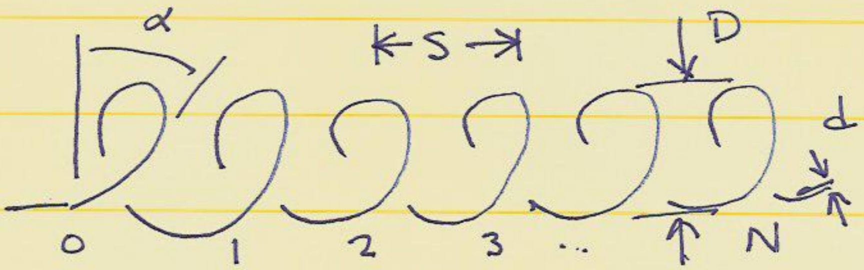
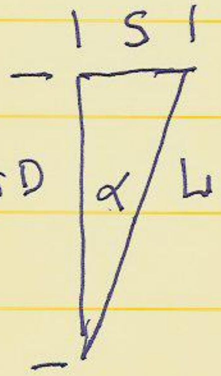
Helical Antennas V - S&T, Kraus (1



— axis



$C = \pi D$

D = diameter, $C = \pi D$

S = spacing between turns

α = pitch angle $= \tan^{-1}[S/C]$

$L = \sqrt{C^2 + S^2}$ = length of turn.

N = # turns.

A = axial length

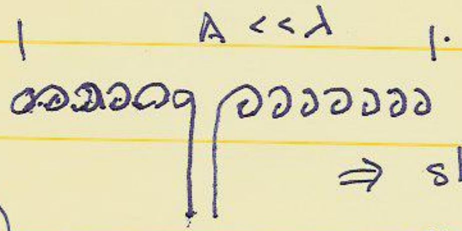
d = dia. of wire

$\alpha = 0 \Rightarrow$ loop

$D = 0 \Rightarrow$ linear antenna

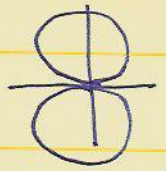
Two Modes of Helical Antenna.

Normal

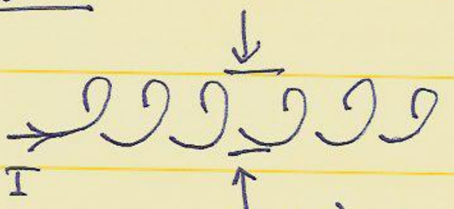


$\Rightarrow$ short or $\approx$ ideal dipole

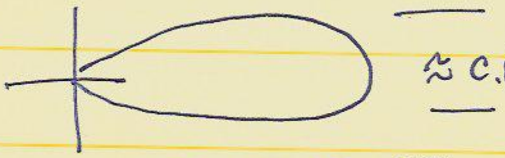
ALWAYS ELLIPTICAL.


C.P. TOROID

Axial



$D \approx \frac{\lambda}{\pi}$

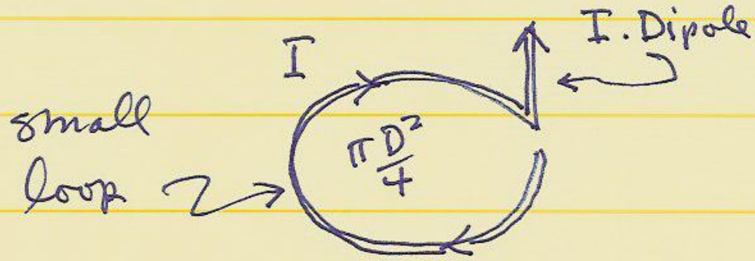

$\approx$ C.P.

END FIRE ARRAY

$\frac{3}{4}\lambda < C < \frac{4}{3}\lambda$

Normal Mode $D << \lambda$ electrically small.

model as loop + ideal dipole



$$E_D = j\omega\mu I S \frac{e^{-j\beta r}}{4\pi r} \sin\theta\, \hat{\theta}$$

$$E_L = \eta \beta^2 \underbrace{\frac{\pi}{4} D^2}_{\text{loop area}} I \frac{e^{-j\beta r}}{4\pi r} \sin\theta\, \hat{\phi}$$

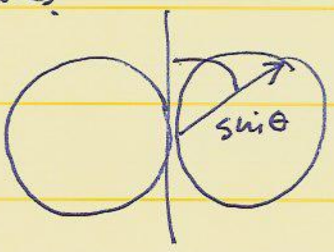
phase and space quadrature!

circularly polarized if A.R. $= 1 \Rightarrow |E_L| = |E_D|$

$$|AR| = \frac{4\,\omega\mu S}{\sqrt{\mu/\epsilon}\;\omega\sqrt{\mu\epsilon}\,(2\pi/\lambda)\,\pi D^2} = \frac{2S\lambda}{\pi^2 D^2}$$

$$|AR| = 1 \Rightarrow \boxed{\pi D = \sqrt{2S\lambda}} \Leftrightarrow \text{circular pol.}$$

for this choice. Normal mode is C.P. in all directions.



