Γεωμετρική Ακουστική

Ακουστικές Ακτίνες

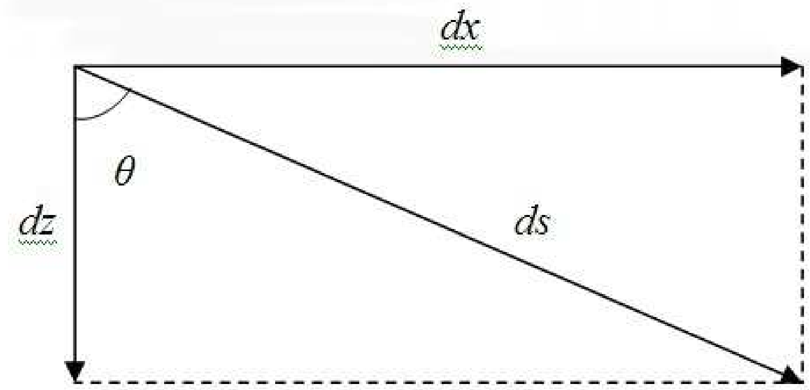
Εισαγωγή στην Ακουστική Ωκεανογραφία

$$\frac{\sin\theta(z)}{c(z)} = a$$

Νόμος Snell

$$ds = \frac{dz}{\cos\theta} \qquad dx = \tan\theta\, dz$$

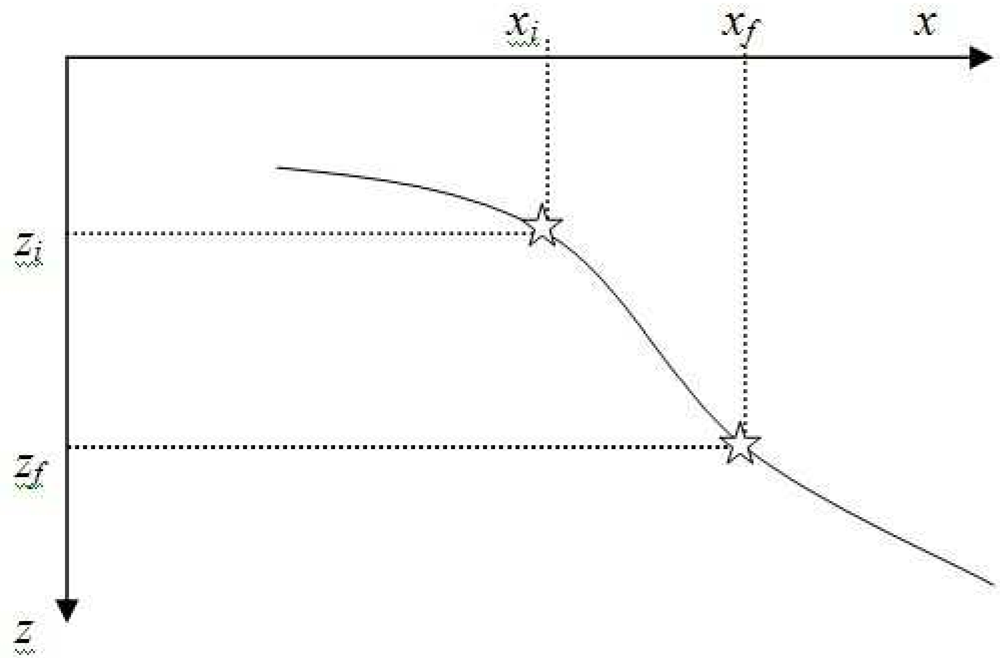
$$dt = \frac{ds}{c(z)} = \frac{dz}{c(z)\cos\theta}$$

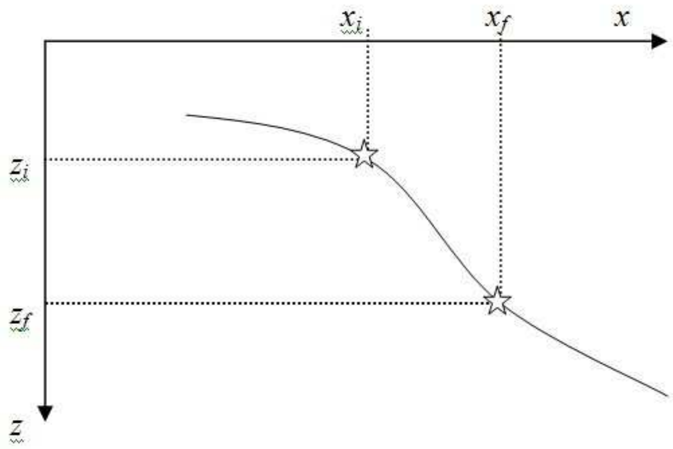


$$\sin\theta = ac(z)$$

$$\cos\theta = [1 - a^2 c^2(z)]^{1/2}$$

$$\tan\theta = ac(z)/[1 - a^2 c^2(z)]^{1/2}$$


x_i
x_f
x
z_i
z_f
z



$$x_f - x_i = \int_{x_i}^{x_f} dx = \int_{z_i}^{z_f} \frac{ac(z)dz}{[1-a^2c^2(z)]^{1/2}}$$

