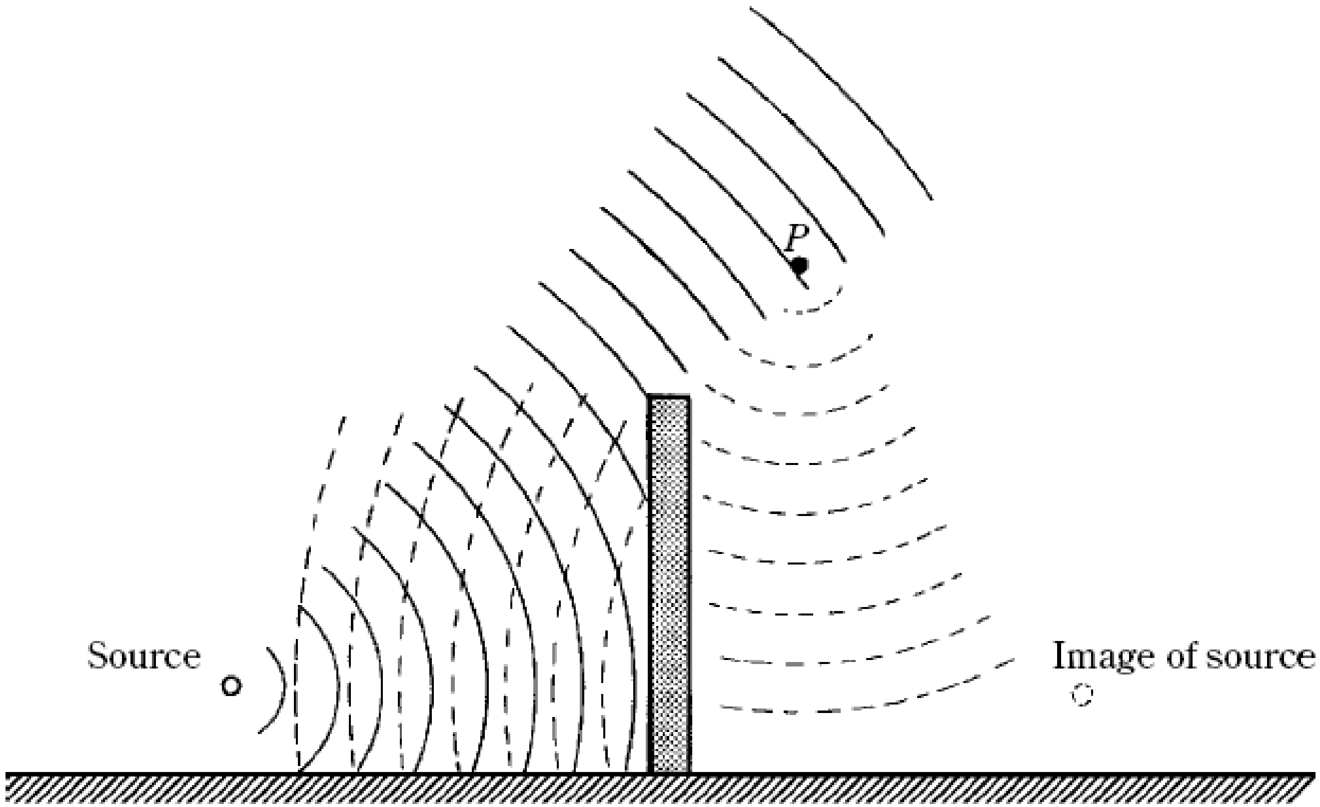


FIGURE 11-4

The classic sound barrier case. The sound striking the wall is reflected as though the sound is radiated from a virtual image of the source. That sound passing the top edge of the wall acts as though the wavefronts are lines of sources radiating sound energy into the shadow zone.

Útlm zvuku zvukovou bariérou

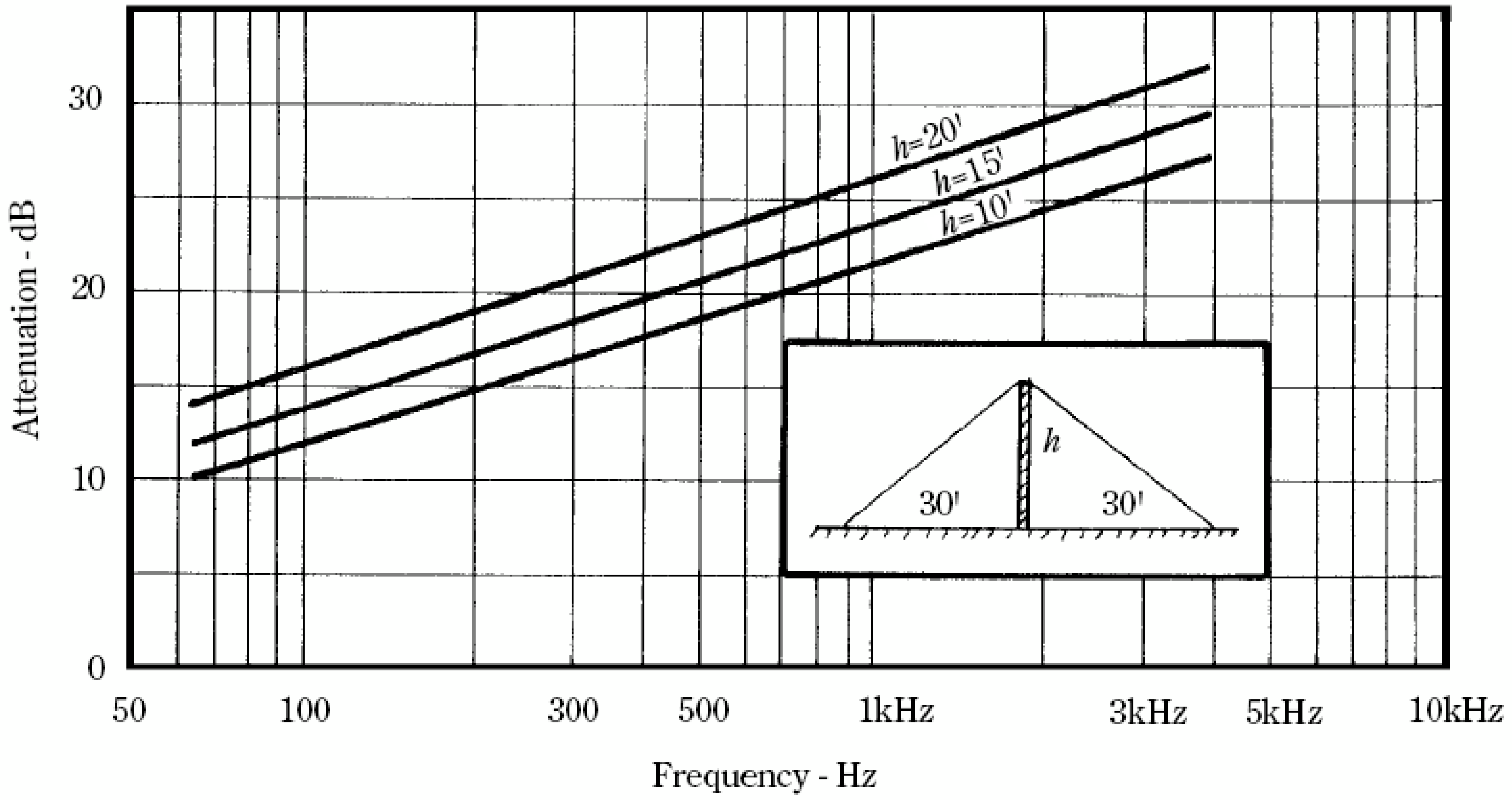


FIGURE 11-5

An estimation of the effectiveness of a sound barrier in terms of sound (or noise) attentuation as a function of frequency and barrier height. *(After Rettinger.*[4]*)*

Akustická šošovka

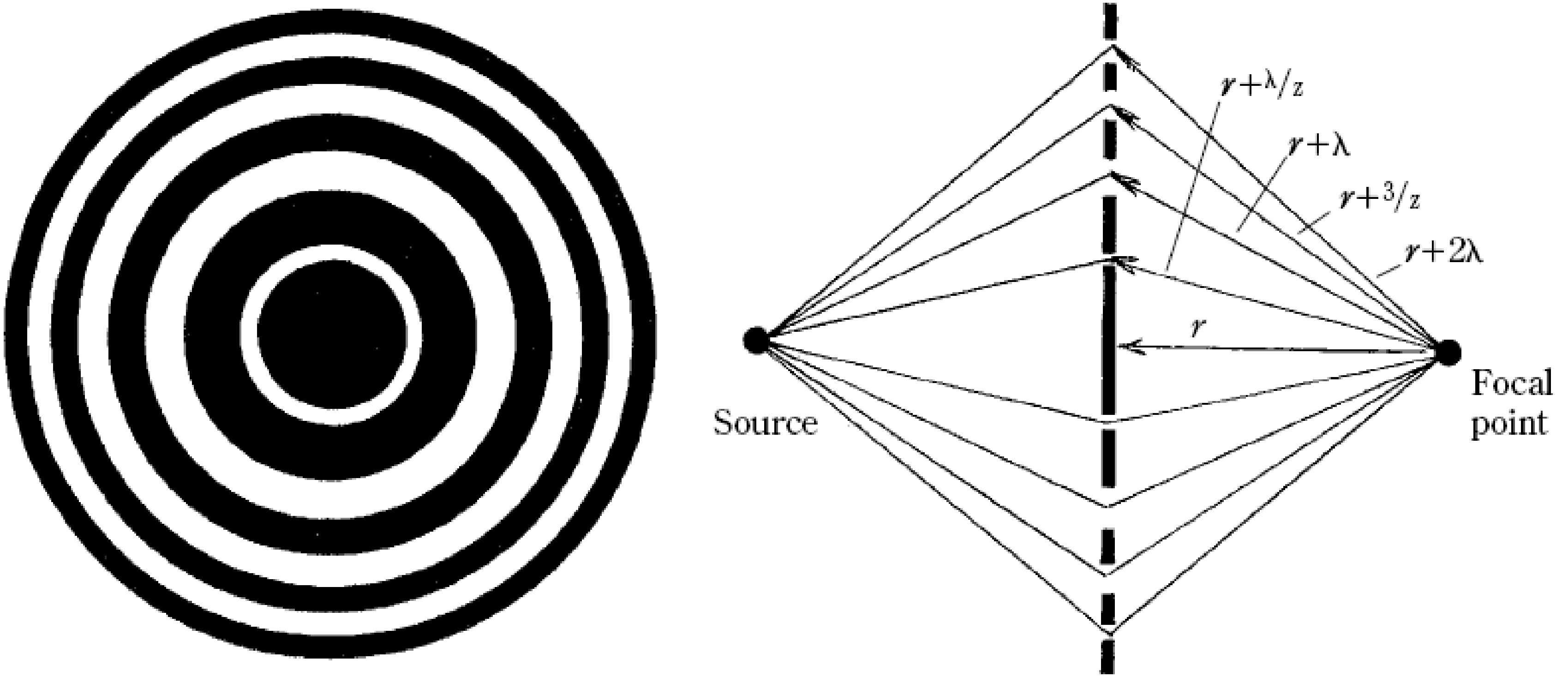


FIGURE 11-7

The zone plate or acoustic lens. The slits are so arranged that the several path lengths differ by multiples of a half wavelength of the sound so that all diffracted rays arrive at the focal point in phase, combining constructively. *(After Olson.[2])*

Ohyb zvuku v okolí ľudskej hlavy

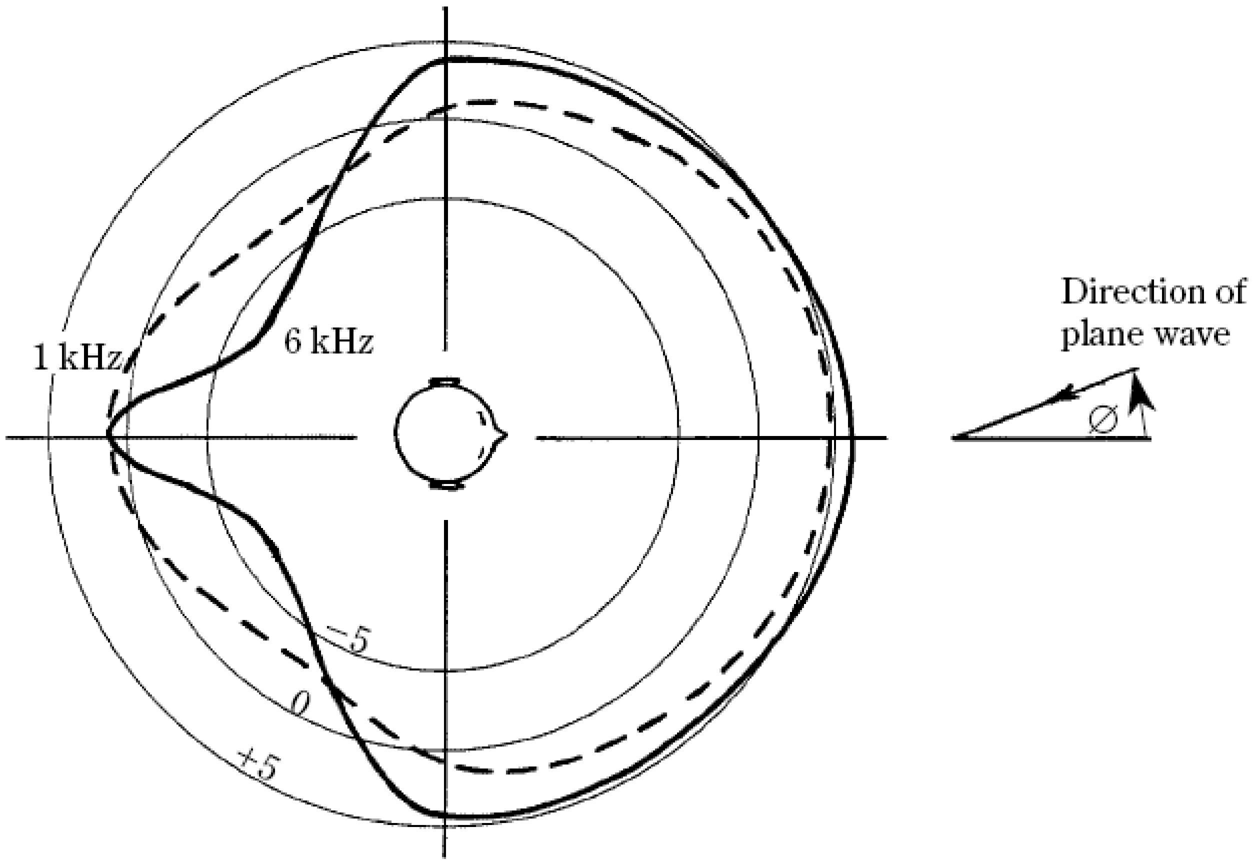


FIGURE 11-8

Diffraction around a solid sphere about the size of a human head. For sound in the 1-6 kHz range, sound pressure is generally increased in the front hemisphere and generally reduced in the rear. *(After Muller, Black and Davis, as reported by Olson.[2])*

Ohyb zvuku na ozvučnici

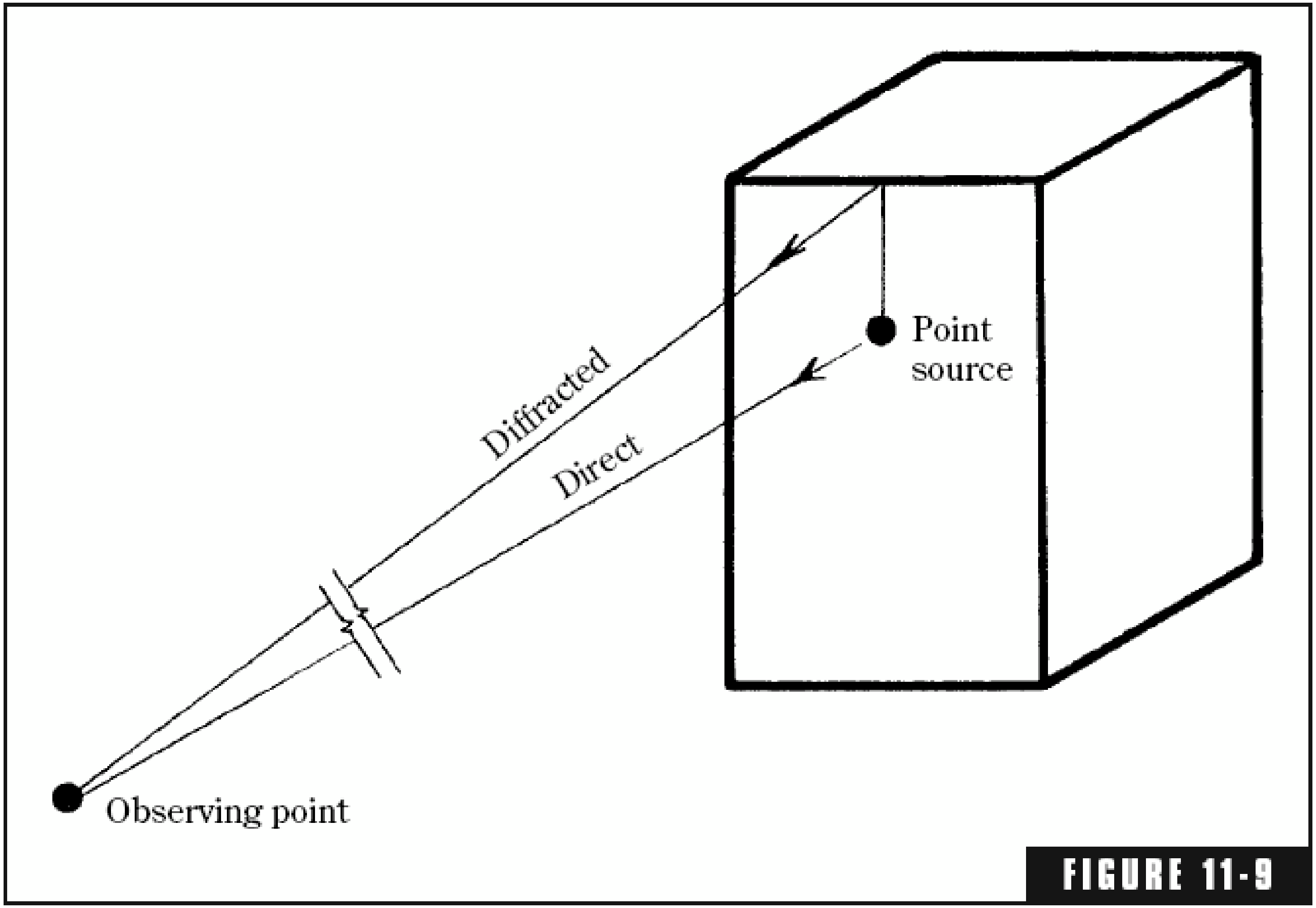


FIGURE 11-9

Arrangement for Vanderkooy's calculation of loudspeaker cabinet edge diffraction, shown in Fig. 11-10.

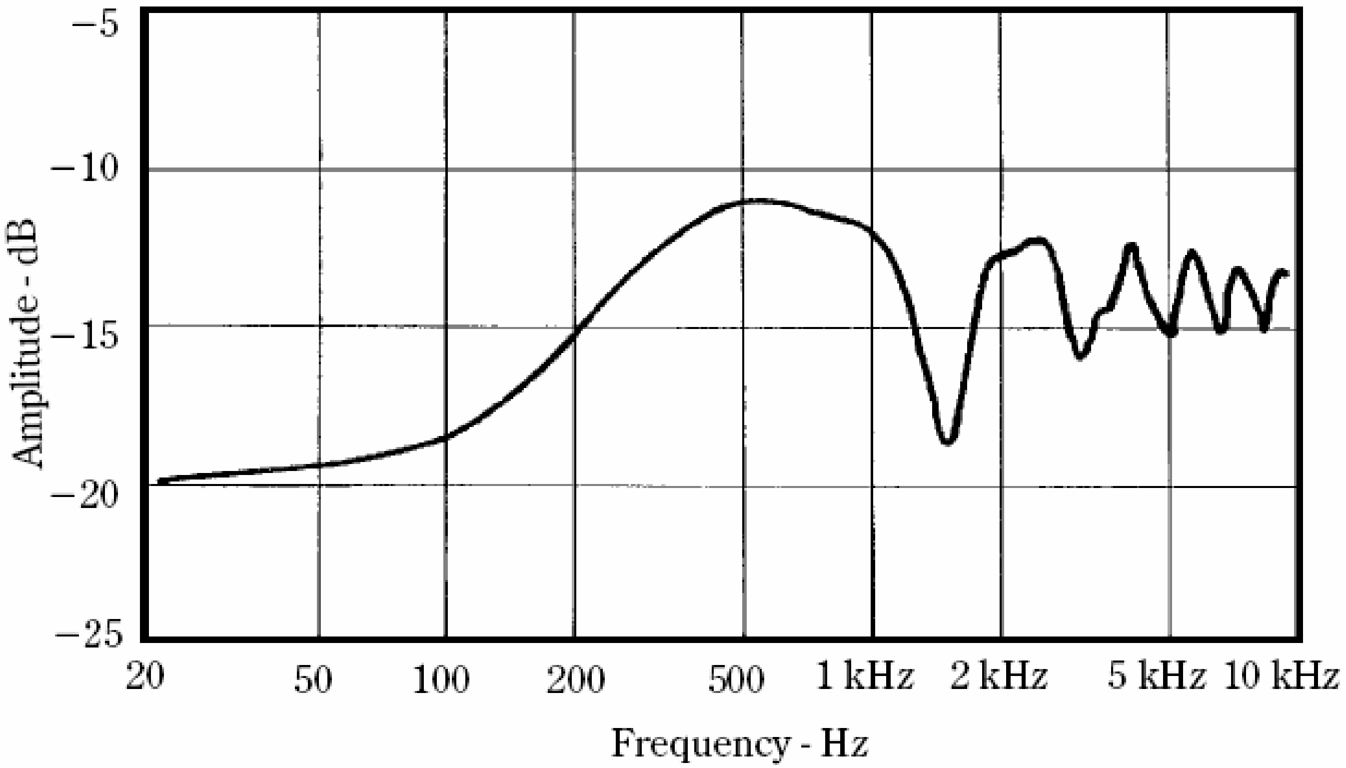
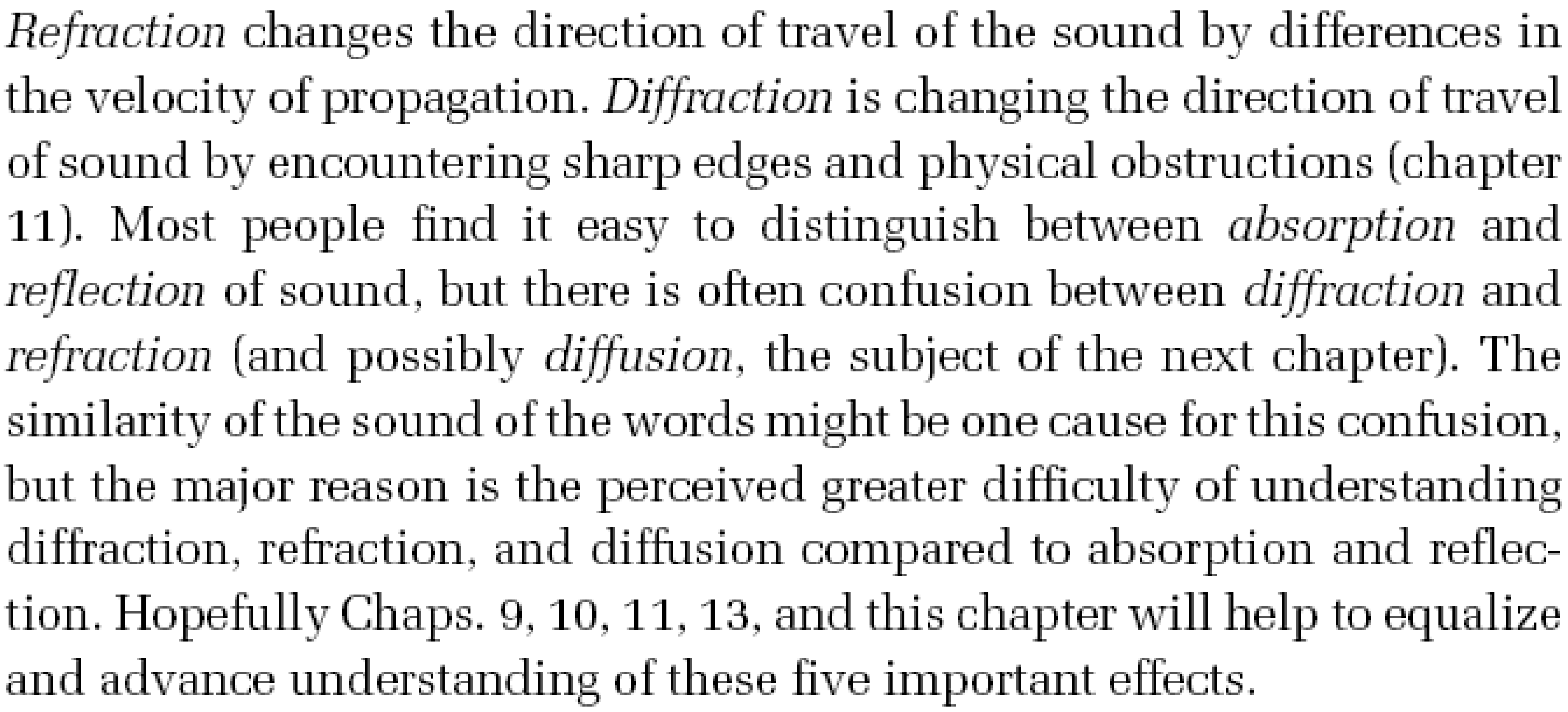


FIGURE 11-10

The calculated effects of loudspeaker edge diffraction on the direct signal in the arrangement of Fig.11-9. *(After Vanderkooy,[5] and Kessel.[6])*

Lom zvuku (refraction)



Refraction changes the direction of travel of the sound by differences in the velocity of propagation. *Diffraction* is changing the direction of travel of sound by encountering sharp edges and physical obstructions (chapter 11). Most people find it easy to distinguish between *absorption* and *reflection* of sound, but there is often confusion between *diffraction* and *refraction* (and possibly *diffusion*, the subject of the next chapter). The similarity of the sound of the words might be one cause for this confusion, but the major reason is the perceived greater difficulty of understanding diffraction, refraction, and diffusion compared to absorption and reflection. Hopefully Chaps. 9, 10, 11, 13, and this chapter will help to equalize and advance understanding of these five important effects.

