EE-609 Radiating System

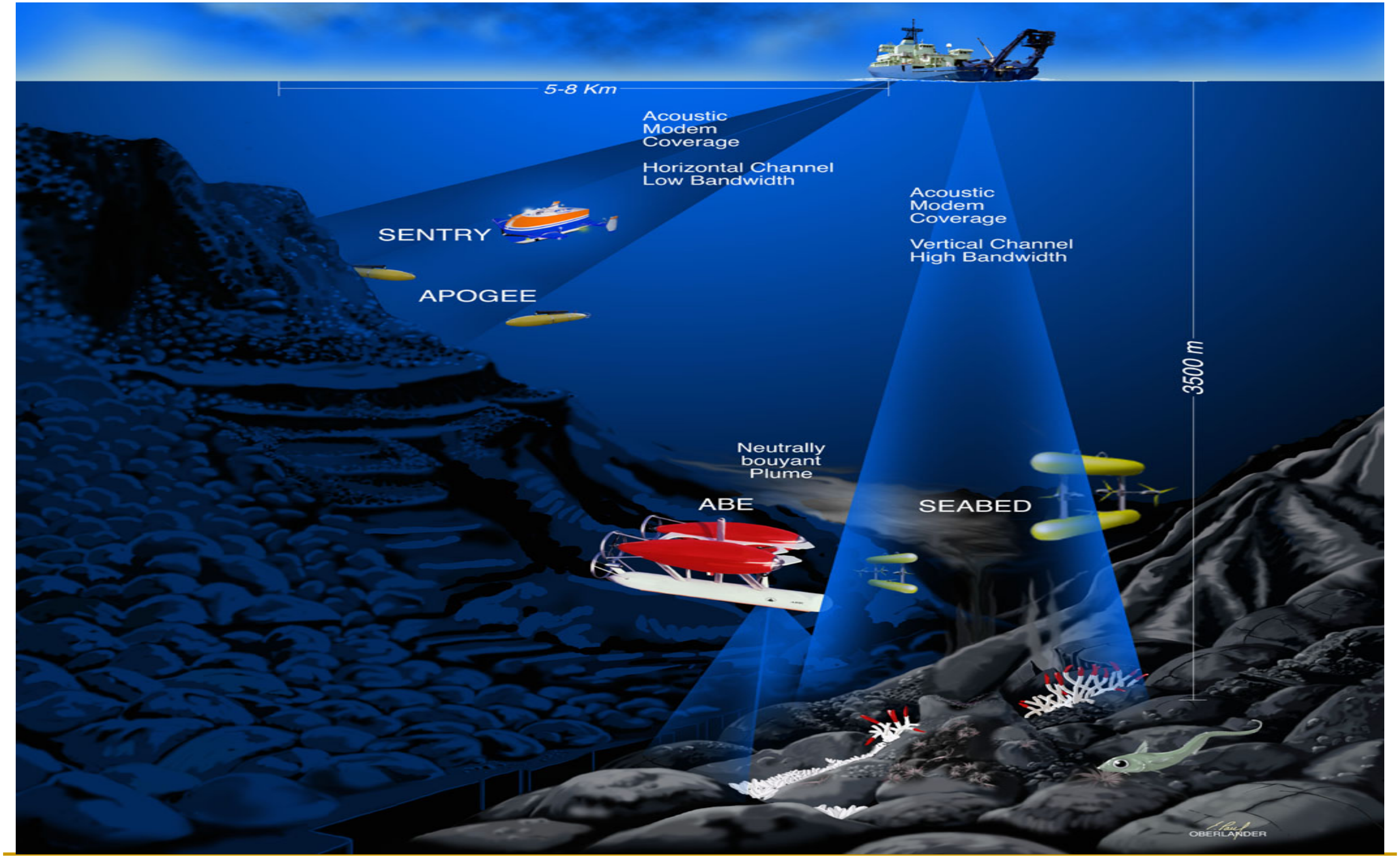
Antennas For Under Water Acoustics

Vinit Gawande (03D07025)

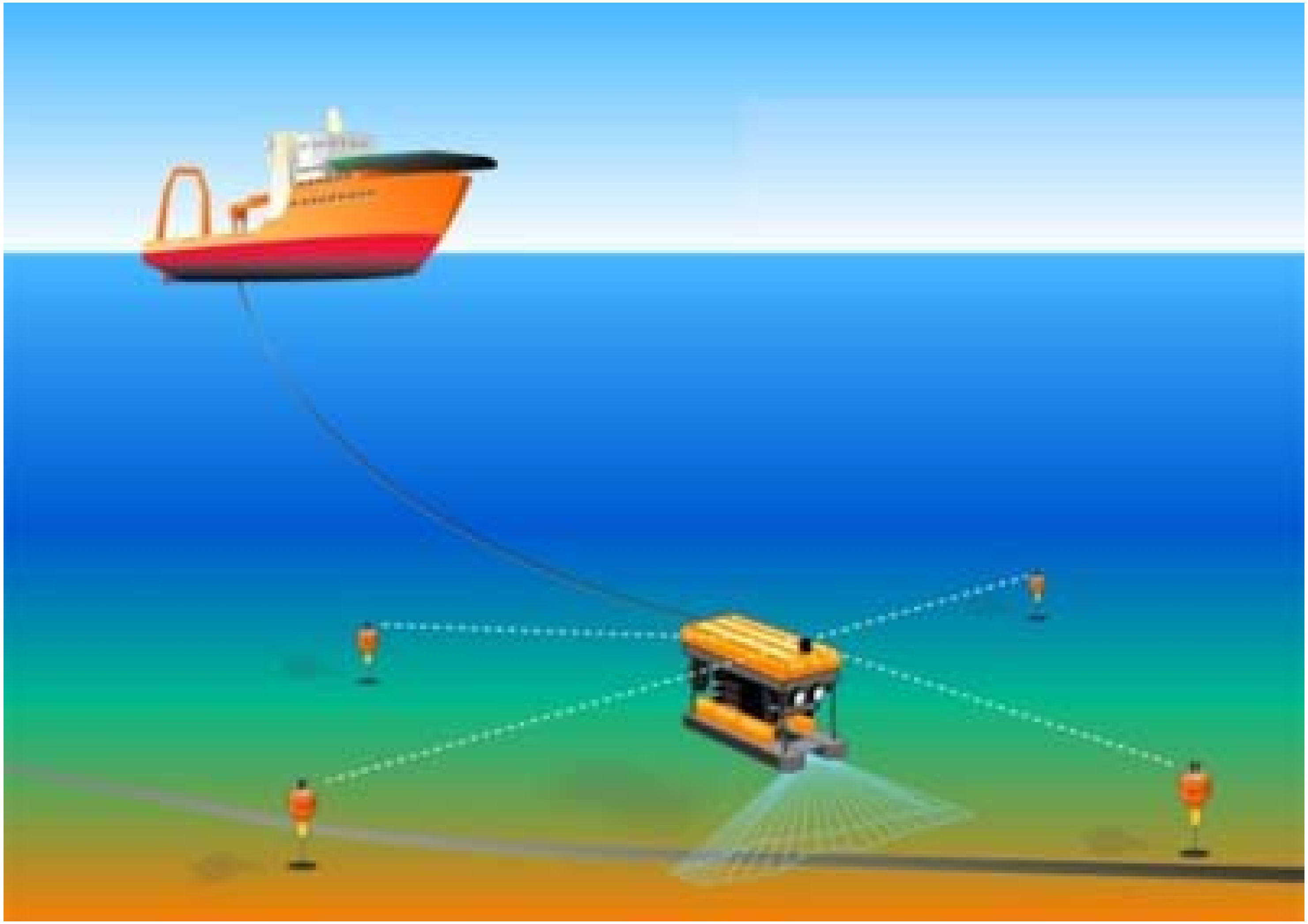
Outline:

