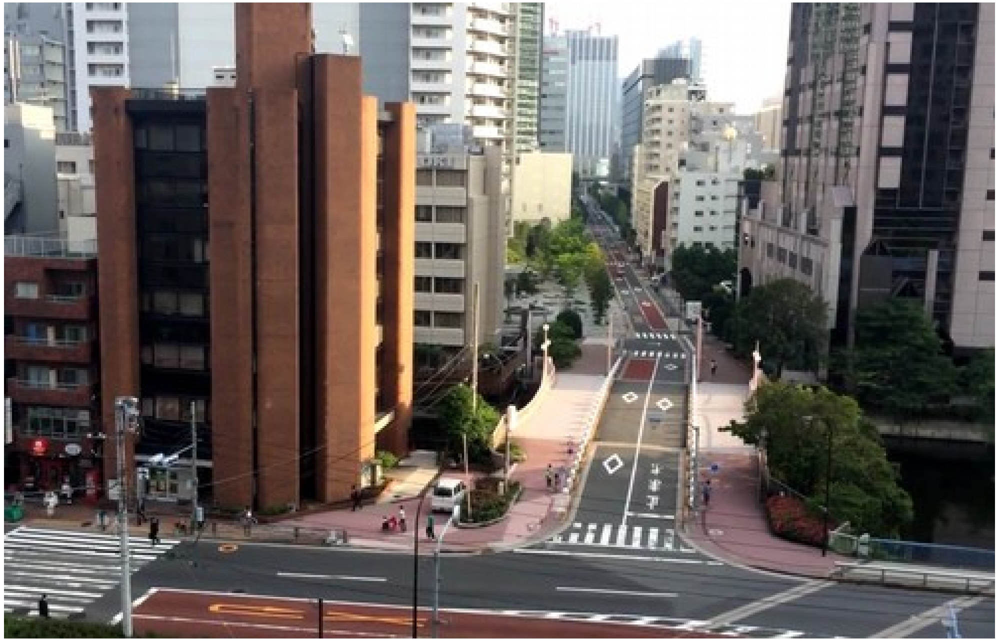
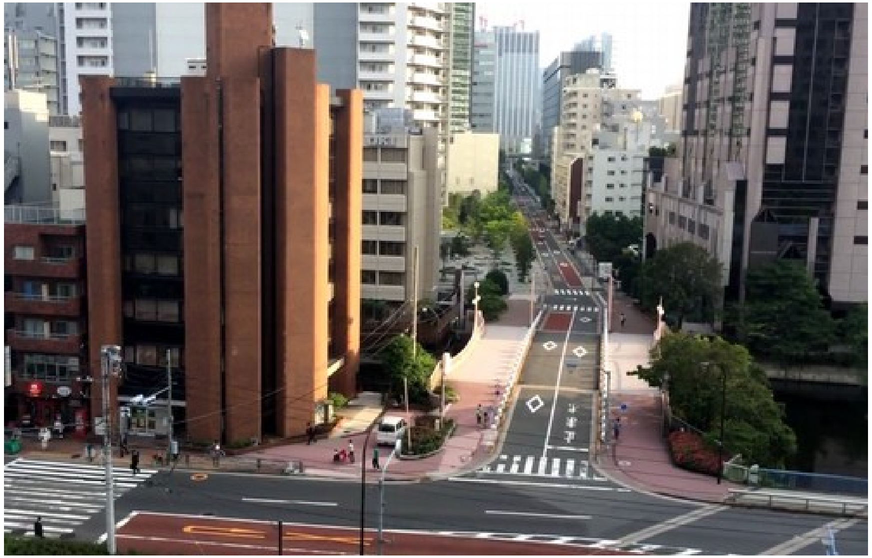
THE ACOUSTIC ENVIRONMENT

