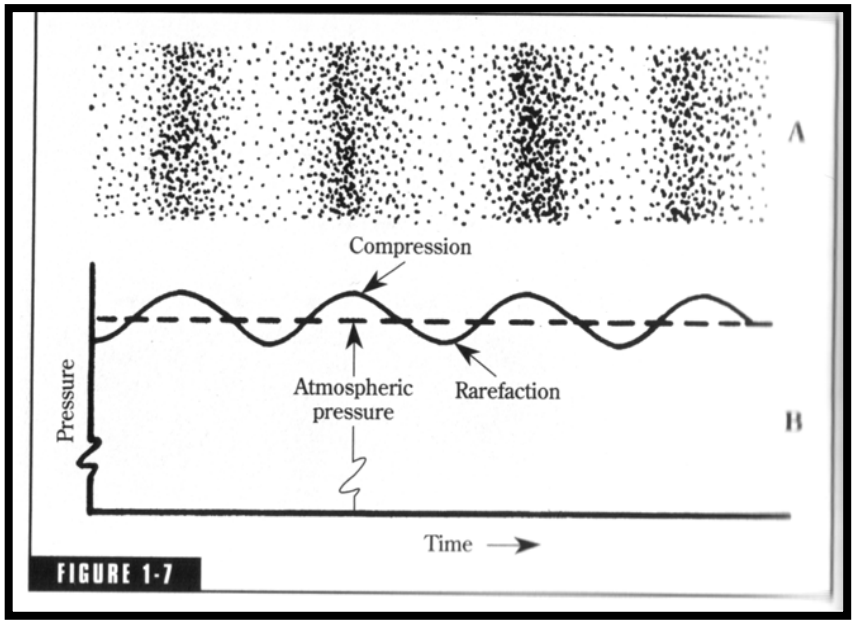
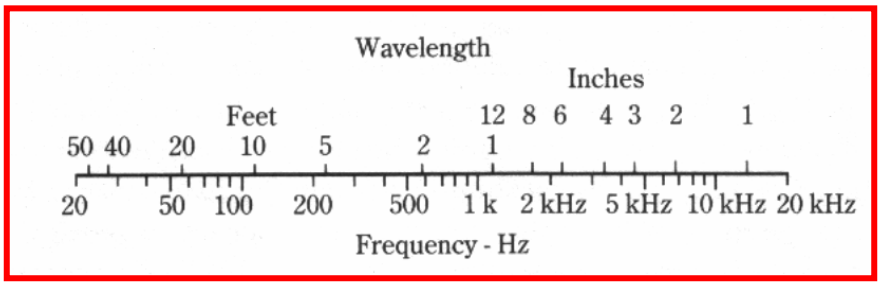
Grundläggande Akustik





- Läran om ljud och ljudutbredning
  - Ljud i fritt fält
    - Ljudet utbreder sig som tryckväxlingar kring atmosfärstrycket
  - Våglängden= c/f
    - I luft, ljudhastigheten c= 344 m/s eller 1130 ft/s
    - 1ft= 0.3048 m

Grundläggande Akustik

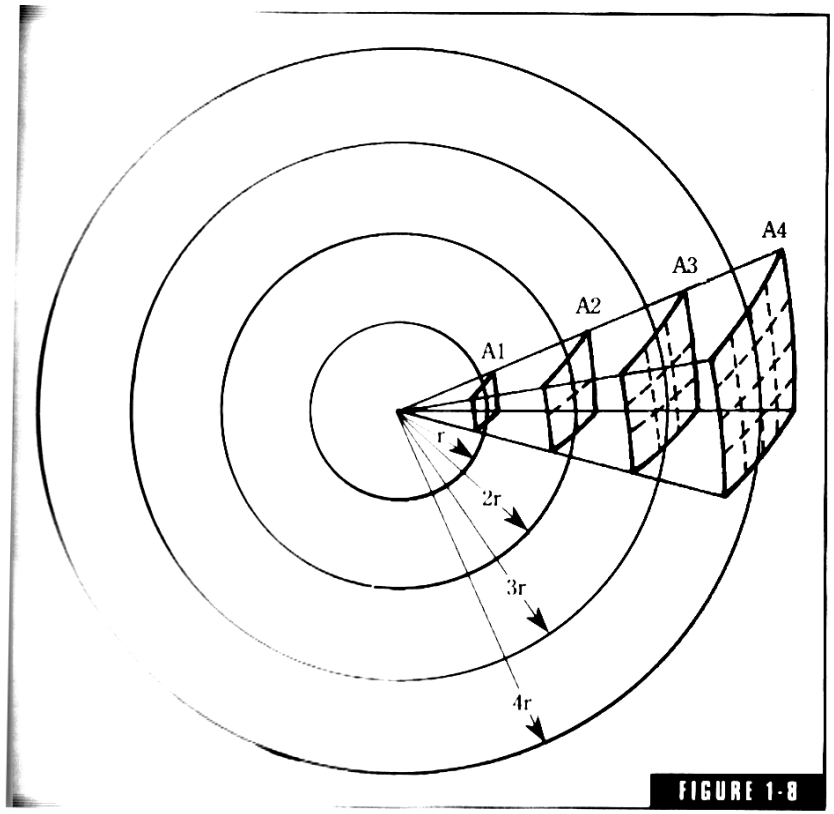
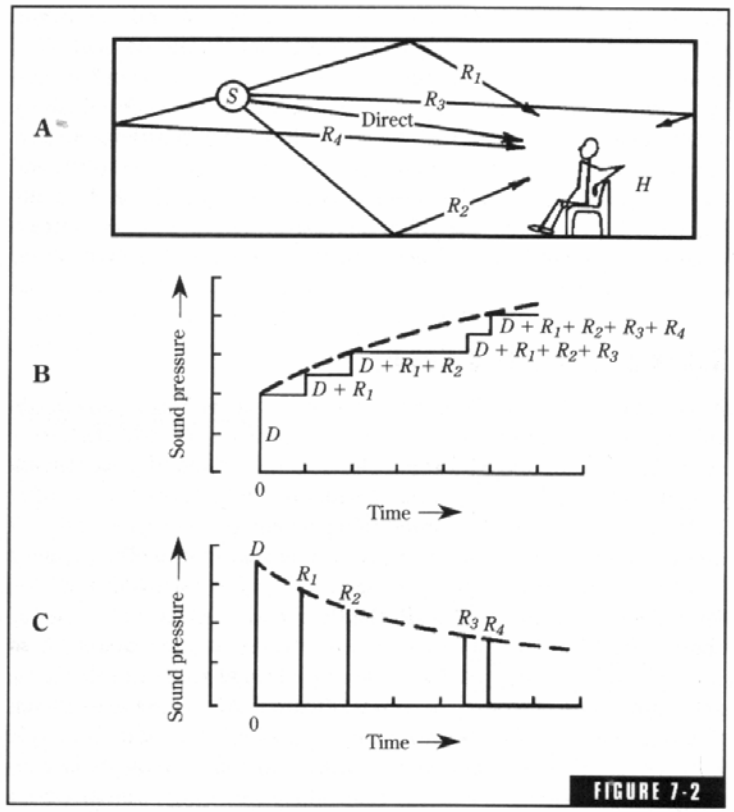


FIGURE 1-8

- Intensiteten på ljudet~$1/r^2$

Grundläggande Akustik



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.

