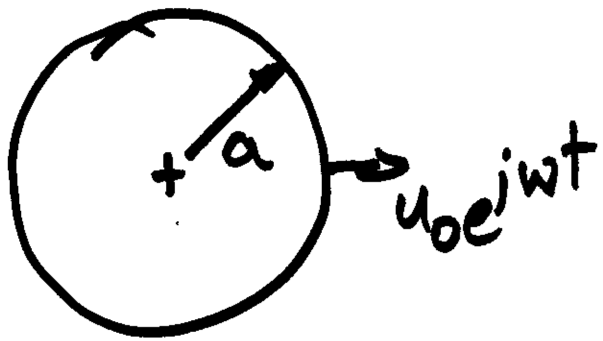


$\tilde{p}$, $\tilde{u}_r$, I_r, W

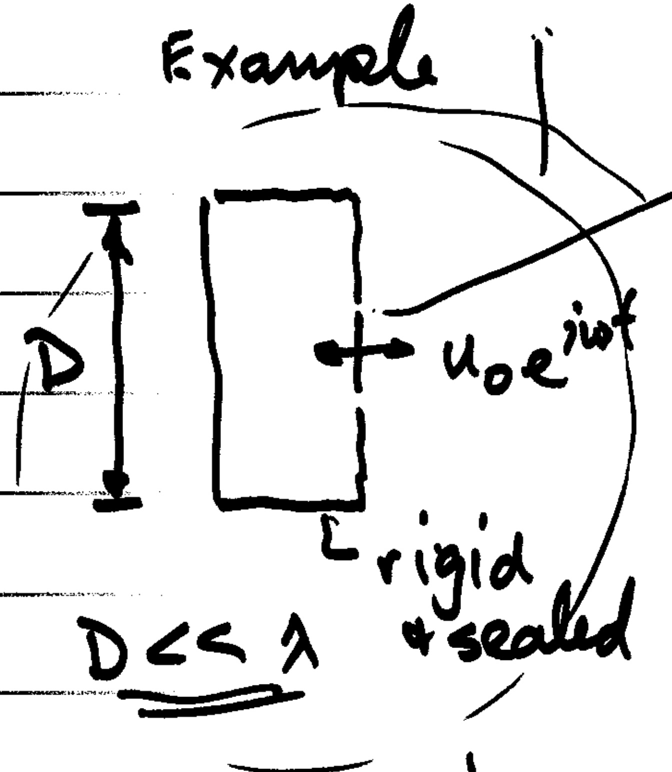
$a \to 0$ point monopole

$$\tilde{p}(r) = j\rho_0 c \frac{kQ}{4\pi r} e^{-jkr}$$

Q volume source strength

simple sources.

Example



$D \ll \lambda$

piston of radius a
- diaphragm of a l/s

$$Q = \pi a^2 u_o \quad [m^3/s]$$

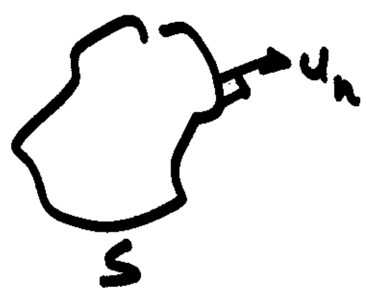
replace the l/s by a pt. monopole

$$\hat{p}(r) = j\rho_0 c \frac{kQ}{4\pi r} e^{-jkr}$$

$I_r \qquad W = \int I_r \, dS = \rho_0 c \frac{k^2 Q^2}{8\pi}$

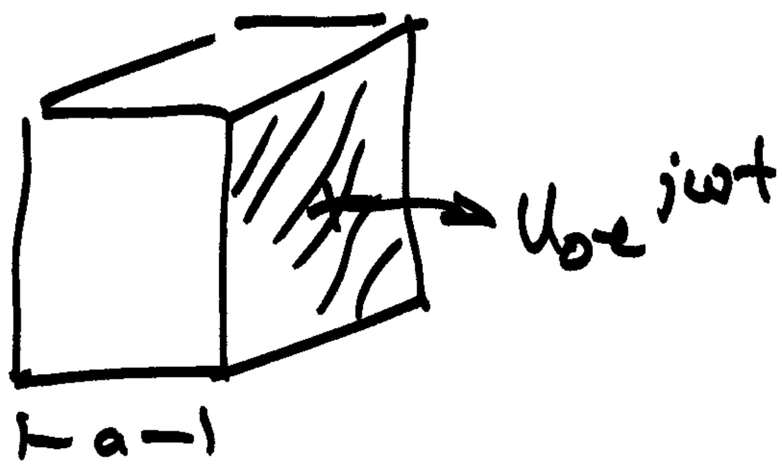
5.3.2 Simple Volume Source

Any source that displaces Q m^3/s and is small (compared to a wavelength) radiates like a point monopole.