$$t_f - t_i = \int_{t_i}^{t_f} dt = \int_{z_i}^{z_f} \frac{dz}{c(z)[1-a^2c^2(z)]^{1/2}}$$

$$\sin\theta_i = c(z_i)/c(z)$$ Οριζοντιοποίηση

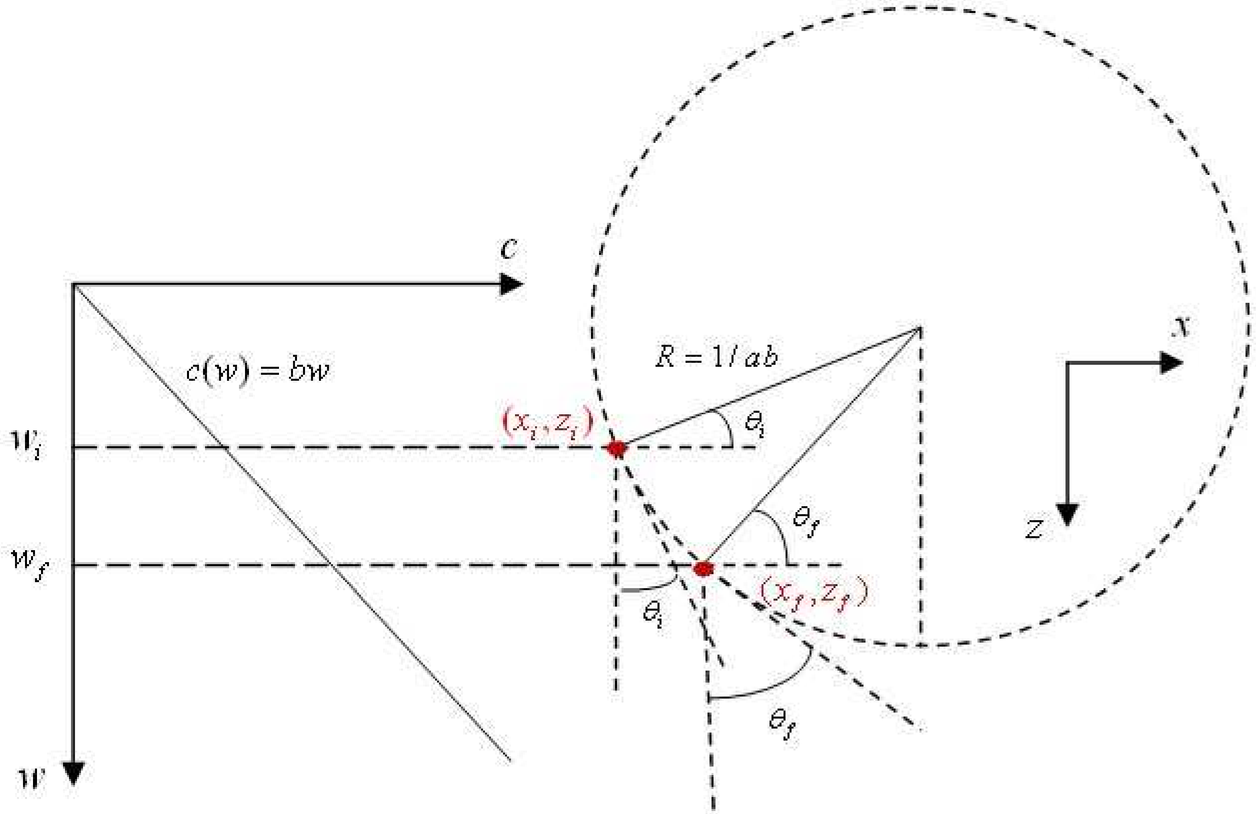
Περίπτωση γραμμικά μεταβαλλόμενου προφίλ ταχύτητας