- Slutet rum
  - Direkt ljud
  - Reflekterat ljud
    - När ljudkällan varit på en stund uppnås en jämnvikt där ljudstyrkan ej längre ökar.
    - Om inga förluster fanns skulle ljudnivån fortsätta att öka med tillförd energi
    - Tidsskillnaden mellan direktljud och reflekterat ljud brukar man kalla ”predelay”. Kan ofta justeras i burkar som tillverkar efterklang ”reverb” på elektroniksväg.

Grundläggande Akustik

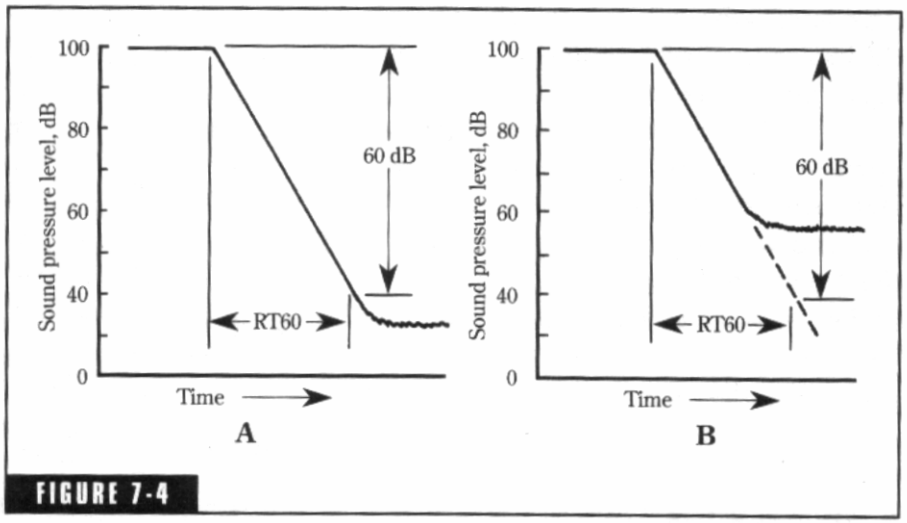
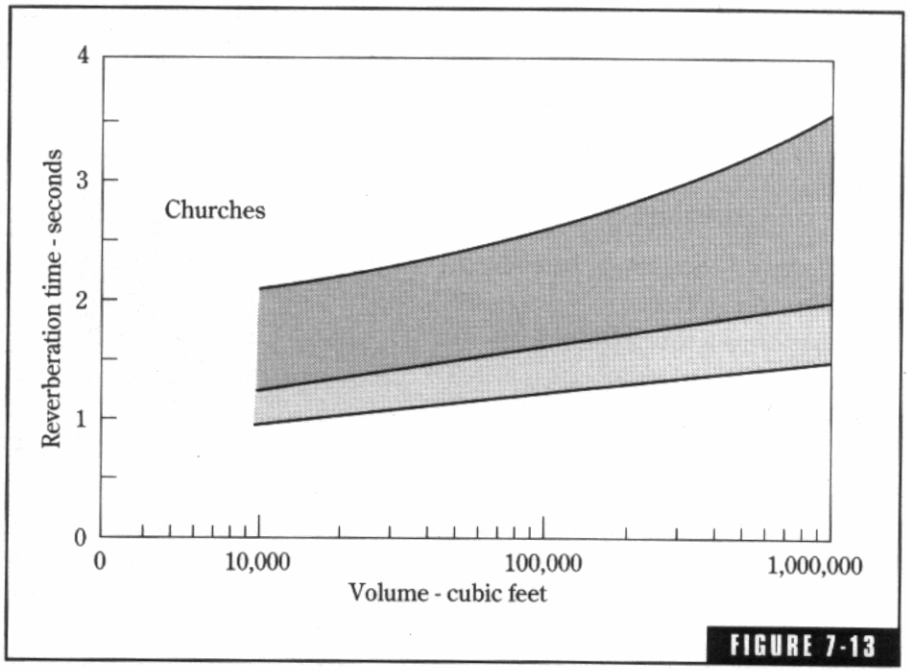


FIGURE 7-4

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.

- Slutet rum
  - Efterklang
    - Ljudkällan stängs av, ljudets intensitet klingar ut.
    - Ett mått på efterklang är efterklangstid som definieras när nivån sjunkit med 60 dB

Grundläggande Akustik



"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.

- Lämplig efterklangs tid i stora lokaler
  - Tal kräver något kortare efterklangs tid än musik

Grundläggande Akustik

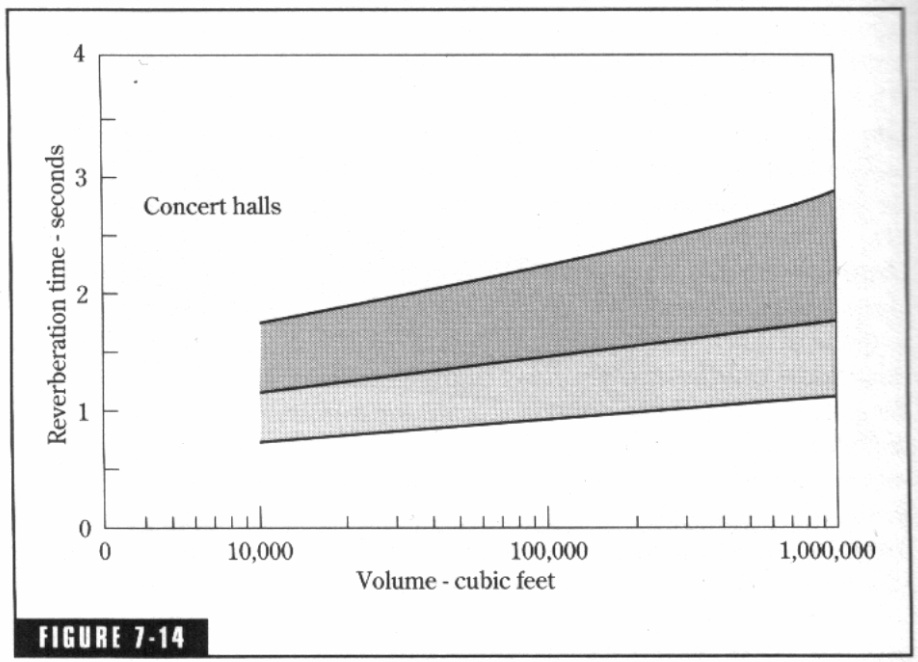
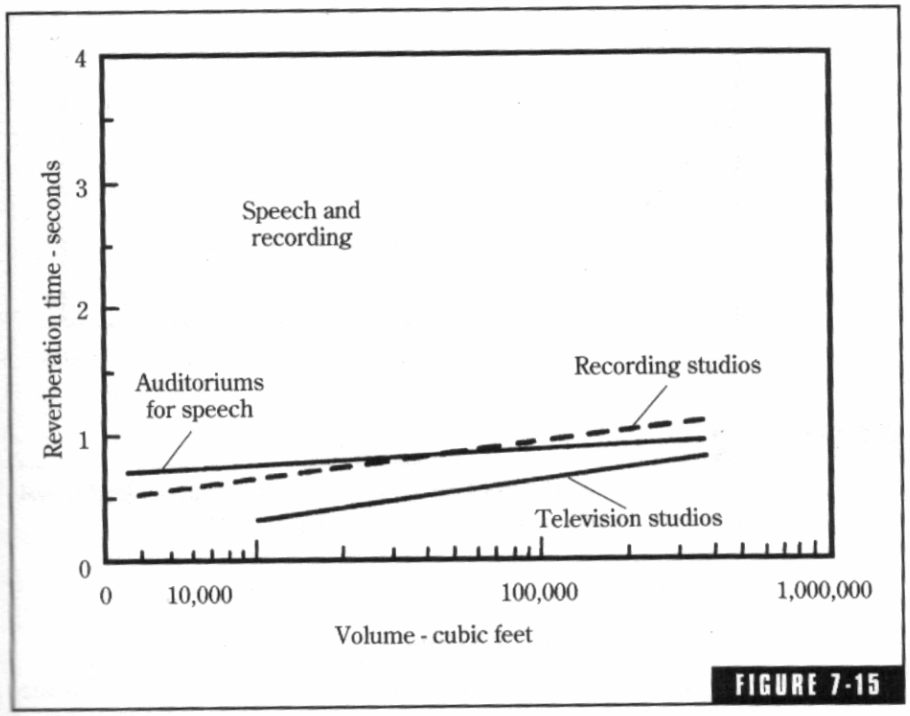


FIGURE 7-14

"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.