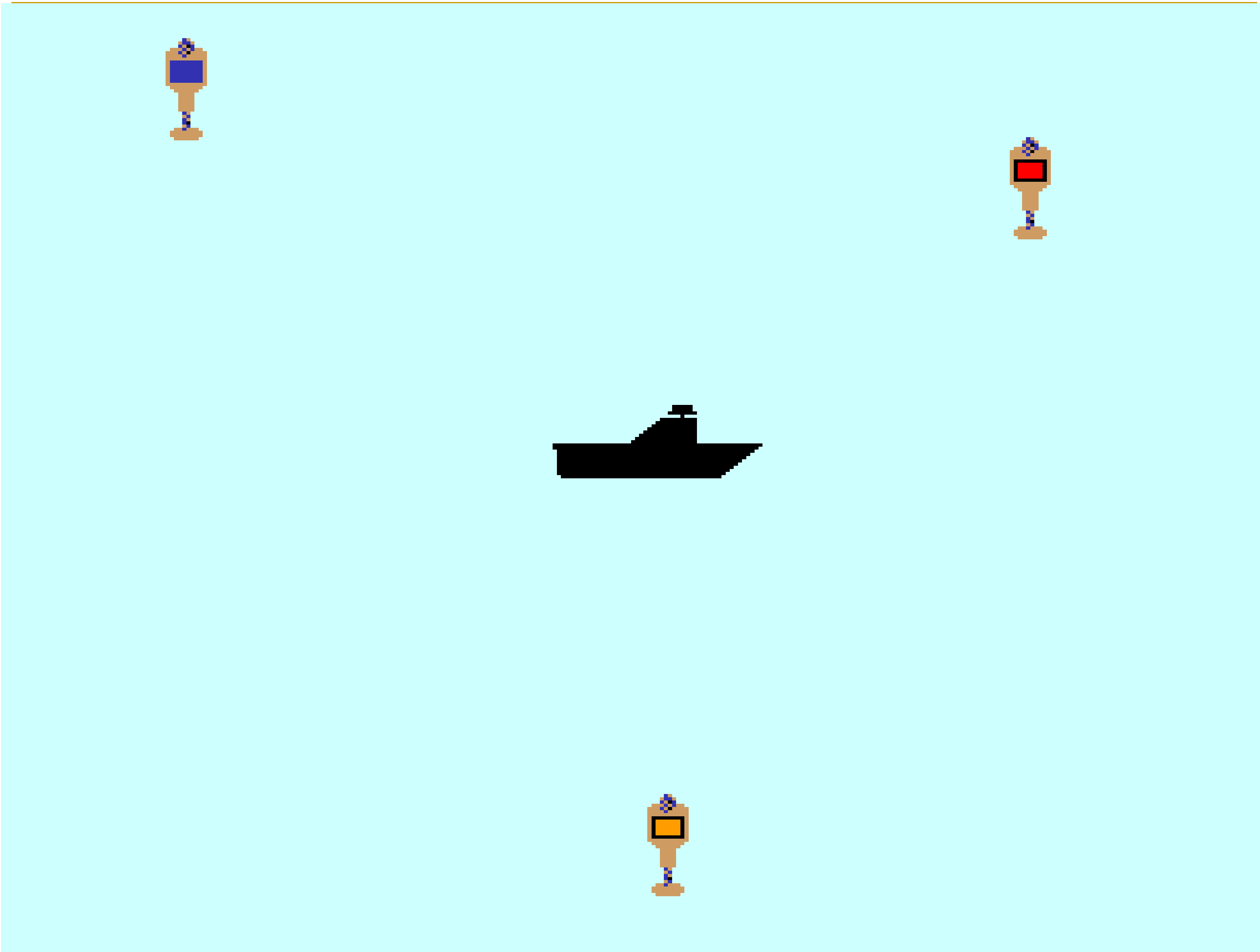
- Various Applications of UWA
- Acoustic Rod Antenna
- Acoustic helical Antenna
- Equiangular Spiral Antenna
- Experimental Results
- Conclusions