$$c(z) = c(z_1) + b(z - z_1) \qquad z_1 \le z \le z_2$$

$$w = z - z_1 + \frac{c(z_1)}{b}$$

$$dw = dz$$

$$c(z) = bw$$


c
c(w) = bw
R = 1 / ab
x
z
(x_i, z_i)
(x_f, z_f)
θ_i
θ_f
θ_i
θ_f
w_i
w_f
w

$$x_f - x_i = \int_{w_i}^{w_f} \frac{abw\,dw}{(1 - a^2 b^2 w^2)^{1/2}}$$

$$t_f - t_i = \int_{w_i}^{w_f} \frac{dw}{bw(1 - a^2 b^2 w^2)^{1/2}}$$

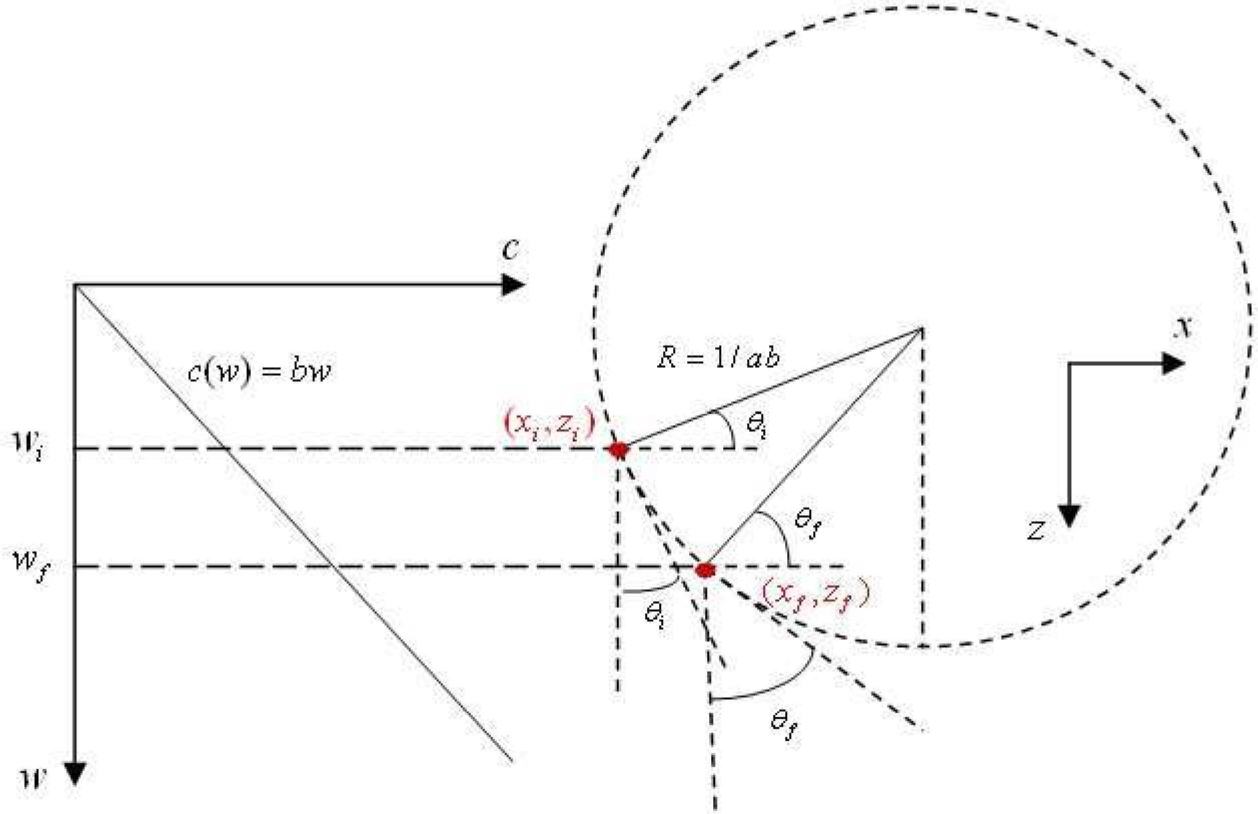
$$t_f - t_i = \frac{1}{b} \log_e \frac{w_f [1 + (1 - a^2 b^2 w_i^2)^{1/2}]}{w_i [1 + (1 - a^2 b^2 w_f^2)^{1/2}]}$$

$$t_f - t_i = \frac{1}{b}\log_e \frac{w_f(1+\cos\theta_i)}{w_i(1+\cos\theta_f)}$$