...

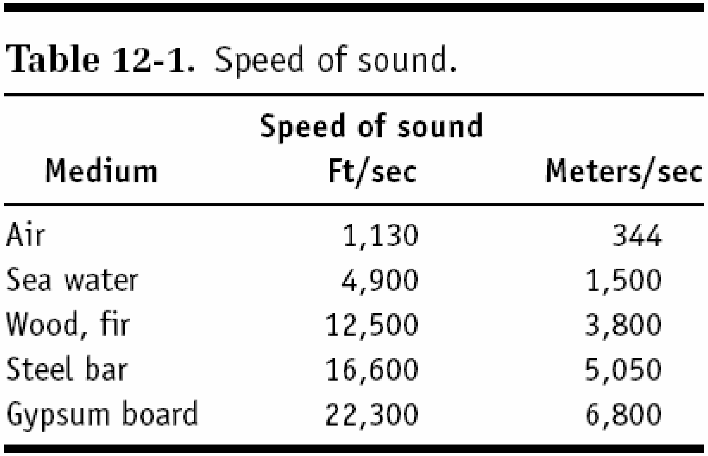


Table 12-1. Speed of sound.

Medium	Speed of sound Ft/sec	Meters/sec
Air	1,130	344
Sea water	4,900	1,500
Wood, fir	12,500	3,800
Steel bar	16,600	5,050
Gypsum board	22,300	6,800

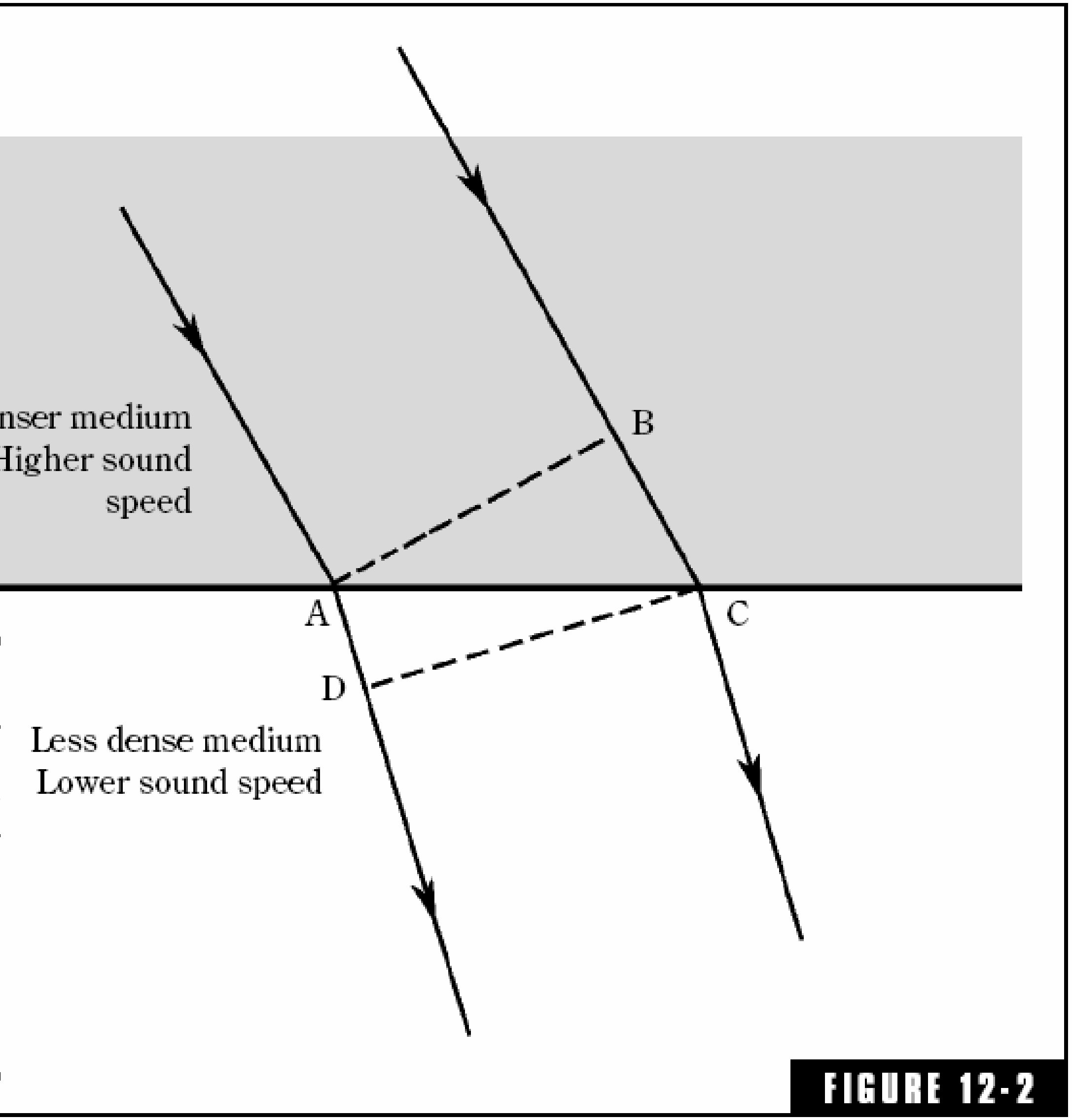


FIGURE 12-2

Rays of sound traveling from a denser medium having a certain sound speed into a less dense medium having a lower sound speed. The wavefront *AB* is not parallel to wavefront *DC* because the direction of the wave is changed due to refraction.

Lom zvuku v atmosfére

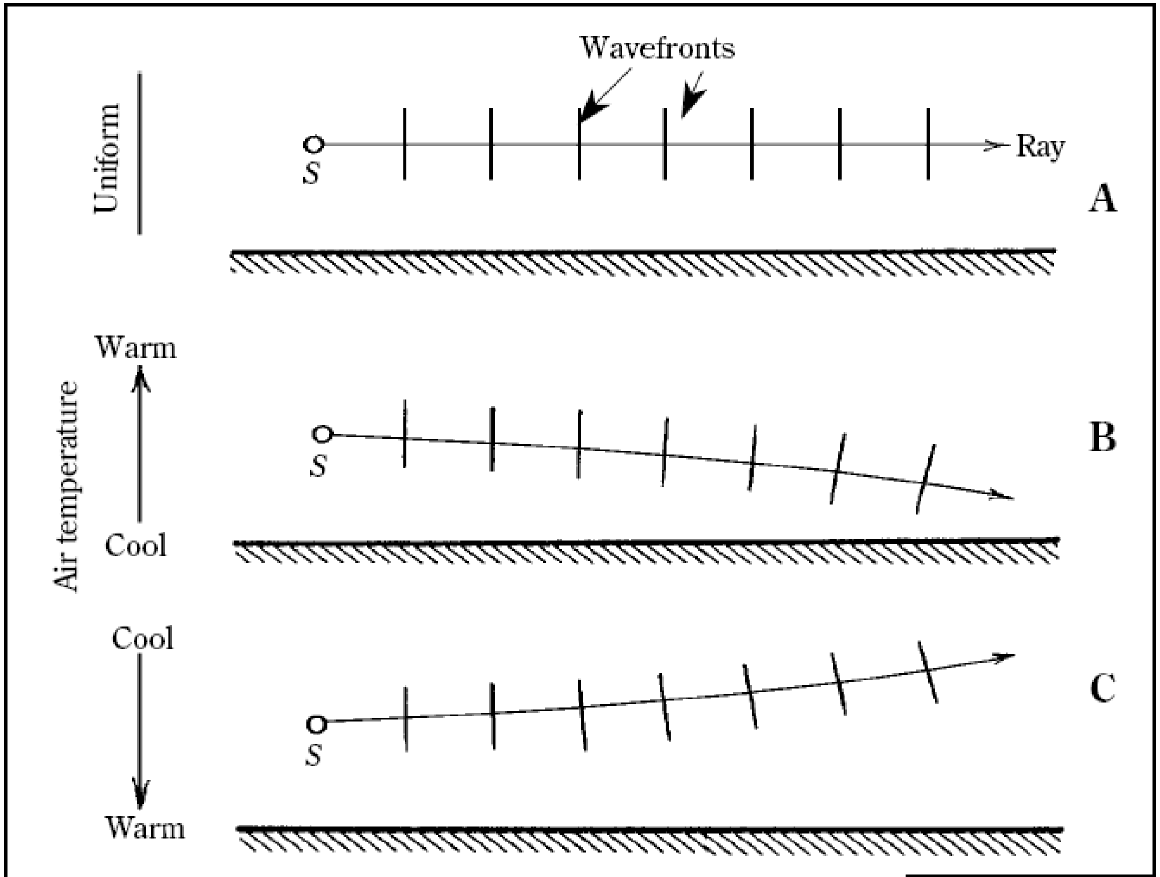


FIGURE 12-3

Refraction of sound paths resulting from temperature gradients in the atmosphere; (A) air temperature constant with height, (B) cool air near the surface of the earth and warmer air above, (C) warm air near the earth and cooler air above.

...

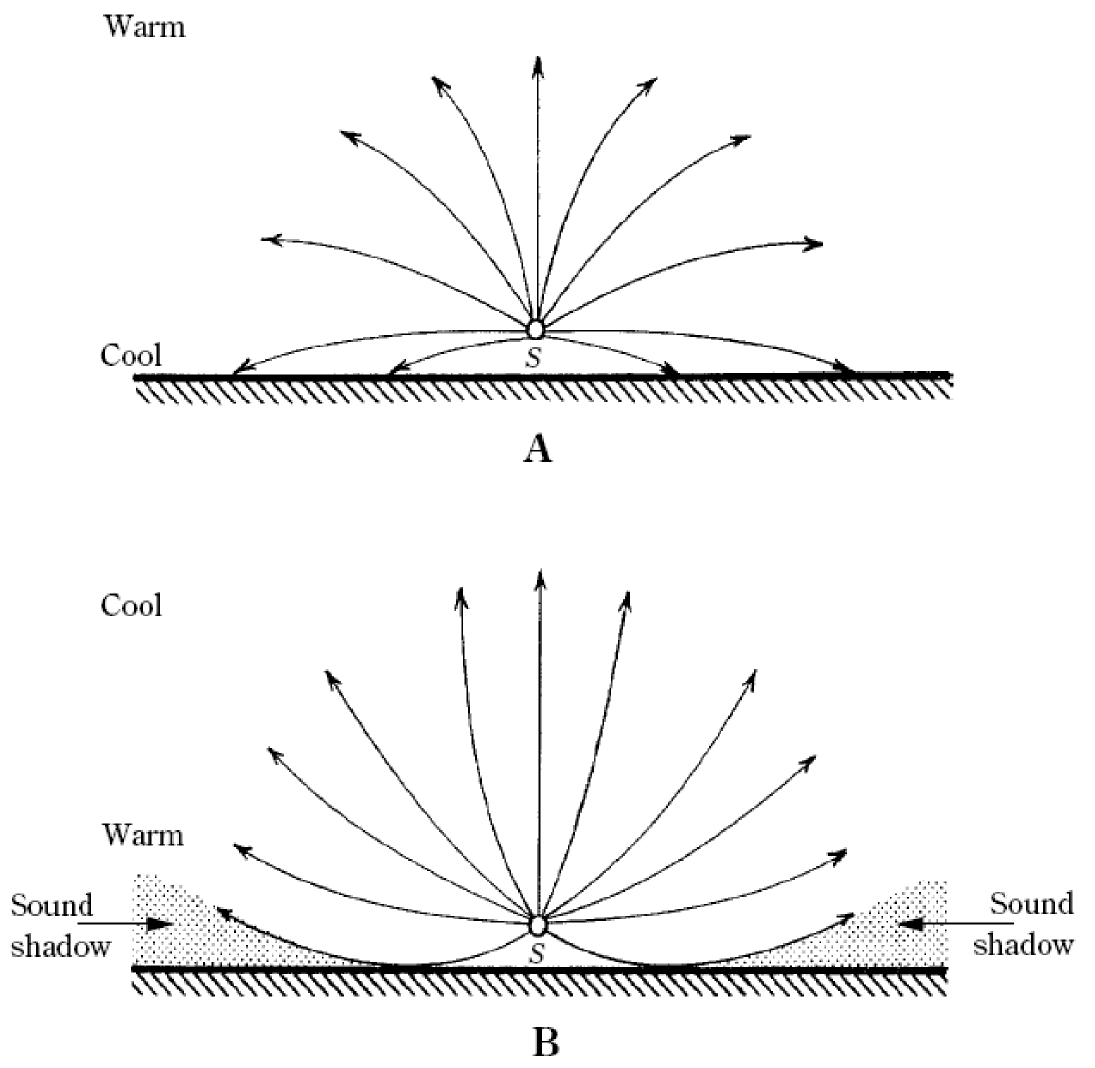


FIGURE 12-4

Comprehensive illustration of refraction of sound from source S; (A) cool air near the ground and warmer air above, (B) warm air near the ground and cooler air above. In (B) note that sound shadow areas result from the upward refraction.

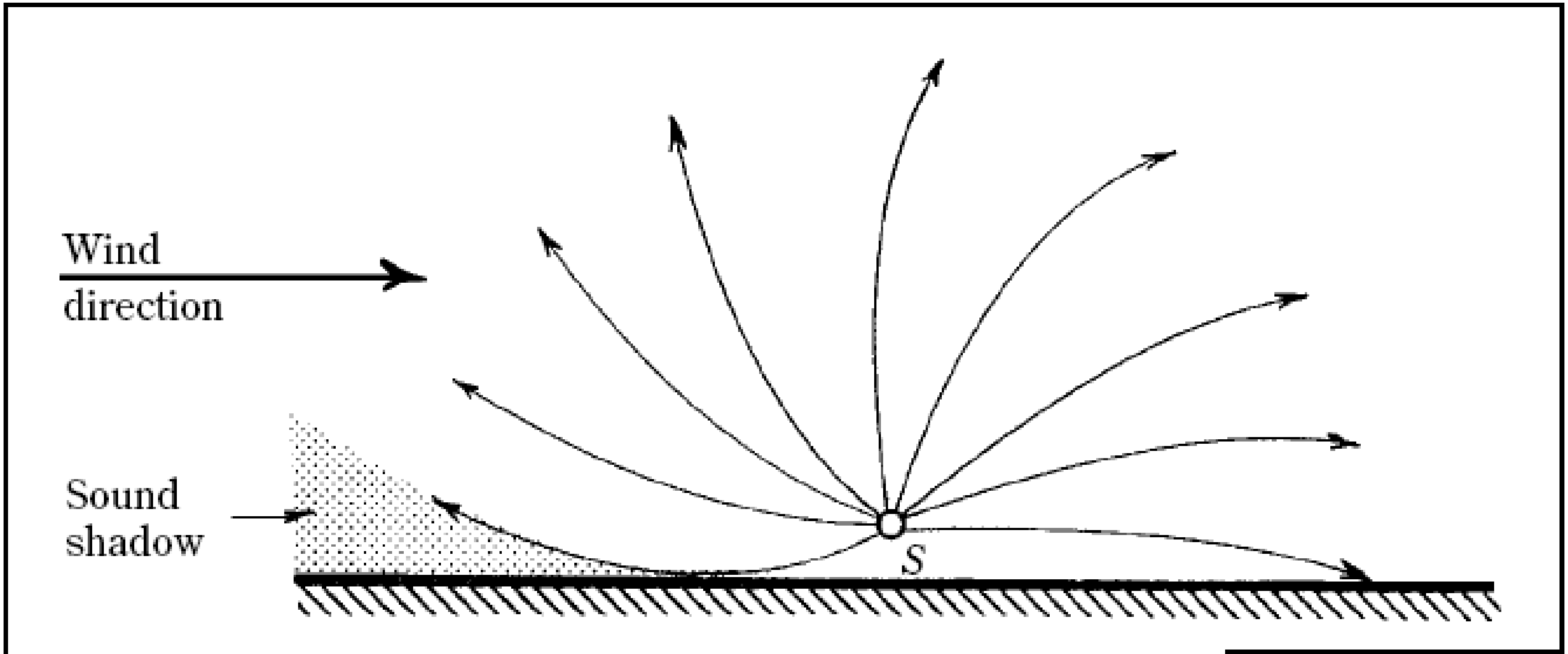


FIGURE 12-5

Wind gradients refract (not a true refraction) sound. A shadow sound is created upwind and good listening conditions downwind.

...

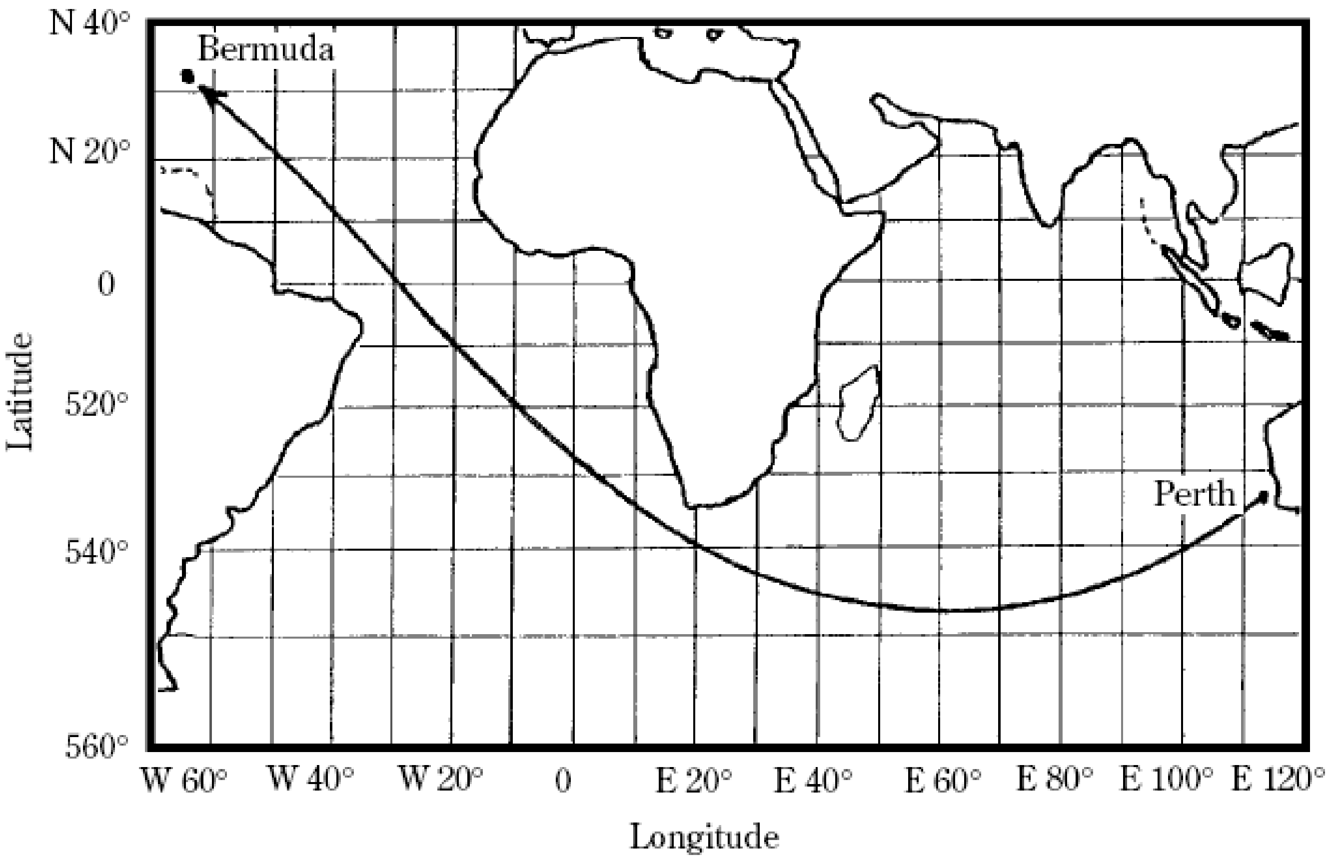
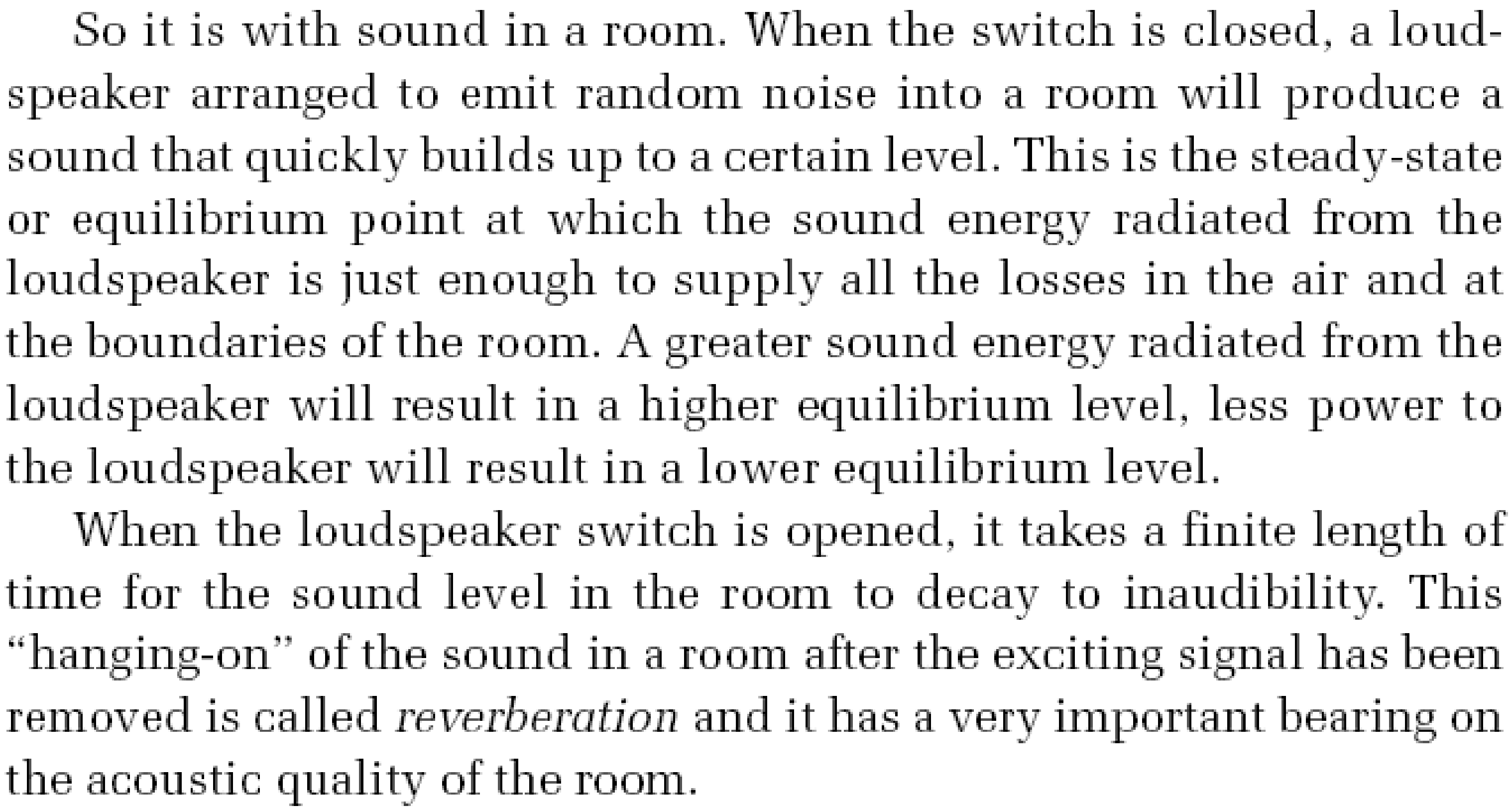


FIGURE 12-6

Refraction of sound in the ocean. A 600-lb charge was detonated near Perth, Australia, and the sound was recorded at Bermuda, over 12,000 miles away. The secret lies in the fact that the sound was confined to a sound channel by refraction that reduced losses. The sound took 3.71 hours to travel almost half way around the world. Such long-distance transmission of sound in the sea is being used to study long-range warming effects of the ocean. (After Heaney et al.[2])

Doba dozvuku (reverberation time)



So it is with sound in a room. When the switch is closed, a loudspeaker arranged to emit random noise into a room will produce a sound that quickly builds up to a certain level. This is the steady-state or equilibrium point at which the sound energy radiated from the loudspeaker is just enough to supply all the losses in the air and at the boundaries of the room. A greater sound energy radiated from the loudspeaker will result in a higher equilibrium level, less power to the loudspeaker will result in a lower equilibrium level.