Applications

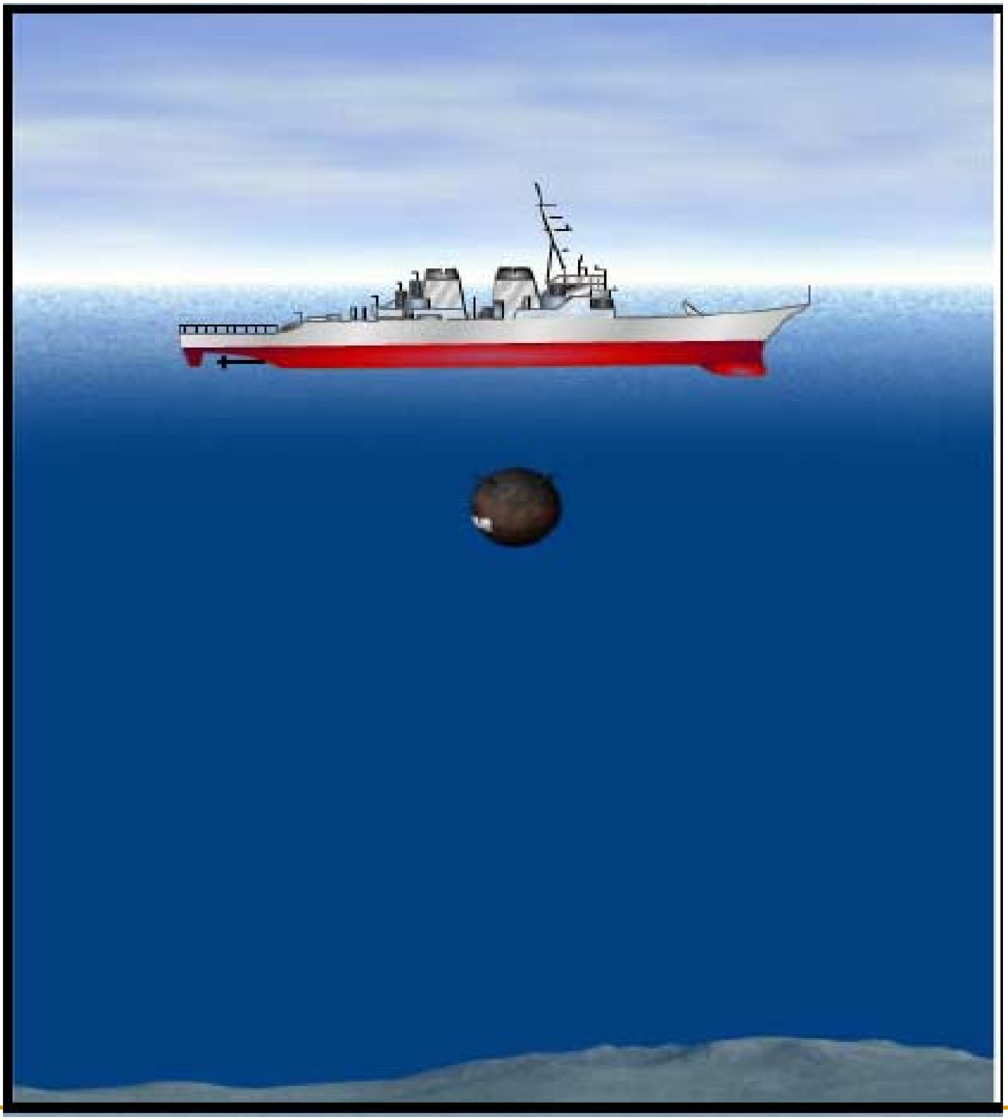


Remotely Operated Vehicle Navigating





Detection of Underwater mines

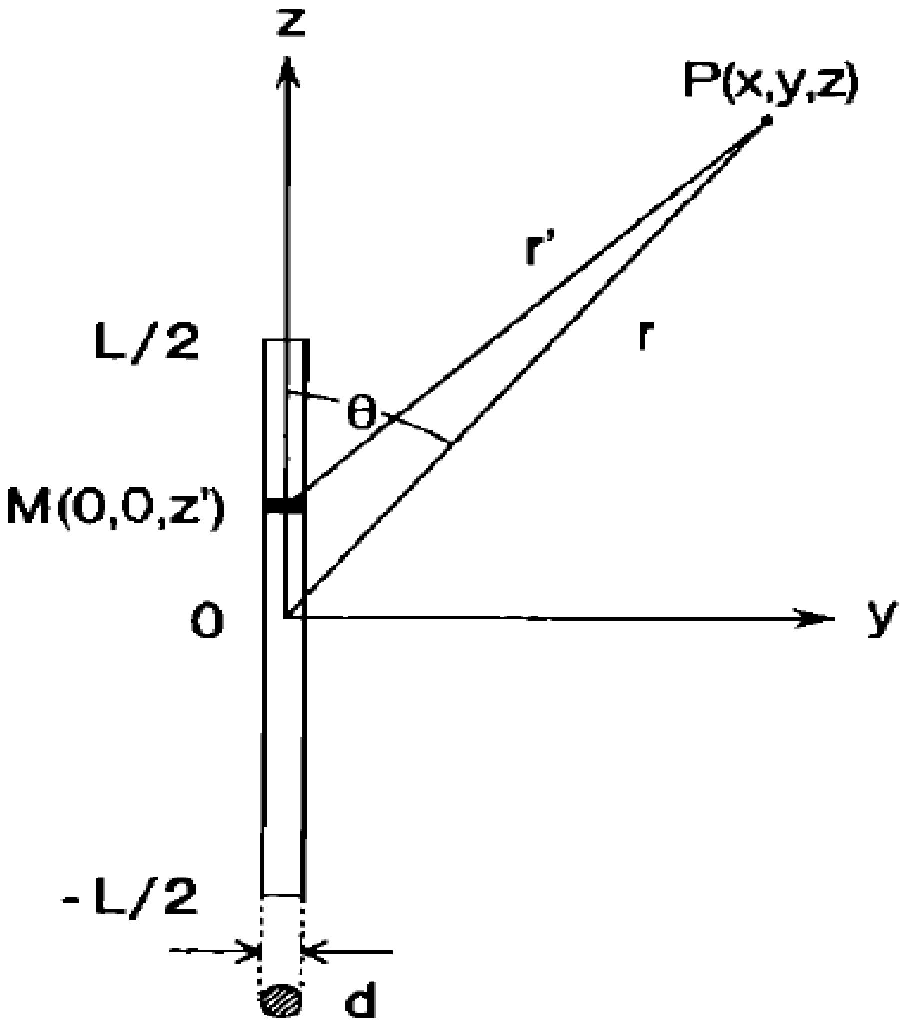




Other Applications

- Real time underwater video
- Underwater Image transmission
- Under water sensor networks

Acoustic Rod Antenna



Assuming $d/\lambda_w \ll 1$

Radiation Pattern : $D(\theta) = \sin u/u$

Where $u = (k_w L/2)(k_{rod}/k_w - \cos\theta)$

3 types:

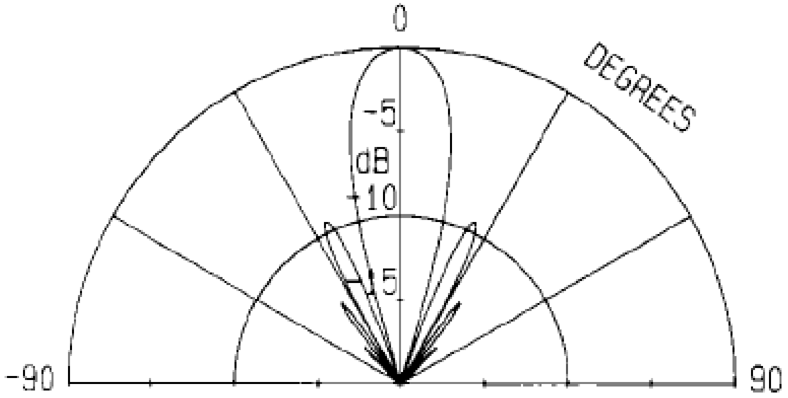
- Slow wave antenna…. $k_{rod}/k_w > 1$
- Equal wave antenna… $k_{rod}/k_w = 1$ **Ordinary Endfire**
- First wave antenna ….. $k_{rod}/k_w < 1$

Hansen- Woodyard endfire condition:

