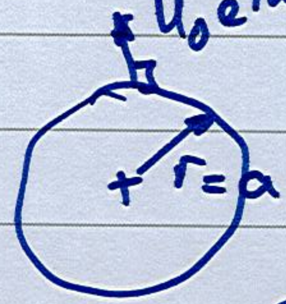
ME 513 Session 32 11/9/15

Sound Generation and Radiation in 3-D



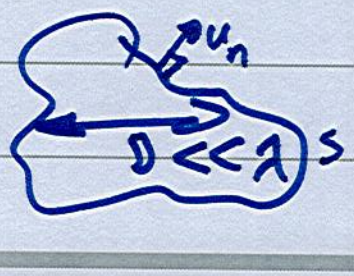
Simple Source

→ monopole → let $a \to 0$

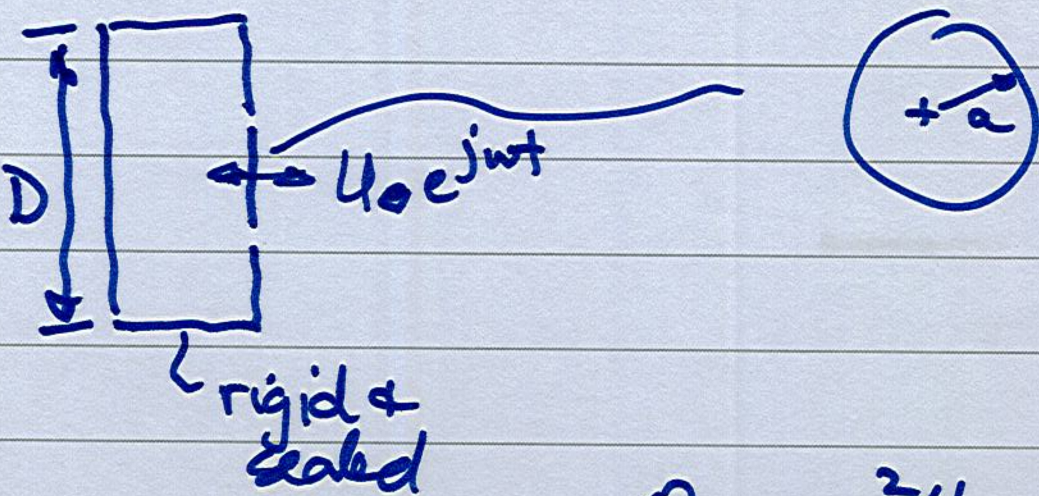
$$\hat{p}(r) = j \rho_0 c \frac{k Q}{4\pi r} e^{-jkr}$$

Q = volume source strength $[m^3/s]$

represent any compact source That exhibits a periodic volume change



$$Q = \int_S u_n \, dS \quad [m^3/s]$$



circular piston of radius a
- diaphragm of a l/s

$D << \lambda$

$$Q = \pi a^2 u_0 \quad [m^3/s]$$

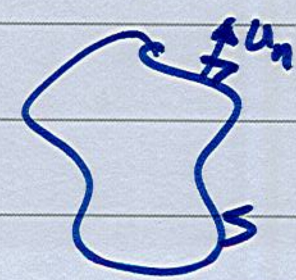
replace the l/s by a monopole

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

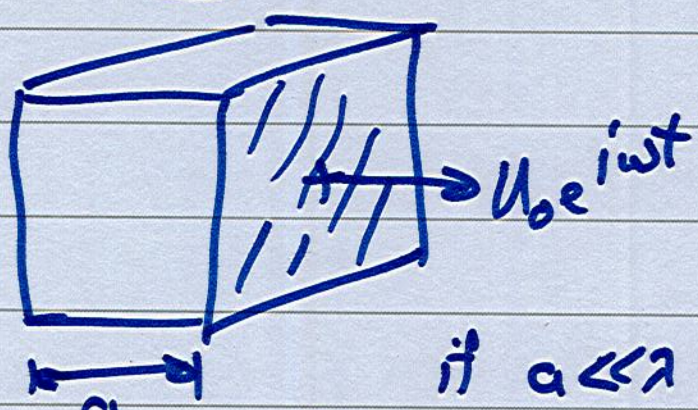
$$I_r \qquad W = \int I_r \, dS = \rho_0 c \frac{k^2 Q^2}{8\pi}$$

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.