When the loudspeaker switch is opened, it takes a finite length of time for the sound level in the room to decay to inaudibility. This "hanging-on" of the sound in a room after the exciting signal has been removed is called *reverberation* and it has a very important bearing on the acoustic quality of the room.

Dozvuk (Reverberation)

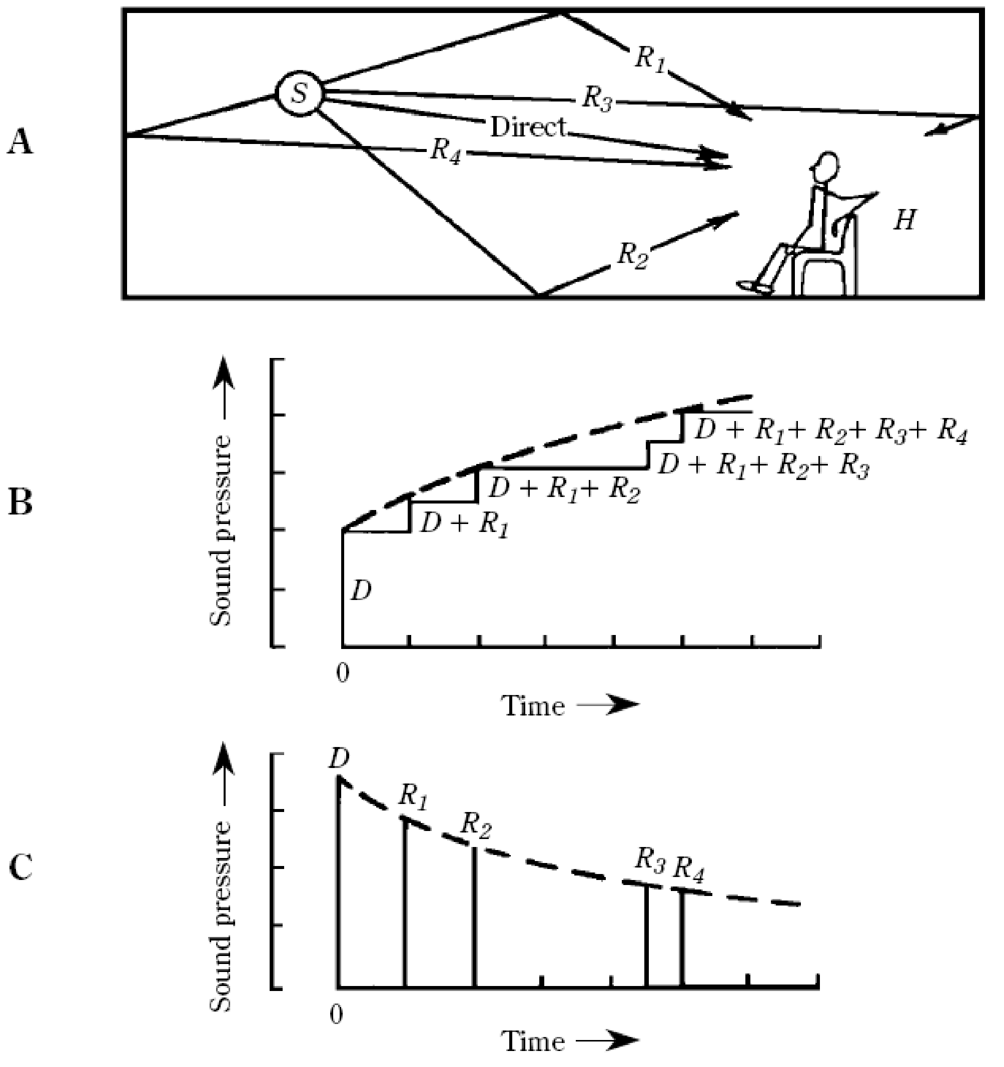


FIGURE 7-2

The buildup and decay of sound in a room. (A) The direct sound arrives first at time = 0, reflected components arriving later. (B) The sound pressure at *H* builds up stepwise. (C) The sound decays exponentially after the source ceases.

Ideálny nárast a pokles zvukovej energie

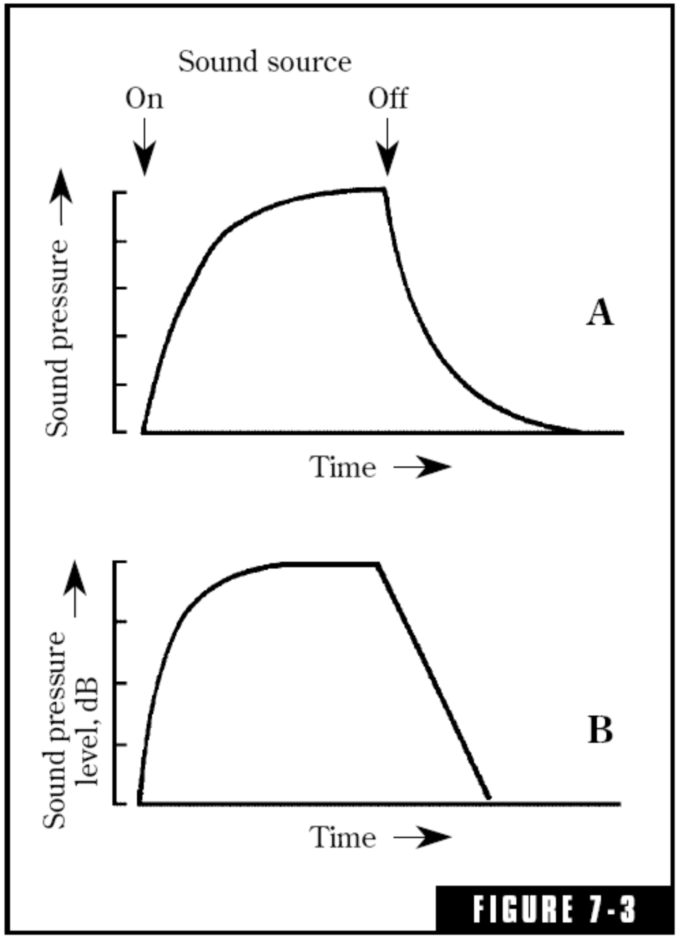
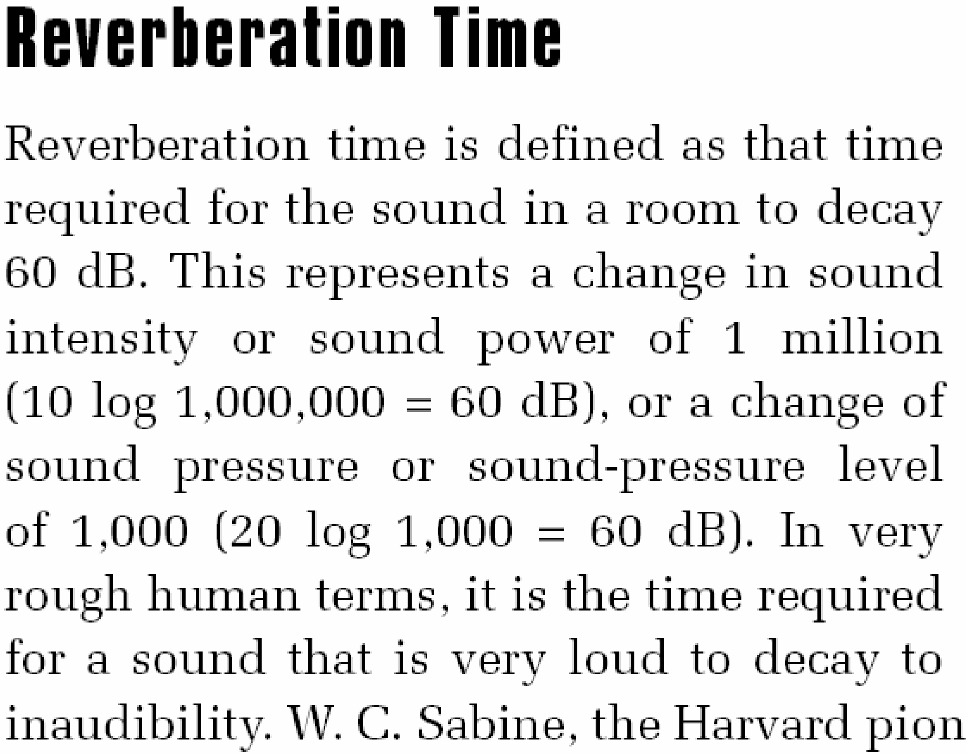


FIGURE 7-3

The growth and decay of sound in a room. (A) Vertical scale in linear sound pressure units. (B) The vertical scale in logarithmic units (decibels).

Doba dozvuku



Reverberation Time

Reverberation time is defined as that time required for the sound in a room to decay 60 dB. This represents a change in sound intensity or sound power of 1 million (10 log 1,000,000 = 60 dB), or a change of sound pressure or sound-pressure level of 1,000 (20 log 1,000 = 60 dB). In very rough human terms, it is the time required for a sound that is very loud to decay to inaudibility. W. C. Sabine, the Harvard pion

Meranie doby dozvuku

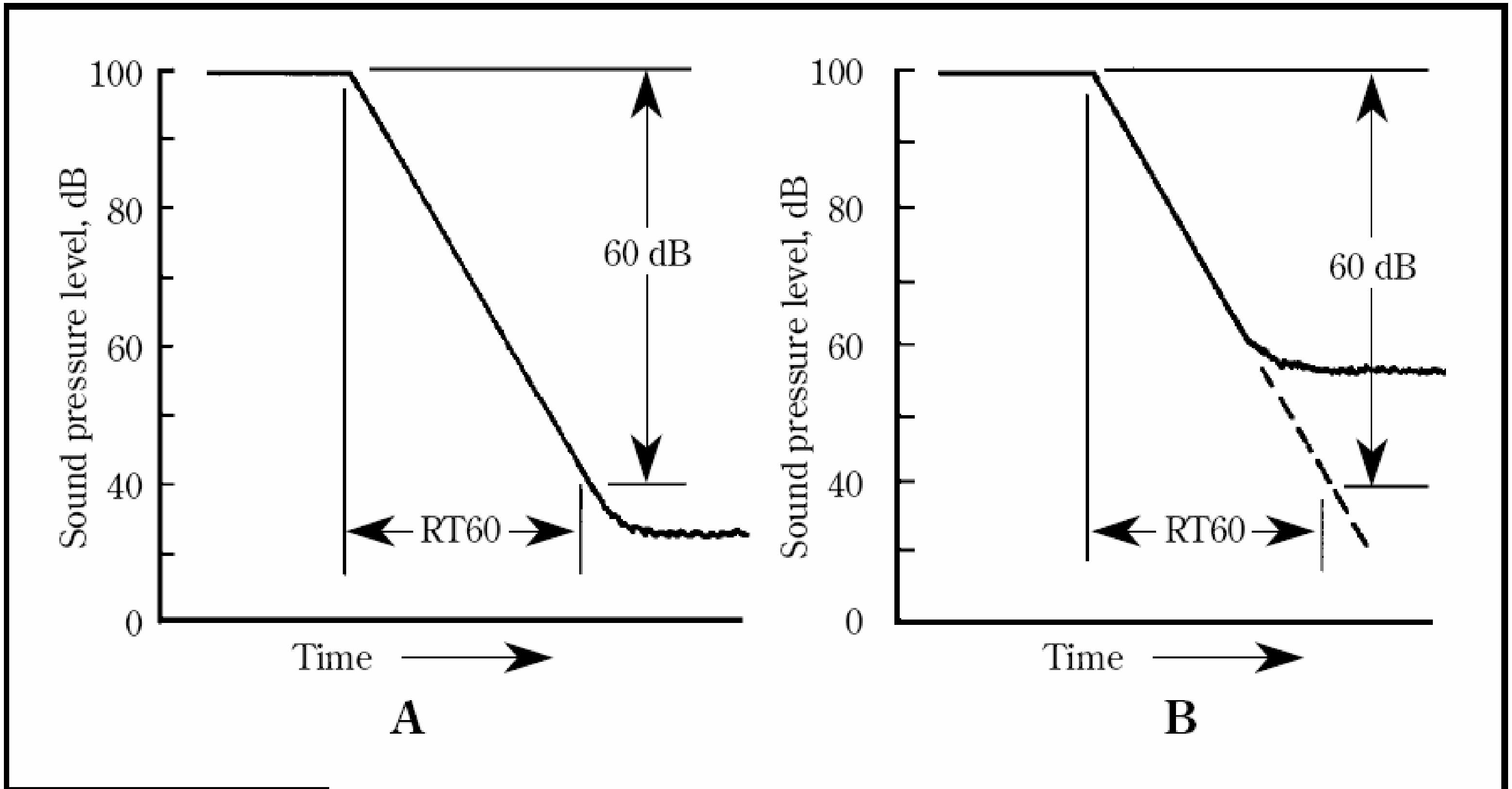


FIGURE 7-4

The length of the decay dependent on strength of the source and the noise level. (A) Rarely do practical circumstances allow a full 60-dB decay. (B) The slope of the limited decay is extrapolated to determine the reverberation time.

Vplyv dozvuku na zrozumiteľnosť reči

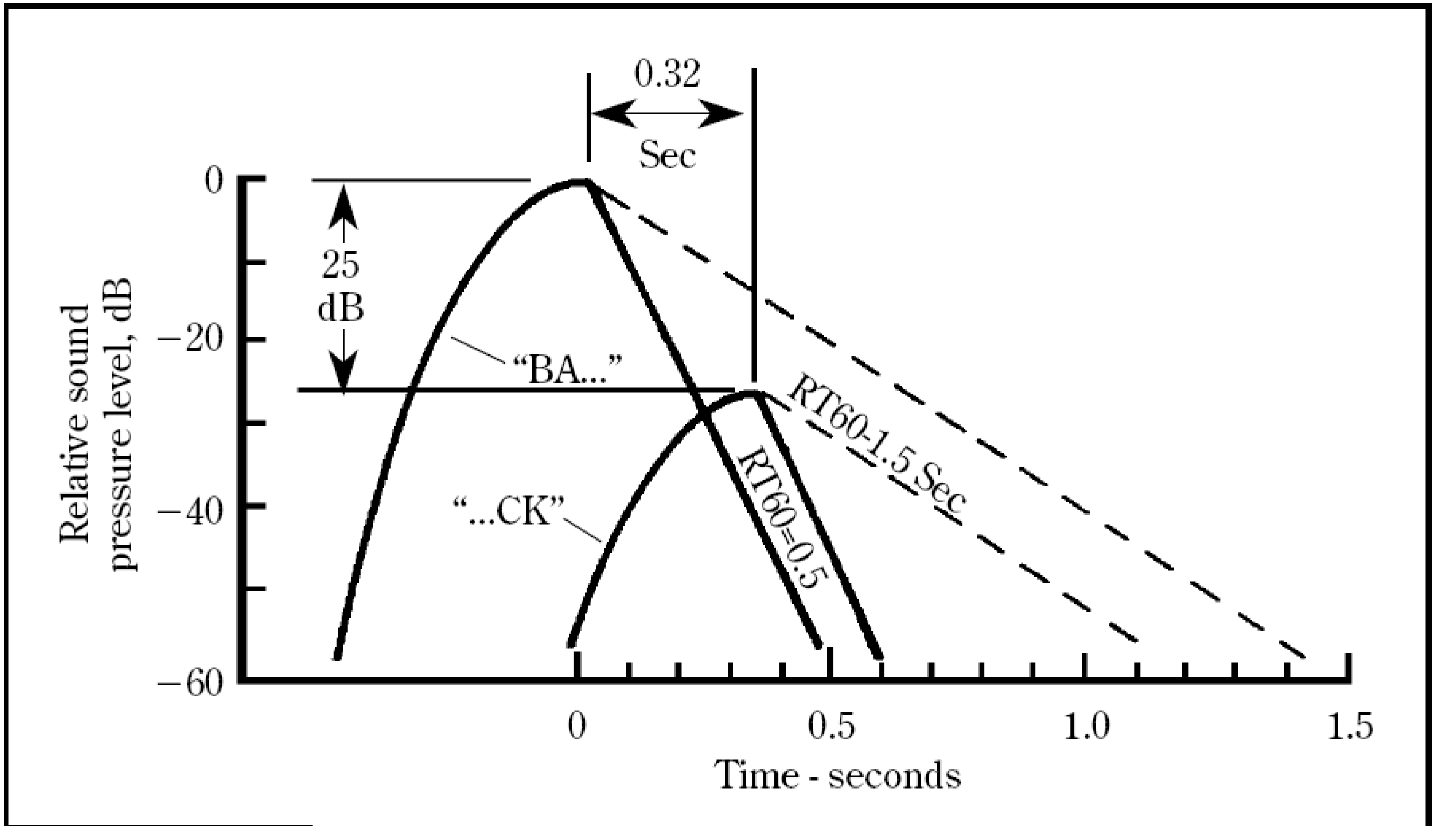
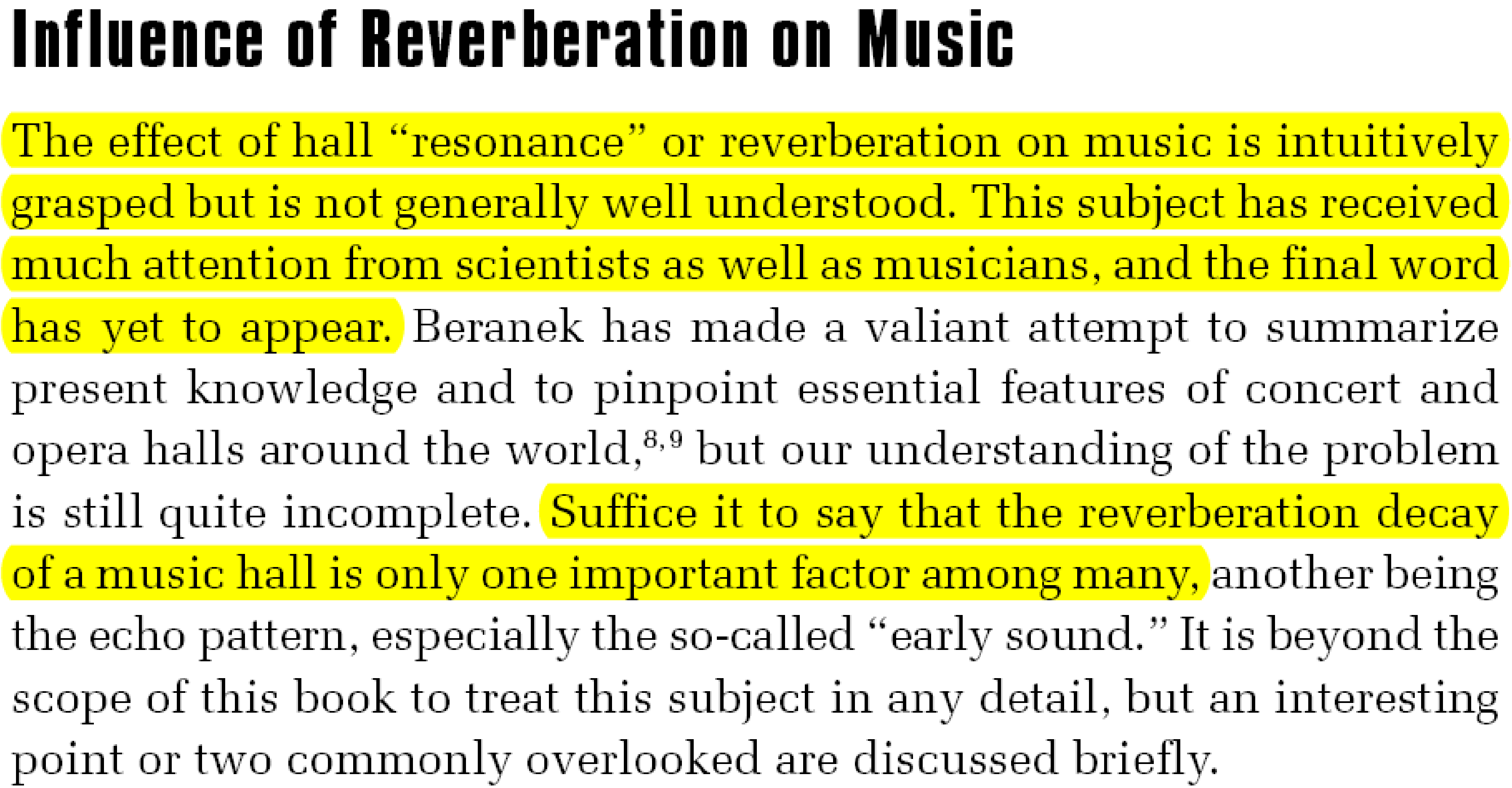


FIGURE 7-12

An illustration of the effects of reverberation on the intelligibility of speech. Understanding the word "back" depends on apprehending the later, lower level consonant "....ck," which is masked by reverberation if the reverberation time is too long.

Vplyv dozvuku na hudbu



Influence of Reverberation on Music

The effect of hall "resonance" or reverberation on music is intuitively grasped but is not generally well understood. This subject has received much attention from scientists as well as musicians, and the final word has yet to appear. Beranek has made a valiant attempt to summarize present knowledge and to pinpoint essential features of concert and opera halls around the world,[8,9] but our understanding of the problem is still quite incomplete. Suffice it to say that the reverberation decay of a music hall is only one important factor among many, another being the echo pattern, especially the so-called "early sound." It is beyond the scope of this book to treat this subject in any detail, but an interesting point or two commonly overlooked are discussed briefly.