Except null along the axis!

$L \sin\alpha = S$, $\alpha = \sin^{-1}(S/L)$, $C^2 + S^2 = L^2$

$C^2 = 2S\lambda$ for C.P.

$S^2 + C^2 = S^2 + 2\lambda S = L^2$ quadratic

$$S = \frac{-2\lambda \pm \sqrt{4\lambda^2 + 4L^2}}{2} = \lambda\left[-1 \pm \sqrt{1 + \left(\frac{L}{\lambda}\right)^2}\right]$$

$$\alpha_{CP} = \sin^{-1}\left(\frac{S}{L}\right) = \sin^{-1}\left[\frac{-1 + \sqrt{1 + (L/\lambda)^2}}{L/\lambda}\right]$$

Axial Mode $C \approx \lambda$

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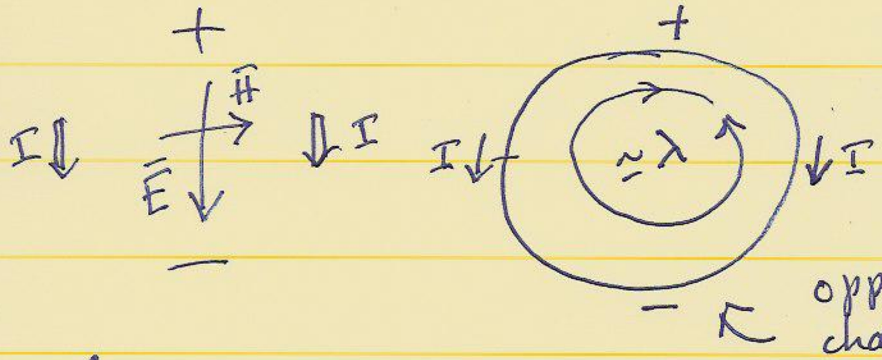
CHARACTERIZED BY PURE TRAVELING WAVE MOVING OUTWARD FROM FEED!

EFFECTIVE NEAR $\lambda/2 \approx 1/2$ circumference



currents on opposite sides in spatial alignment

opposite charges top & bottom.

VIEW ALONG AXIS

PICTURE ABOVE ROTATES AT SOURCE/WAVE FREQUENCY

(7

Axial Mode

EFFECTIVE $\frac{3}{4}\lambda \lesssim C \lesssim \frac{4}{3}\lambda$

$$BW \approx \frac{f_u}{f_L} = \frac{4/3}{3/4} = \frac{16}{9} \approx 1.78$$

VERY LITTLE REFLECTION AT END

$\bar{E}, \bar{I}, \bar{H}$ ROTATE ABOUT AXIS OF HELIX!

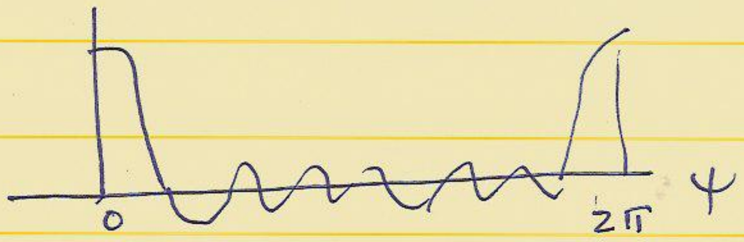
$|S| < \lambda$

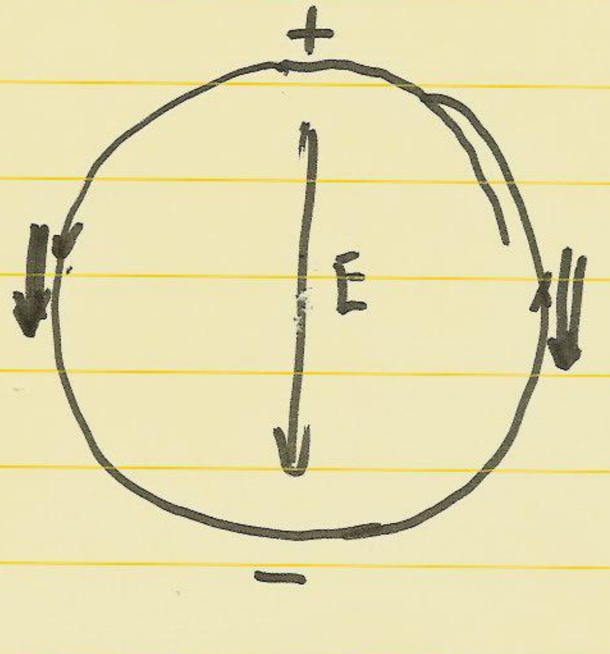
How to understand ?