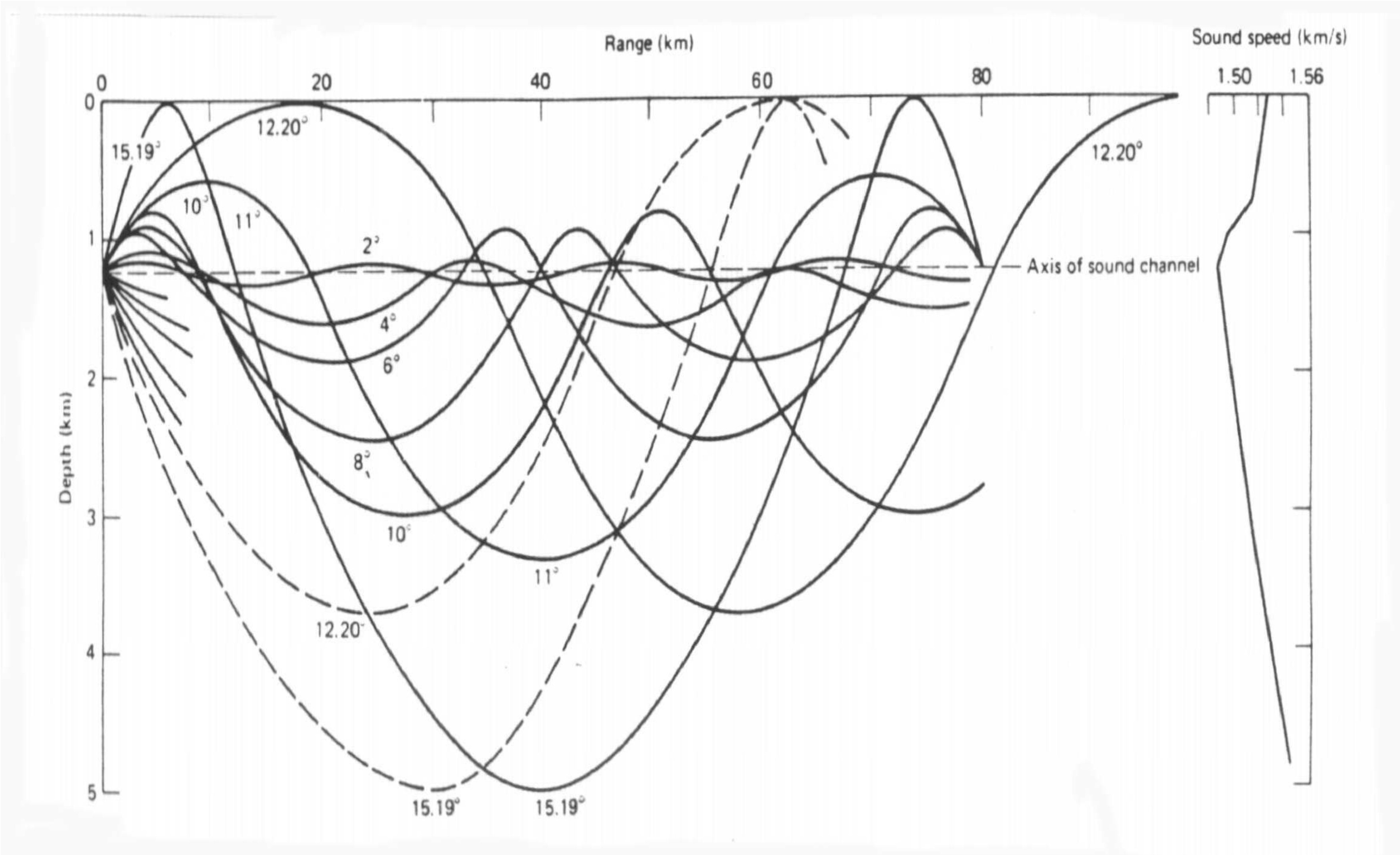
$$x_f - x_i = \frac{1}{ab}[(1-a^2b^2w_i^2)^{1/2} - (1-a^2b^2w_f^2)^{1/2}]$$

$$x_f - x_i = \frac{1}{ab}(\cos\theta_i - \cos\theta_f) = R(\cos\theta_i - \cos\theta_f)$$

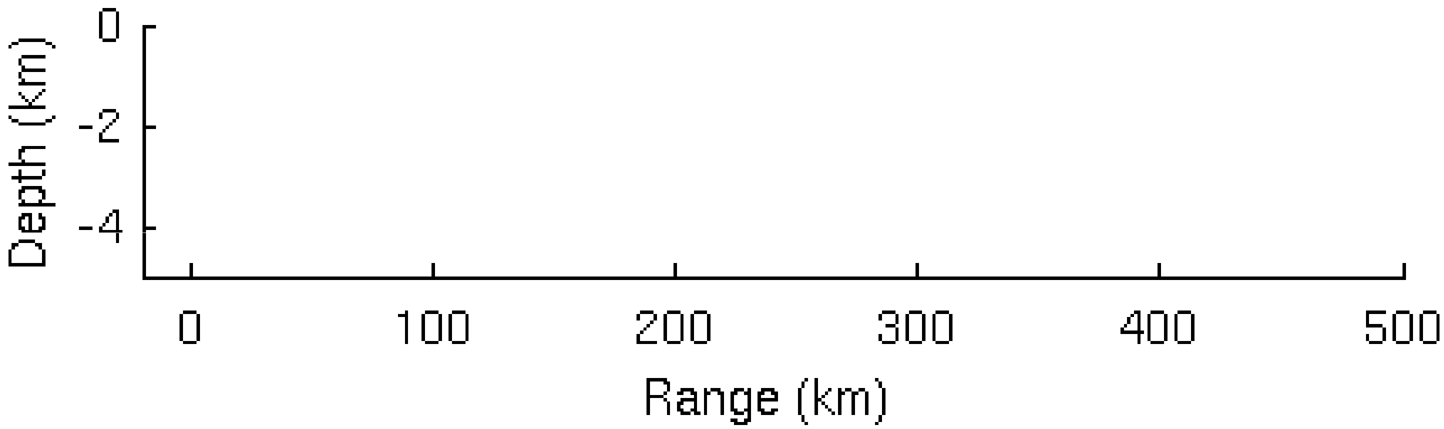
$$z_f - z_i = R(\sin\theta_f - \sin\theta_i)$$