Optimálna doba dozvuku pre kostoly

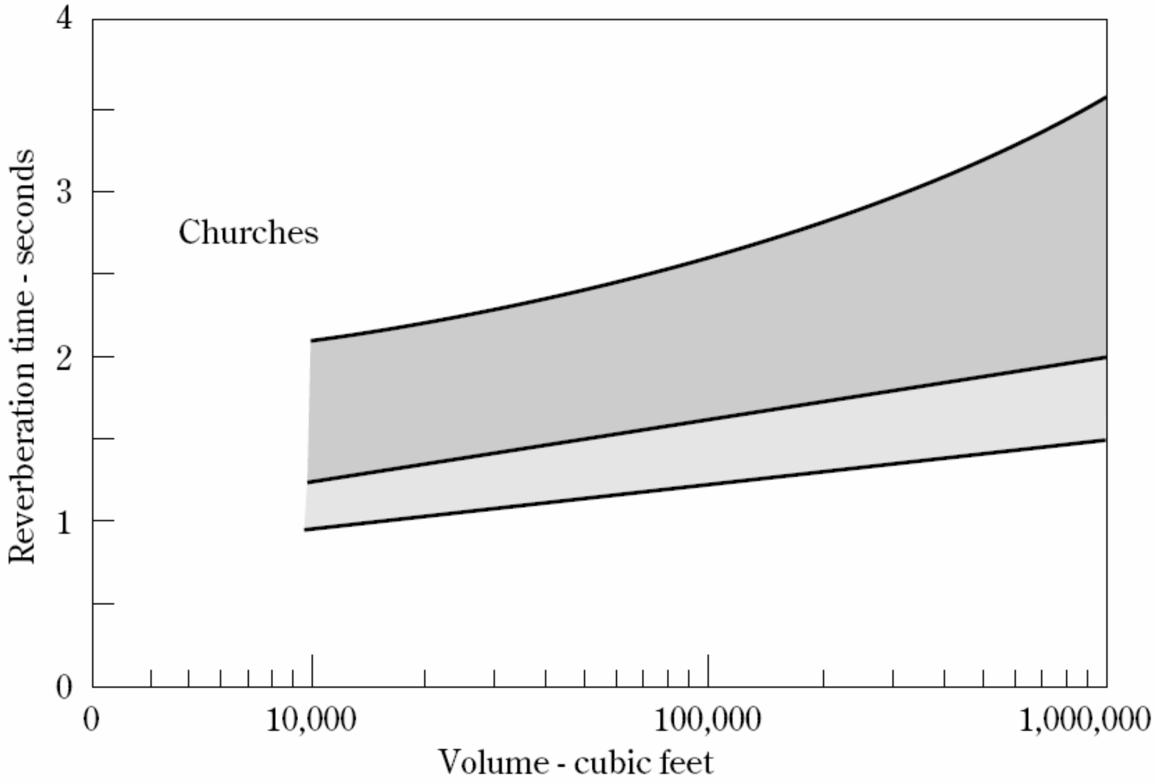


FIGURE 7-13

"Optimum" reverberation time for churches. The upper area applies to the more reverberant liturgical churches and cathedrals, the lower to churches having services more oriented to speech. A compromise between music and speech is required in most churches.

Optimálna doba dozvuku pre koncertné sály

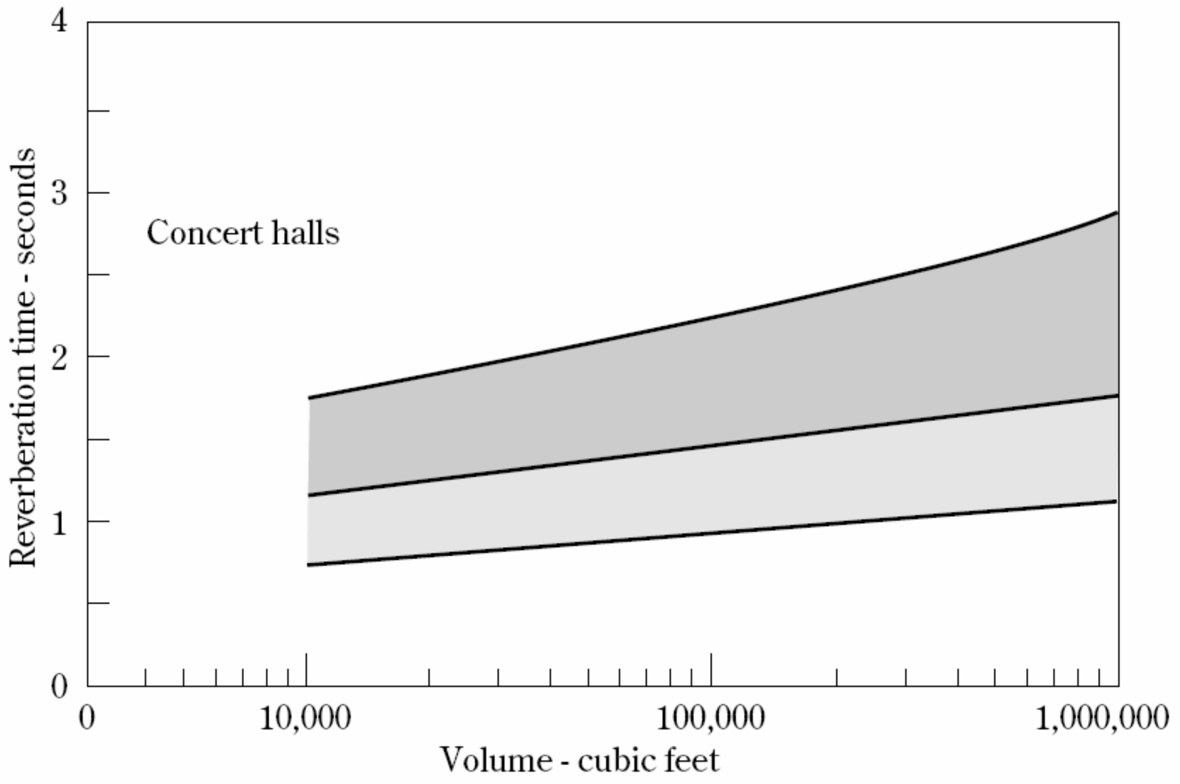


FIGURE 7-14

"Optimum" reverberation time for concert halls. Symphony orchestras are near the top of the shaded areas; lighter music is lower. The lower shaded area applies to opera and chamber music.

Optimálna doba dozvuku

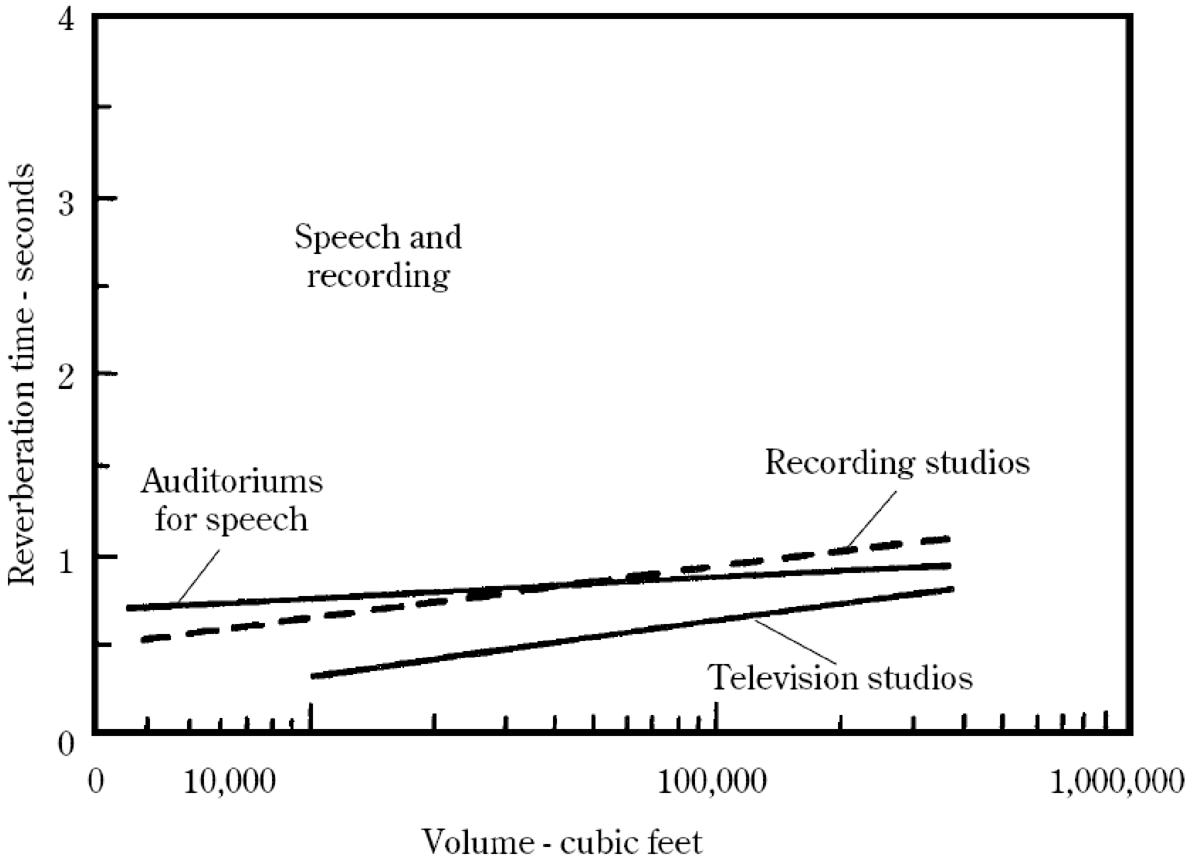
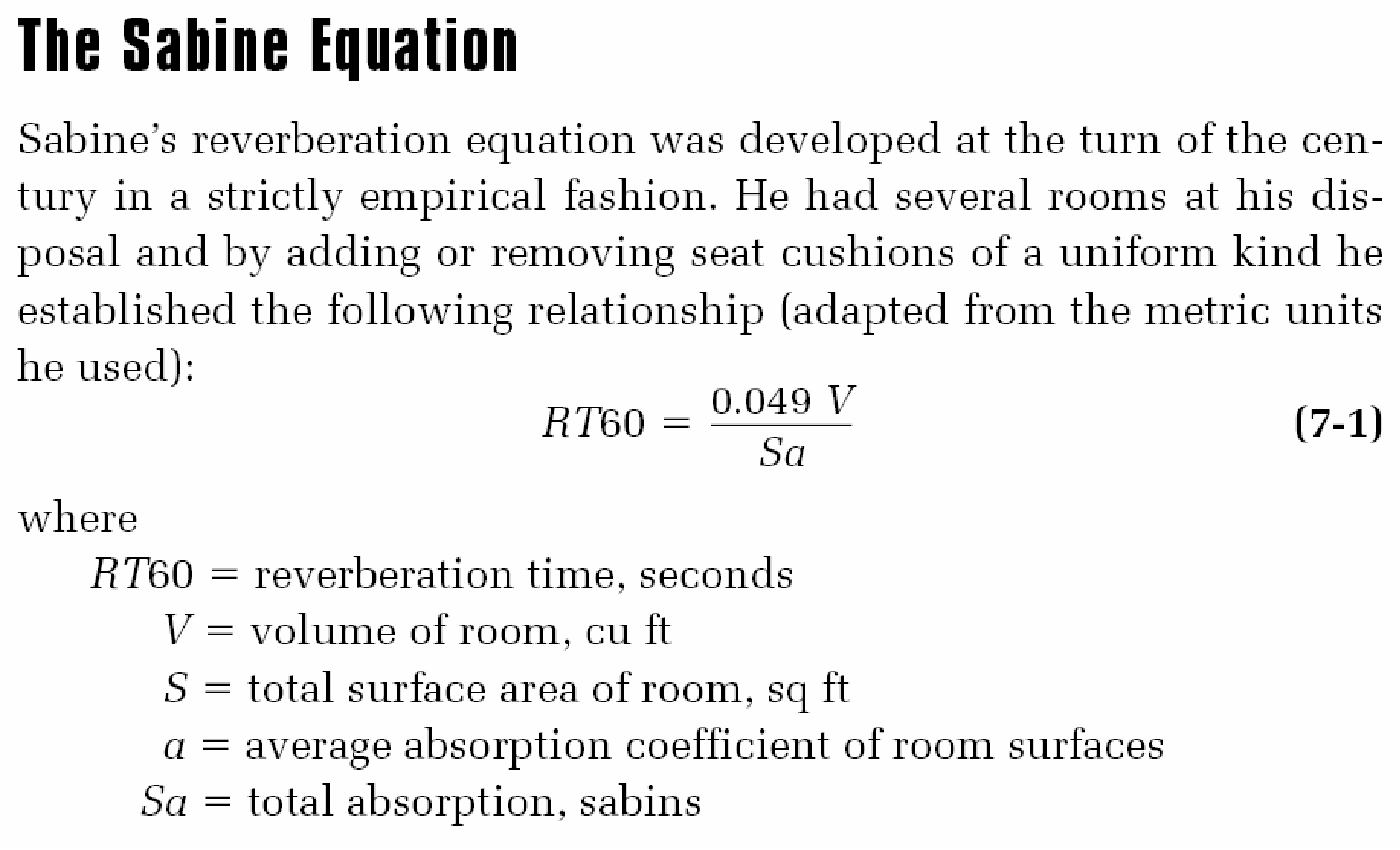


FIGURE 7-15

Spaces designed for speech and music recording require shorter reverberation times.

Výpočet doby dozvuku



The Sabine Equation

Sabine's reverberation equation was developed at the turn of the century in a strictly empirical fashion. He had several rooms at his disposal and by adding or removing seat cushions of a uniform kind he established the following relationship (adapted from the metric units he used):

$$RT60 = \frac{0.049\,V}{Sa} \tag{7-1}$$

where

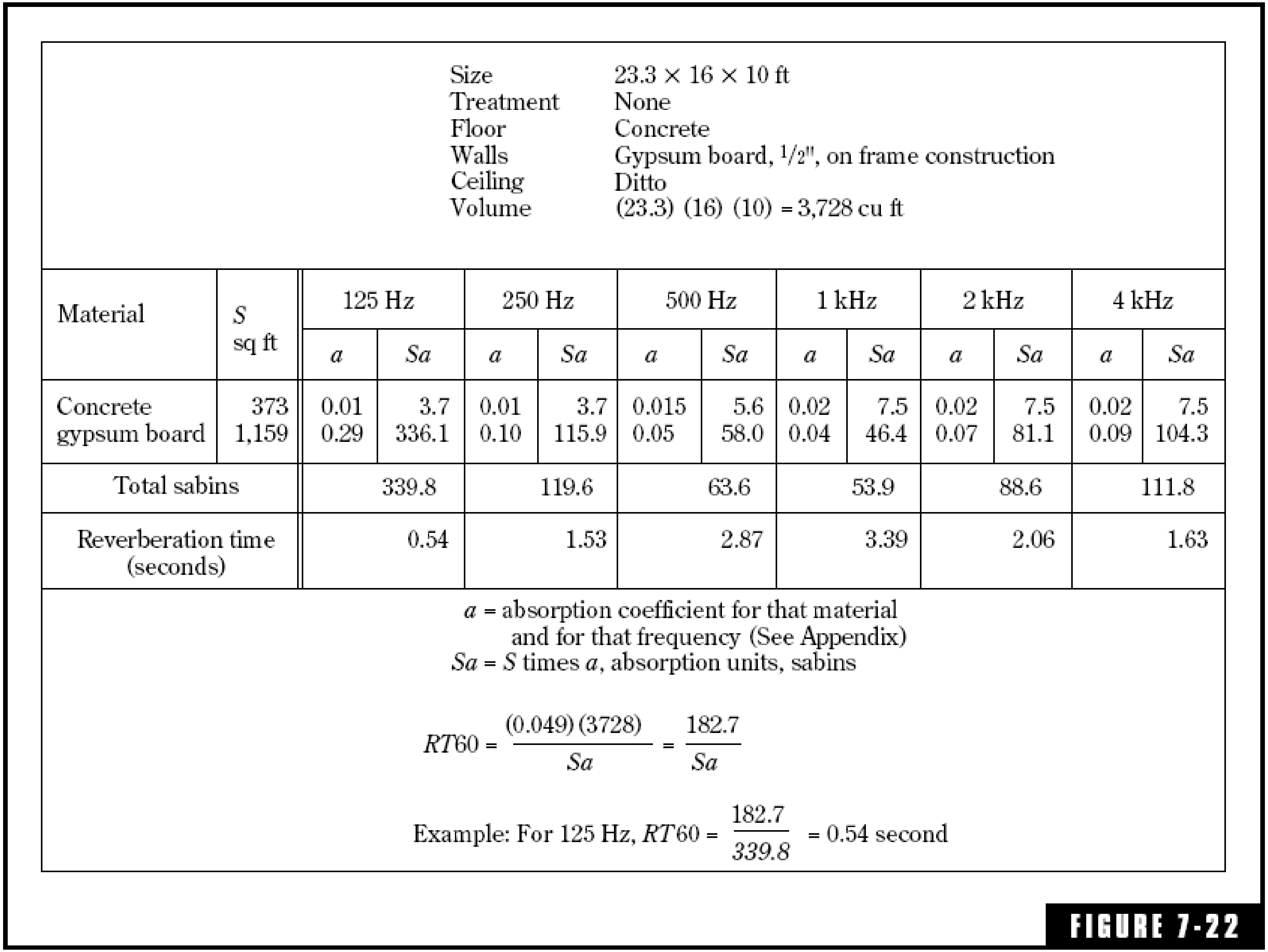
$RT60$ = reverberation time, seconds

V = volume of room, cu ft

S = total surface area of room, sq ft

a = average absorption coefficient of room surfaces

Sa = total absorption, sabins



Size	23.3 × 16 × 10 ft
Treatment	None
Floor	Concrete
Walls	Gypsum board, 1/2", on frame construction
Ceiling	Ditto
Volume	(23.3) (16) (10) = 3,728 cu ft

Material	*S* sq ft	125 Hz		250 Hz		500 Hz		1 kHz		2 kHz		4 kHz	
		a	*Sa*	*a*	*Sa*	*a*	*Sa*	*a*	*Sa*	*a*	*Sa*	*a*	*Sa*
Concrete	373	0.01	3.7	0.01	3.7	0.015	5.6	0.02	7.5	0.02	7.5	0.02	7.5
gypsum board	1,159	0.29	336.1	0.10	115.9	0.05	58.0	0.04	46.4	0.07	81.1	0.09	104.3
Total sabins		339.8		119.6		63.6		53.9		88.6		111.8	
Reverberation time (seconds)		0.54		1.53		2.87		3.39		2.06		1.63	

a = absorption coefficient for that material and for that frequency (See Appendix)
Sa = *S* times *a*, absorption units, sabins

$$RT60 = \frac{(0.049)(3728)}{Sa} = \frac{182.7}{Sa}$$

Example: For 125 Hz, $RT60 = \frac{182.7}{339.8} = 0.54$ second

FIGURE 7-22

Room conditions and calculations for Example 1.

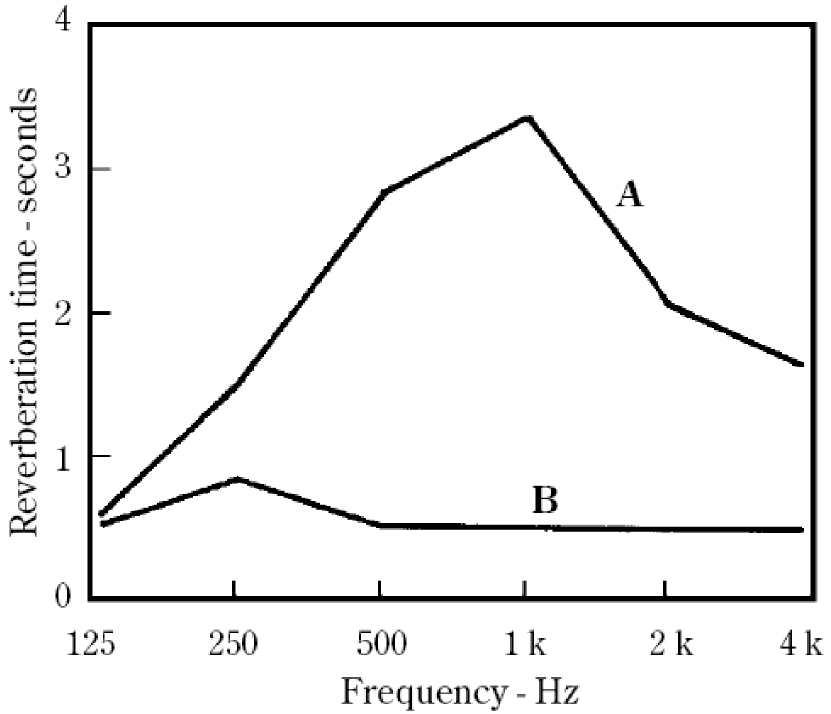
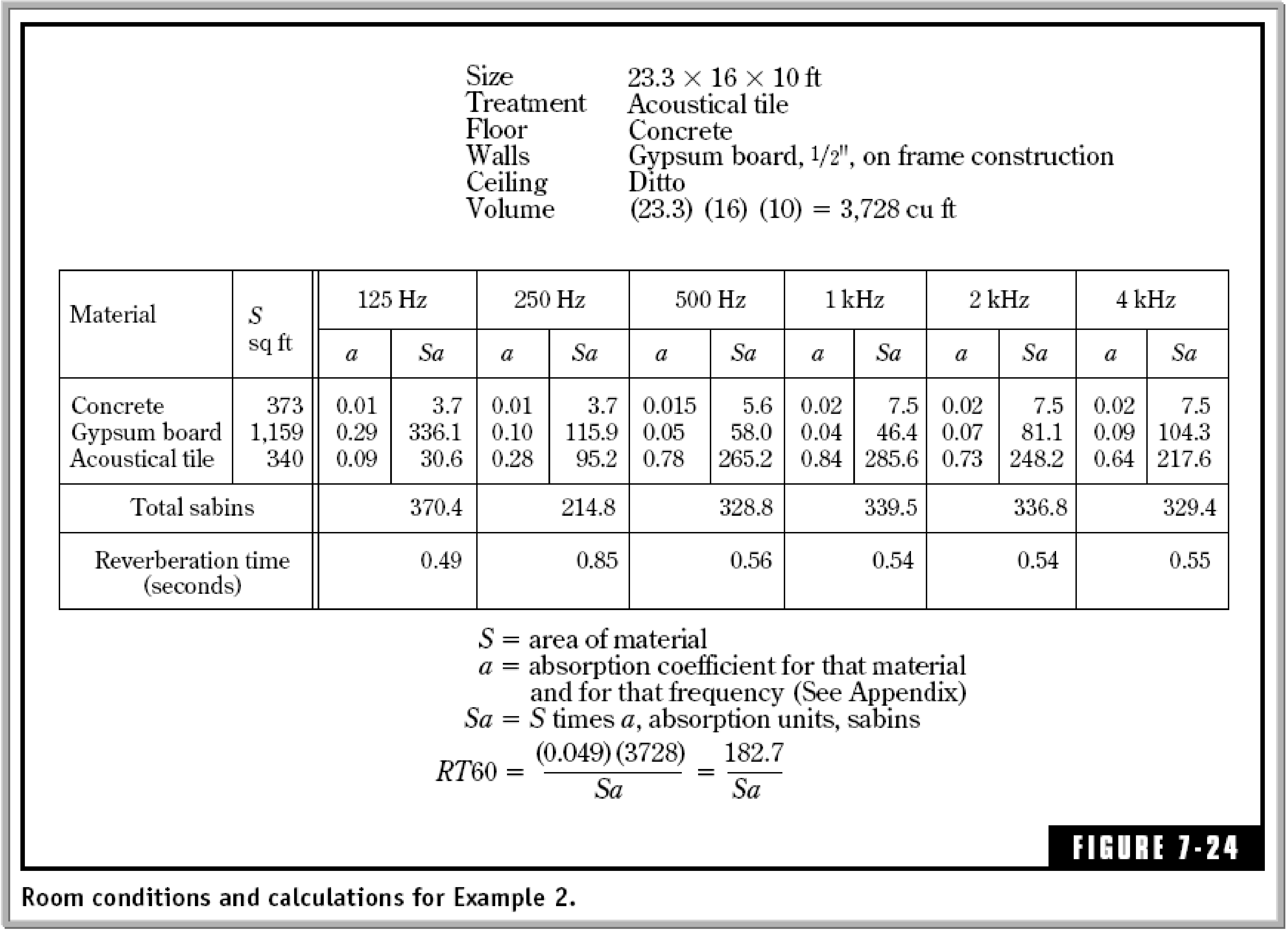


FIGURE 7-23

The calculated reverberation characteristics of a 23.3 × 16 × 10 ft room: (A) the "as found," untreated condition of Example 1, (B) treated condition of Example 2.

Reverberation Calculation: Example 2

The goal now is to correct the reverberation of curve *A* of Fig. 7-23. It is evident that much absorption is needed at midband frequencies, a modest amount at higher frequencies, and very little at lower frequencies. The need is for a material having an absorption characteristic shaped more or less like the reverberation curve *A*. Skipping the laborious thumbing through of handbooks, ¾-in acoustical tile seems to have the right shape. Giving no thought at this point to how it is to be distributed, what area of this tile is required to correct for Fig. 7-23A?