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



5 rigid sides

$$Q = a^2 U_0$$

if $a \ll \lambda$ $\quad \hat{p}(r) = i\rho_0 c \dfrac{kQ}{4\pi r} e^{-ikr}$

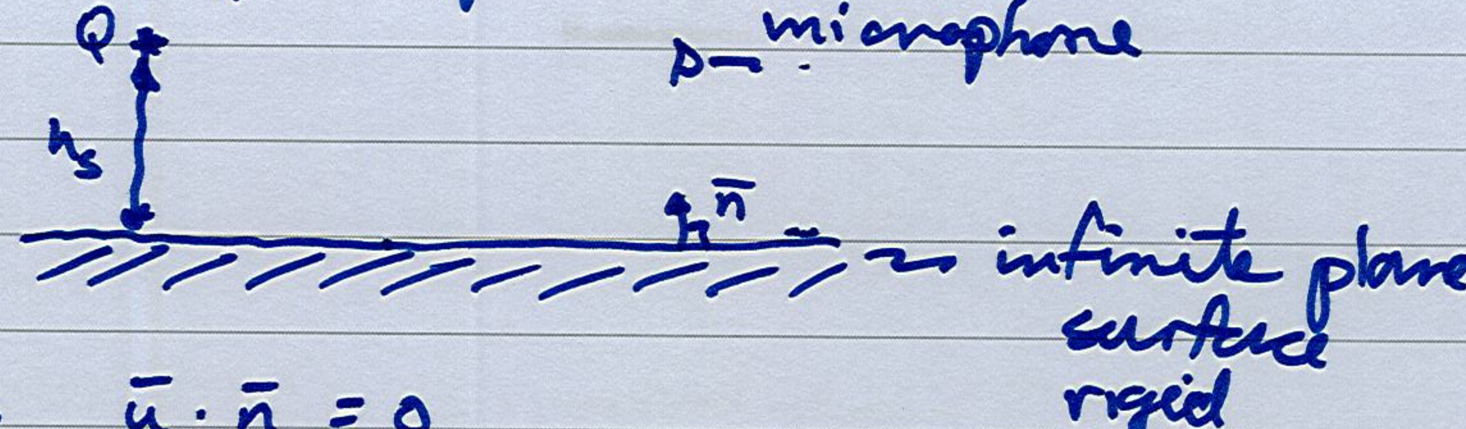
some sources do not change their volume

unbaffled l/s

not volume sources.