the daily 5 PM bells in Shibaura neighborhood of Tokyo



https://www.youtube.com/watch?v=SgdnYBT6XuA

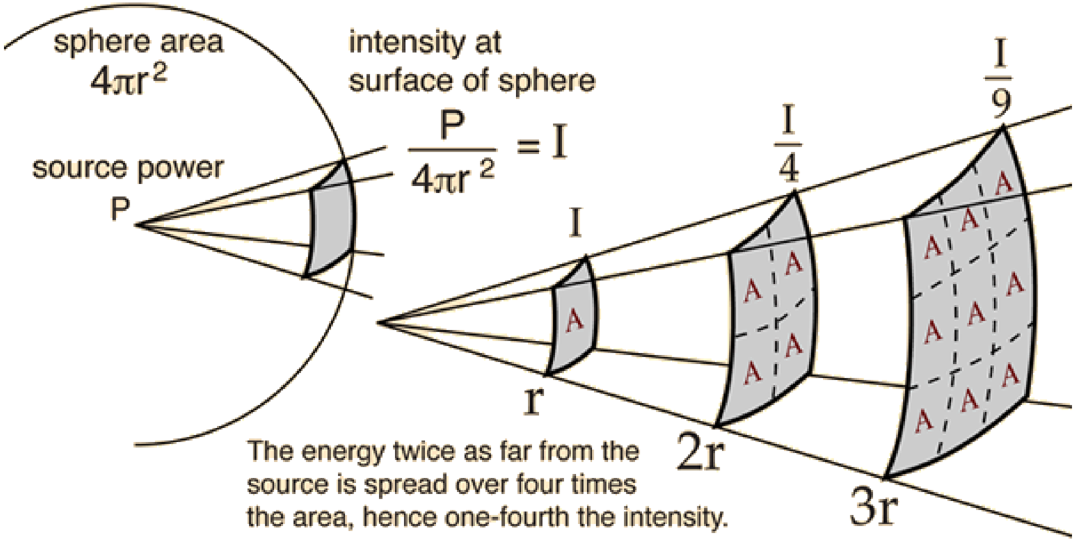


https://www.youtube.com/watch?v=SgdnYBT6XuA

Factors

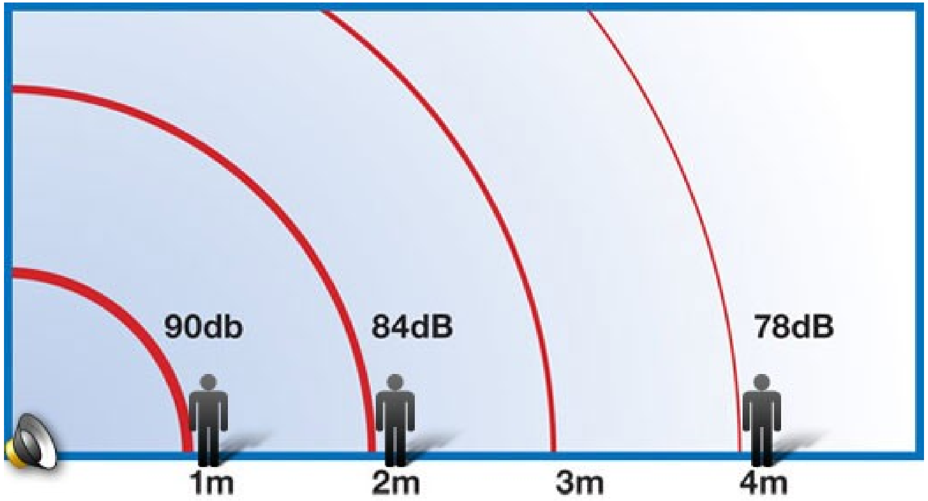
1. Inverse square law
2. attenuation due to atmospheric absorption
3. refraction by wind and temperature
4. reflection and diffraction by solid object
5. reflection and absorption by the ground surface