$$k_{rod}/k_w = 1 + (2L/\lambda_w)^{-1}$$

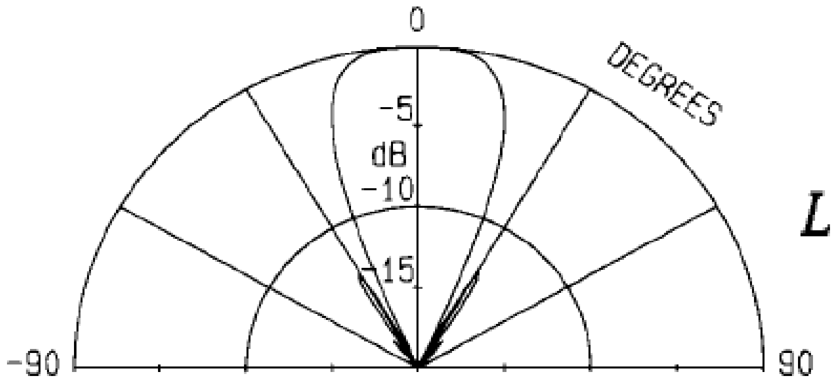
- (a) Hansen Woodyard endfire

$$k_{\text{rod}} / k_w = 1.05$$



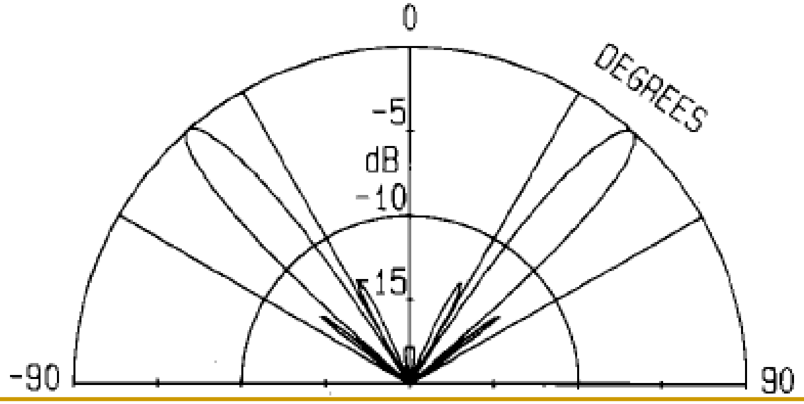
- (b) Ordinary Endfire

$$k_{\text{rod}} / k_w = 1$$



$$L / \lambda_w = 10$$

- (c) $k_{\text{rod}} / k_w = 0.75$



Gains and 3 dB Beam Widths

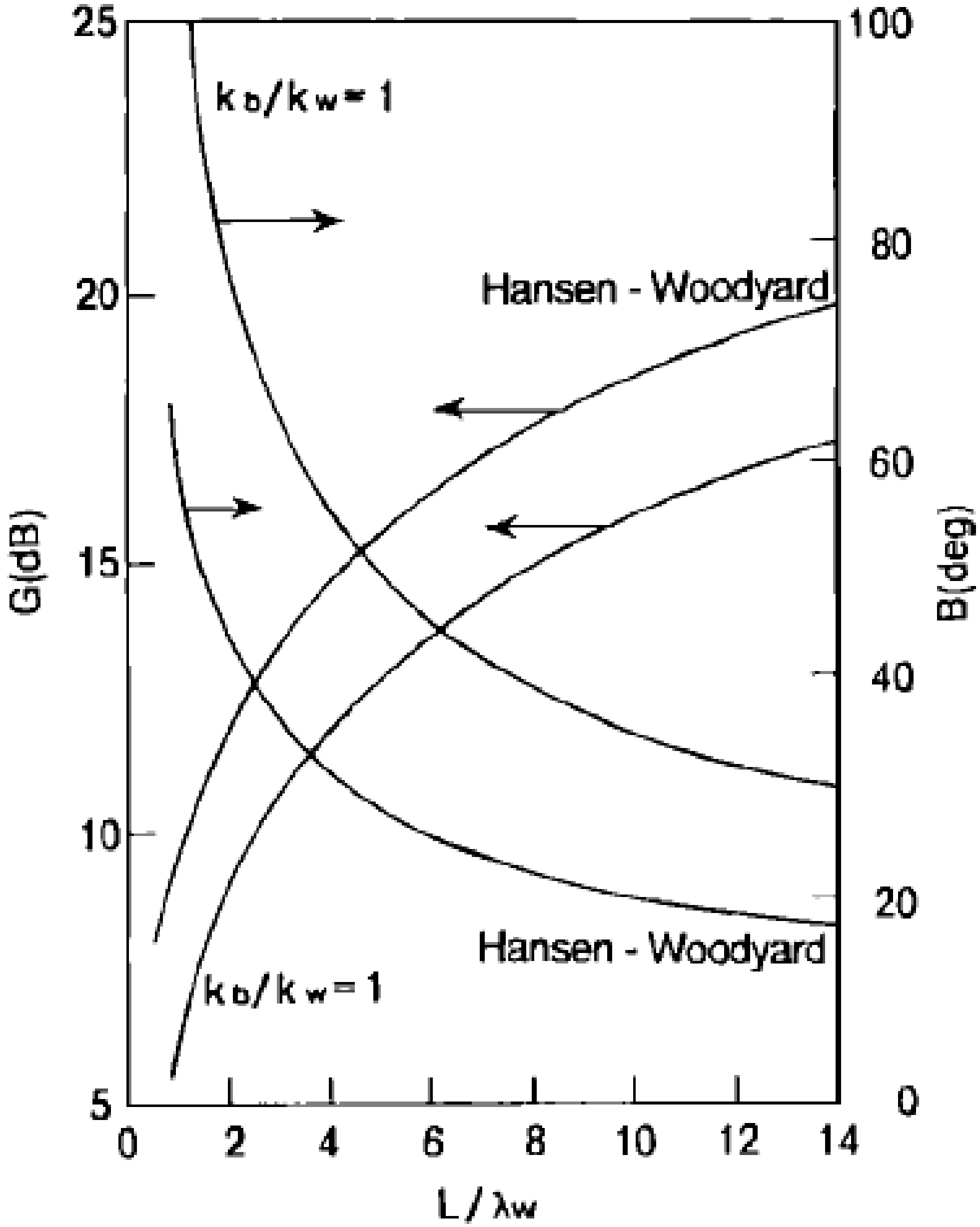
- Ordinary Endfire

$$G = 4(L/\lambda_w) \qquad B \simeq \frac{108^\circ}{\sqrt{L/\lambda_w}}$$

- Hansen-Woodyard endfire

$$G = 4g(L/\lambda_w) \qquad B \simeq \frac{60.6^\circ}{\sqrt{L/\lambda_w}}$$

L/λ_w	2	5	10	20
g	1.99	1.87	1.83	1.81

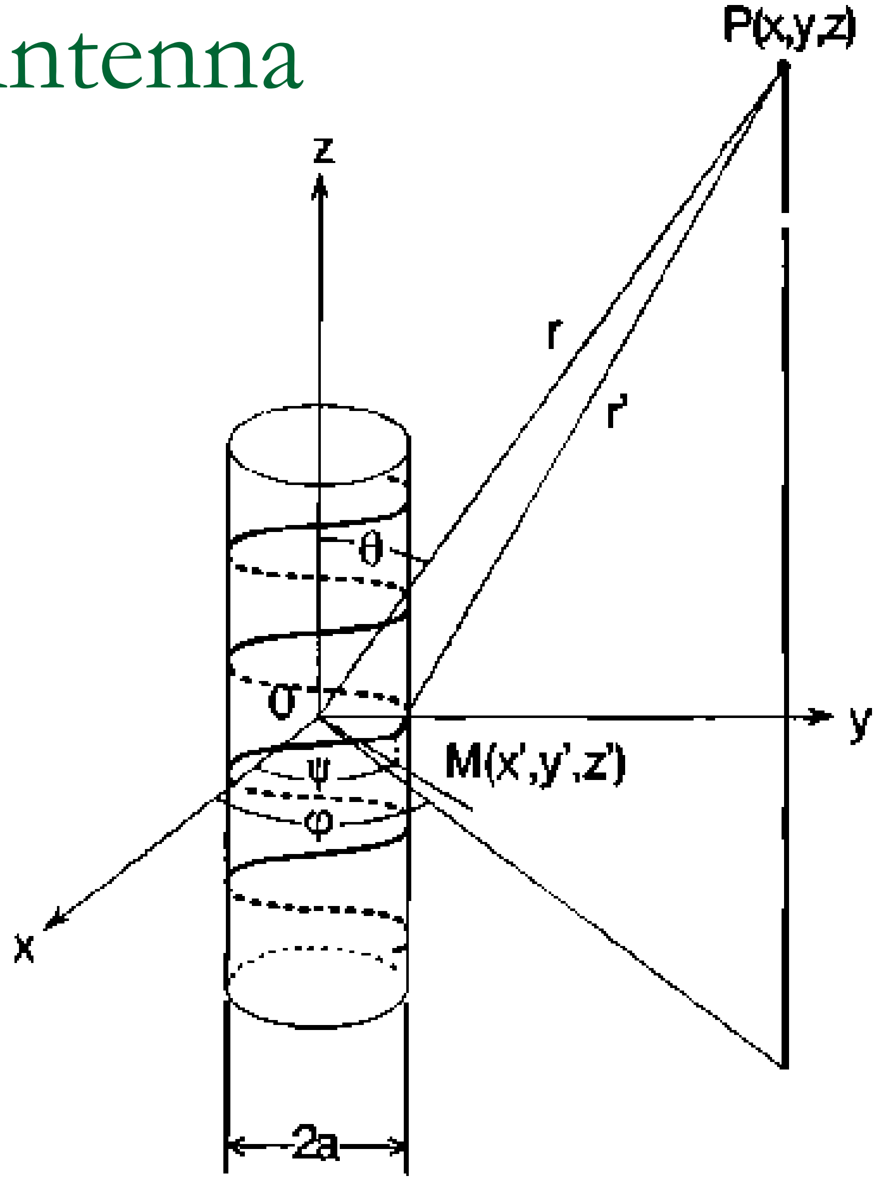


k b/k w= 1
Hansen - Woodyard
Hansen - Woodyard
k b/k w= 1
G(dB)
B(deg)
L / λw
25
20
15
10
5
100
80
60
40
20
0
0
2
4
6
8
10
12
14

Acoustic Helical Antenna

- Consists of:
  - Brass Cylindrical Helix Rod
  - Lead Zirconate Titanate Transducer Driver
- Sound velocity in brass rod higher than sound speed in water
- Therefore a simple brass rod cannot be used as an endfire antenna