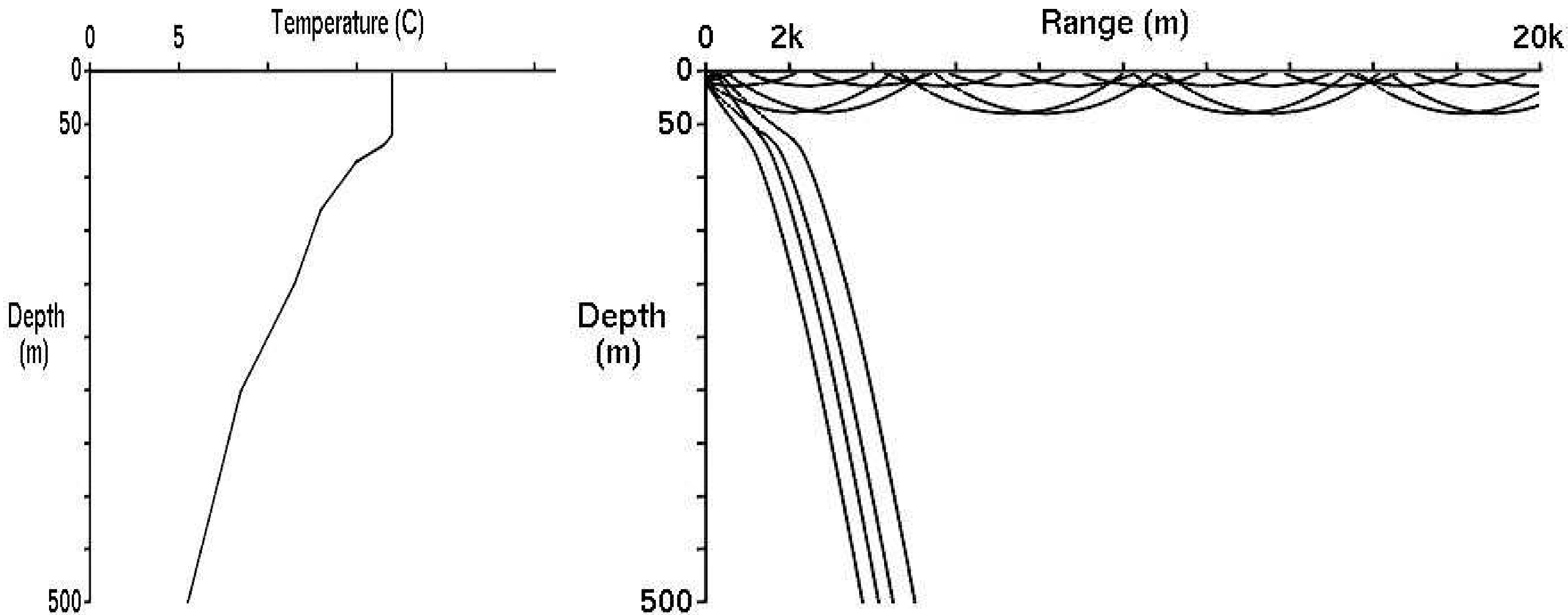


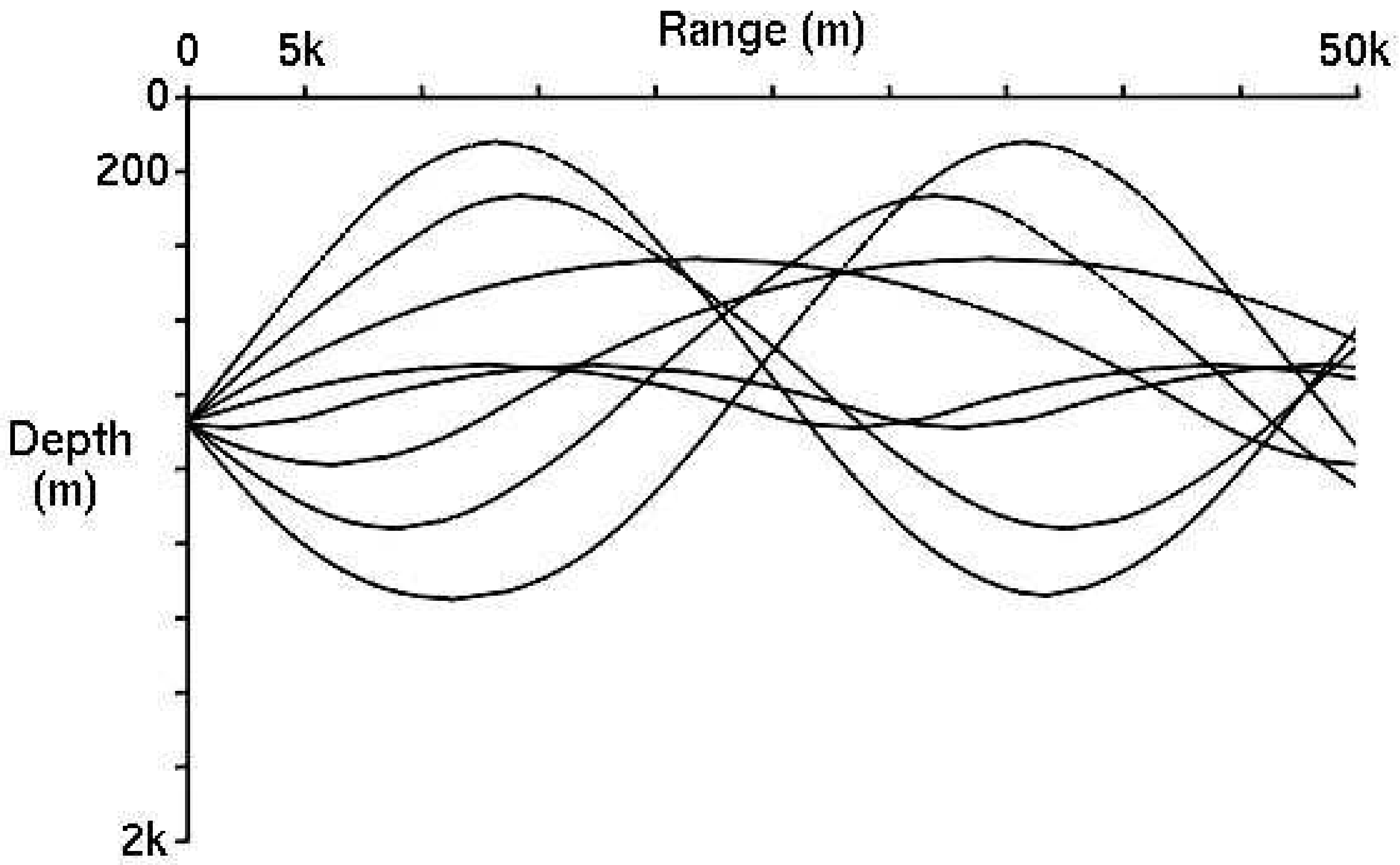
c
$c(w) = bw$
$R = 1/ab$
x
(x_i, z_i)
w_i
θ_i
θ_f
z
w_f
(x_f, z_f)
θ_i
θ_f
w