- Konserthallar
  - Symfoni orkester, i det mörk gråa området
  - ”Lättare musik” typ opera och kammar musik, i det ljus gråa området

Grundläggande Akustik



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

- Studios
  - TV-studio
  - Aula
  - Inspelningsstudio

Grundläggande Akustik

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.

- Beräkning av efterklangsstid
  - Sabines Formel

$$RT_{60} = \frac{0.049 \cdot V}{S \cdot \overline{a}}$$

  - V= volymen av rummet (ft^3)
  - S= totalytan av rummet (ft^2)
  - a= medel absorptionskoefficient
  - Om olika ytor har olika absorptionskoefficient beräknas nämnaren som:

$$S \cdot \overline{a} = \sum_i S_i \cdot a_i$$

Grundläggande Akustik

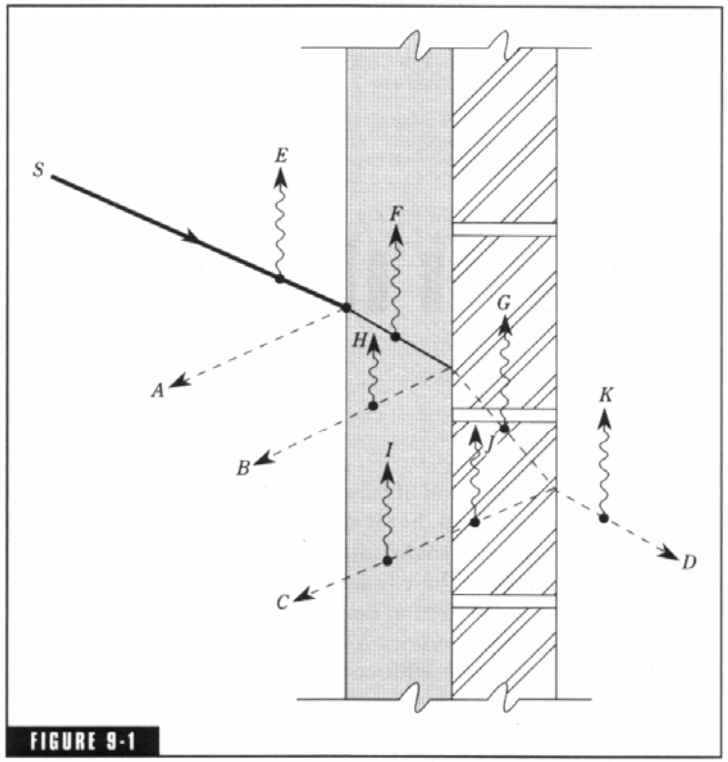


FIGURE 9-1

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.

- Absorption
  - Ljudvågorna absorberas i materialet och övergår i värme

Grundläggande Akustik

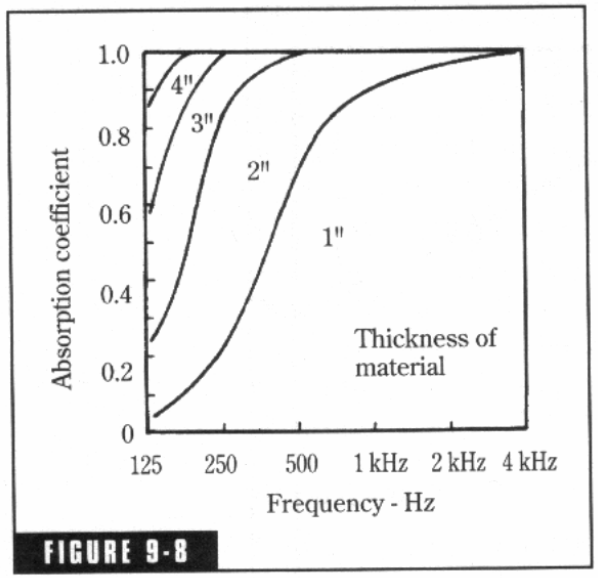


FIGURE 9-8

The thickness of glass-fiber sound-absorbing material determines the low-frequency absorption (density, 3 lb/cu ft). The material is mounted directly on a hard surface.

- Tjockleken påverkar absorptionen

Grundläggande Akustik

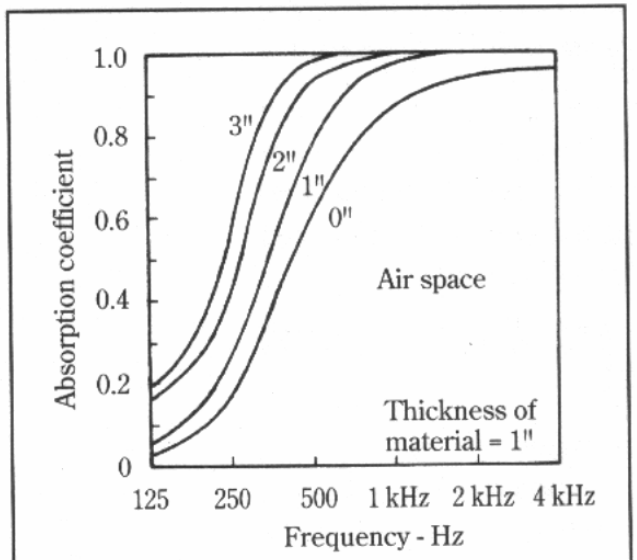


FIGURE 9-9

The low-frequency absorption of 1-inch glass fiberboard is improved materially by spacing it out from the solid wall.

- Ökat avstånd mellan vägg och isolering förbättrar absorptionen vid låga frekvenser

Grundläggande Akustik

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

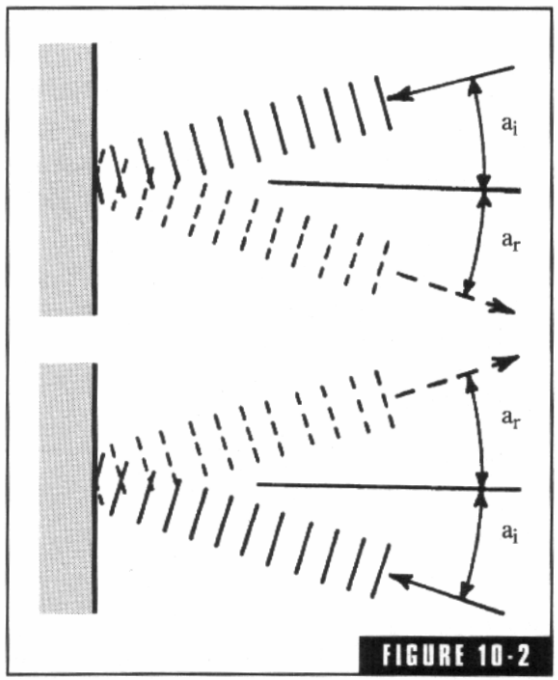
	Frequency, Hz					
	125	250	500	1 kHz	2 kHz	4 kHz
College students informally dressed seated in tablet arm chairs[6]	—	2.5	2.9	5.0	5.2	5.0
Audience seated, depending on spacing and upholstery of seats[22]	2.5–4.0	3.5–5.0	4.0–5.5	4.5–6.5	5.0–7.0	4.5–7.0