Helical Antenna

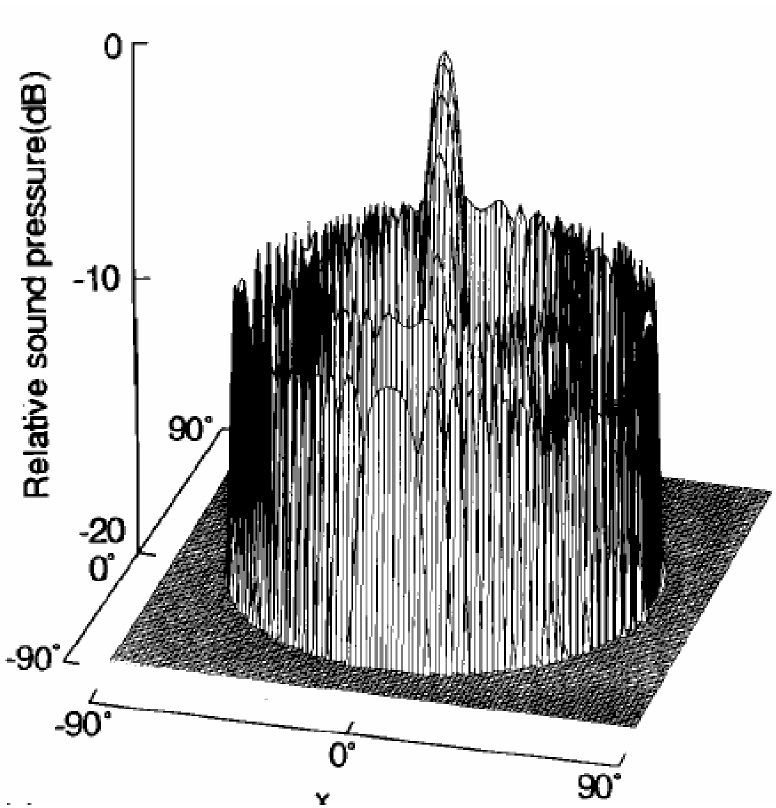


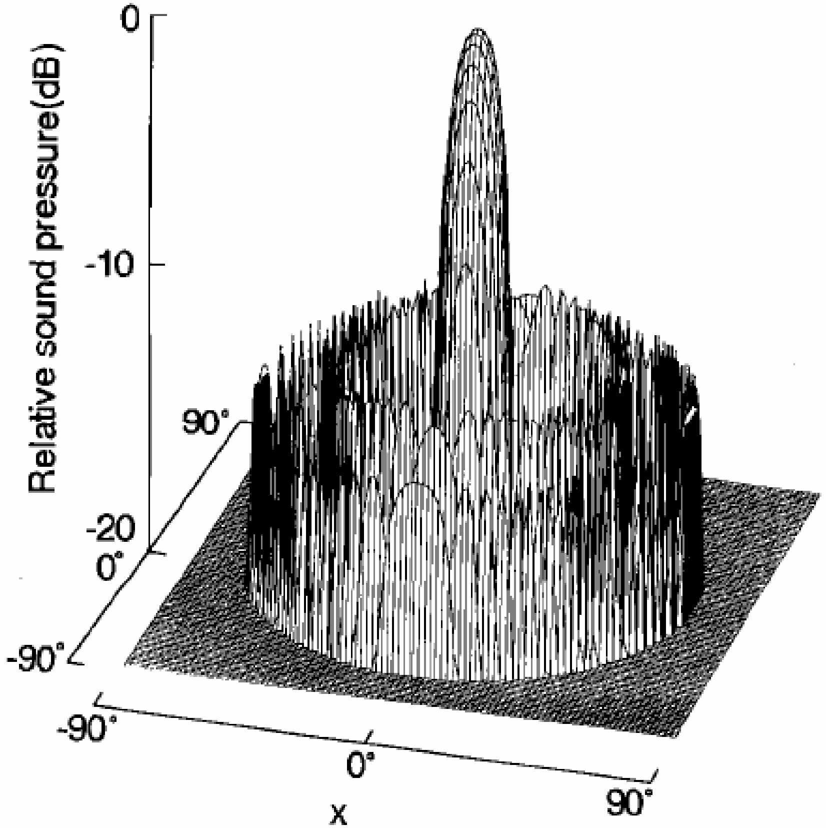
- On Helix $x' = a\cos\psi, \quad y' = a\sin\psi, \quad z' = (a\tan\alpha)\psi$
- Pt of Observation $x = r\sin\theta\cos\varphi, \quad y = r\sin\theta\sin\varphi, \quad z = r\cos\theta.$
- On Calculations $r' \simeq r - a\sin\theta\cos(\psi - \varphi) - (a\tan\alpha\cos\theta)\psi.$
- Velocity Potential of Radiation

$$\phi = \frac{1}{4\pi}\int_l \frac{e^{-jk_w r'}}{r'}\Phi(t,l)\,dl, \qquad \Phi(t,l) = \Phi_0 e^{j\omega t - jk_b l}.$$

$$\phi = \frac{\Phi_0}{4\pi r} n l_h e^{j\omega t - jk_w r} \sum_{m=-\infty}^{\infty} j^m e^{jm\varphi} \times Jm(k_u a\sin\theta)\frac{\sin[n(m-w)\pi]}{n(m-w)\pi}$$

- Where $w = (k_w a/\cos\alpha)(k_b/k_w - \sin\alpha\cos\theta)$
- Ordinary Endfire Condition $k_b l_h = k_w P_h$
- Hansen-Woodyard Endfire $k_b l_h = k_w P_h + \pi/n$





Hansen Woodray endfire

$a/\lambda_w = 1 \qquad n = 10$

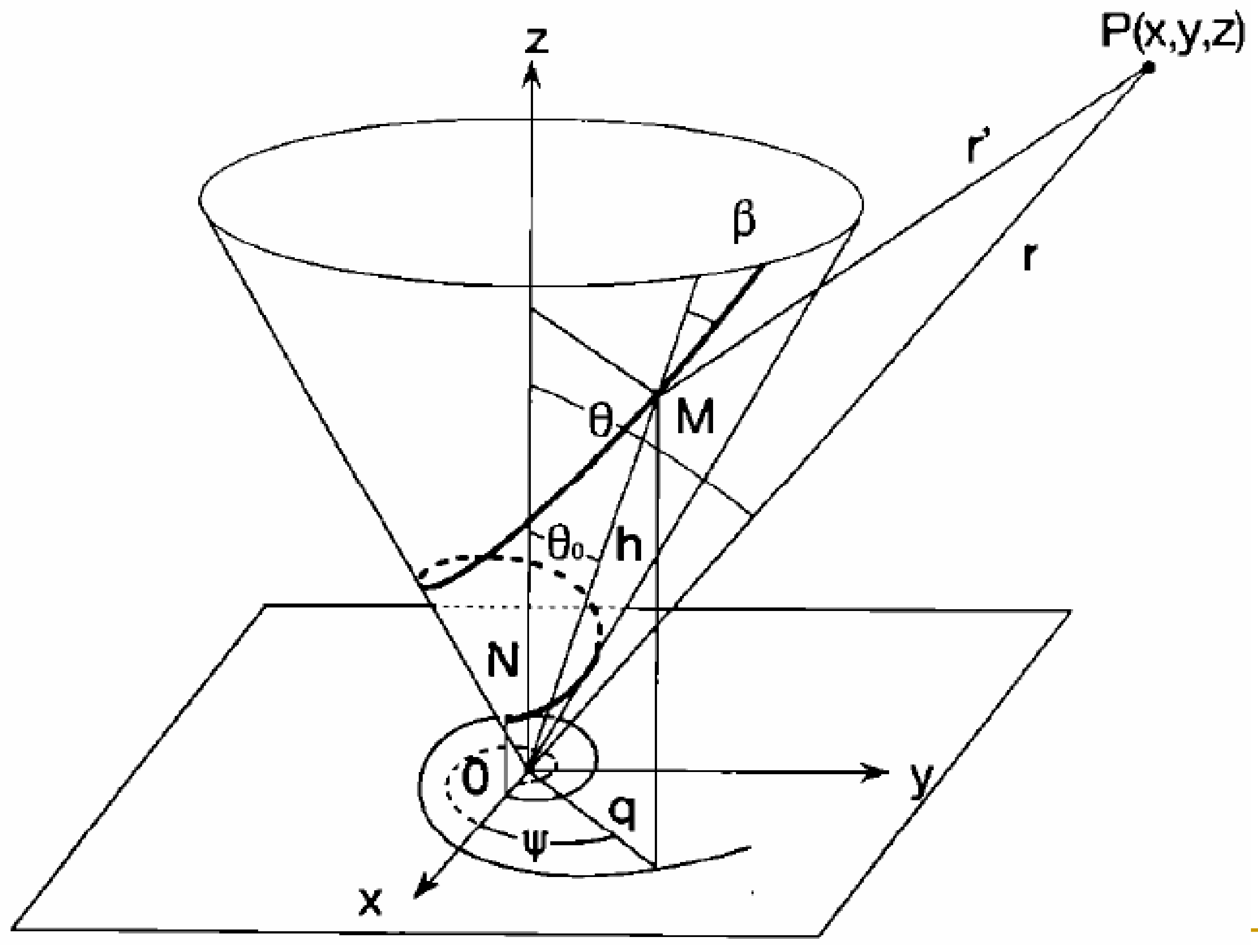
$P_h/\lambda_w = 2.97$

Ordinary endfire

$P_h/\lambda_w = 3.00$

$c_b/c_w = 2.3$

Equiangular Spiral Antenna



- Radius vector *h* $h = h_0 e^{b\psi}$, $b = \sin\theta_0 / \tan\beta$.
- Arc length $l = h / \cos\beta$
- Pts on Spiral $x' = h \sin\theta_0 \cos\psi$, $y' = h \sin\theta_0 \sin\psi$ $z' = h\cos\theta_0$
- Far field approx.