Size	23.3 × 16 × 10 ft
Treatment	Acoustical tile
Floor	Concrete
Walls	Gypsum board, 1/2", on frame construction
Ceiling	Ditto
Volume	(23.3) (16) (10) = 3,728 cu ft

Material	*S* sq ft	125 Hz		250 Hz		500 Hz		1 kHz		2 kHz		4 kHz	
		a	*Sa*	*a*	*Sa*	*a*	*Sa*	*a*	*Sa*	*a*	*Sa*	*a*	*Sa*
Concrete	373	0.01	3.7	0.01	3.7	0.015	5.6	0.02	7.5	0.02	7.5	0.02	7.5
Gypsum board	1,159	0.29	336.1	0.10	115.9	0.05	58.0	0.04	46.4	0.07	81.1	0.09	104.3
Acoustical tile	340	0.09	30.6	0.28	95.2	0.78	265.2	0.84	285.6	0.73	248.2	0.64	217.6
Total sabins			370.4		214.8		328.8		339.5		336.8		329.4
Reverberation time (seconds)			0.49		0.85		0.56		0.54		0.54		0.55

S = area of material
a = absorption coefficient for that material and for that frequency (See Appendix)
Sa = S times a, absorption units, sabins

$$RT60 = \frac{(0.049)(3728)}{Sa} = \frac{182.7}{Sa}$$

FIGURE 7-24

Room conditions and calculations for Example 2.

Absorpcia zvuku

The law of the conservation of energy states that energy can neither be created nor destroyed, but it can be changed from one form to another. If we have some sound energy in a room to get rid of, how can it be done? Sound is the vibratory energy of air particles, and it can be dissipated in the form of heat. If it takes the sound energy of a million people talking to brew a cup of tea, we must give up any idea of heating our home with sound from the high-fidelity loud speakers.

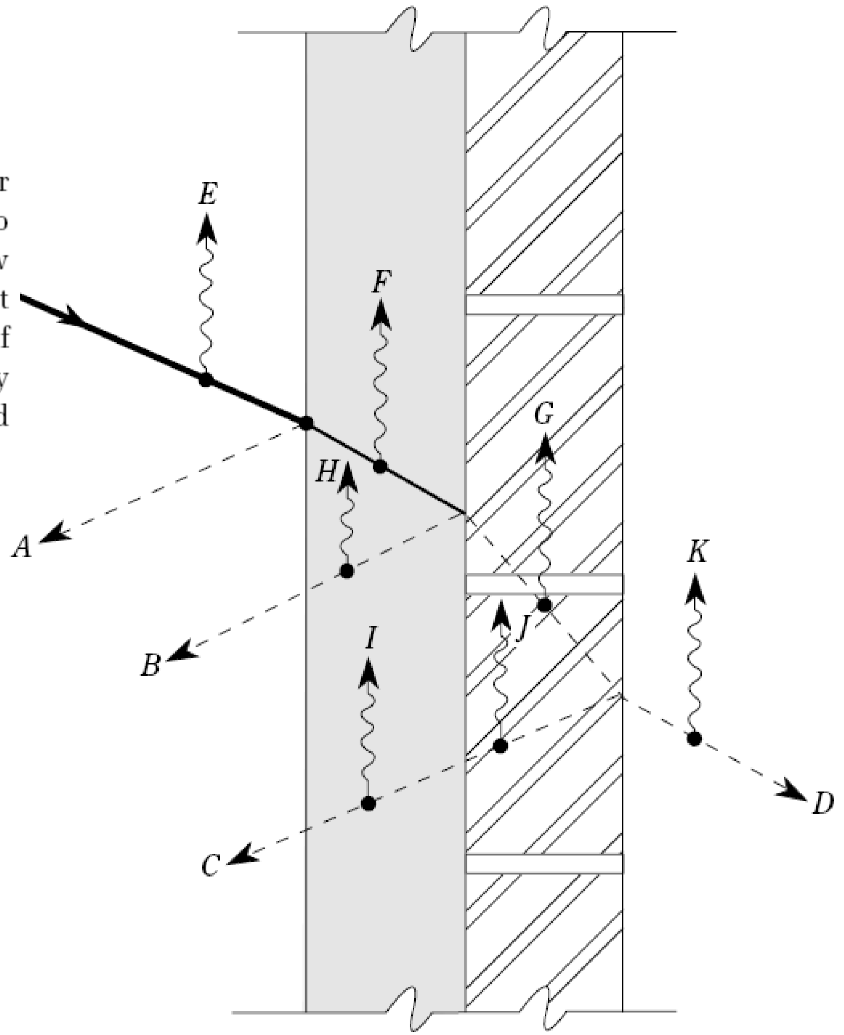
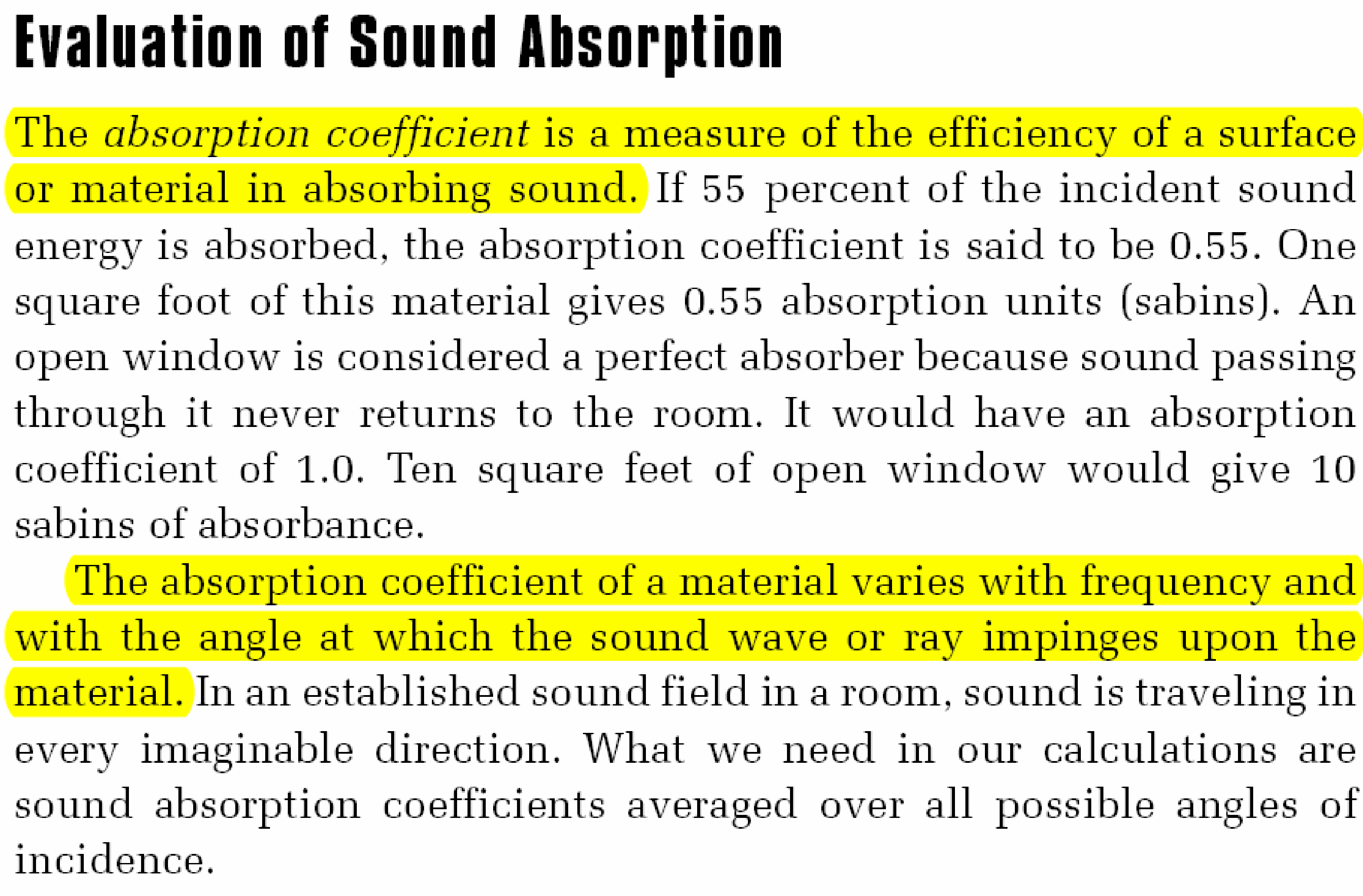


FIGURE 9-1

A sound ray impinging on an acoustical material on a masonry wall undergoes reflection from three different surfaces and absorption in the air and two different materials, with different degrees of refraction at each interface. In this chapter, the absorbed component is of chief interest.

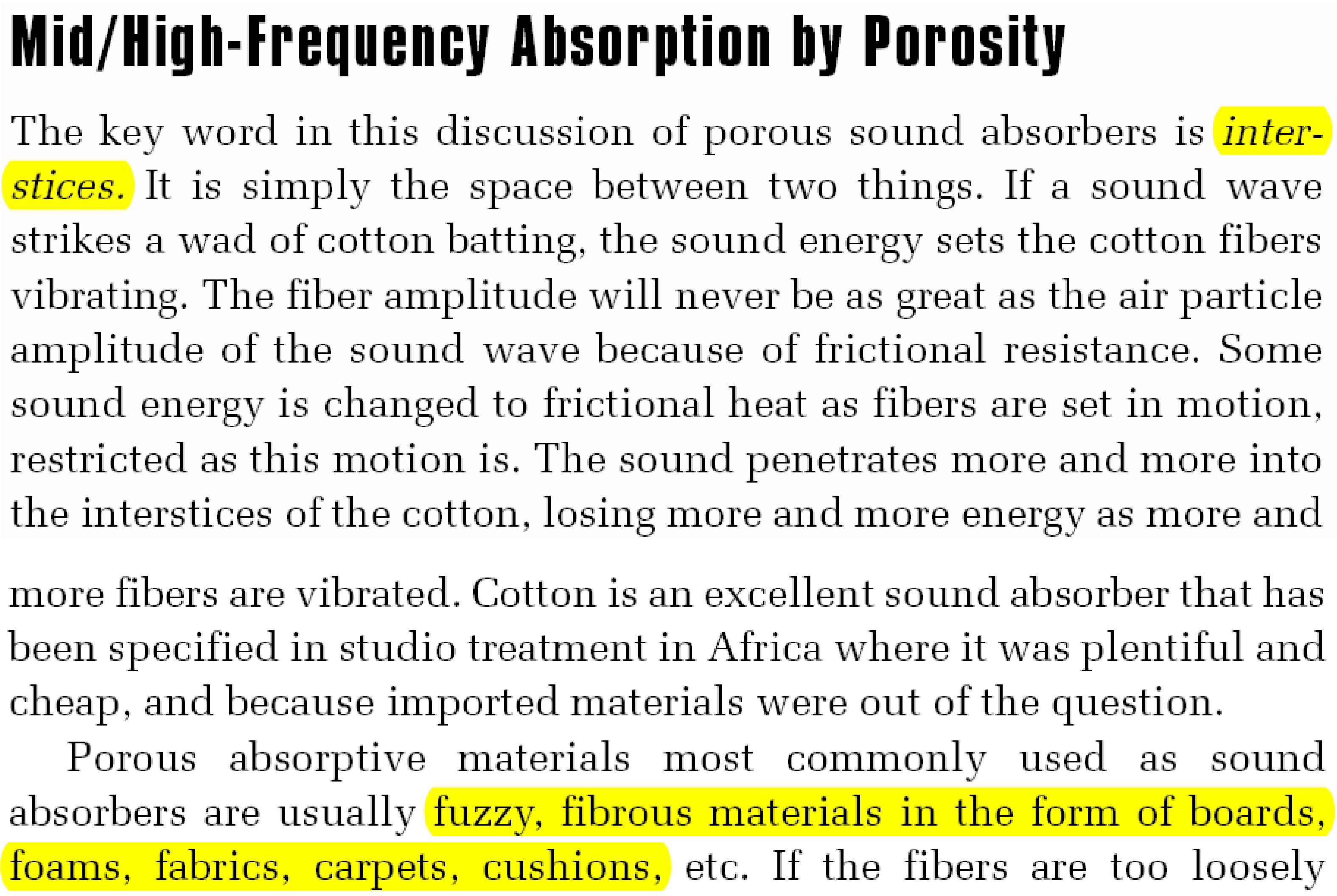


Evaluation of Sound Absorption

The *absorption coefficient* is a measure of the efficiency of a surface or material in absorbing sound. If 55 percent of the incident sound energy is absorbed, the absorption coefficient is said to be 0.55. One square foot of this material gives 0.55 absorption units (sabins). An open window is considered a perfect absorber because sound passing through it never returns to the room. It would have an absorption coefficient of 1.0. Ten square feet of open window would give 10 sabins of absorbance.

The absorption coefficient of a material varies with frequency and with the angle at which the sound wave or ray impinges upon the material. In an established sound field in a room, sound is traveling in every imaginable direction. What we need in our calculations are sound absorption coefficients averaged over all possible angles of incidence.

Absorpcia zvuku stredných a vysokých frekvencií



Mid/High-Frequency Absorption by Porosity

The key word in this discussion of porous sound absorbers is *interstices.* It is simply the space between two things. If a sound wave strikes a wad of cotton batting, the sound energy sets the cotton fibers vibrating. The fiber amplitude will never be as great as the air particle amplitude of the sound wave because of frictional resistance. Some sound energy is changed to frictional heat as fibers are set in motion, restricted as this motion is. The sound penetrates more and more into the interstices of the cotton, losing more and more energy as more and more fibers are vibrated. Cotton is an excellent sound absorber that has been specified in studio treatment in Africa where it was plentiful and cheap, and because imported materials were out of the question.

Porous absorptive materials most commonly used as sound absorbers are usually fuzzy, fibrous materials in the form of boards, foams, fabrics, carpets, cushions, etc. If the fibers are too loosely

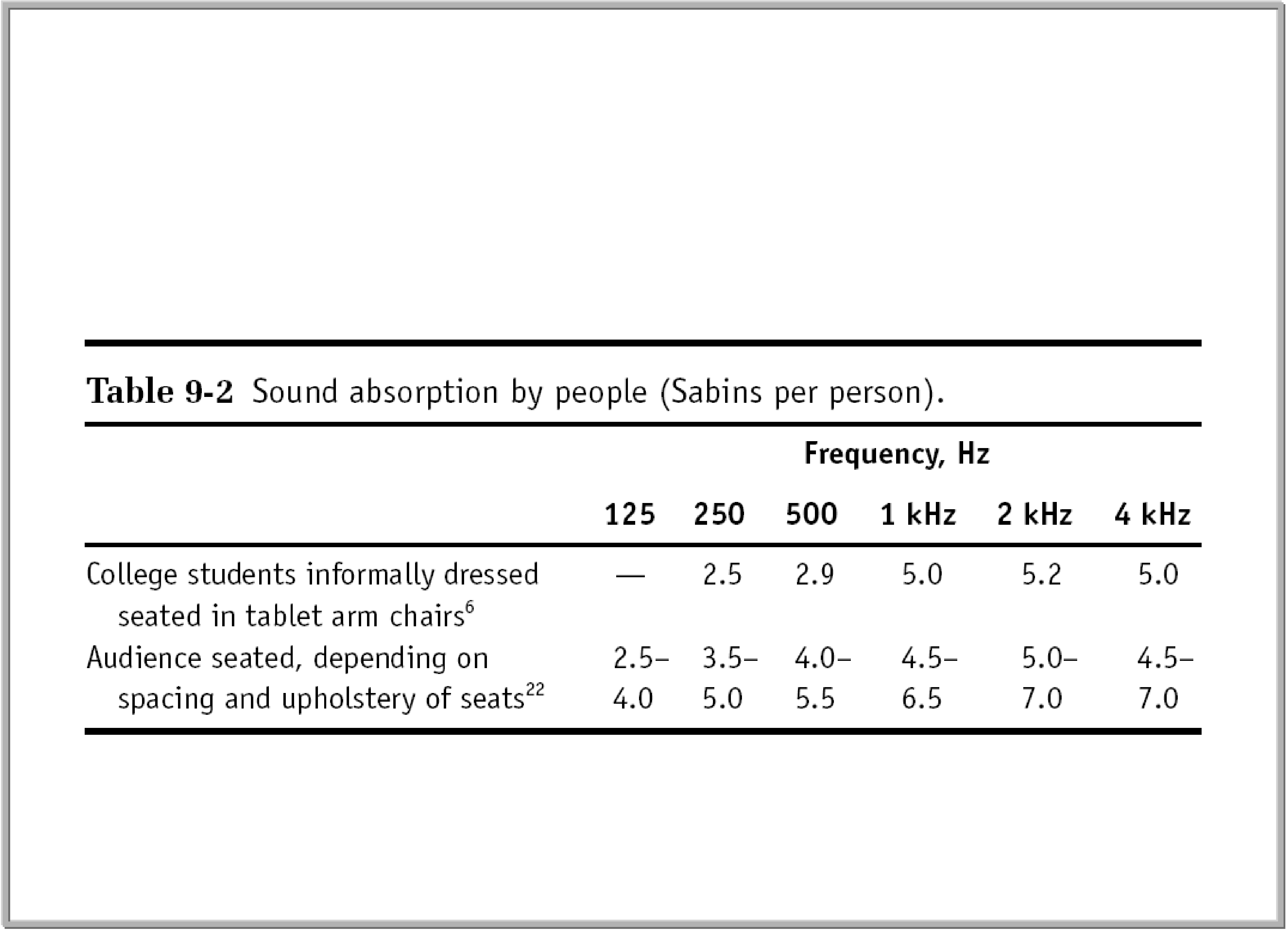
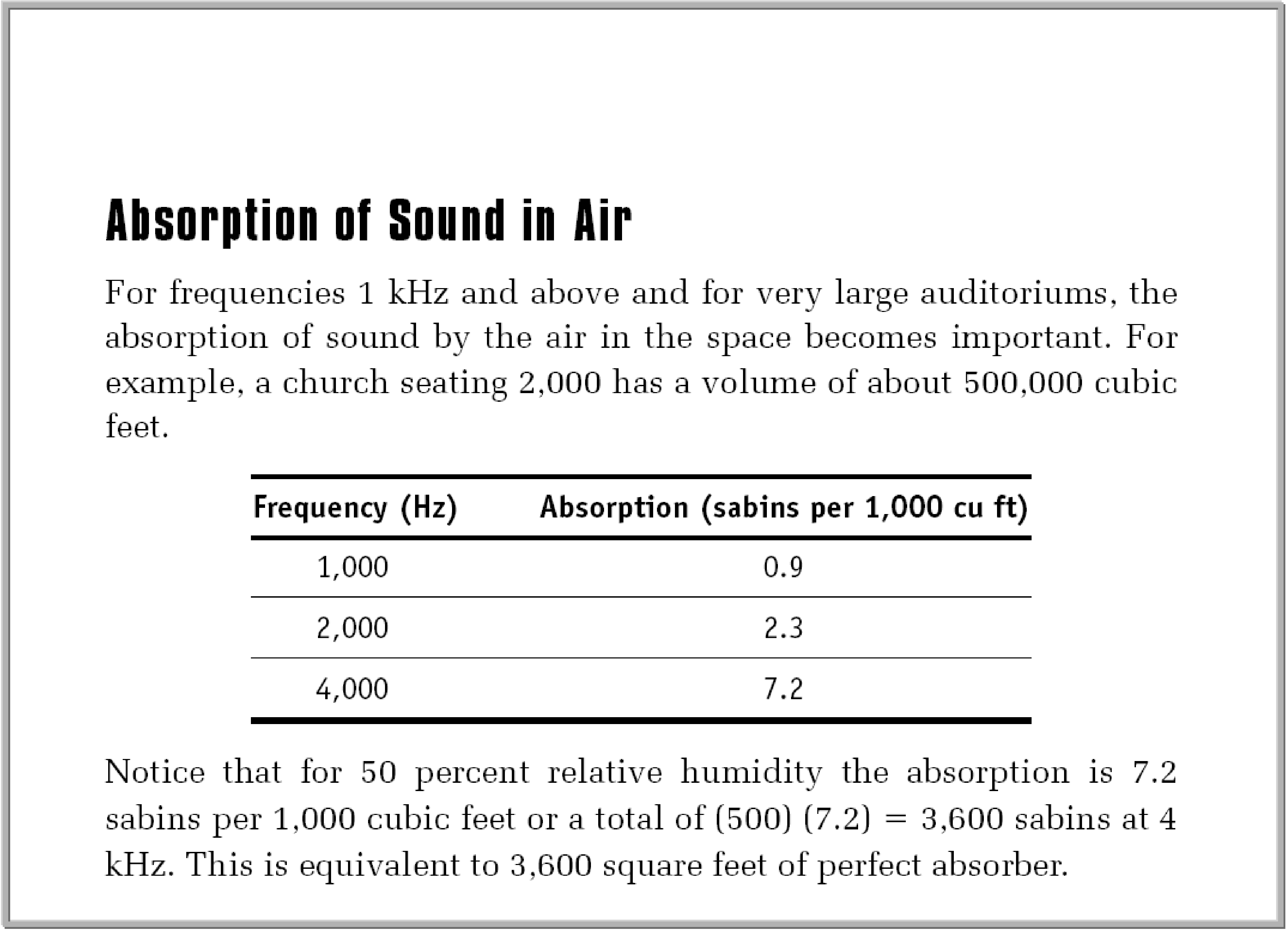


Table 9-2 Sound absorption by people (Sabins per person).

	Frequency, Hz					
	125	250	500	1 kHz	2 kHz	4 kHz
College students informally dressed seated in tablet arm chairs[6]	—	2.5	2.9	5.0	5.2	5.0
Audience seated, depending on spacing and upholstery of seats[22]	2.5–4.0	3.5–5.0	4.0–5.5	4.5–6.5	5.0–7.0	4.5–7.0



Absorption of Sound in Air

For frequencies 1 kHz and above and for very large auditoriums, the absorption of sound by the air in the space becomes important. For example, a church seating 2,000 has a volume of about 500,000 cubic feet.

Frequency (Hz)	Absorption (sabins per 1,000 cu ft)
1,000	0.9
2,000	2.3
4,000	7.2

Notice that for 50 percent relative humidity the absorption is 7.2 sabins per 1,000 cubic feet or a total of (500) (7.2) = 3,600 sabins at 4 kHz. This is equivalent to 3,600 square feet of perfect absorber.

Absorpcia nízkych frekvencií rezonátormi

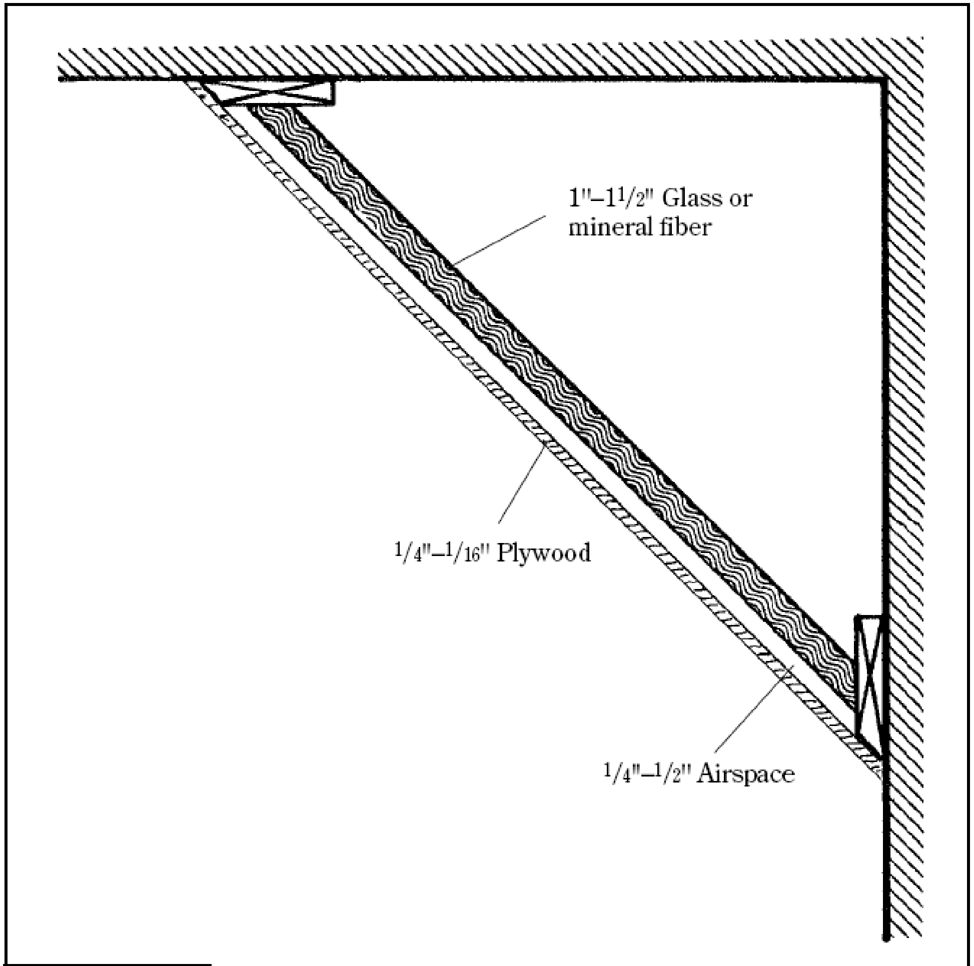


FIGURE 9-24

Typical resonant panel absorber for either vertical or horizontal corner mounting.