- Antalet människor påverkar absorptionen
  - Sabins= S*a

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

- Vägsträckan i luft påverkar absorptionen för högre frekvenser

Grundläggande Akustik



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

- Reflektion
  - För frekvenser under 300-400 Hz har ljudet egenskaper som en våg
  - För frekvenser över 300-400 Hz har ljudet mer karaktären av en riktad ”stråle” jmf optik

Grundläggande Akustik

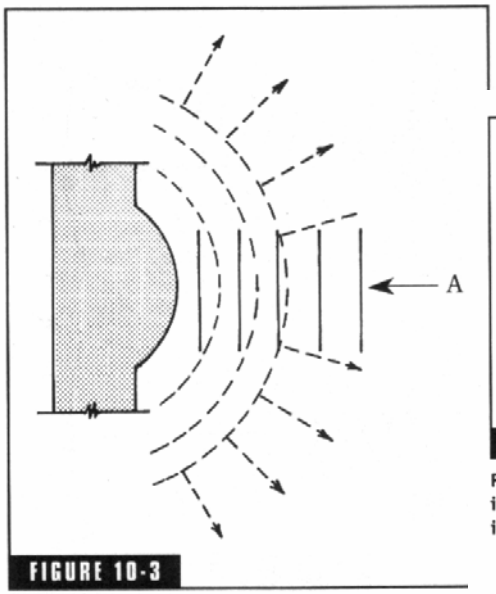


FIGURE 10-3

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.

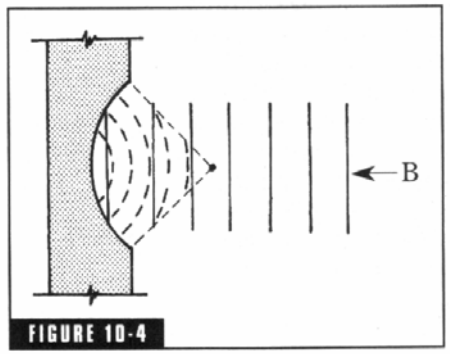


FIGURE 10-4

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.

- Reflektion
  - Plant inkommande våg sprids sfäriskt om det spridande objektet är stort i förhållande till ljudets våglängd
  - Paraboliskt beteende som i B bör undvikas i rummets uppbyggnad

Grundläggande Akustik

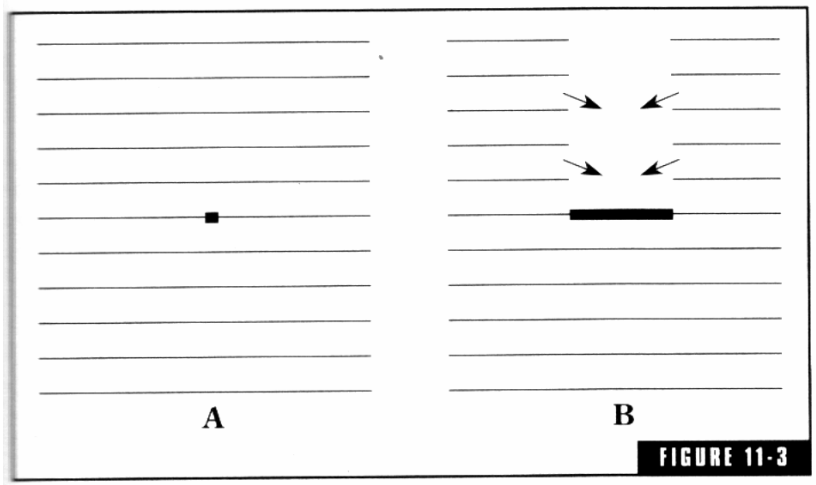


FIGURE 11-3

(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.

- Diffraktion ”böjning”
  - Ljud kan färdas runt hörn och hinder. Om föremålet är stort i förhållande till våglängden förändras vågutbredningen

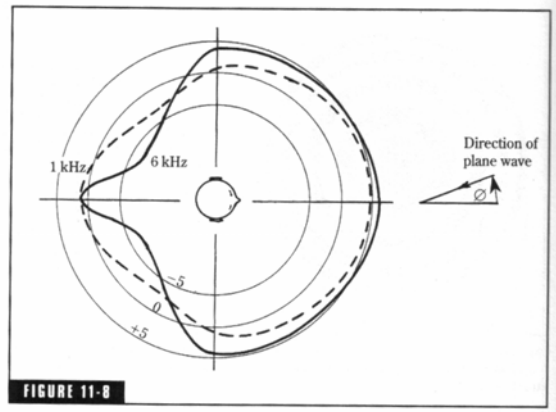
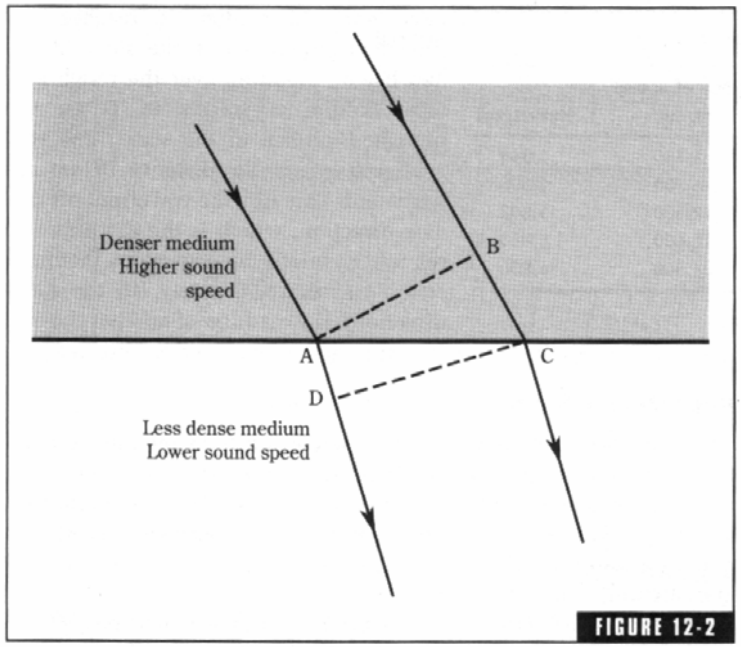


FIGURE 11-8

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])*

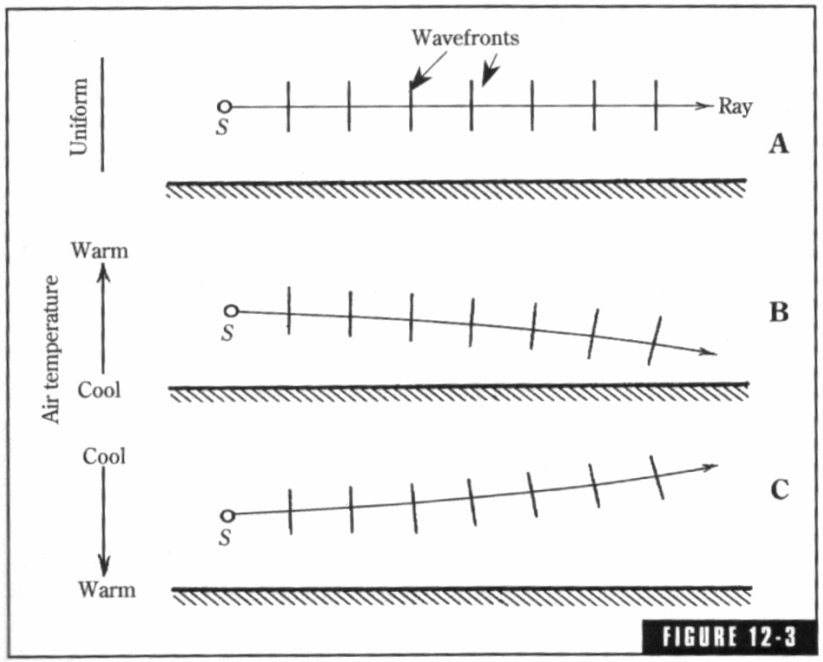
Grundläggande Akustik



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.