$$Q = \int_S u_n \, dS$$

cube



1 active surface

$Q = a^2 U_0$

5 rigid sides

if $a \ll \lambda$

$$\tilde{p}(r) = j\rho_0 c \frac{kQ}{4\pi r} e^{-jkr}$$

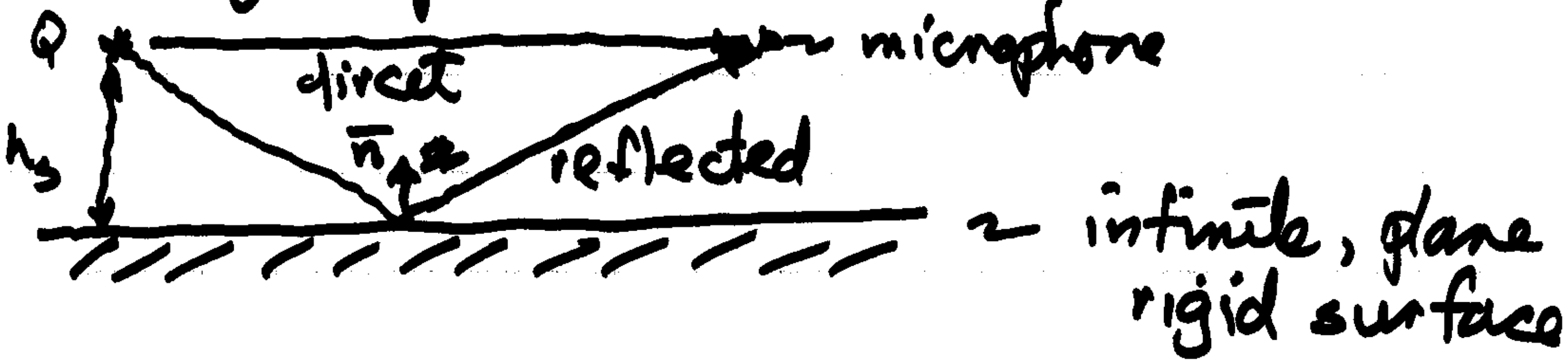
some sound sources do not change their volume

unbaffled l/s

not volume source

5.3.3 Reflection at a hard surface

5.3.3.1 Single Reflection

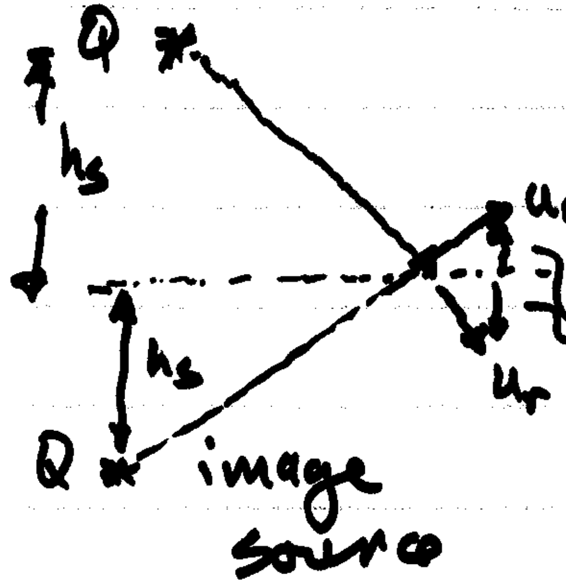


b.c. $\quad \bar{u} \cdot \bar{n} = 0 \qquad u_n = 0$

zero normal particle velocity at the surface

– rigid surface.