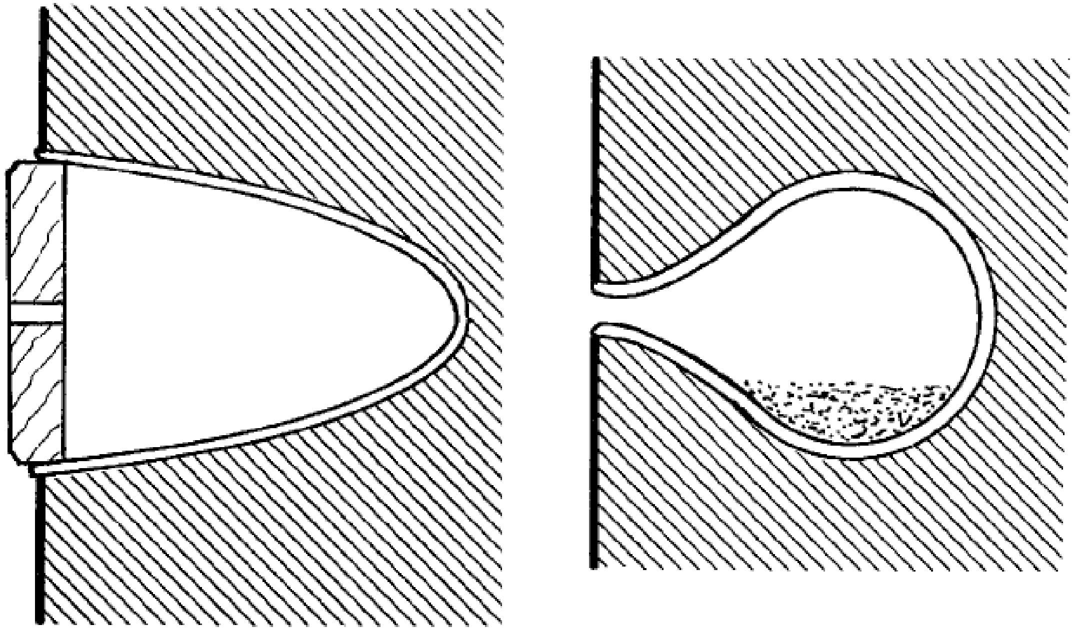


FIGURE 9-30

Pots embedded in the walls of medieval churches in Sweden and Denmark served as Helmholtz resonators, absorbing sound. Ashes, found in some of the pots, apparently served as a dissipative agent. (After Brüel.[11])

FIGURE 9-39A

Typical Helmholtz resonator made of readily available materials.

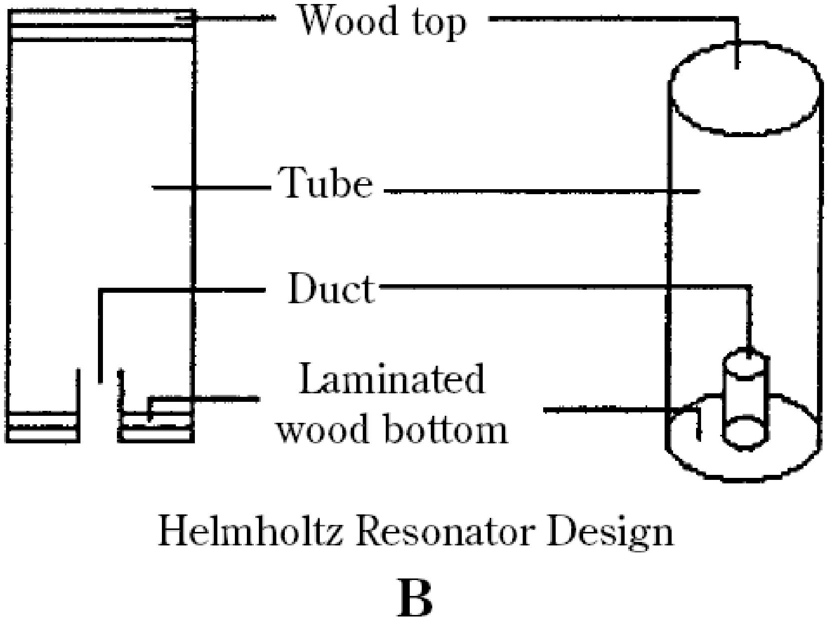
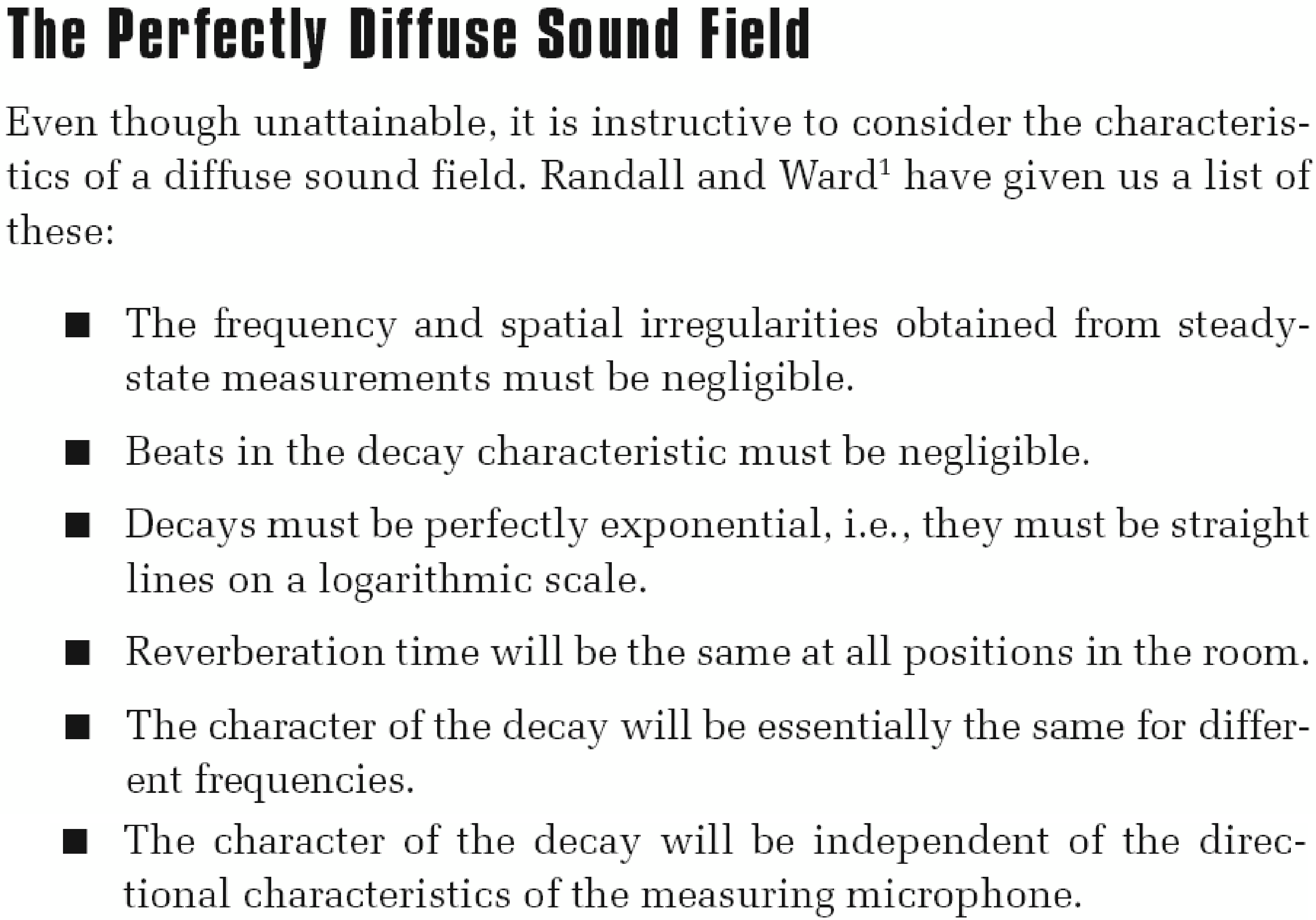


FIGURE 9-39B

Details of Helmholtz resonator design.

Difúzia (rozptyl) zvuku



The Perfectly Diffuse Sound Field

Even though unattainable, it is instructive to consider the characteristics of a diffuse sound field. Randall and Ward[1] have given us a list of these:

- The frequency and spatial irregularities obtained from steady-state measurements must be negligible.
- Beats in the decay characteristic must be negligible.
- Decays must be perfectly exponential, i.e., they must be straight lines on a logarithmic scale.
- Reverberation time will be the same at all positions in the room.
- The character of the decay will be essentially the same for different frequencies.
- The character of the decay will be independent of the directional characteristics of the measuring microphone.

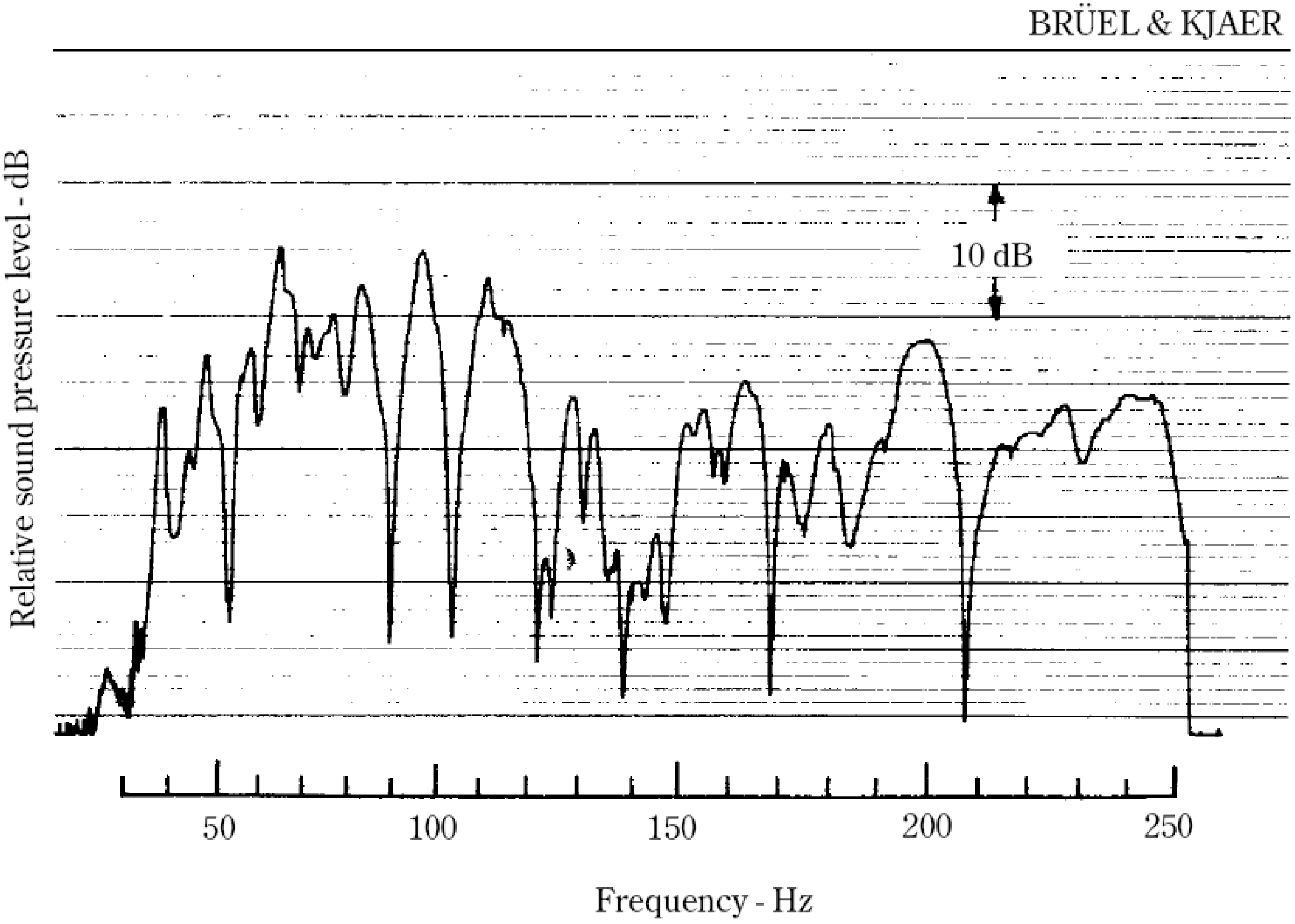


FIGURE 13-1

Slowly swept sine-wave sound-transmission response of a 12,000-cu ft. video studio. Fluctuations of this magnitude, which characterize the best of studios, are evidence of nondiffusive conditions.

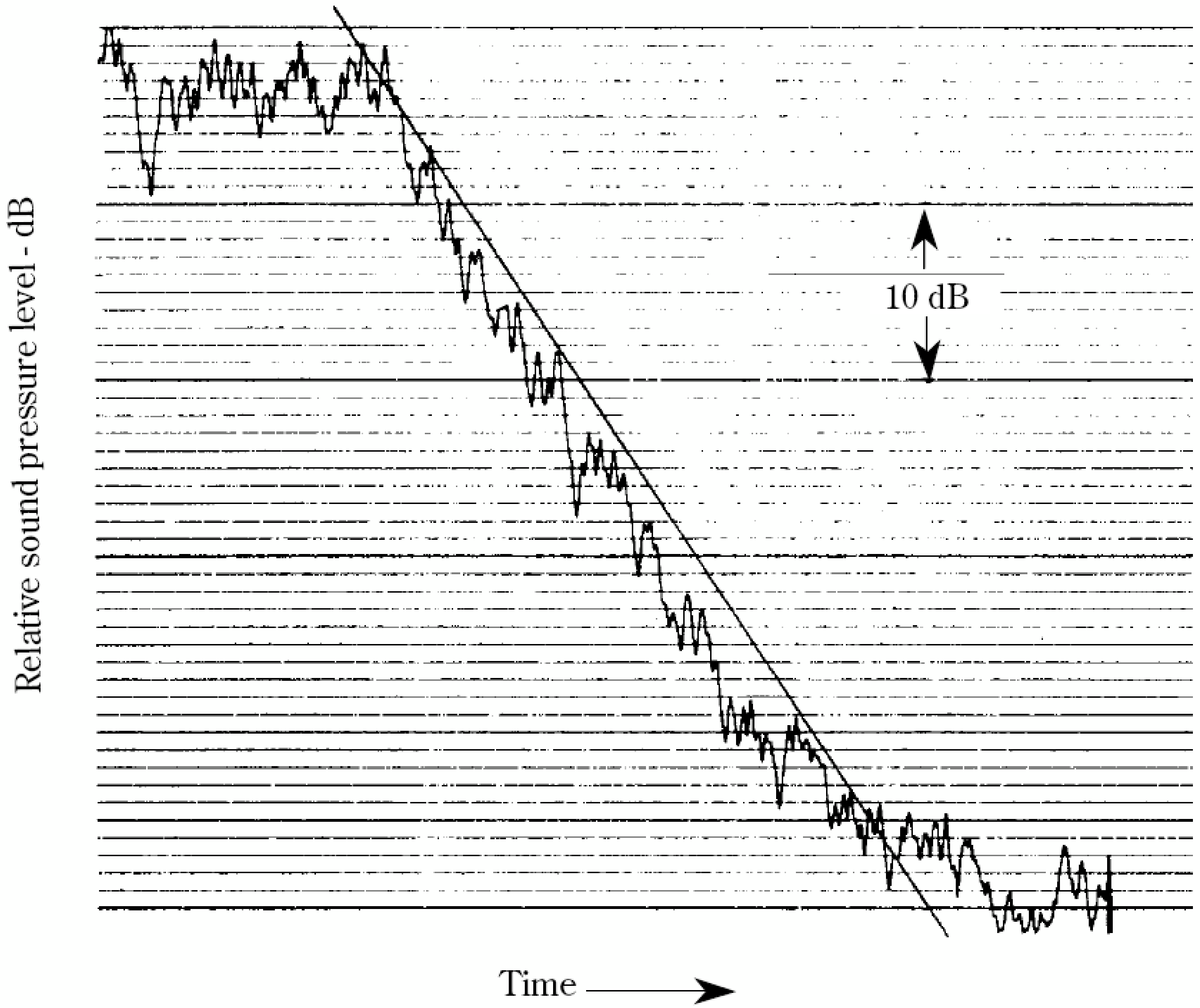


FIGURE 13-3

The nonexponential form of this decay, taken in a 400-seat chapel, is attributed to acoustically coupled spaces. The absence of a diffuse sound field is indicated.

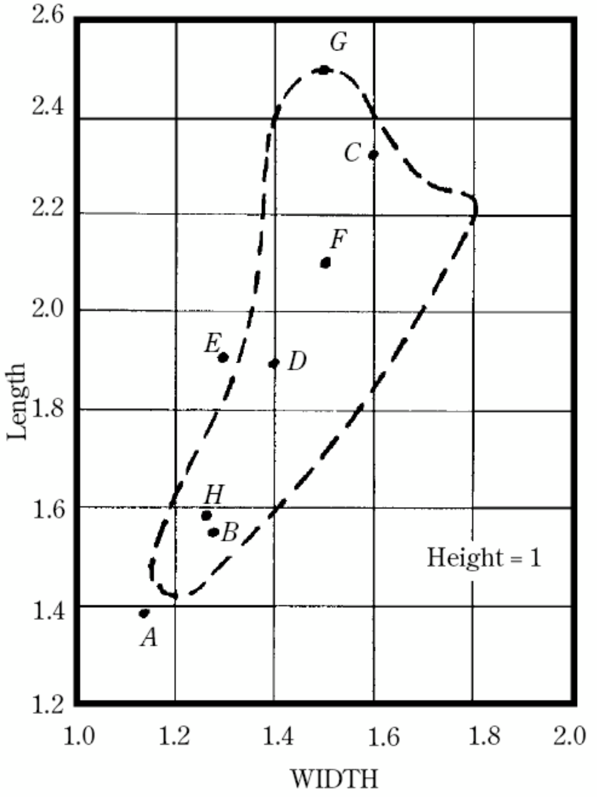


FIGURE 13-6

A chart of favorable room dimensional ratios to achieve uniform distribution of modal frequencies of a room. The broken line encloses the so-called “Bolt-Area.”[2] The letters refer to Table 13-2.

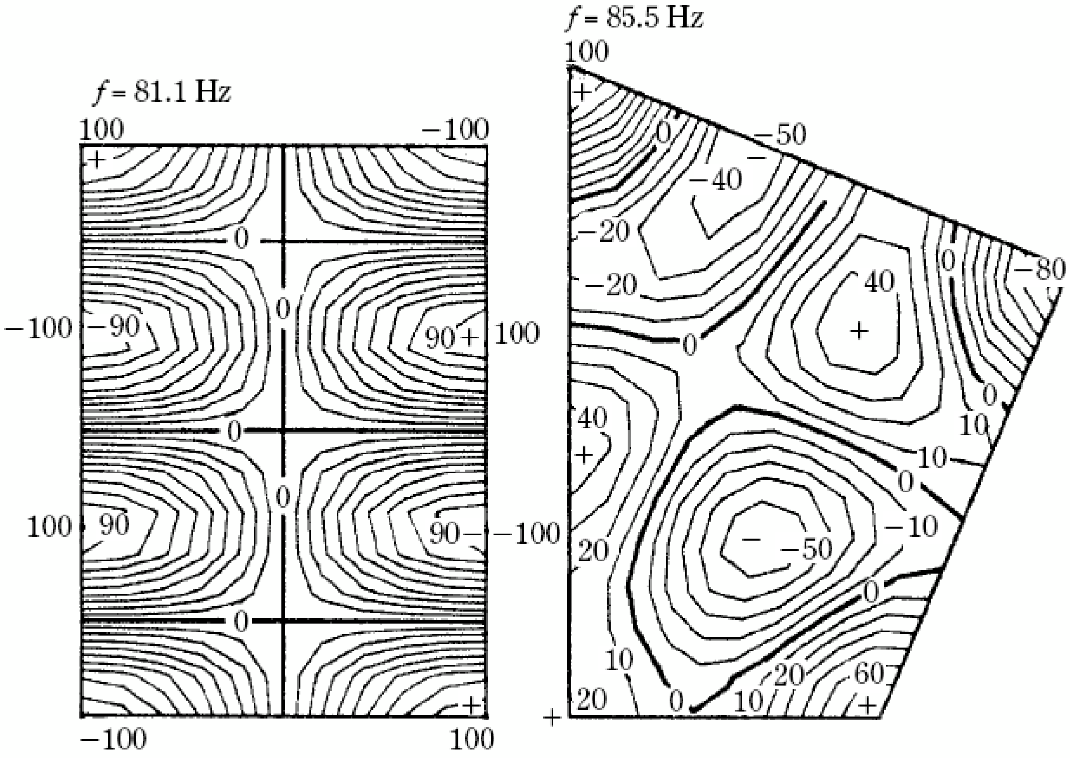


FIGURE 13-11

The 1,3 mode for the 5 x 7 meter room of Fig. 13-10 compared to a nonrectangular room of the same area. The sound field is distorted and the frequency is shifted.[8]

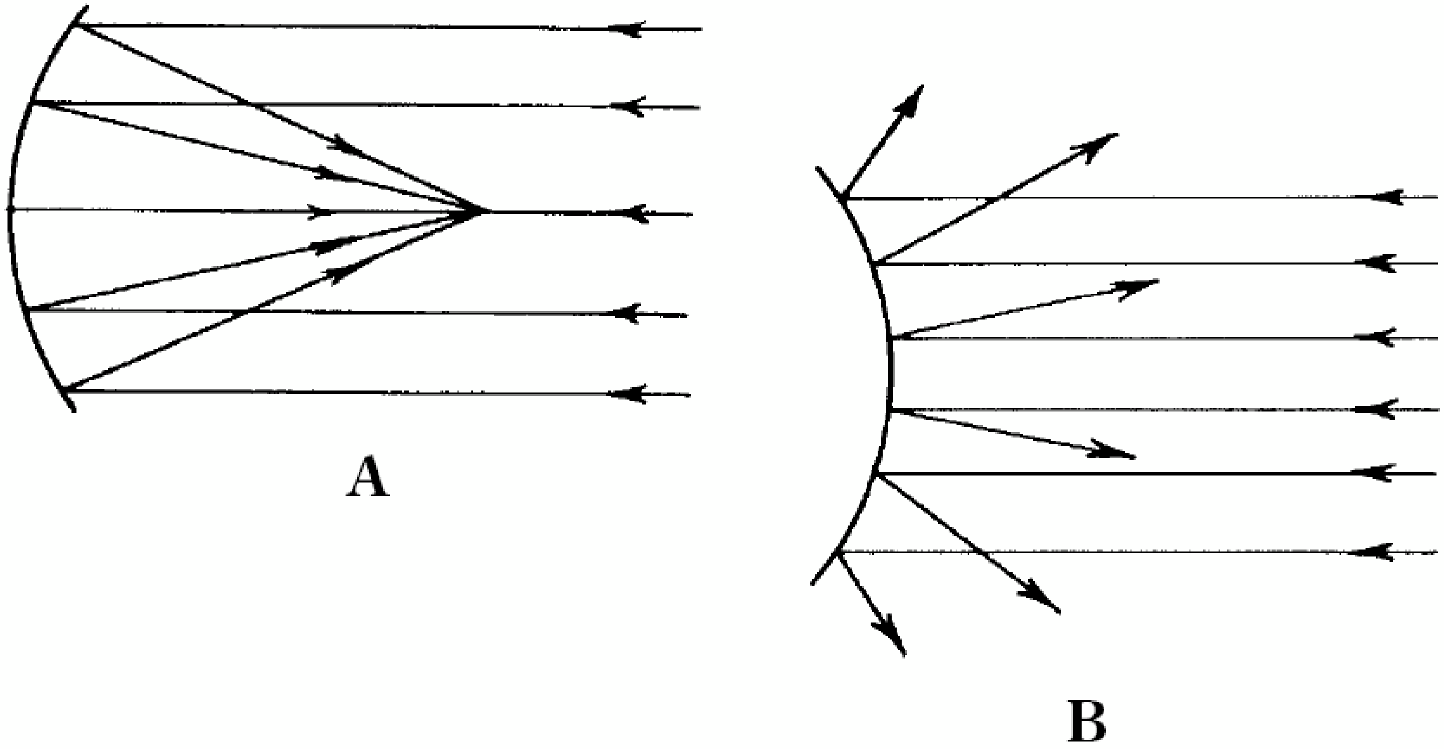


FIGURE 13-14

Concave surfaces (A) tend to focus sound, convex surfaces (B) tend to diffuse it. Concave surfaces should be avoided if the goal is to achieve well-diffused sound.