- Refraktion
  - Förändring av ljudutbredning pga förändring av utbredningshastigheten

Grundläggande Akustik



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.

- Refraktion
  - ”Ljudet” blåser bort!?
  - Nej det är utbredningshastigheten som förändras då varma och kalla luftlager störs av vinden. Kan höras exempelvis vid utomhus -konserter

Grundläggande Akustik

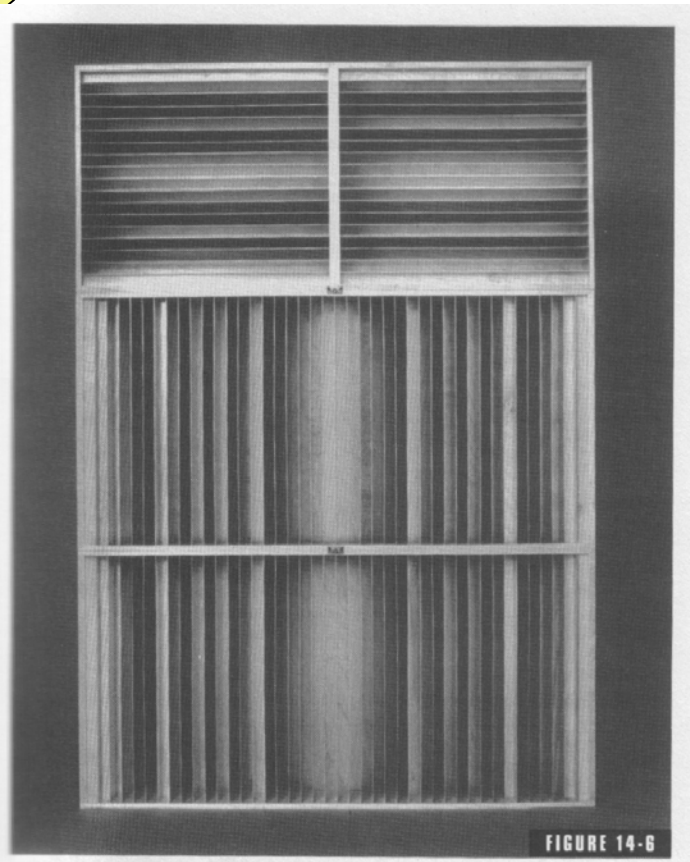


FIGURE 14-6

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.

- Diffusion (Spridning av ljudet)
  - Nivåvariationer i ytan måste vara minst 1/7 av ljudets våglängd för att ha någon effekt

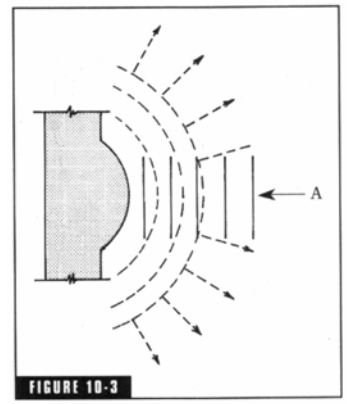
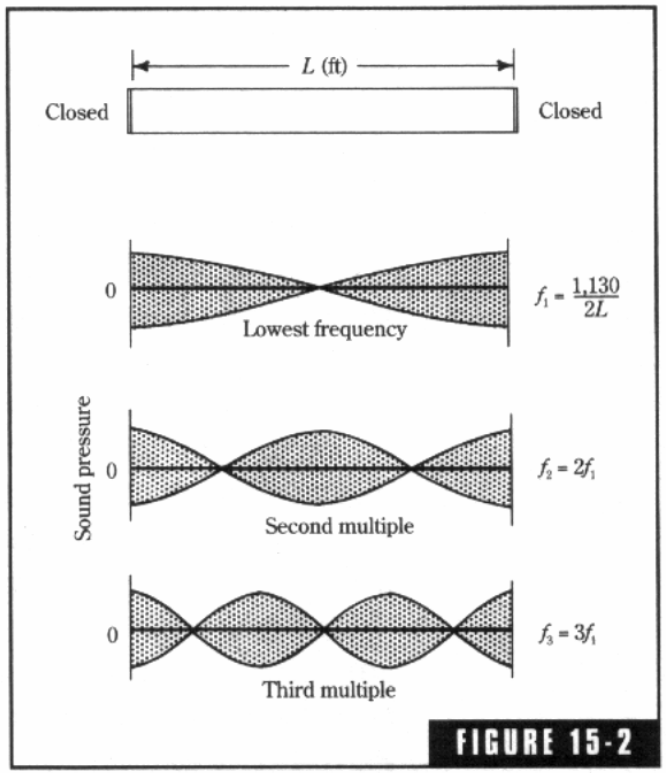


FIGURE 10-3

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.

Grundläggande Akustik



A pipe closed at both ends helps us to understand how resonance occurs between two opposing walls of a listening room or studio. The distance between the walls determines the characteristic frequency of resonance.

- Stående vågor
  - Första stående vågen uppkommer då avståndet mellan två parallella ytor är en ½ våglängd, sedan uppstår stående vågor med heltalsmultiplar av grundfrekvensen f_1

Grundläggande Akustik

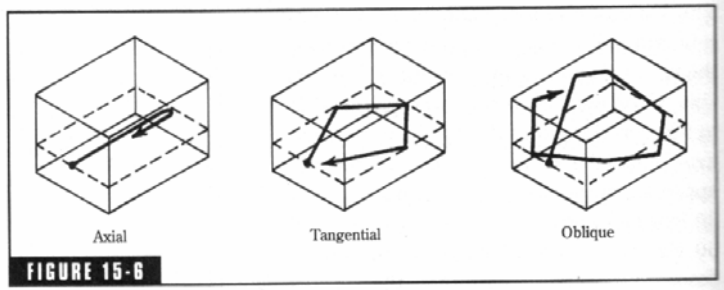


FIGURE 15-6

Visualization of axial, tangential, and oblique room modes using the ray concept.