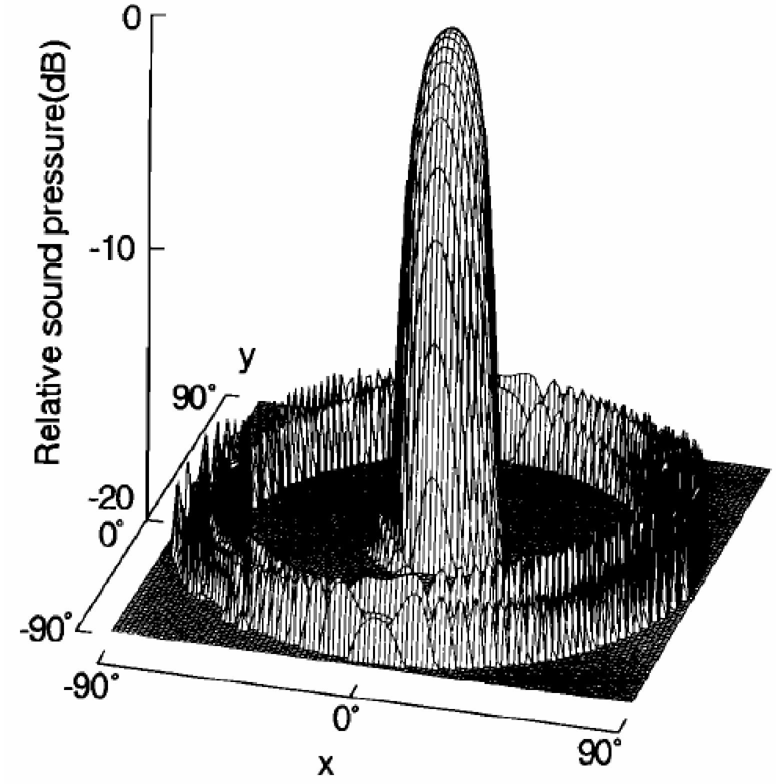
$r' \simeq r - h\delta$, where $\delta = \sin\theta_0 \sin\theta\cos(\psi - \varphi) + \cos\theta_0\cos\theta$.

- Velocity Potential

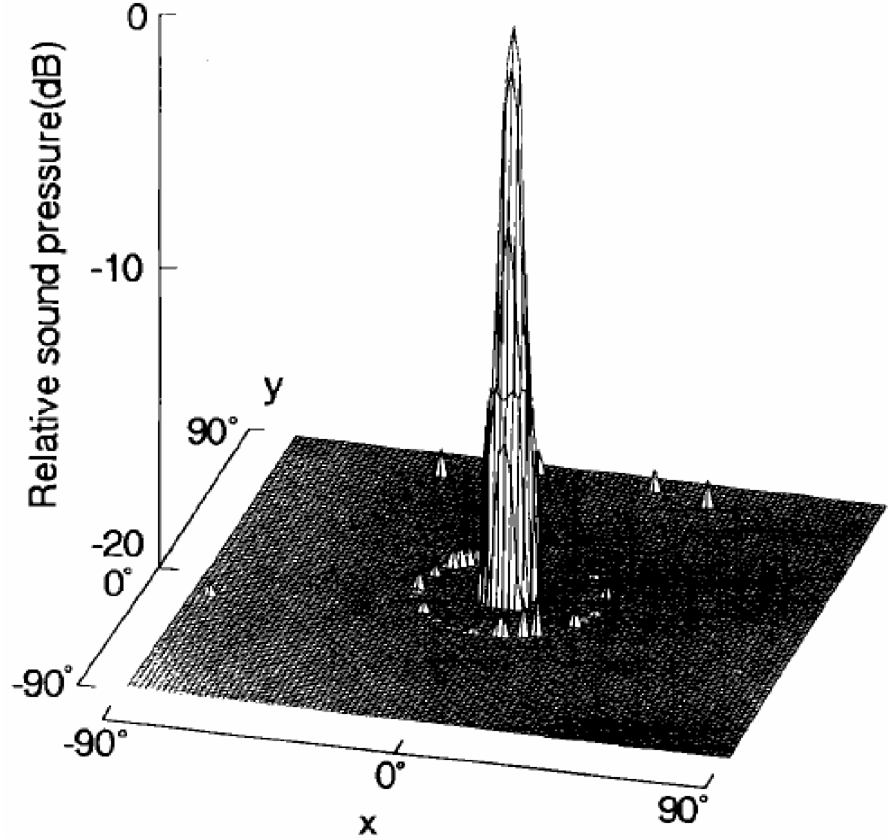
$$\phi = \frac{\Phi_0}{4\pi r}\frac{b}{\cos\beta} e^{j\omega t - jk_w r}\exp\left[j\left(\frac{k_b h_0}{\cos\beta}\right)\right] \times \int_0^{2n\pi} \exp\left[jk_w\left(\delta - \frac{k_b}{k_w}\frac{1}{\cos\beta}\right)h\right] h\, d\psi$$

- Ordinary endfire condition

$$\frac{l_s}{P_s} = \frac{1}{\cos\theta_0 \cos\beta} = \frac{c_b}{c_w}$$



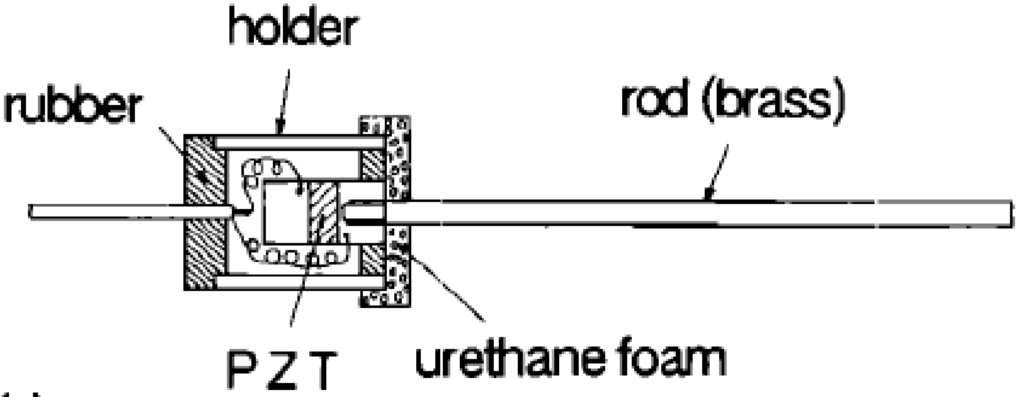
$k_\omega q_0 = 2/3\pi$



$k_\omega q_0 = 4\pi$

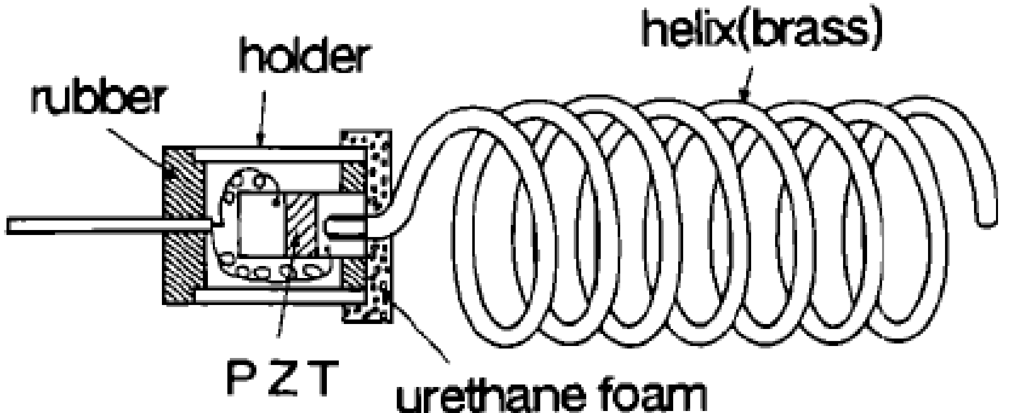
$\theta_0 = 2^\circ,\ c_b/c_w = 2.3,\ n = 10$

Measurement results



(a)