- current pattern repeats $\simeq$ with period S.
- SOME DIFFICULT TO PREDICT PHASE SHIFT DUE TO INTERACTIONS AMONG TURNS.
- MODEL AS ELEMENT W/ 1-λ loop $\Rightarrow \cos\theta$
- ARRAY PATTERN GIVEN BY

$$F(\theta) = K \cos\theta \cdot \frac{\sin N\psi/2}{\sin \psi/2}$$

$$\psi = \beta S \cos\theta + \alpha$$





We know helix is endfire antenna (9

$\Rightarrow \alpha = -\beta S \Rightarrow$ endfire

but 2π phase delay for one turn

$\Rightarrow \alpha = -\beta S - 2\pi$

but gain characteristics are superior to regular array — beam is sharped by $\simeq \times 2:1$

$$\Rightarrow \alpha \simeq -\left(\beta S + 2\pi + \pi/N\right)$$

$$\alpha = \beta_n L \Rightarrow \beta_n = -\frac{1}{L}\left(\beta S + 2\pi + \pi/N\right)$$

We can use the above to infer the basic mechanism of operation. (10

$$p = \frac{V}{c} = \frac{\omega/c}{\omega/V} = \beta/\beta_n$$

V = phase velocity along the helix.

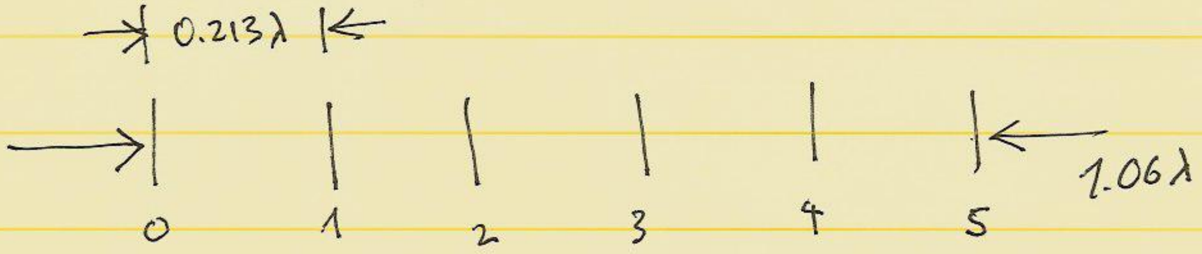
$$p = \frac{L/\lambda}{S/\lambda + (2N+1)/2N}$$

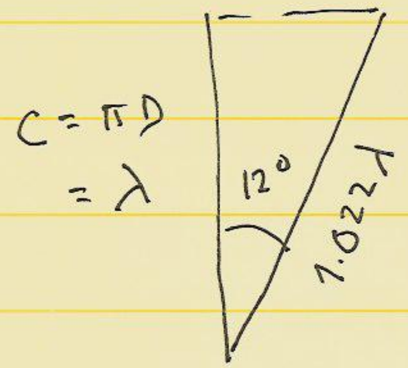
$$\frac{\beta}{\beta_n} = \frac{\beta}{\frac{1}{L}\left(\beta S + 2\pi + \frac{\pi}{N}\right)} = \frac{\beta L}{\beta S + 2\pi + \pi/N}$$

$p \simeq 0.7 - 0.9 < 1 \Rightarrow$

SLOW WAVE ON HELIX.

$$\boxed{\text{Typically} \approx 5 \text{ turns}/\lambda}$$





spacing comparable to Yagi-Uda spacings!

End fire of n-sources.