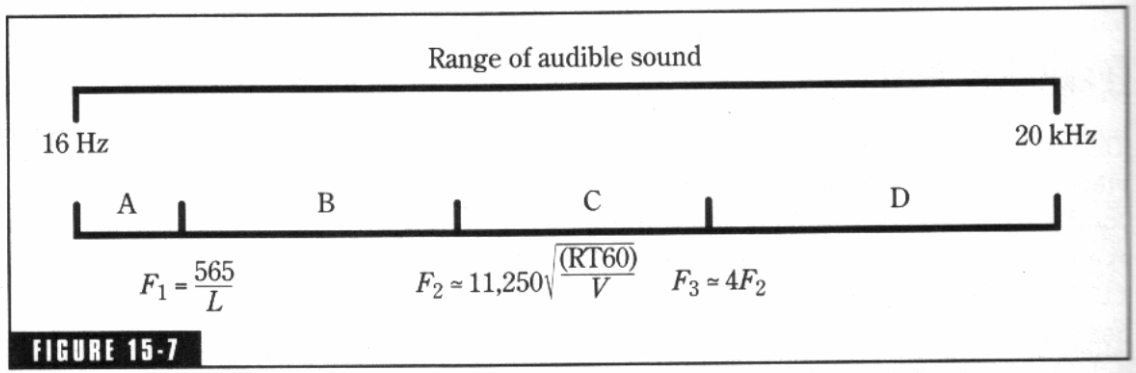


FIGURE 15-7

When dealing with the acoustics of enclosed spaces, it is convenient to consider the audible frequency range as composed of four regions: A, B, C, and D demarked by the frequencies F_1, F_2, and F_3. In region D, specular reflections and ray acoustics prevail. In region B, room modes dominate. Region C is a transition zone in which diffraction and diffusion dominate. There is no modal boost for sound in region A.

- Stående vågor i ett rum:
  - A, Frekvenser under lägsta grundfrekvensen f1
  - B, rummets geometri och ljudets våglängd är jämförbara, stående vågor dominerar med rumsliga nivåvariationer
  - C, Övergångsområde mellan område B och D, diffraktion och diffusion dominerar
  - D, Stående våg densiteten är hög, ljudet får en mer slumpmässig utbrednings riktning, Varje utbrednings riktning har karaktären av en stråle

Grundläggande Akustik

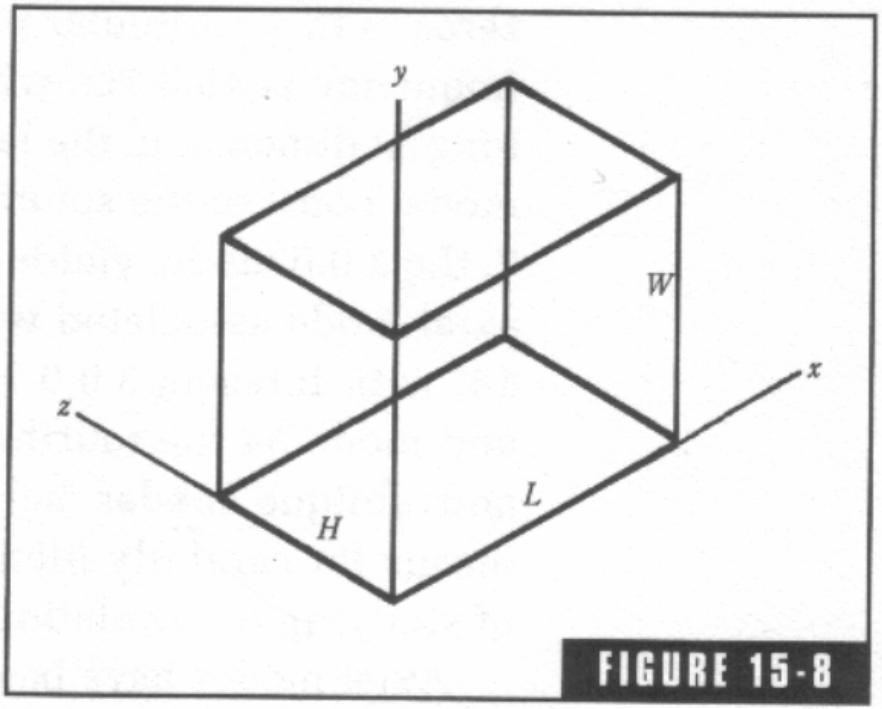


FIGURE 15-8

Orientation of rectangular room of length *L*, width *W*, and height *H* with respect to the *x*, *y*, and *z* coordinates for calculating room modal frequencies.

- Hur beräknas stående vågor?

$$f = \frac{c}{2}\sqrt{\frac{p^2}{L^2} + \frac{q^2}{W^2} + \frac{r^2}{H^2}}$$

  - *C*= ljudets hastighet
  - *L,W,H*= Rummets dimensioner
  - *p, q ,r* = Heltal 0,1,2,3……

Grundläggande Akustik

Table 15-1. Mode calculations. Room dimensions: 12.46 × 11.42 × 7.90 ft.

Mode number	Integers *p q r*	Mode frequency, Hz	Axial	Tangential	Oblique
1	1 0 0	45.3	x		
2	0 1 0	49.5	x		
3	1 1 0	67.1		x	
4	0 0 1	71.5	x		
5	1 0 1	84.7		x	
6	0 1 1	87.0		x	
7	2 0 0	90.7	x		
8	2 0 1	90.7		x	
9	1 1 1	98.1			x
10	0 2 0	98.9	x		
11	2 1 0	103.3		x	
12	1 2 0	108.8		x	
13	0 2 1	122.1		x	
14	0 1 2	122.1		x	
15	2 1 1	125.6			x
16	1 2 1	130.2			x
17	2 2 0	134.2		x	
18	3 0 0	136.0	x		
19	0 0 2	143.0	x		
20	3 1 0	144.8		x	
21	0 3 0	148.4	x		
22	2 2 1	152.1			x
23	3 0 1	153.7		x	
24	1 1 2	158.0			x
25	3 1 1	161.5			x
26	0 3 1	164.8		x	
27	3 2 0	168.2		x	
28	2 0 2	169.4		x	
29	1 3 1	170.9			x
30	0 2 2	173.9		x	
31	2 3 0	173.9		x	
32	2 1 2	176.4			x
33	1 2 2	179.7			x
34	4 0 0	181.4	x		
35	3 2 1	182.8			x

Table 15-1. *Continued.*

Mode number	Integers *p q r*	Mode frequency, Hz	Axial	Tangential	Oblique
36	2 3 1	188.1			x
37	2 2 2	196.2			x
38	0 4 0	197.9	x		
39	3 0 2	197.9		x	
40	3 3 0	201.3		x	
41	3 1 2	203.5			x
42	0 3 2	206.1		x	
43	1 3 2	211.1			x
44	0 0 3	214.6	x		
45	1 0 3	219.3		x	
46	0 1 3	220.2		x	
47	3 2 2	220.8			x
48	1 1 3	224.8			x
49	2 3 2	225.2			x
50	2 0 3	232.9		x	
51	4 3 0	234.4		x	
52	0 2 3	236.3		x	
53	2 1 3	238.1		x	
54	3 4 0	240.2		x	
55	1 2 3	240.6			x
56	3 3 2	247.0			x
57	2 2 3	253.1			x
58	3 0 3	254.0		x	
59	0 3 3	260.9		x	
60	3 2 3	272.6			x
61	2 3 3	276.2			x
62	4 0 3	281.0		x	
63	0 0 4	286.1	x		
64	0 4 3	291.1		x	
65	3 0 4	316.8		x	
66	0 3 4	322.3		x	