Inverse Square Law

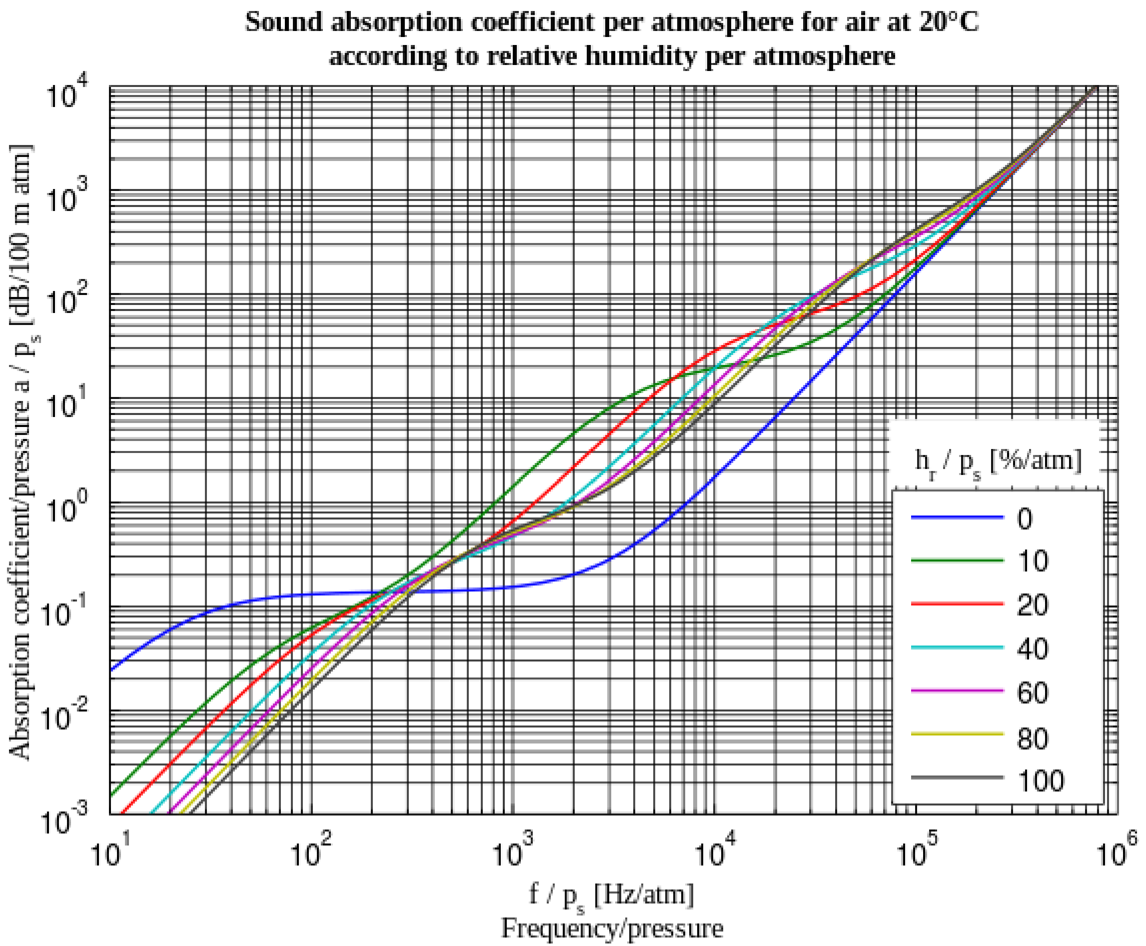


http://hyperphysics.phy-astr.gsu.edu/hbase/Acoustic/invsqs.html

https://www.extron.com/calculators/inverse-square-law/?tab=tools



Atmospheric absorption



https://en.wikibooks.org/wiki/Engineering_Acoustics/Outdoor_Sound_Propagation

Atmospheric absorption

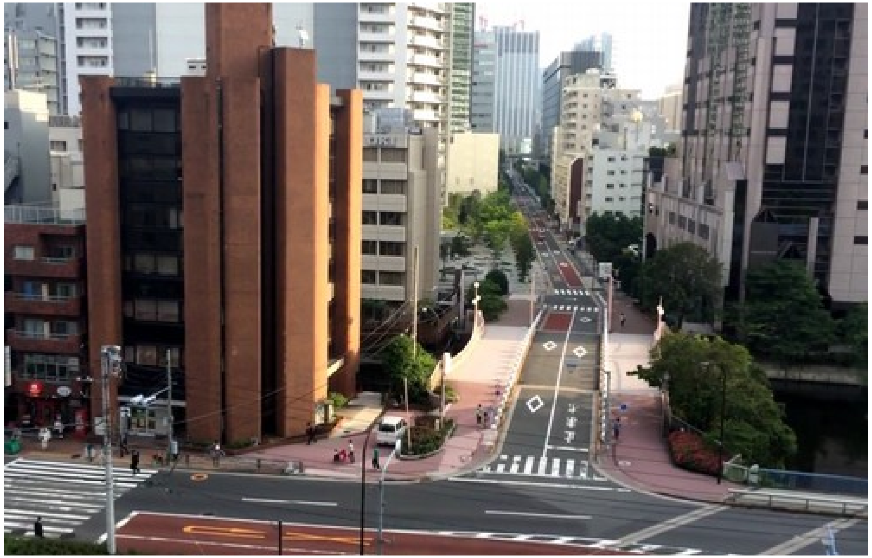


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Table 1 - Atmospheric attenuation coefficient α (dB/km) at selected frequencies at 1 atm[10]