1 Helical turn = 1 source

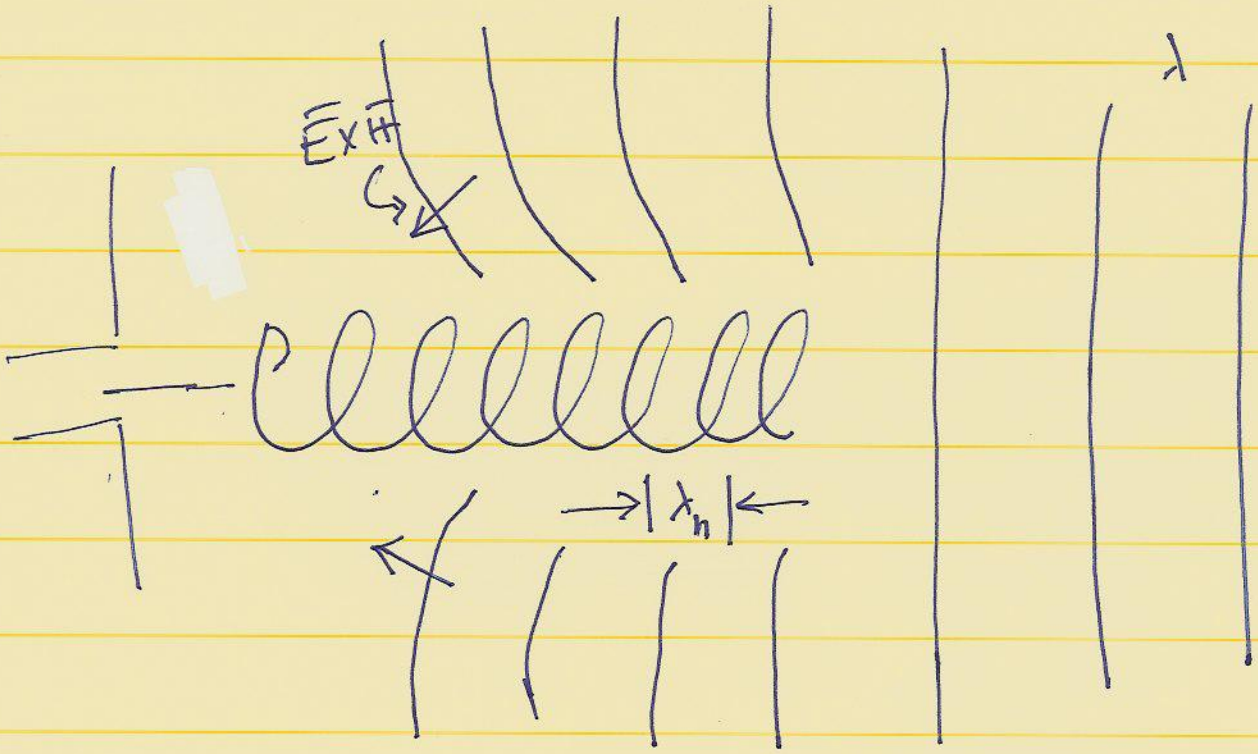
$$E(\theta) \propto \cos\theta \, \frac{\sin[n(\psi/2)]}{\sin(\psi/2)}$$

$$\psi = \beta s \cos\theta + \alpha$$

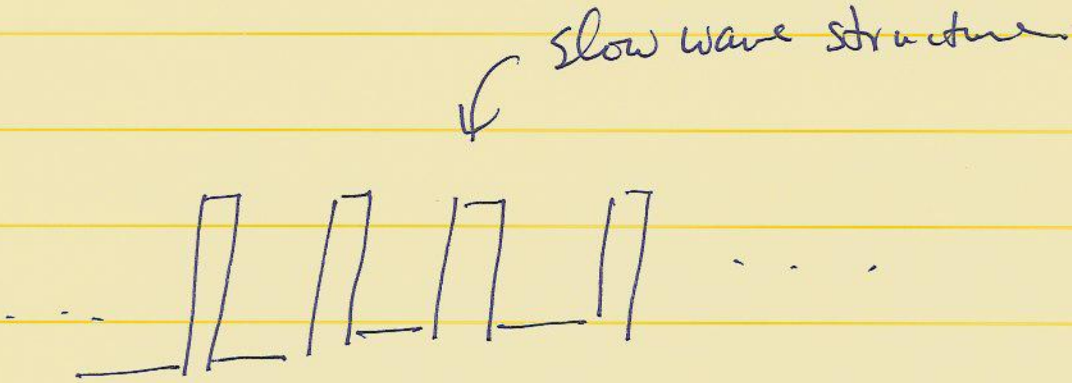
$$= -\frac{\beta s}{p}$$

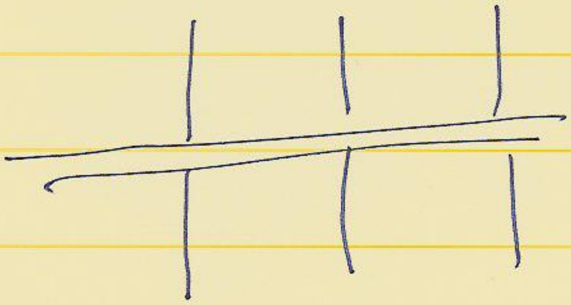
p = relative phase velocity of array.

$$\boxed{\Delta\psi \simeq -2\pi}$$

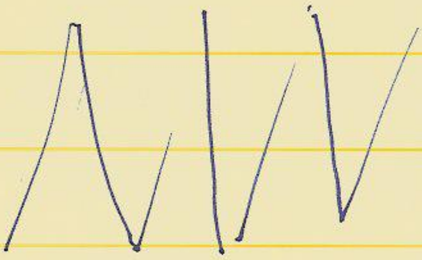


RECEIVING.





YAGI.



Helix.