free space

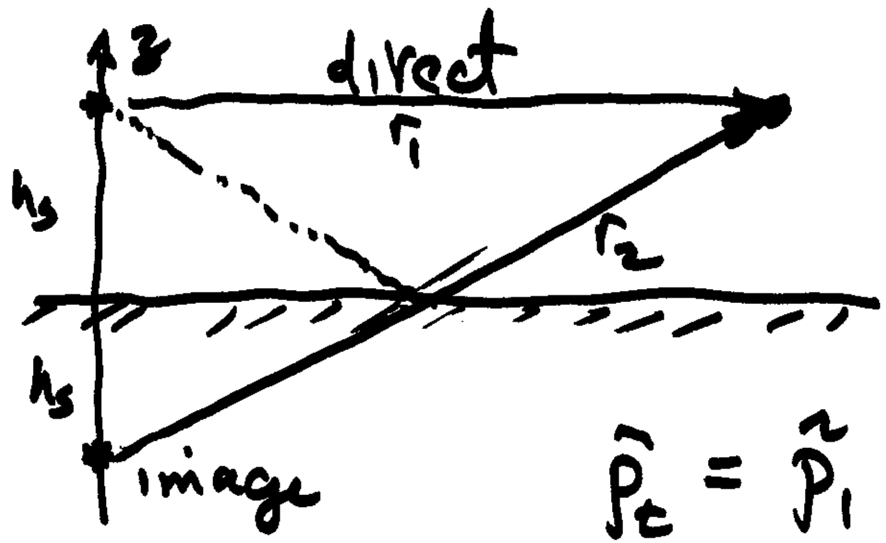


nominal surface location

vertical components are equal and opposite

so $\bar{u} \cdot \bar{n}$ is satisfied everywhere along the "surface" location

This arrangement is equivalent to the real source + reflecting surface everywhere in the upper hemisphere

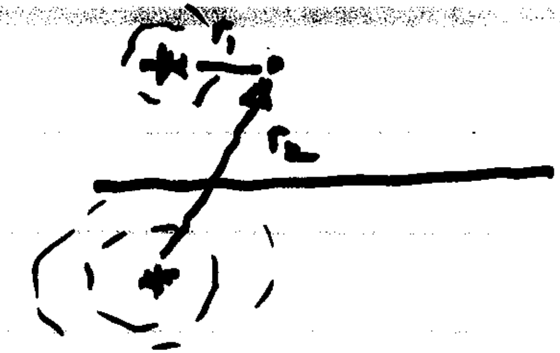


$$\tilde{p}_t = \tilde{p}_1 + \tilde{p}_2$$

solution applies when $z \geq 0$

$$\tilde{p}_t = \tilde{p}_1 + \tilde{p}_2$$

$$= j\rho_0 c \frac{kQ}{4\pi r_1} e^{-jkr} + j\rho_0 c \frac{kQ}{4\pi r_2} e^{-jkr_2}$$



$p \propto \frac{1}{r}$

$r_2 \geq r_1$

$$\tilde{p}_t = j\rho_0 c \frac{kQ}{4\pi r_1} e^{-jkr_1}\left[\underbrace{1}_{\text{direct component}} + \underbrace{\left(\frac{r_1}{r_2}\right)e^{-jk(r_2-r_1)}}_{\text{reflection}}\right]$$

$\left(\frac{r_1}{r_2}\right)$ = spherical spreading

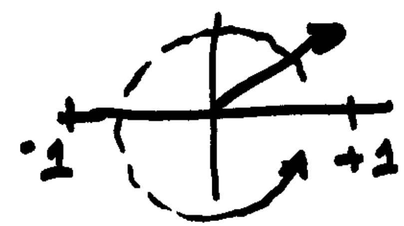
$(r_2 - r_1)$ = path length difference
pld

$k(r_2 - r_1)$ = phase difference between the direct & reflected signals

$$0 \leqslant \left(\frac{r_1}{r_2}\right) \leqslant 1$$

reflected sound is usually attenuated with respect to the direct sound.