Temperature	Relative humidity (%)	62.5 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
30 °C	10	0.362	0.958	1.82	3.40	8.67	28.5	96.0	260
	20	0.212	0.725	1.87	3.41	6.00	14.5	47.1	165
	30	0.147	0.543	1.68	3.67	6.15	11.8	32.7	113
	50	0.091	0.351	1.25	3.57	7.03	11.7	24.5	73.1
	70	0.065	0.256	0.963	3.14	7.41	12.7	23.1	59.3
	90	0.051	0.202	0.775	2.71	7.32	13.8	23.5	53.5
20 °C	10	0.370	0.775	1.58	4.25	14.1	45.3	109	175
	20	0.260	0.712	1.39	2.60	6.53	21.5	74.1	215
	30	0.192	0.615	1.42	2.52	5.01	14.1	48.5	166
	50	0.123	0.445	1.32	2.73	4.66	9.86	29.4	104
	70	0.090	0.339	1.13	2.80	4.98	9.02	22.9	76.6
	90	0.071	0.272	0.966	2.71	5.30	9.06	20.2	62.6
10 °C	10	0.342	0.788	2.29	7.52	21.6	42.3	57.3	69.4
	20	0.271	0.579	1.20	3.27	11.0	36.2	91.5	154
	30	0.225	0.551	1.05	2.28	6.77	23.5	76.6	187
	50	0.160	0.486	1.05	1.90	4.26	13.2	46.7	155
	70	0.122	0.411	1.04	1.93	3.66	9.66	32.8	117
	90	0.097	0.348	0.996	2.00	3.54	8.14	25.7	92.4
0 °C	10	0.424	1.30	4.00	9.25	14.0	16.6	19.0	26.4
	20	0.256	0.614	1.85	6.16	17.7	34.6	47.0	58.1
	30	0.219	0.469	1.17	3.73	12.7	36.0	69.0	95.2
	50	0.181	0.411	0.821	2.08	6.83	23.8	71.0	147
	70	0.151	0.390	0.763	1.61	4.64	16.1	55.5	153
	90	0.127	0.367	0.760	1.45	3.66	12.1	43.2	138

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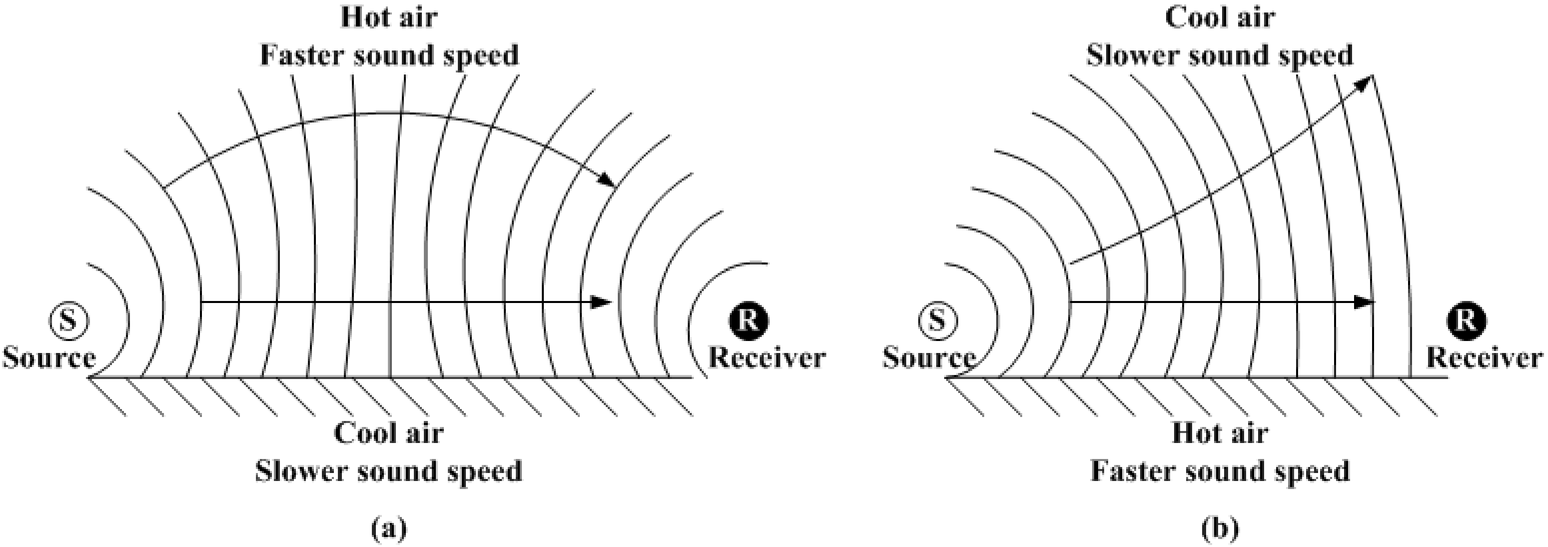
Speed of Sound