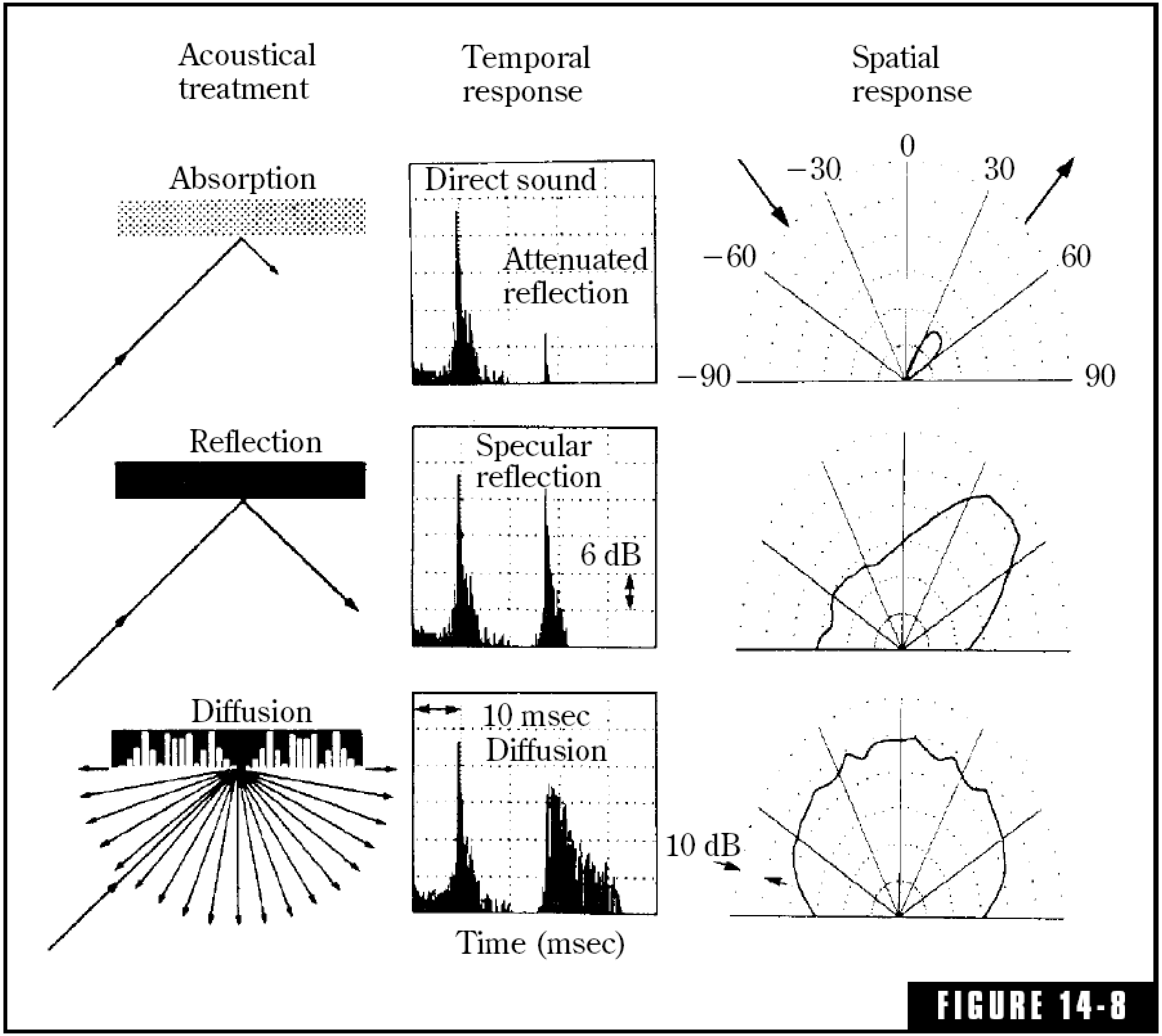


FIGURE 14-8

A comparision of the three physical principles of absorption, reflection, and diffusion.
Peter D'Antonio, RPG Diffusor Systems, Inc. and the Audio Engineering Society.

The Schroeder Diffusor

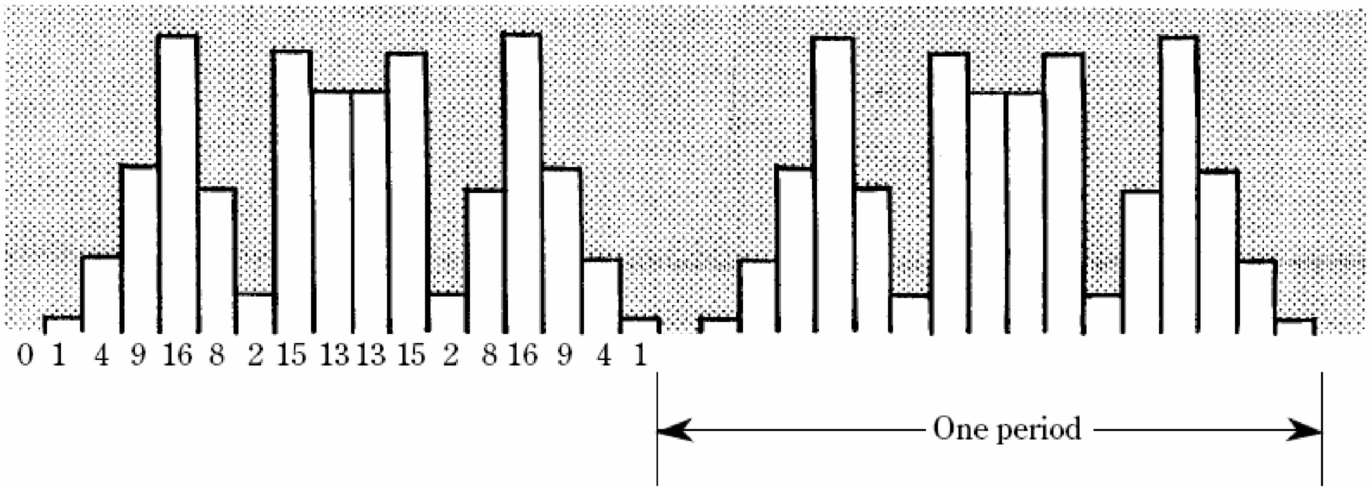


FIGURE 14-4

A typical quadratic-residue diffusor based upon the prime number 17 column of Fig 14-3. The depths of the wells are proportional to the sequence of numbers in the prime-17 column. Two periods are shown illustrating how adjacent periods are fitted together.

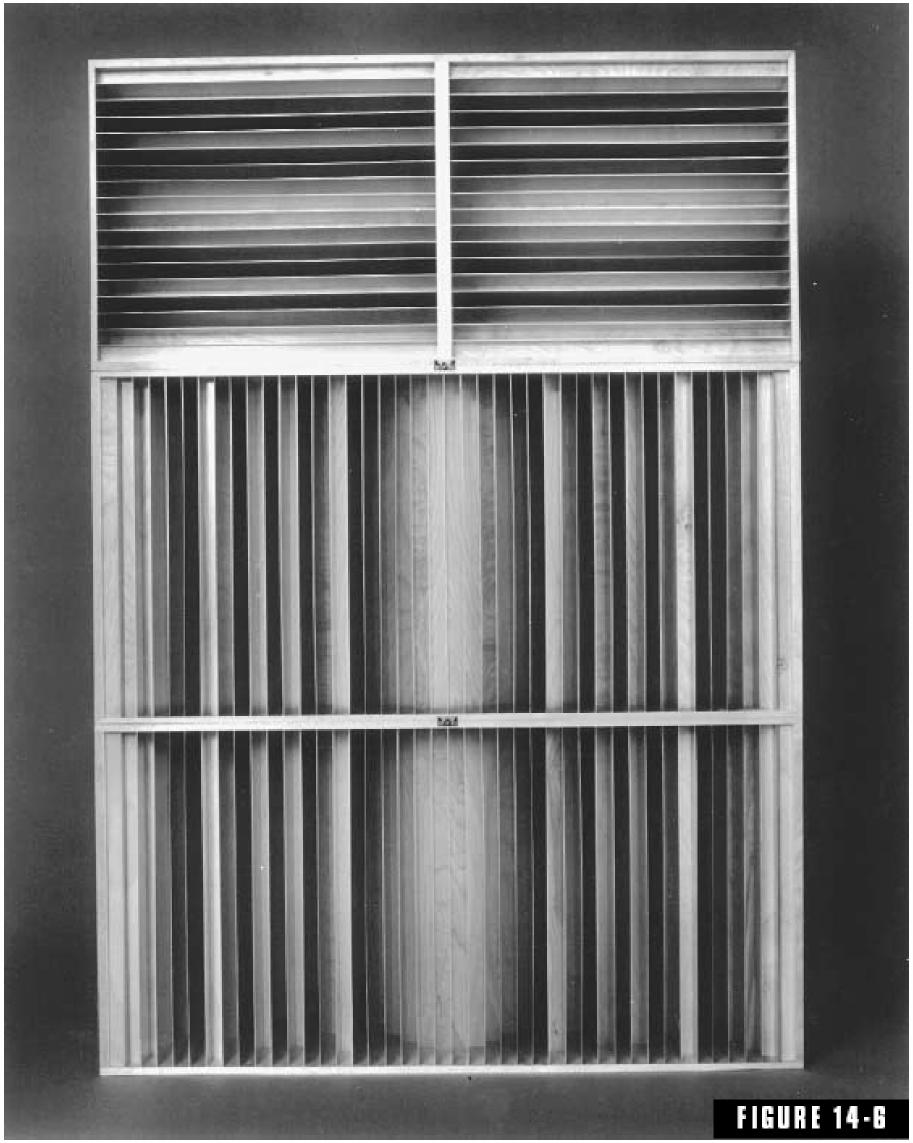
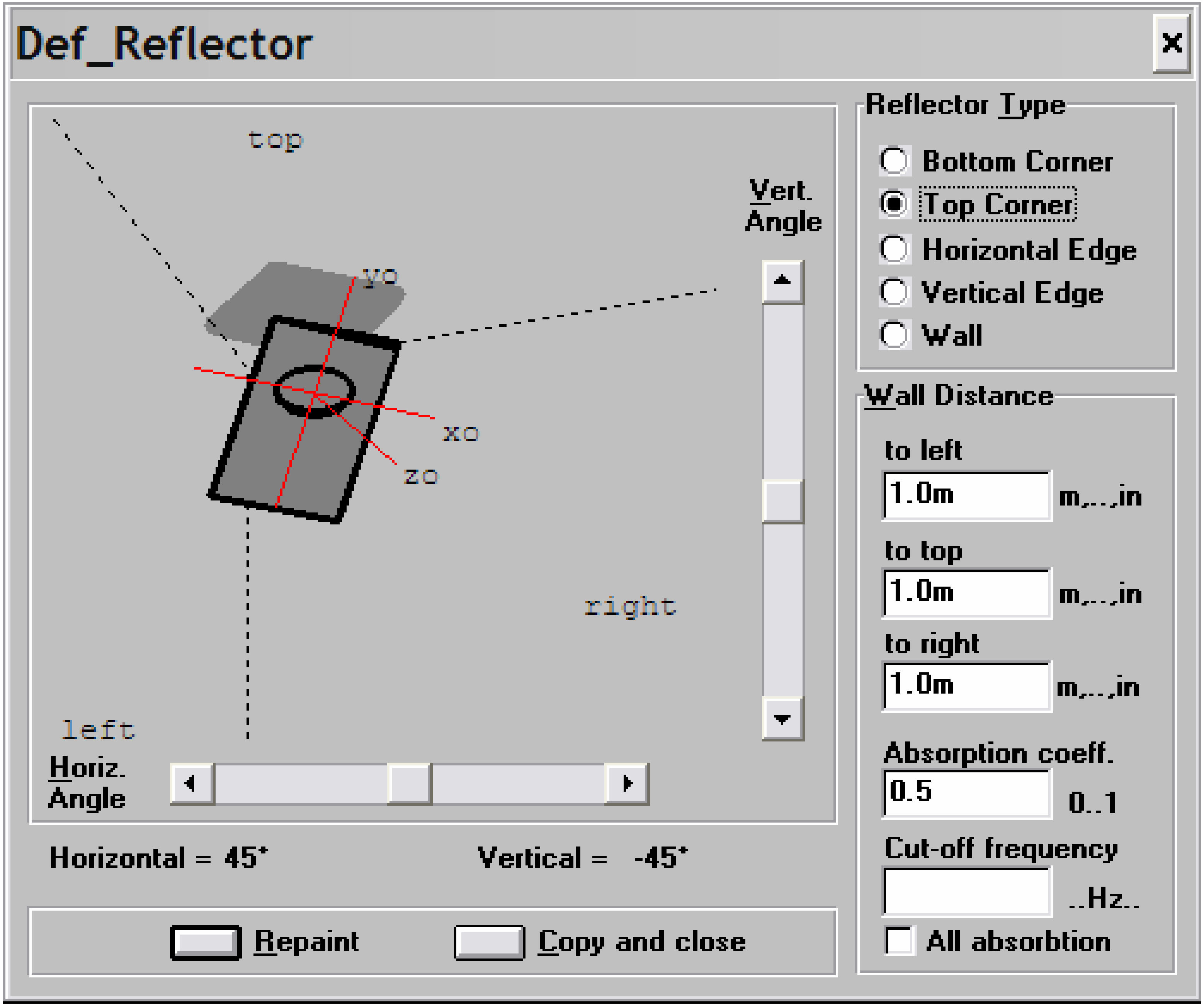


FIGURE 14-6

A cluster of commercial quadratic-residue diffusors. Below are two QRD-4311™ diffusing modules with a single QRD-1911™ mounted above. The hemidisc of diffusion for the lower unit is horizontal, that of the upper unit is vertical. Peter D'Antonio, RPG Diffusor System, Inc. and the Audio Engineering Society, Inc.



Reflector Type
- ○ Bottom Corner
- ● Top Corner
- ○ Horizontal Edge
- ○ Vertical Edge
- ○ Wall

Wall Distance

to left: 1.0m

to top: 1.0m

to right: 1.0m

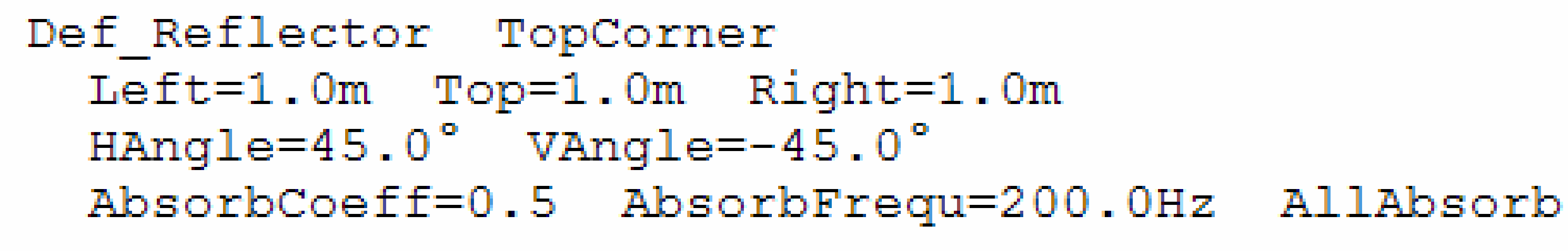
Absorption coeff.: 0.5

Cut-off frequency:

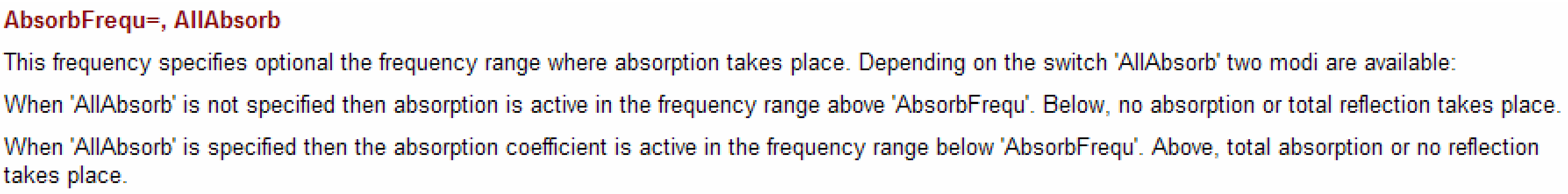
☐ All absorbtion

Horizontal = 45°

Vertical = -45°



```
Def_Reflector  TopCorner
  Left=1.0m  Top=1.0m  Right=1.0m
  HAngle=45.0°  VAngle=-45.0°
  AbsorbCoeff=0.5  AbsorbFrequ=200.0Hz  AllAbsorb
```

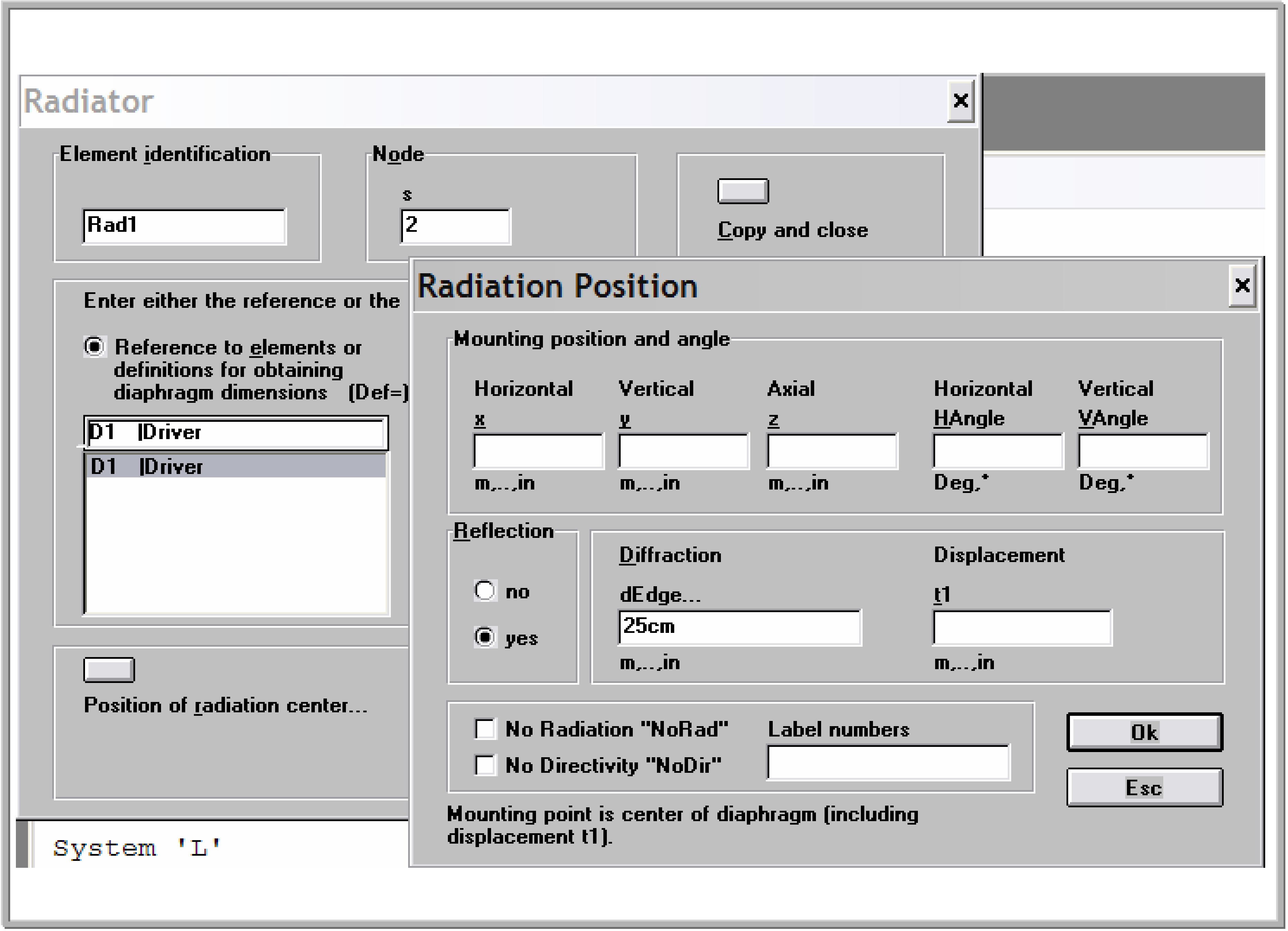


AbsorbFrequ=, AllAbsorb

This frequency specifies optional the frequency range where absorption takes place. Depending on the switch 'AllAbsorb' two modi are available:

When 'AllAbsorb' is not specified then absorption is active in the frequency range above 'AbsorbFrequ'. Below, no absorption or total reflection takes place.

When 'AllAbsorb' is specified then the absorption coefficient is active in the frequency range below 'AbsorbFrequ'. Above, total absorption or no reflection takes place.



Radiator

Element identification: Rad1

Node s: 2

Enter either the reference or the

● Reference to elements or definitions for obtaining diaphragm dimensions (Def=)

D1 |Driver

D1 |Driver

Position of radiation center...