5.3.3 Reflection at hard surfaces

5.3.3.1 Single Reflection



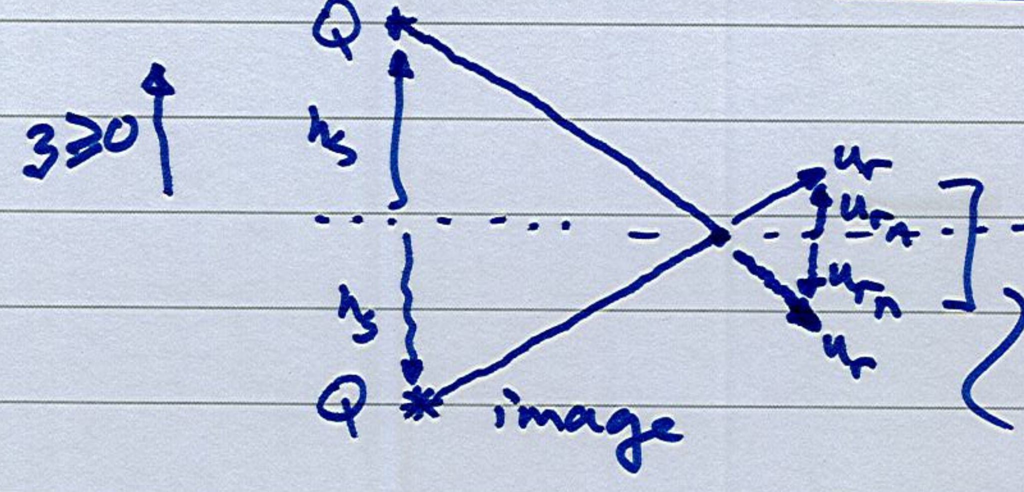
b.c. $\bar{u} \cdot \bar{n} = 0$

$u_n = 0$ at the surface

zero normal particle velocity
at the surface

* rigid surface

Equivalent system in <u>free space</u>

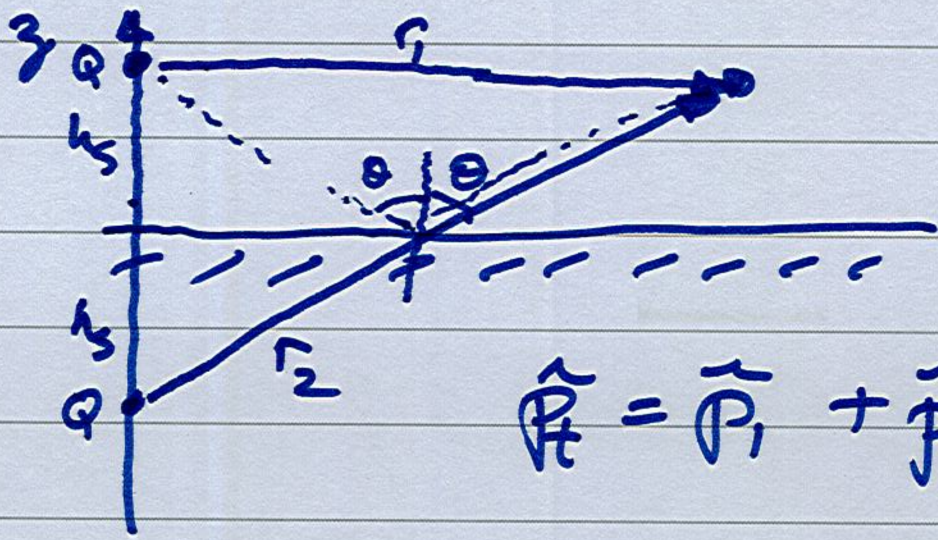


nominal surface location

vertical components are equal & opposite

so $\bar{u}\cdot\bar{n}=0$ is satisfied everywhere along the "surface"

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



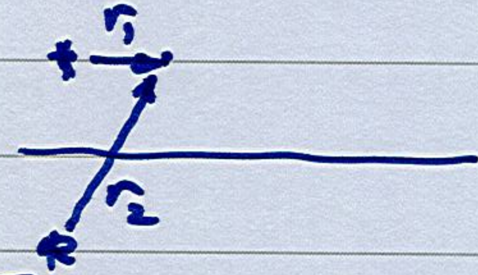
$$\hat{P}_t = \hat{P}_1 + \hat{P}_2$$

solution applies in region $z \geq 0$

$$\hat{P}_t = \hat{P}_1 + \hat{P}_2$$

$$= j\rho_0 c \frac{kQ}{4\pi r_1} e^{-ikr_1} + j\rho_0 c \frac{kQ}{4\pi r_2} e^{-ikr_2}$$

$\underline{\underline{r_2 \geq r_1}}$



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

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

1: direct component

$\left(\frac{r_1}{r_2}\right) e^{-jk(r_2 - r_1)}$: reflected component

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

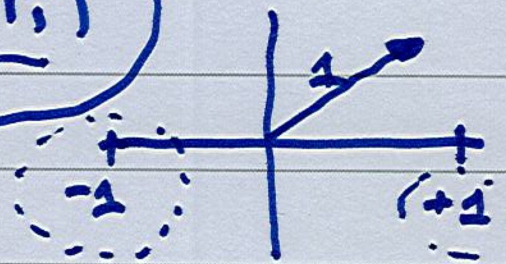
$(r_2 - r_1)$ path length difference

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

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

reflected sound is attenuated with respect to the direct sound by spherical ~~sprc~~ spreading