$$\underbrace{\left| e^{-ik(r_2 - r_1)} \right|} = 1$$

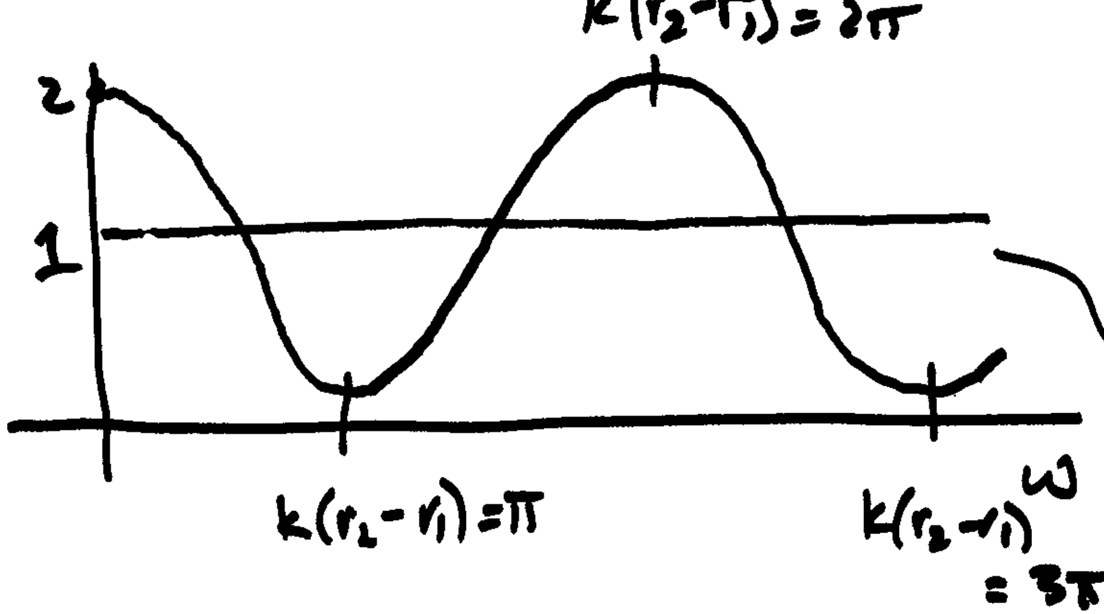


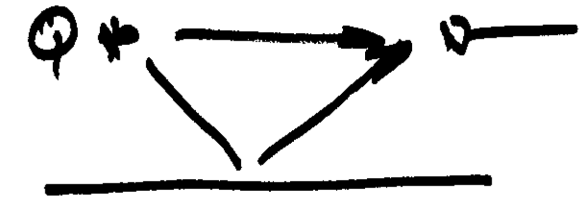
$k(r_2 - r_1) = 0, \; 2\pi, \; 4\pi \; \ldots$ approximately a maximum

pld.	0	λ	2λ

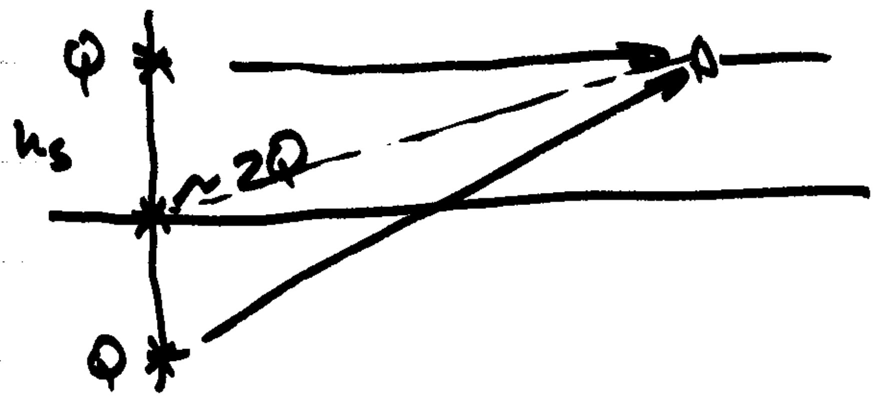
$= \pi, \; 3\pi, \; 5\pi \; \ldots$ approximately a minimum

pld	$\lambda/2$	$\frac{3\lambda}{2}$	$\frac{5\lambda}{2}$





spectrum at the receiver location in the absence of reflection



$\underline{h_s \to 0}$

true source & the image source coalesce at the surface

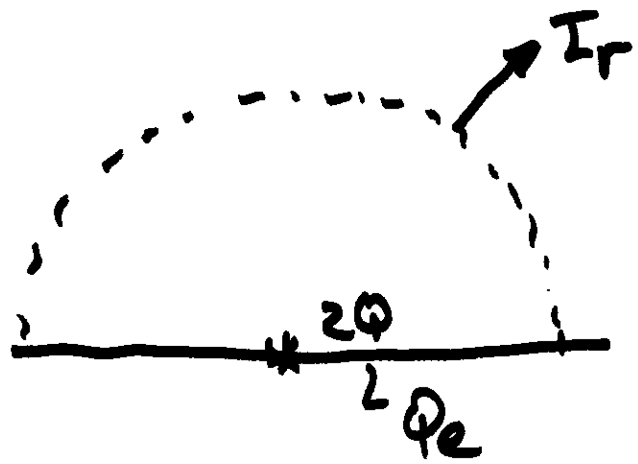
$r_1 = r_2 = r$

$$\tilde{p}(r) = j\rho_0 c \frac{kQ}{4\pi r} e^{-jkr} \underbrace{\left[1 + \underbrace{\left(\frac{r}{r}\right)}_{1} \underbrace{e^{-jk(r-r)}}_{1}\right]}_{2}$$

$$= j\rho_0 c k \frac{2Q}{4\pi r} e^{-jkr}$$

pressure at the receiver location is doubled wrt a single monopole in free space.

$h_s = 0$



$$I_r = \frac{\rho_0 c}{2} \frac{k^2 Q_e^2}{(4\pi r^2)}$$

$$= 2\rho_0 c \frac{k^2 Q^2}{(4\pi r)^2}$$