System 'L'

Radiation Position

Mounting position and angle

Horizontal x	Vertical y	Axial z	Horizontal HAngle	Vertical VAngle
m,...,in	m,...,in	m,...,in	Deg,°	Deg,°

Reflection

○ no

● yes

Diffraction dEdge...: 25cm (m,...,in)

Displacement t1: (m,...,in)

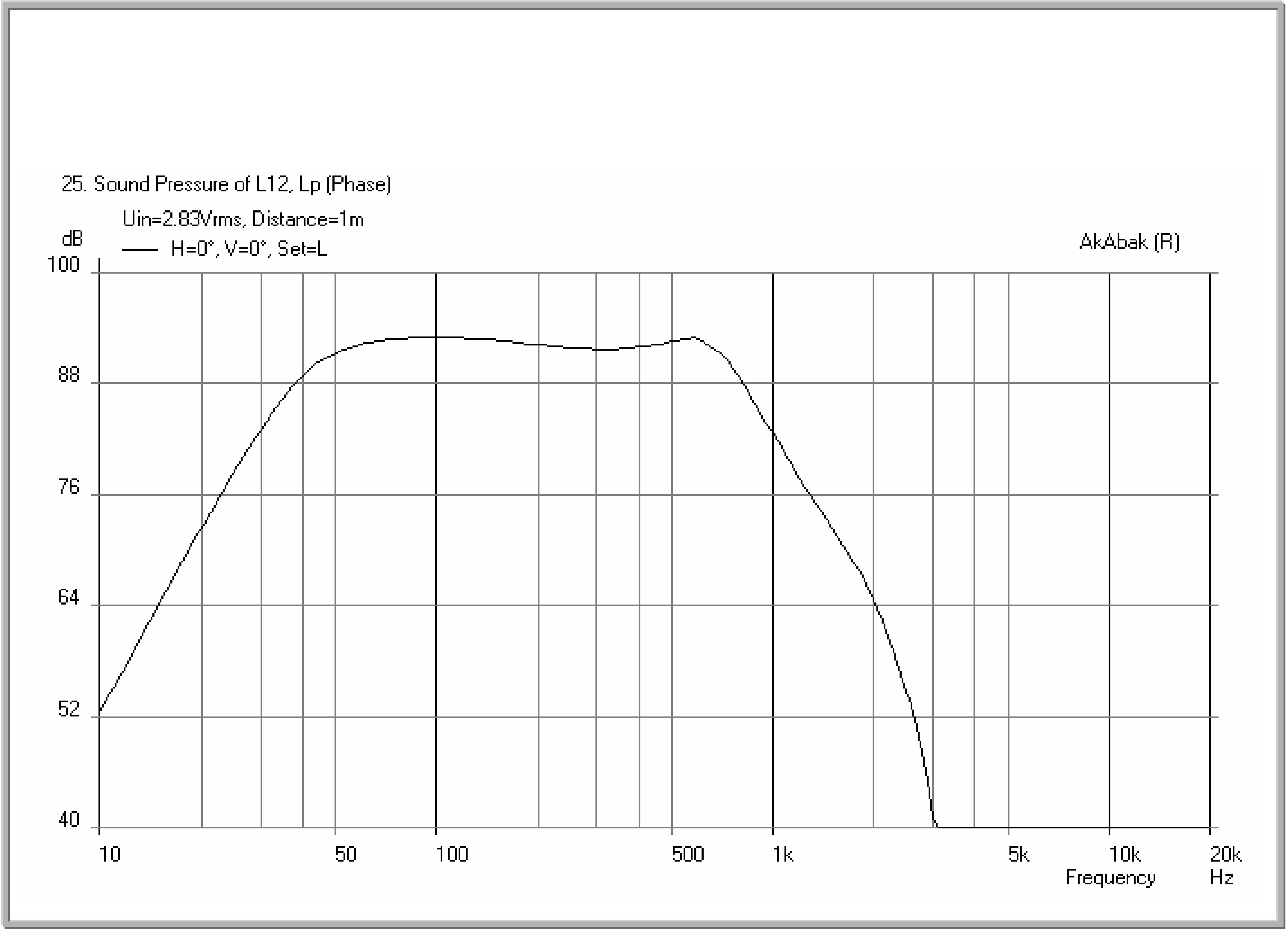
☐ No Radiation "NoRad"

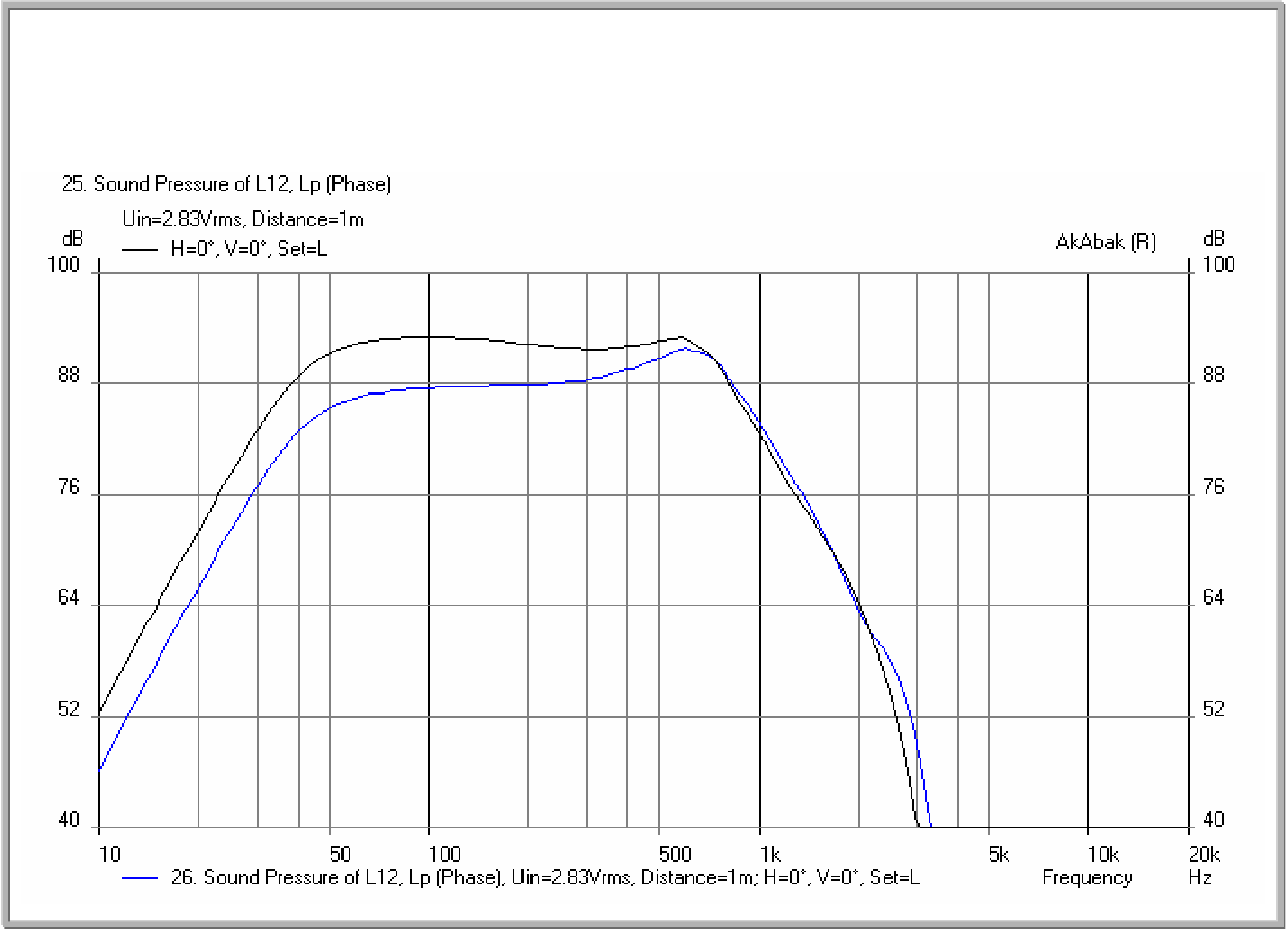
☐ No Directivity "NoDir"

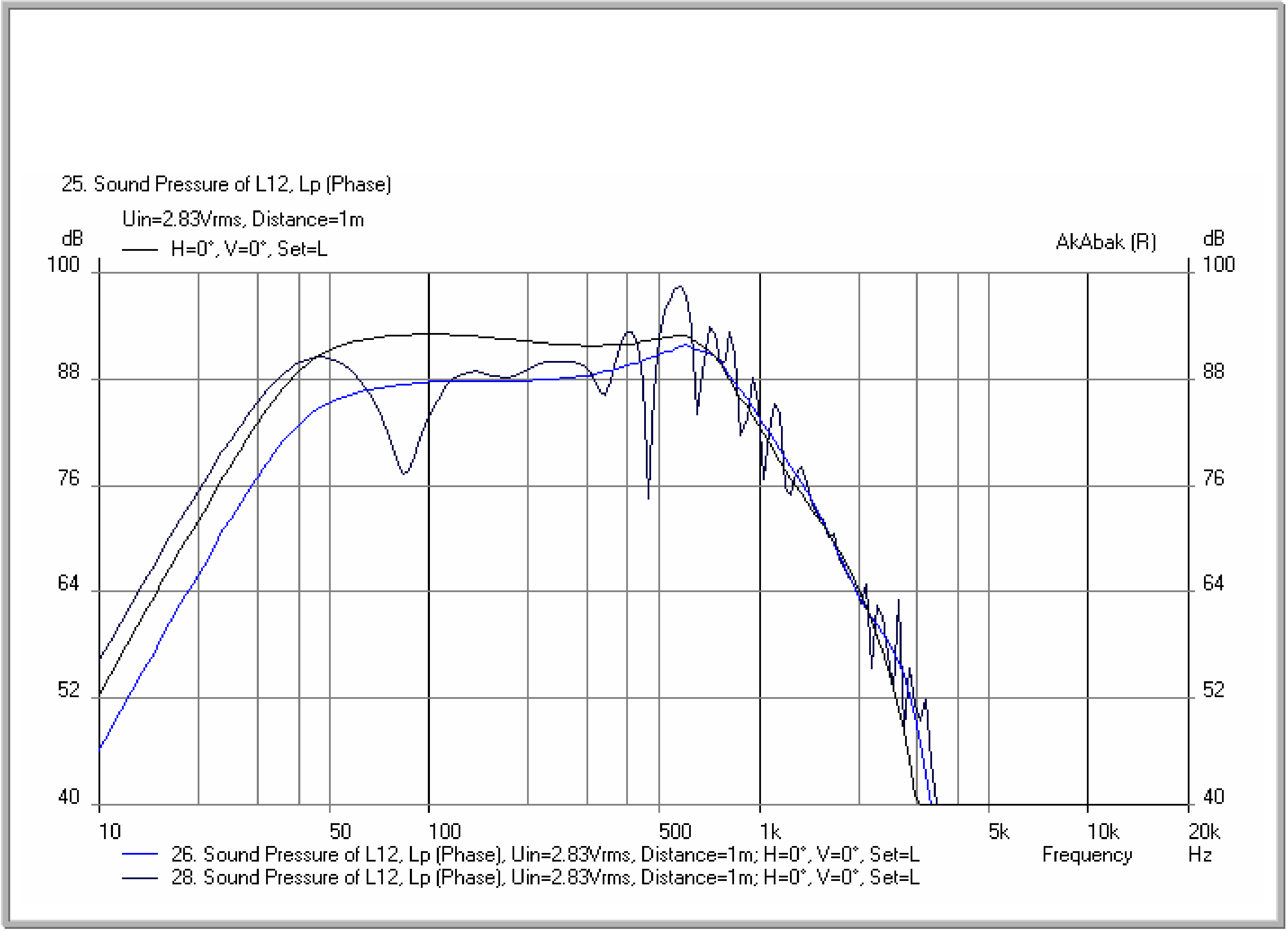
Label numbers:

Mounting point is center of diaphragm (including displacement t1).

```
| Seas Prestige CA26RE4X H1316
| Revc=6.1Ohms; Levc=3.08mH; Bl=11.6N/A;
|Mmd=38.5g; Mmrd=3.8g; Rms=1.66Ns/m; Cms=1.1mm/N; Sd=350cm2
| Fs=25Hz; Qts=0.28; Qms=3.99; Qes=0.30; Vas=164lit.
|ymax=4mm; sens=91dB; Pe(lt)=80W

Def_Reflector  BottomCorner
  Left=1.0m  Bottom=1.0m  Right=1.0m
  HAngle=45.0°  VAngle=0
|  AbsorbCoeff=1 AbsorbFrequ=200.0Hz

Def_Driver  'Woofer'
  SD=350cm2  dD1=5.5cm  tD1=6.5cm   |Cone
  fs=25Hz  Vas=164L  Qms=3.99
  Qes=0.3  Re=6.1ohm  Le=3.08mH  ExpoLe=0.618

System 'L'
  Filter    'LPF-LR2'
    fo=1000Hz  vo=1
    {b0=1; a2=1;  a1=2;  a0=1;  }
  Driver 'D1'  Def='Woofer'  Node=1=0=2=3
  Radiator  'Rad1'  Def='D1'    Node=2
    x=0  y=0  z=0  HAngle=0  VAngle=0
    dEdge=25cm  Reflection      Label=1
  Enclosure    'E1'  Node=3
    Vb=45L  Sb=350cm2
    fb=34Hz  dD=8cm  QD/fo=0.34  Visc=0
    x=0  y=0  z=0  HAngle=0  VAngle=0
    dEdge=25cm  Reflection      Label=2
```

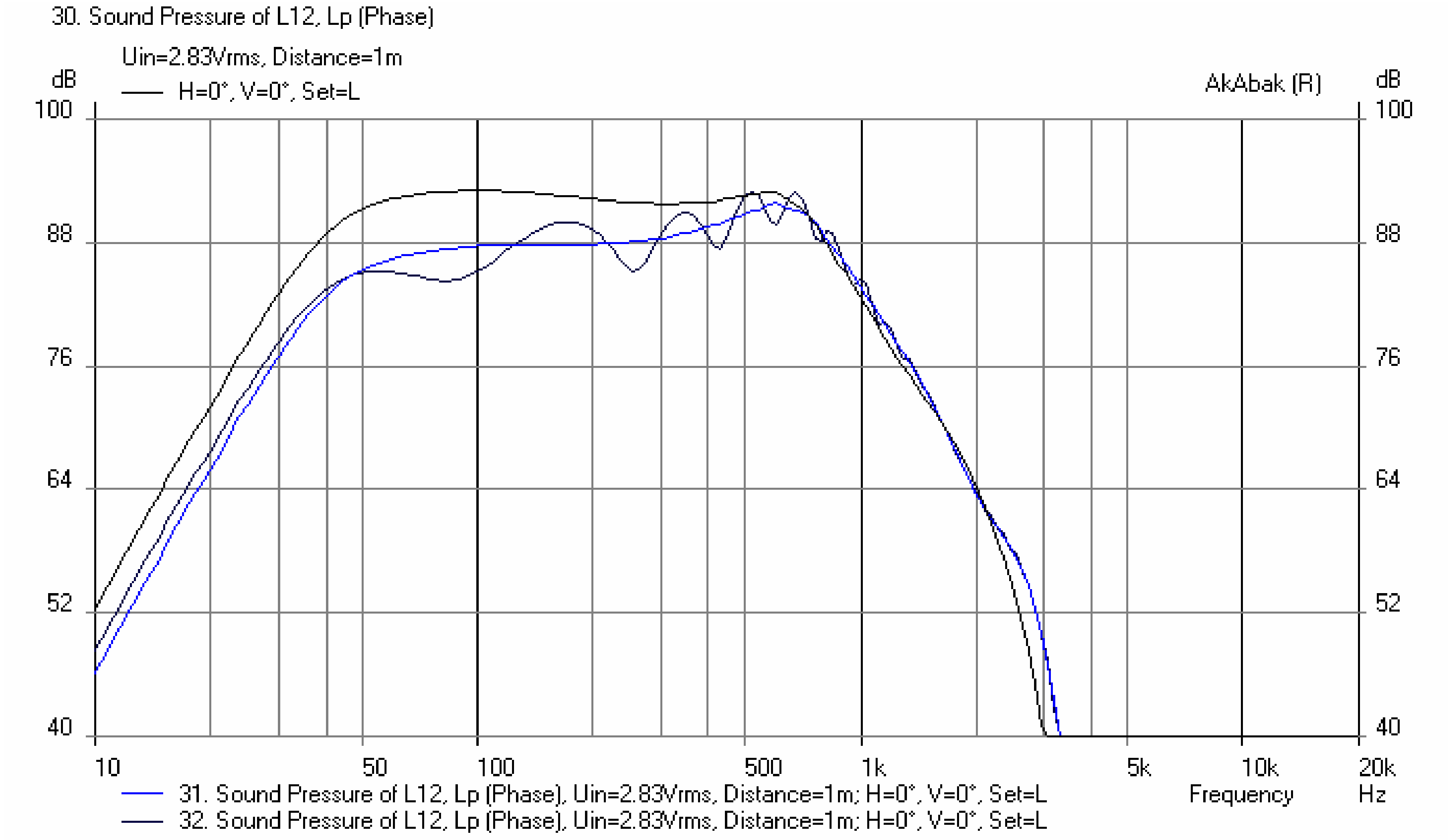

25. Sound Pressure of L12, Lp (Phase)
Uin=2.83Vrms, Distance=1m
H=0°, V=0°, Set=L
AkAbak (R)
dB
100
88
76
64
52
40
10
50
100
500
1k
5k
10k
20k
Frequency
Hz


25. Sound Pressure of L12, Lp (Phase)
Uin=2.83Vrms, Distance=1m
H=0°, V=0°, Set=L
AkAbak (R)
dB
100
88
76
64
52
40
dB
100
88
76
64
52
40
10
50
100
500
1k
5k
10k
20k
Frequency
Hz
26. Sound Pressure of L12, Lp (Phase), Uin=2.83Vrms, Distance=1m; H=0°, V=0°, Set=L

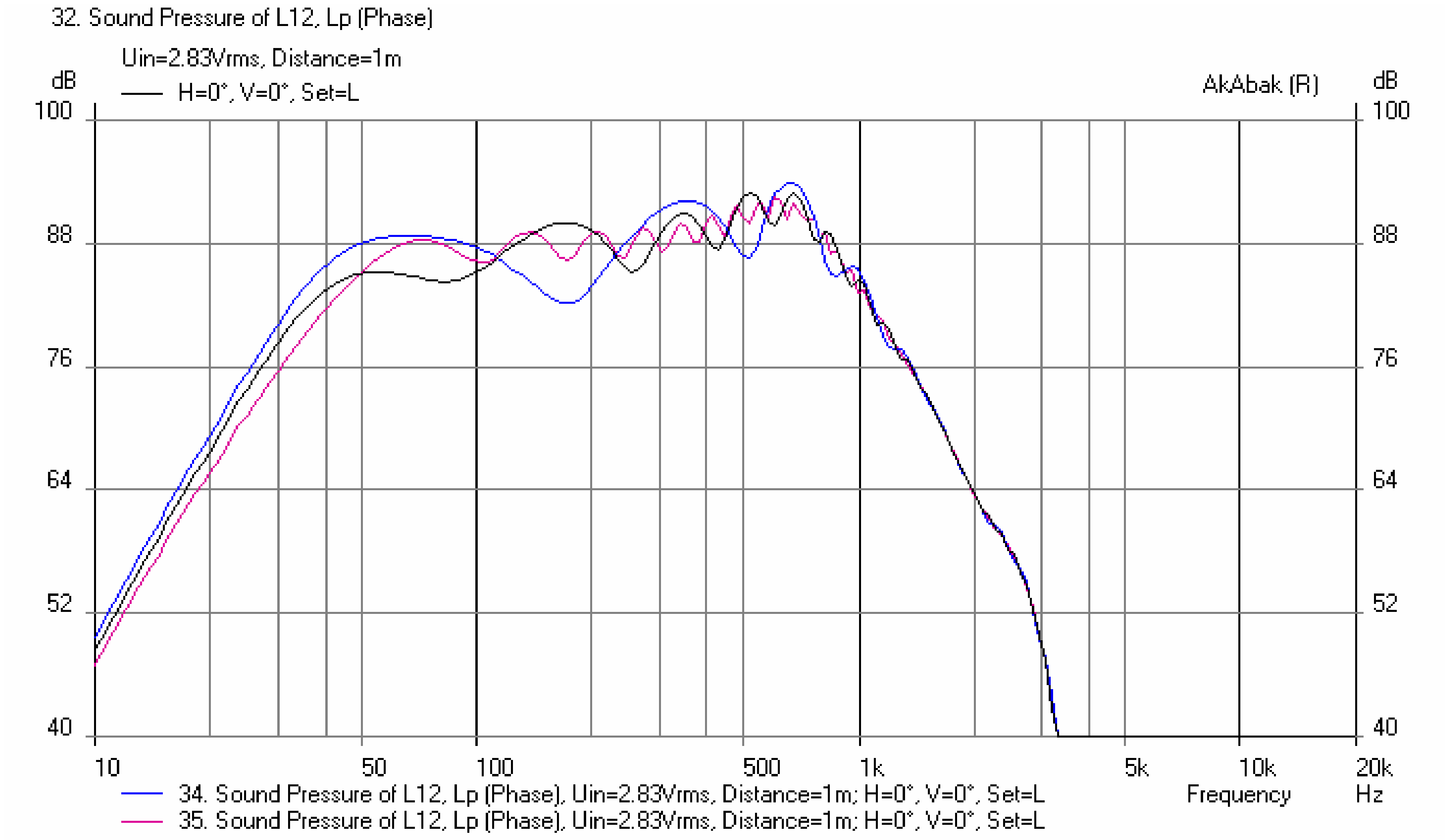

25. Sound Pressure of L12, Lp (Phase)
Uin=2.83Vrms, Distance=1m
H=0°, V=0°, Set=L
AkAbak (R)
dB
100
88
76
64
52
40
dB
100
88
76
64
52
40
10
50
100
500
1k
5k
10k
20k
Frequency
Hz
26. Sound Pressure of L12, Lp (Phase), Uin=2.83Vrms, Distance=1m; H=0°, V=0°, Set=L
28. Sound Pressure of L12, Lp (Phase), Uin=2.83Vrms, Distance=1m; H=0°, V=0°, Set=L

Odraz od steny:

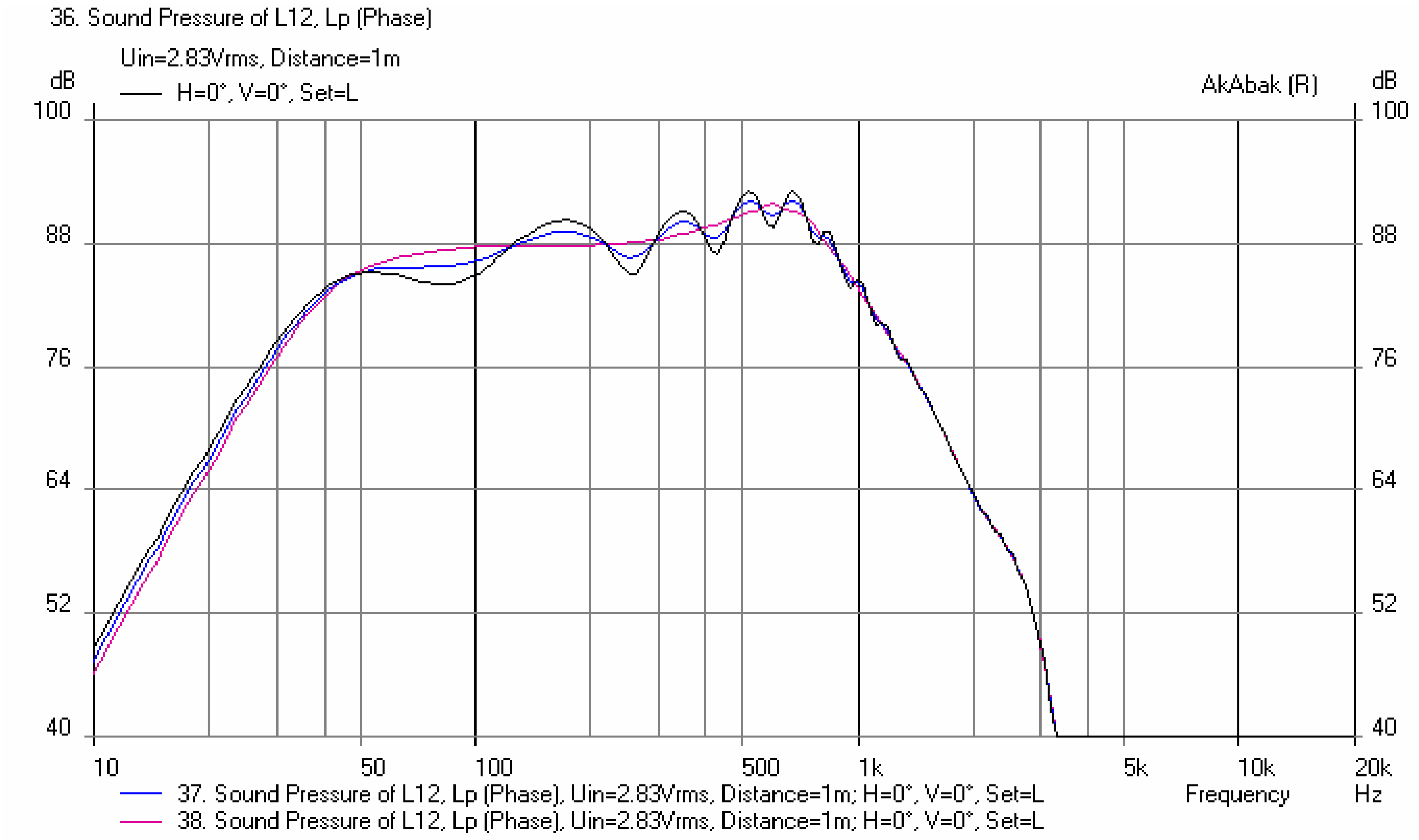
Def_Reflector Wall=2.5m
HAngle=0 VAngle=0
AbsorbCoeff=0.01 |AbsorbFrequ=1.0kHz



Vplyv vzdialenosti od steny: 0.5m (modrá), 1m (čierna), 2.5m (fialová)



Vplyv absorpčných vlastností steny: 0.01 (čierna), 0.5 (modrá), 1 (fialová)



TECHNICKÁ UNIVERZITA V KOŠICIACH