$e^{-jk(r_2 - r_1)}$



$+1 \quad k(r_2 - r_1) = 0,\ 2\pi,\ 4\pi \ldots\ldots$

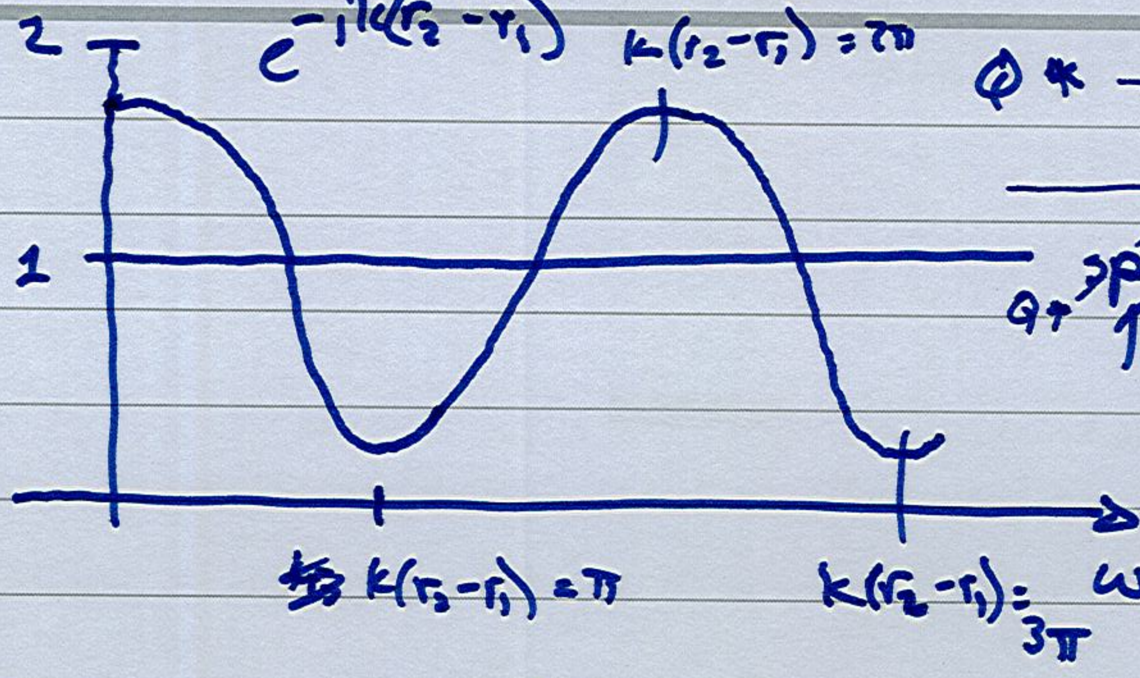
approximately a maximum

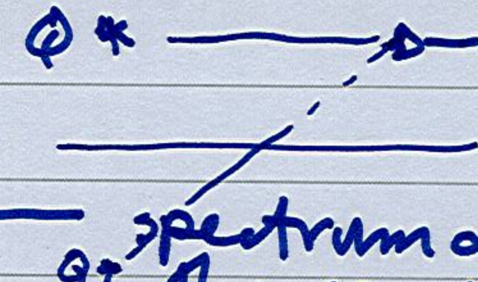
pld $\quad 0 \quad \lambda \quad 2\lambda$

$-1 \quad k(r_2 - r_1) = \pi,\ 3\pi,\ 5\pi \ldots$

approximately a minimum

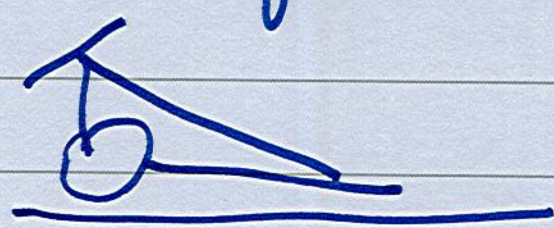
pld $\quad \lambda/2 \quad \frac{3\lambda}{2} \quad 5\lambda/2$



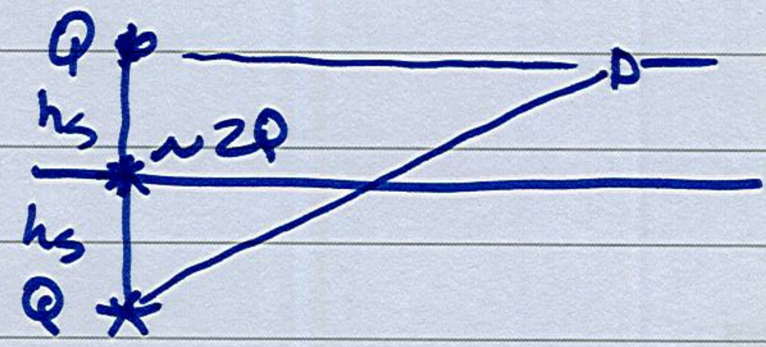


$\left(\frac{r_1}{r_2}\right)$

periodic ripple on The spectrum due to reflection



QRD



$h_s \to 0$