10.20 A helical antenna of *4 turns* is operated in the *normal mode* at a frequency of 880 MHz and is used as an antenna for a wireless cellular telephone. The length L of the helical antenna is 5 cm and the diameter of each turn is 0.54 cm. Determine the:

(a) Spacing S (*in* λ_0) between the turns.

(b) Length L_0 (*in* λ_0) of each turn.

(c) Overall length L_n (*in* λ_0) of entire helix.

(d) Axial ratio of the helix (dimensionless).

(e) On the basis of the answer in Part *d*, the primary dominant component (E_θ or E_ϕ) of the far-zone field radiated by the helix.

(f) Primary polarization of the helix (*vertical* or *horizontal*) and why? Does the antenna primarily radiate as a linear vertical wire antenna or as a horizontal loop? Why? *Explain.*

(g) Radiation resistance of the helical antenna assuming that it can be determined using

$$R_r \approx 640\left(\frac{L}{\lambda_0}\right)^2$$

(h) Radiation resistance of a single straight wire monopole of length L *(the same L as that of the helix)* mounted above an infinite ground plane.

(i) On the basis of the values of Parts *g* and *h*, what can you say about which antenna is preferable to be used as an antenna for a cellular telephone and why? Explain.

- Assume $L = 5$ cm and diameter is 0.54 cm.

$$\lambda_0 = \frac{c}{f} = \frac{2.998\times10^8}{880\times10^6} = \underline{0.340681\ m}$$

a) Per Fig 10.13, $S = L/N = \frac{0.05}{4} = 0.0125\,m$

$\hookrightarrow 0.0125\left(\frac{\lambda_0}{0.340681}\right) \Rightarrow \underline{\underline{S = 0.03669\lambda_0}}$

b) Per Fig 10.13, $L_0 = \sqrt{S^2+C^2} = \sqrt{0.0125^2 + (\pi\, 0.54\times10^{-2})^2}$

$\hookrightarrow 0.02107\left(\frac{\lambda_0}{0.340681}\right) \Rightarrow \underline{\underline{L_0 = 0.061854\lambda_0}}$

c) Per Fig 10.13, $L_n = N L_0 = 4(0.061854\lambda_0)$

$\underline{\underline{L_n = 0.247415\lambda_0}}$

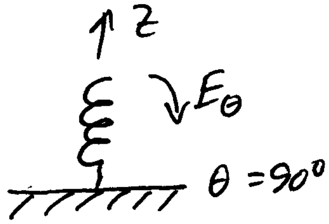
d) Per (10-27), $AR = \frac{2\lambda S}{(\pi D)^2} = \frac{2(0.340681)0.0125}{(\pi\ 0.54\times10^{-2})^2}$

$$\underline{\underline{AR = 29.5939}}$$

e) Per (10-27), $AR = \frac{|E_\theta|}{|E_\phi|} = 29.59 \Rightarrow |E_\theta| = 29.59\,|E_\phi|$

$\Rightarrow$ $\underline{\underline{|E_\theta| \text{ is the dominant component}}}$

f)



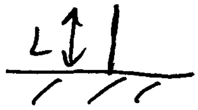
At $\theta = 90°$, E_θ is in the $\pm z$-direction $\Rightarrow$ vertical

$\Rightarrow$ $\underline{\underline{\text{Linear vertical wire antenna}}}$

g) From text, for helix $R_r \cong 640\left(L/\lambda\right)^2 = 640\left(\frac{5\times10^{-2}}{0.34068}\right)^2$

$$\underline{\underline{R_r \simeq 13.7855\ \Omega}}$$

h) R_r for linear monopole of length L



Per notes + (4-106), $Z_{in,mono} = \frac{1}{2} Z_{in,dipole}$

Dipole $2L = 2(5cm) = 10cm = \ell \Rightarrow \frac{\ell}{\lambda} = \frac{0.1}{0.34} = 0.294$

↳ Dipole is <u>NOT</u> small. Use finite length dipole radiation resistance eq'n (4-70) or definite integral (see notes)

h) cont. $$R_{r,dipole} = \frac{\eta}{4\pi}\int_{\theta=0}^{\pi} \frac{\left[\cos\left(\frac{kl}{2}\cos\theta\right) - \cos\left(\frac{kl}{2}\right)\right]^2}{\sin\theta}\,d\theta$$

where $\eta = \eta_0 = 376.7303\,\Omega$, $k = \frac{2\pi}{\lambda_0} = 18.443\,\frac{rad}{m}$

$l = 5cm(2) = 10cm \Rightarrow \frac{kl}{2} = 0.92215$ rad

Using MathCad, $R_{r,dipole} = 12.16912\,\Omega$

$\hookrightarrow R_{r,mono} = \frac{R_{r,dipole}}{2} = \underline{\underline{6.08456\,\Omega}}$

i) Given that $R_{r,helix} = 13.7855\,\Omega$ is roughly twice as large as $R_{r,mono} = 6.08456\,\Omega$, the <u>helix would be preferred</u> from an impedance matching standpoint. Also, the helix structure should be more robust from a mechanical strength standpoint.