Grundläggande Akustik

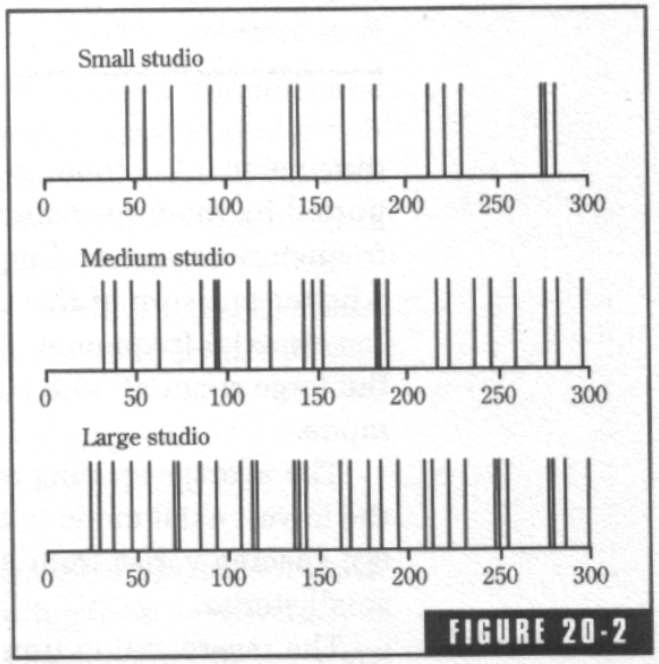


FIGURE 20-2

Comparison of the axial-mode resonances of a small (1,000 cu ft), a medium (3,400 cu ft), and a large (8,000 cu ft) studio all having the proportions 1.00: 1.28: 1.54.

- Flera moder medför en jämnare frekvens återgivning i rummet, vilket uppfylls lättare i större rum
- En tumregel säger att ett studiorum ej bör vara mindre än 1500 ft^3 (enligt BBC)

Grundläggande Akustik

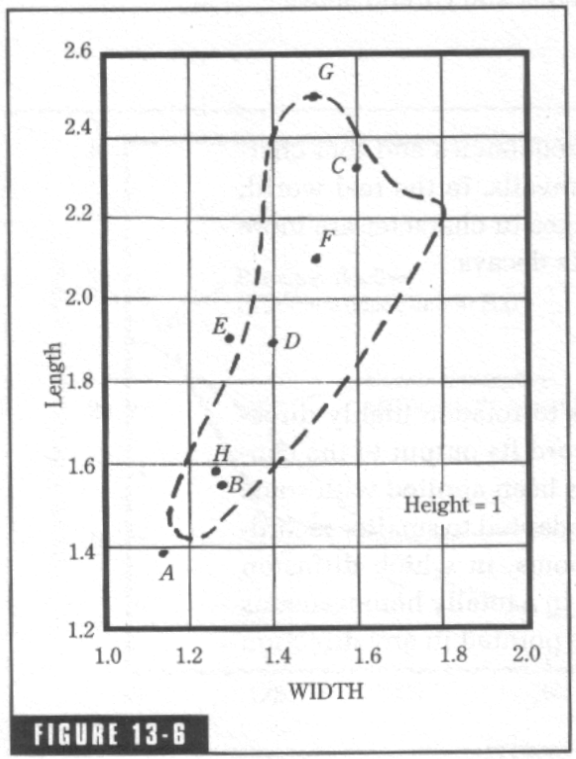


FIGURE 13-6

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.

- Proportioner på ett rum som ger jämnast utbredning av stående vågors frekvensfördelning

Grundläggande Akustik

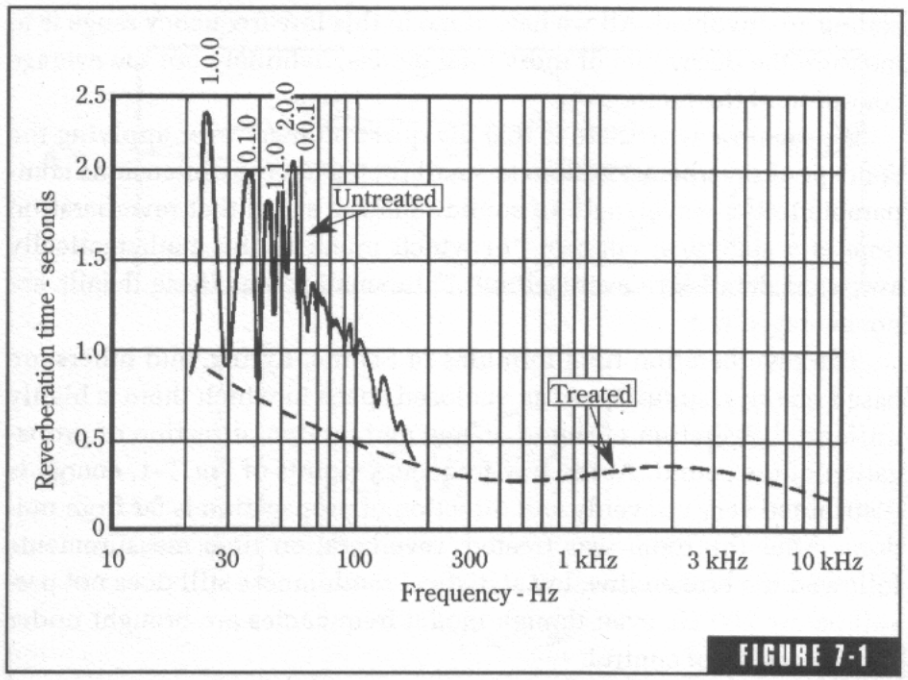
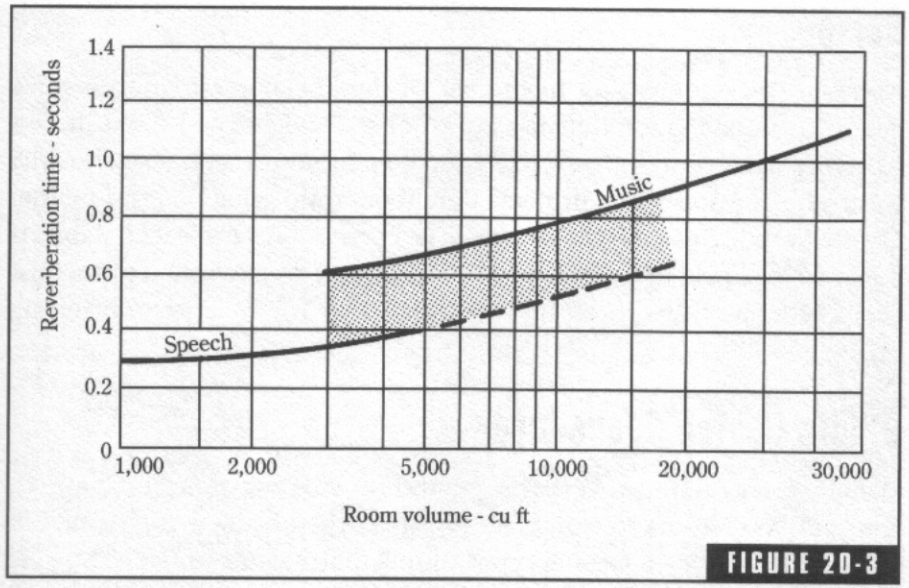


FIGURE 7-1

Reverberation time measured with pure sine signals at low frequencies reveals slow sound decay (long reverberation time) at the modal frequencies. These peaks apply only to specific modes and are not representative of the room as a whole. High modal density, resulting in uniformity of distribution of sound energy and randomizing of directions of propagation, is necessary for reverberation equations to apply. (Beranek,[1] and Schultz.[2])

- Stående vågor i ett rum uppmätta med ett frekvenssvep
  - Efterklangstiden blir väldigt lång för stående vågor. Efterklangstiden för rummet som helhet är betydligt kortare.
  - För att sabines ekvation skall gälla krävs hög ståendevåg densitet och en slumpmässig utbredning riktning

Grundläggande Akustik



Suggested reverberation times for recording studios. The shaded area is a compromise region for studios in which both music and speech are recorded.