Acoustic Rod

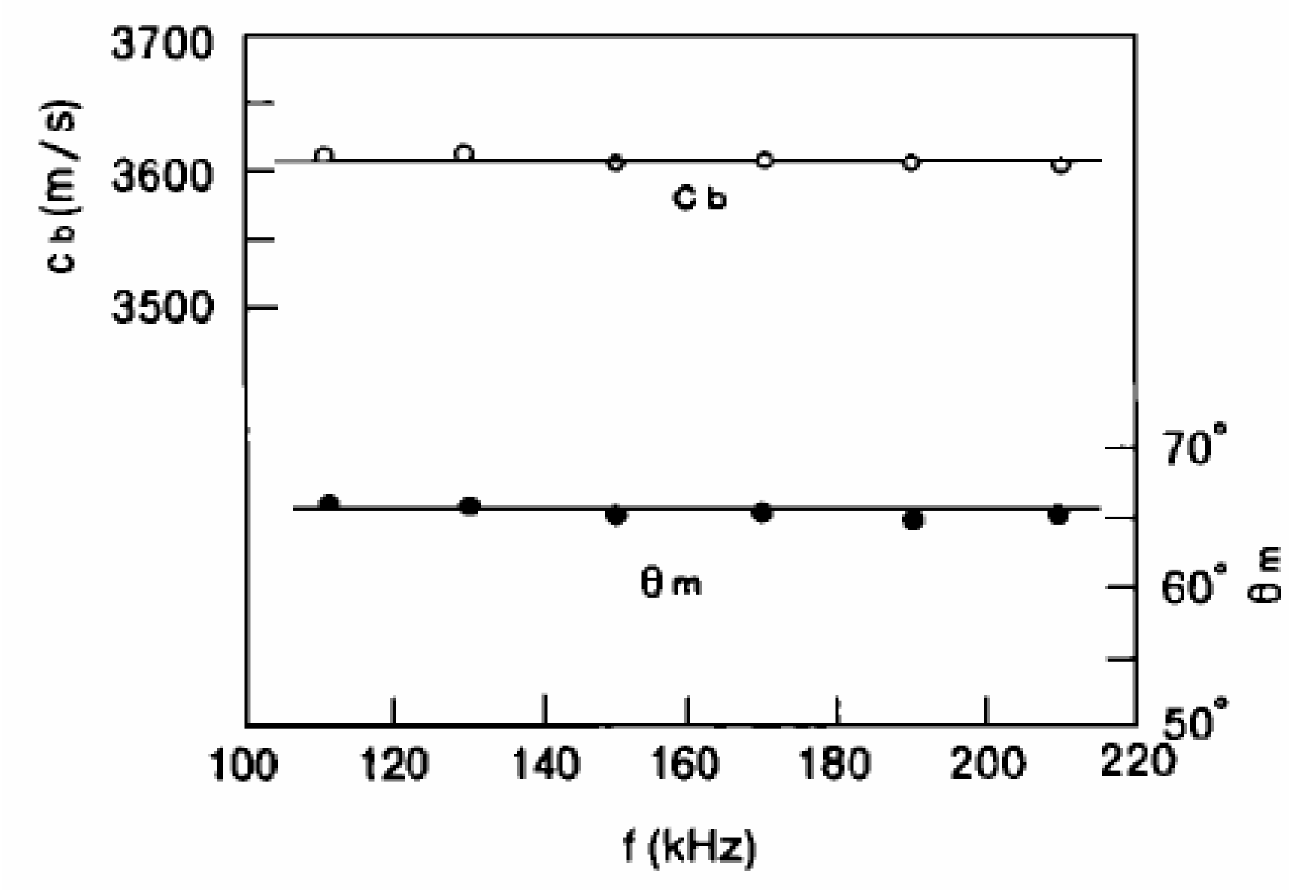


(b)