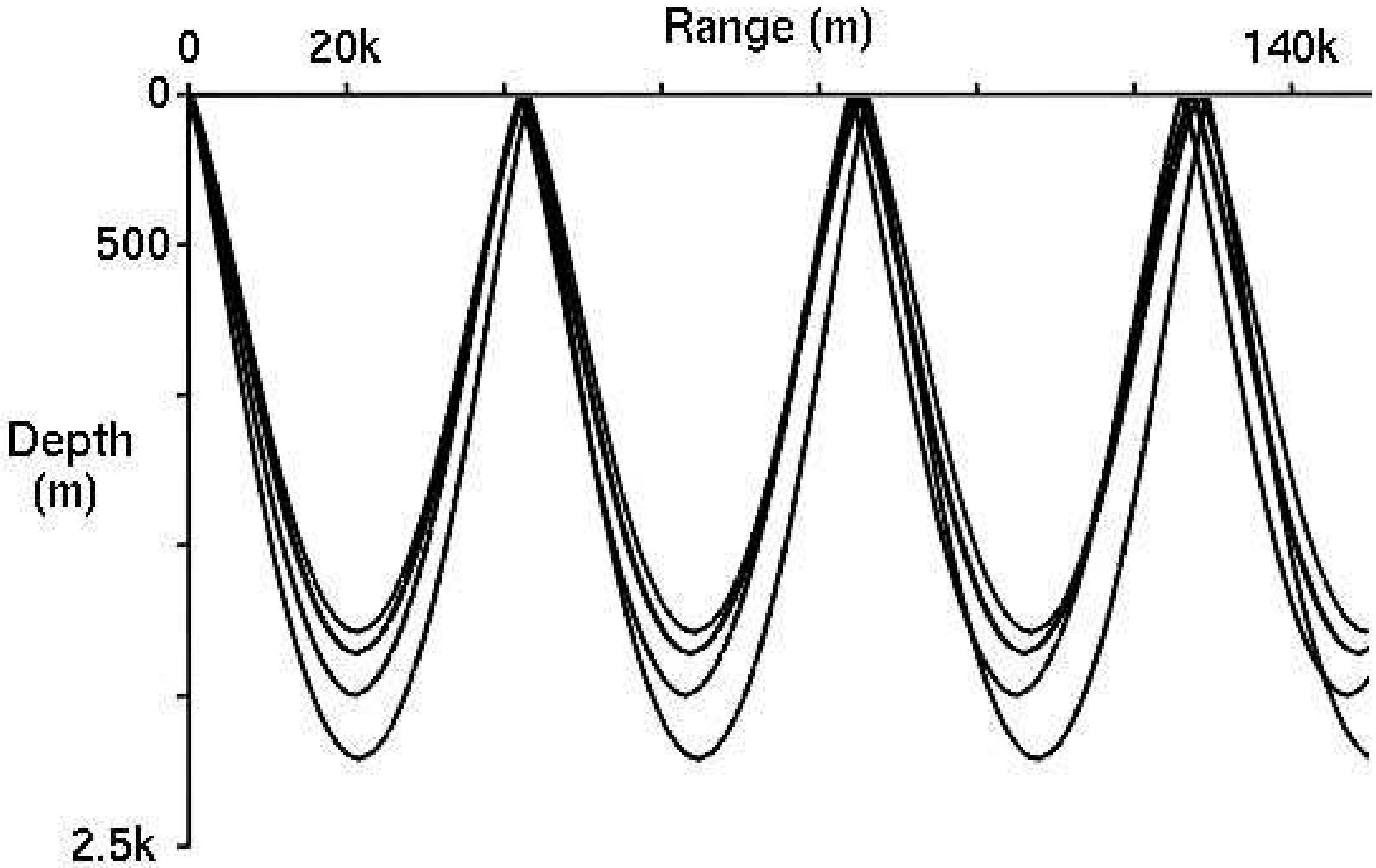


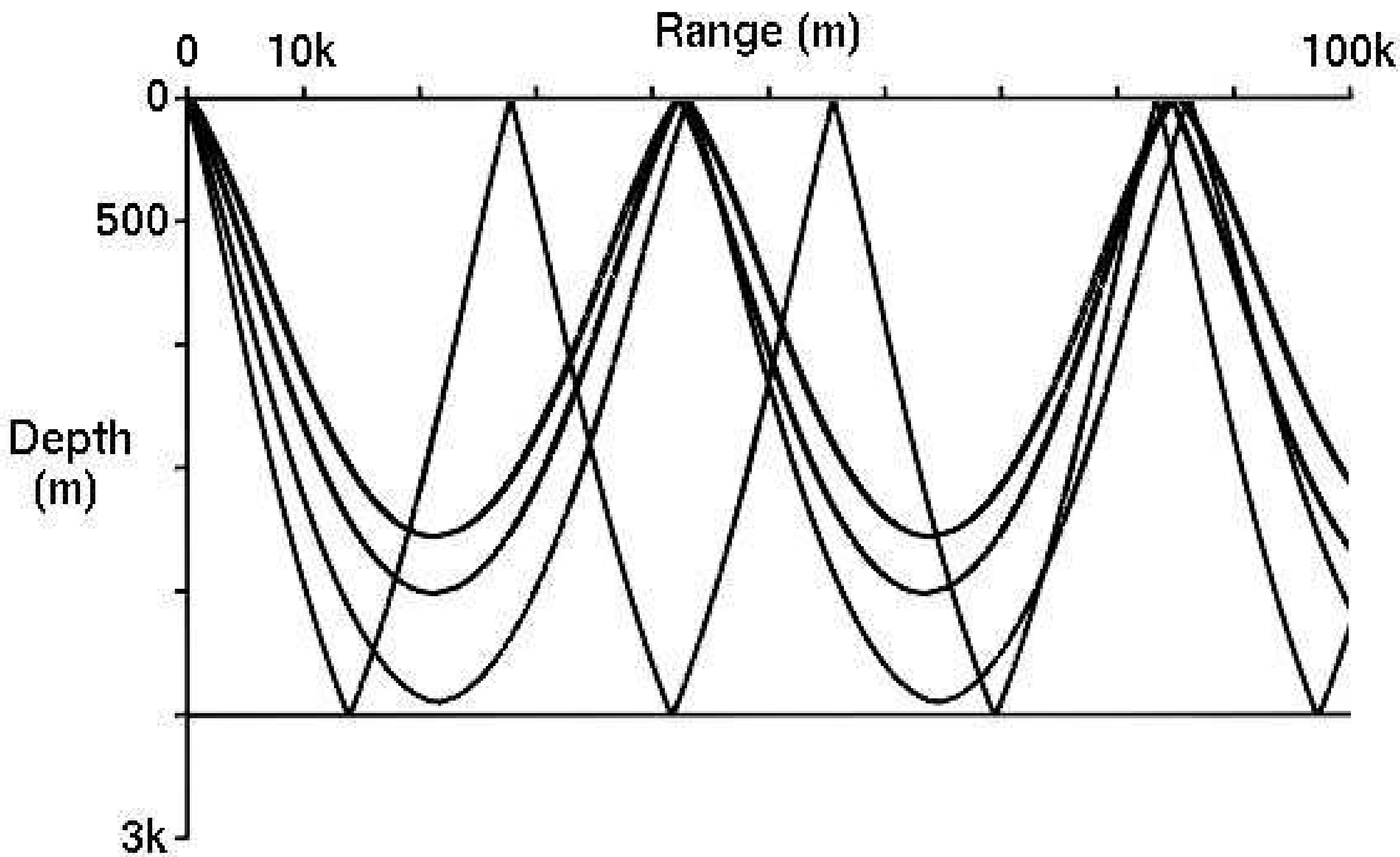
Range (km)
Sound speed (km/s)
0
20
40
60
80
1.50
1.56
Depth (km)
1
2
3
4
5
15.19°
12.20°
10°
11°
2°
4°
6°
8°
10°
11°
12.20°
15.19°
15.19°
12.20°
Axis of sound channel