Speed of sound depends on the type of gas and the temperature

$$c_{\text{sound}} = \sqrt{\frac{\gamma R T}{M}}$$

$$\begin{aligned} \gamma &= \text{adiabatic constant} \\ R &= \text{gas constant} \\ M &= \text{molecular mass of gas} \\ T &= \text{absolute temperature} \end{aligned}$$

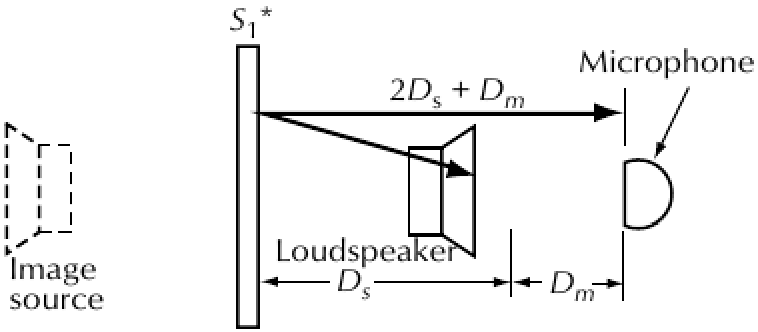
Refraction



https://en.wikibooks.org/wiki/Engineering_Acoustics/Outdoor_Sound_Propagation#/media/File:Outdoor_Sound_Refraction.png

Reflection

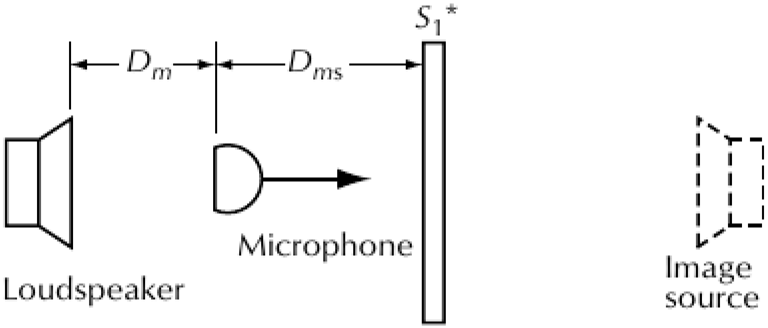
Case No. 1



Influence of surface S_1 on measured signal at microphone equals:

$$\text{Reflected signals relative level} = 20 \log \left[\frac{D_m}{2D_s + D_m}\right]$$