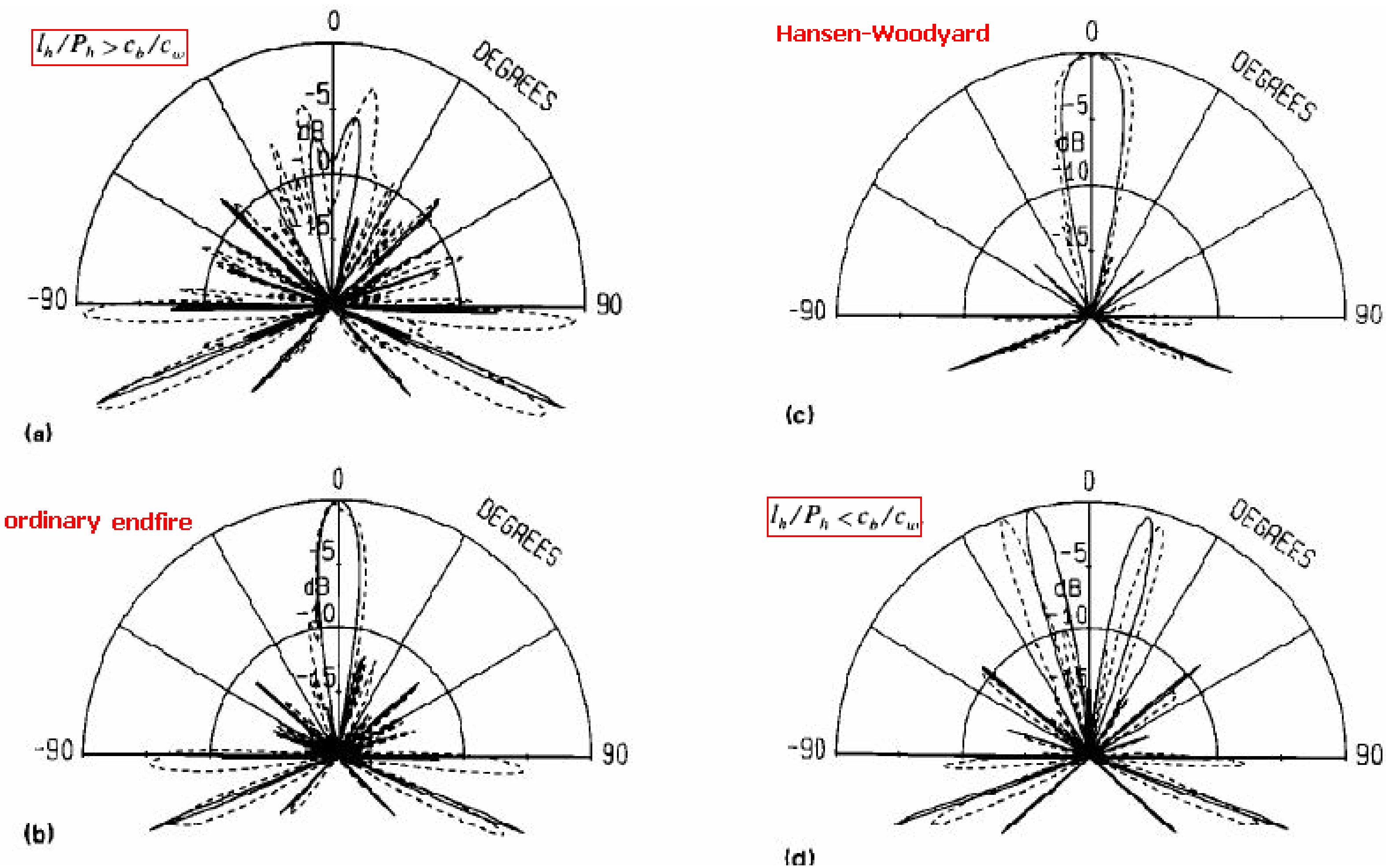
Acoustic helical

Determination of Longitudinal Speed *Cb*

- *d=3.2 mm*
- *L=40 cm*

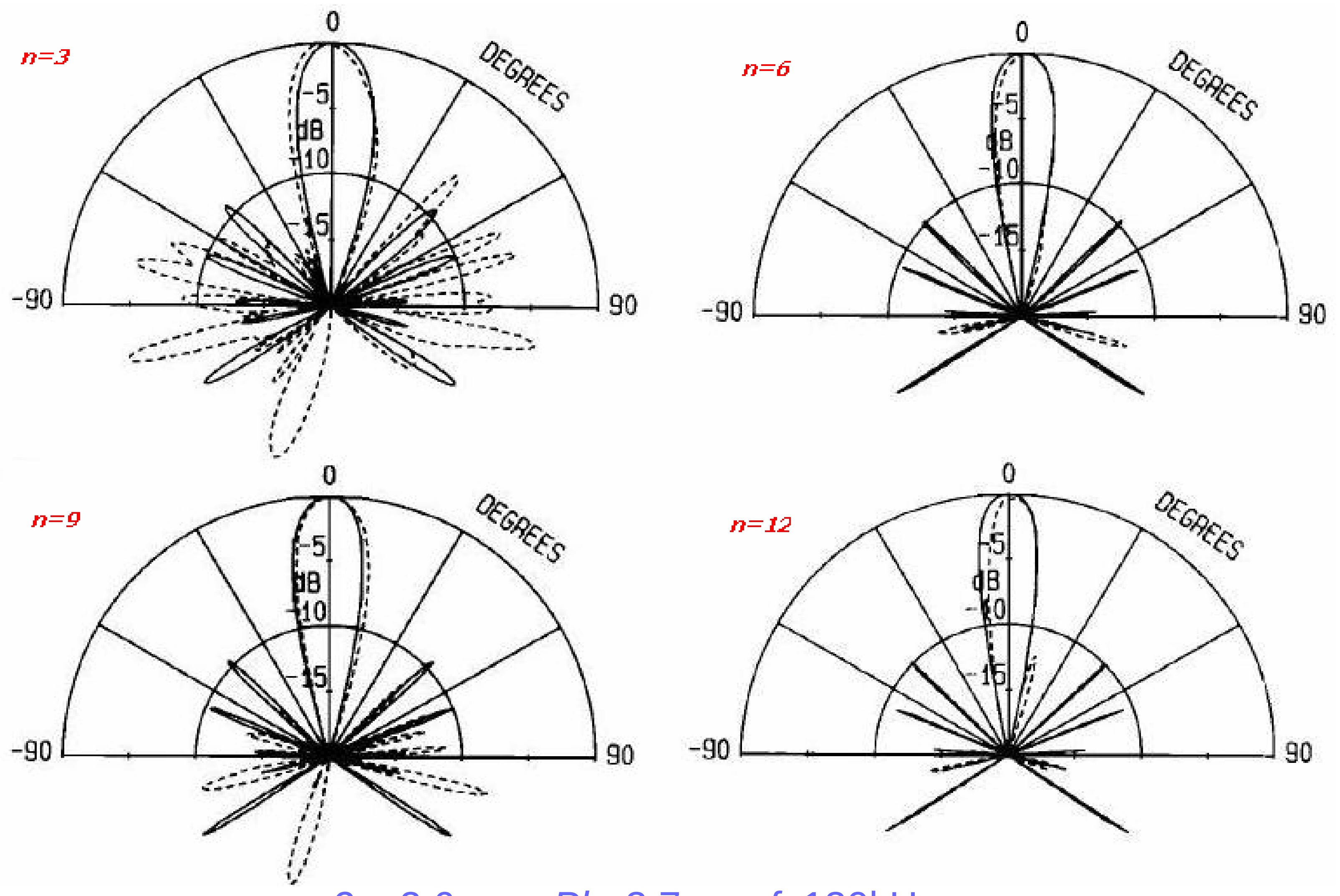


Directional patterns for various values of pitch P_h



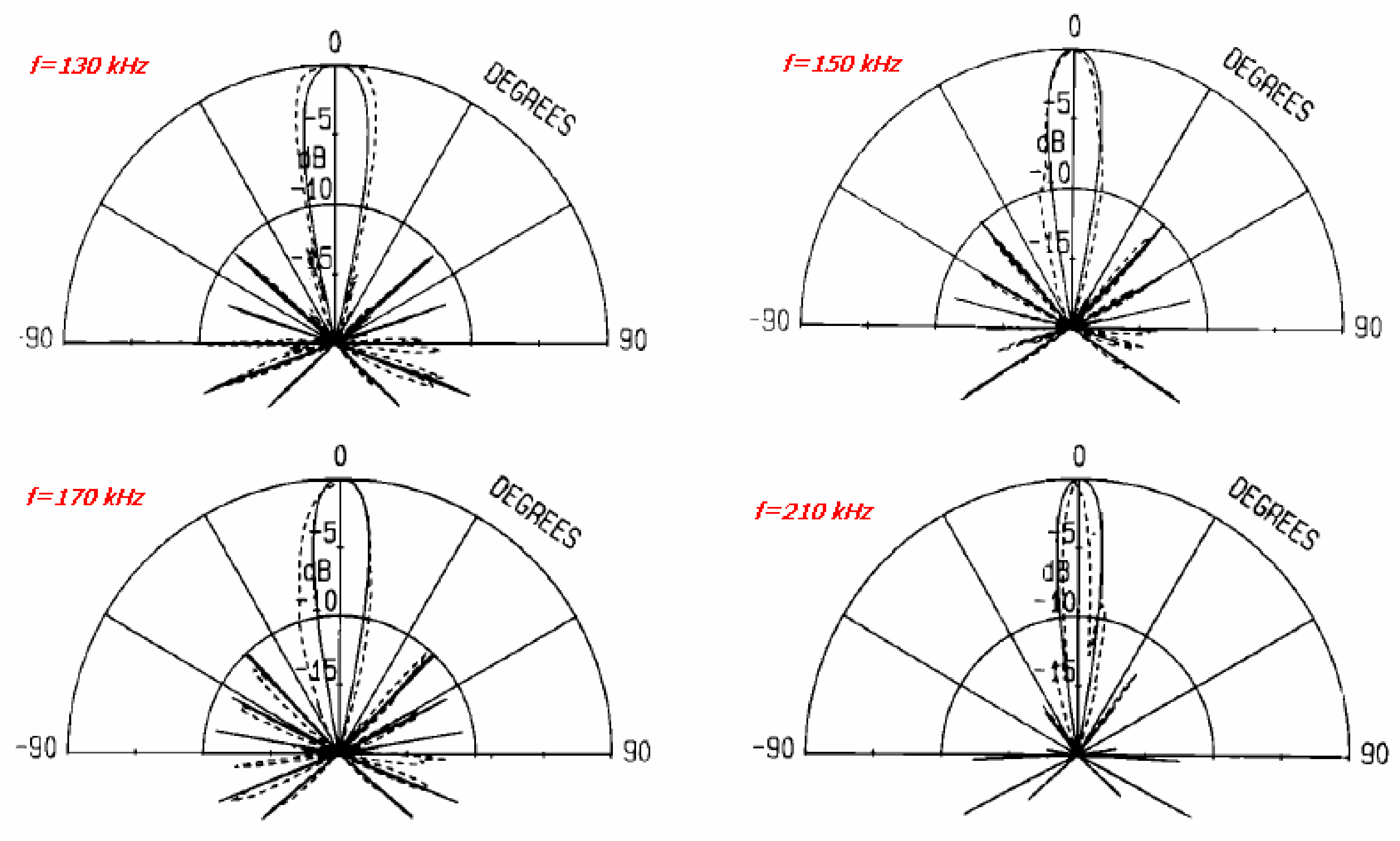
$2a$=2.2 cm n=11 f=130kHz

Directional patterns for various no. of turns *'n'*



2a=2.6 cm *Ph*=3.7cm *f*=130kHz

Directional patterns for various frequencies



2a=2.4 cm *Ph*=3.4cm *n*=11

Conclusions

- A brass rod woubd into a helical shape in conformity with the ordinary endfire condition or Hansen-Woodyard condition acts as an endfire antenna

- Side lobe of ordinary endfire helix is smaller than Hansen-Woodyard endfire helix

- An equiangular Spiral antenna is effective to suppress side lobes. Such a system will actually constitute a super directive acoustic antenna

References

- A. Hasegawa, Toshiaki Kikuchi, “Directional Charecteristics of underwater acoustic helical antennas”
- Under water Acoustic sensor networks http://www.ece.gatech.edu/research/labs/bwn/UWASN/index.html

Many Thanks

Questions ?