0
-2
-4
Depth (km)
0
100
200
300
400
500
Range (km)


Temperature (C)
0
5
0
50
500
Depth
(m)
Range (m)
0
2k
20k
0
50
500
Depth
(m)


Range (m)
0
5k
50k
0
200
Depth
(m)
2k


Range (m)
0
20k
140k
0
500
Depth
(m)
2.5k


Range (m)
0
10k
100k
0
500
3k
Depth
(m)

Υπολογισμός της ακουστικής πίεσης

$$\frac{1}{r^2}\frac{\partial}{\partial r}[r^2\frac{\partial}{\partial r}p(r,t)] = \frac{1}{c^2}\frac{\partial^2}{\partial t^2}p(r,t)$$

$$p(r,t) = \frac{b_c}{r}\exp[i(kr - \omega t)]$$

$$\frac{\partial p}{\partial r} = -\rho\frac{\partial u}{\partial t}$$

Για r >> $$p(r,t) \approx (\rho c)u(r,t)$$

$$p(r,t)u^{*}(r,t)$$

Στιγμιαία ένταση W/m²

$$< I >= \text{Real}(\frac{1}{T}\int_0^T p(r,t)u^{*}(r,t)dt)$$

Μέση ένταση

$$\left\langle \left| p(r,t) \right|^2 \right\rangle = \left| p \right|^2 = \frac{1}{T}\int_0^T \frac{b_c^{\;2}}{r^2} dt = \frac{b_c^2}{r^2}$$

Μέση τετραγωνική πίεση

$$\left| p \right|^2 = \left| p_0 \right|^2 \frac{r_0^2}{r^2}$$

$$< I >= \mathrm{Real}\left(\frac{1}{T}\int_0^T p(r,t)u^*(r,t)dt\right)$$

$$< I >= \frac{|p|^2}{\rho c}$$

$$\Pi = \int_S < I > dS = \int_{4\pi} < I > r^2 d\Omega$$

$$\Pi =< I > r^2 \int d\Omega = 4\pi |p|^2 \frac{r^2}{\rho c}$$

$$|p| = \left(\frac{\Pi \rho c}{4\pi r^2}\right)^{\frac{1}{2}}$$

Επίπεδο έντασης

$$SIL = 10\log_{10}\frac{I}{I_{ref}} \qquad dB\, re\, I_{ref}$$

Επίπεδο πίεσης

$$SPL = 20\log_{10}\left|\frac{p}{p_{ref}}\right| \qquad dB\, re\; p_{ref}$$

$$p_{ref} = 1\mu Pa\ (10^{-6}\ \mathrm{N/m^2})$$

$$|p| = \frac{|p_0| r_0}{r}$$

Απώλεια διάδοσης $$TL_{12} = SPL_1 - SPL_2$$

$$TL_{12} = 20\log_{10}\left|\frac{p_1}{p_{ref}}\right| - 20\log_{10}\left|\frac{p_2}{p_{ref}}\right| = 20\log_{10}\left|\frac{p_1}{p_2}\right| = 20\log_{10}\frac{r_2}{r_1}$$

$$TL = 20\log_{10}\frac{r}{r_0}$$

Απώλεια πυθμένα $$BL = -20\log_{10}\left|\frac{p_r}{p_i}\right| = -20\log_{10}\left|R_{12}\right|$$