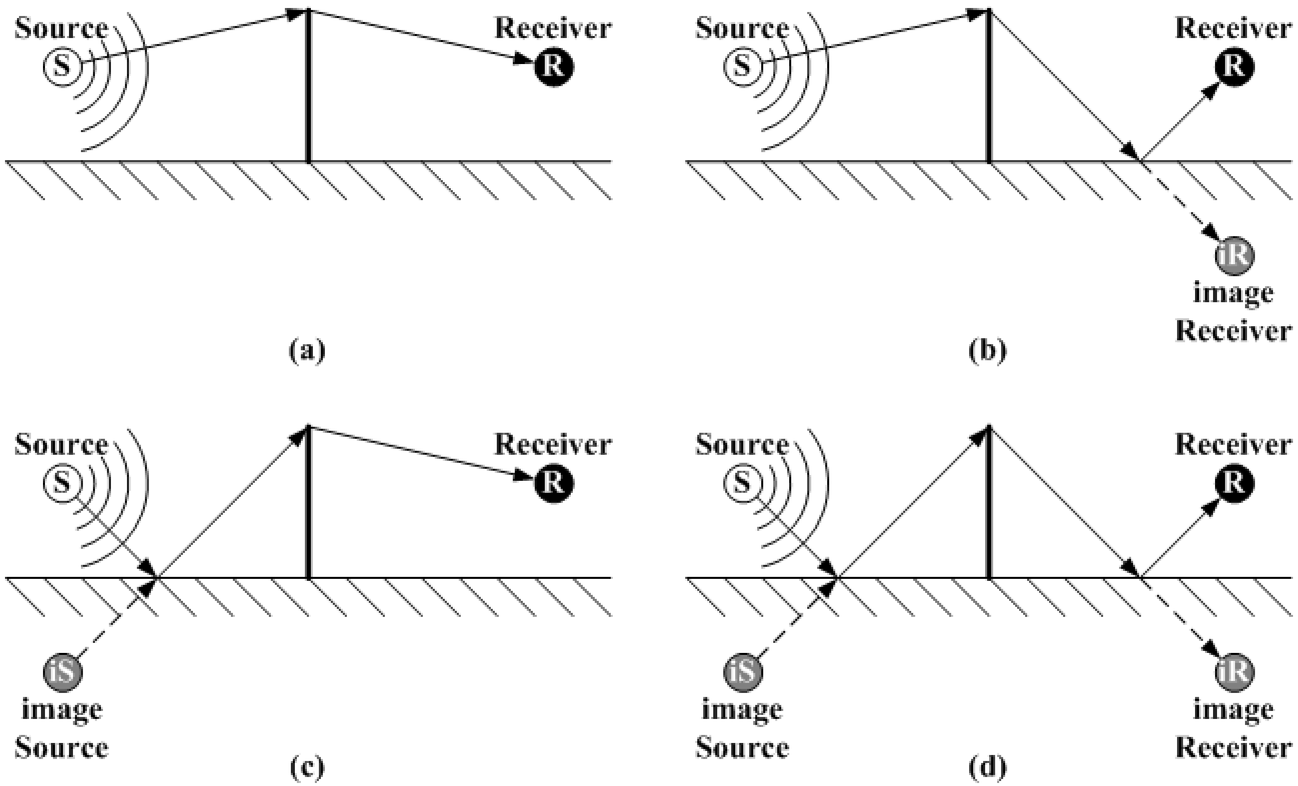
Case No. 2



Influence of surface S_1 on measured signal at microphone equals:

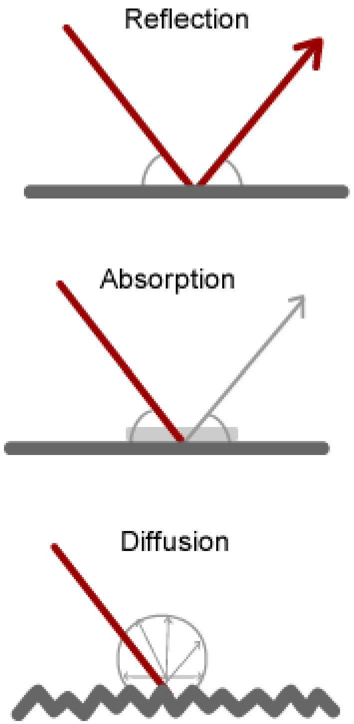
$$\text{Reflected signals relative level} = 20 \log \left[\frac{D_m}{D_m + 2D_{ms}}\right]$$

Diffraction



https://upload.wikimedia.org/wikipedia/commons/1/18/Sound_diffraction_paths.png

Reflection, Absorption and Diffusion



Sound Fields