- Lämplig efterklangstid i inspelningsstudio

Grundläggande Akustik

Öppning mot rummet

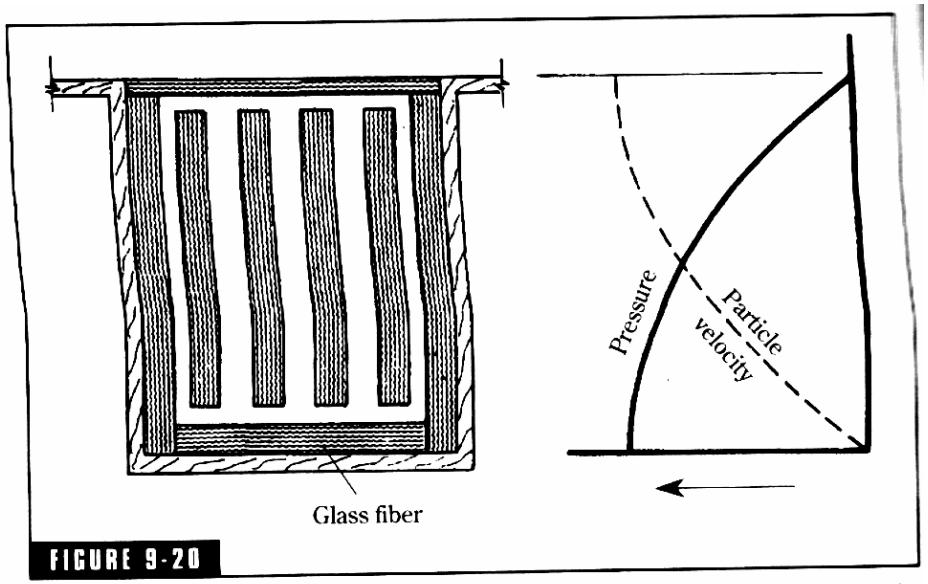
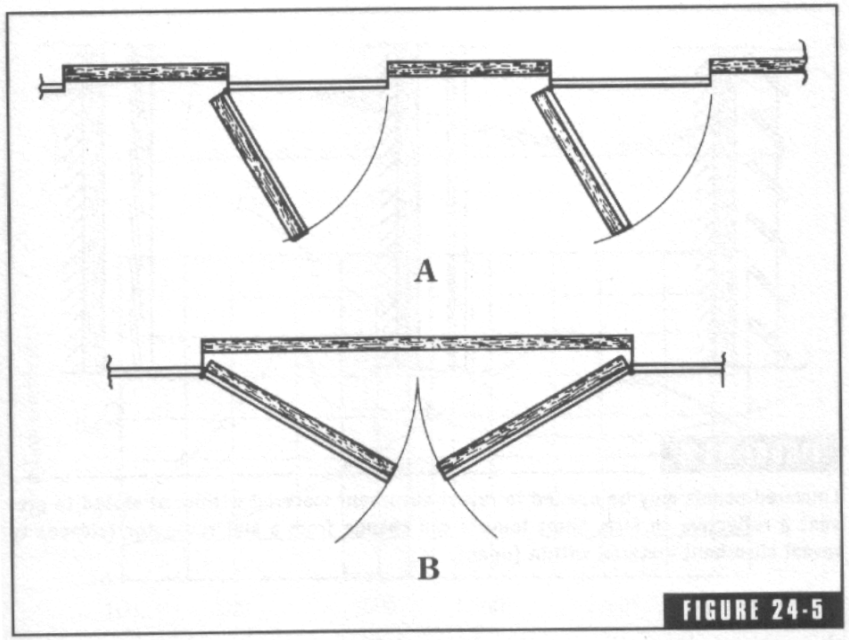


FIGURE 9-20

The bass trap depends upon reflections of sound from the bottom for its action. The pressure for the frequency at which the depth is a quarter wavelength is maximum at the bottom and the particle velocity is zero at the bottom. At the mouth, the pressure is zero (or very low) and the particle velocity is maximum. Absorbent placed where the particle velocity is maximum will absorb sound very effectively. The same action occurs at odd multiples of the quarter wavelength.

- Bas fälla
  - Avstämd kavitet, djupet skall vara $\lambda/4$ av den våglängd som man vill dämpa. Trycket är lägst vid öppningen vilket leder till en dammsugareffekt av basljudet. Effektiviteten blir därmed bättre än vad öppnings arean föranleder

Grundläggande Akustik



An inexpensive and effective method of incorporating variability in room acoustics is through the use of hinged panels, hard on one side and absorbent on the other.

- Att kunna förändra akustiken i ett rum, några exempel

Grundläggande Akustik

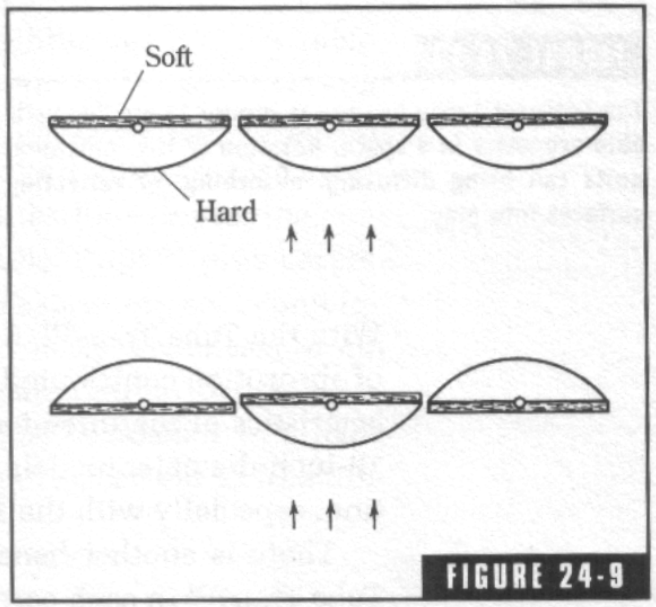


FIGURE 24-9

Rotating elements can vary the reverberation characteristics of a room. They have the disadvantage of requiring considerable space to accommodate the rotating elements.

- Att kunna förändra akustiken i ett rum, några exempel

Grundläggande Akustik

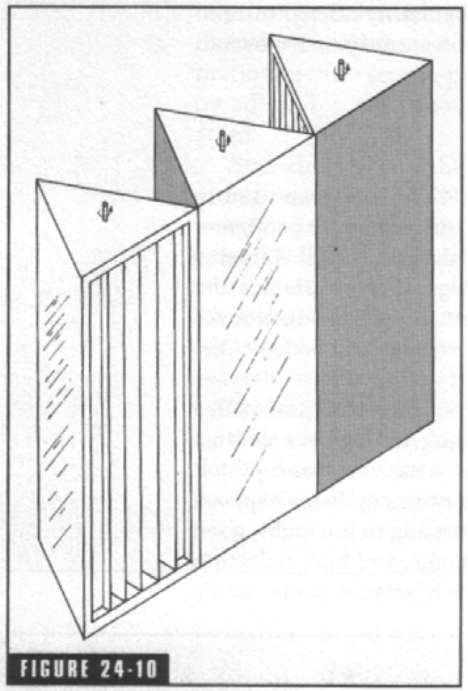


FIGURE 24-10

The Triffusor™ may be used in groups to provide variable acoustics in a space. Rotation of the individual units can bring diffusing, absorbing, or reflecting surfaces into play.

- Att kunna förändra akustiken i ett rum, några exempel