Design a 7-turn helical antenna that operates in the normal mode with circular polarization at 915 MHz for an UHF RFID system. The circumference is constrained to be 25 mm. Calculate the a) turn spacing (in wavelengths and in mm), b) axial length/helix height (in wavelengths and in mm), c) length of a single turn (in wavelengths and in mm), d) overall wire length (in wavelengths and in mm), e) pitch angle (in degrees), and f) the broadside phasor vector electric field at a distance of 6 m (assume I_0 = 12 A, explicitly enter all known quantities and put in polar form).

Normal mode w/ circular polarization ⇒ Wheeler helix

a) Per (10-28), $\frac{2\lambda_0 S}{(\pi D)^2} = 1 \Rightarrow S = \frac{(\pi D)^2}{2\lambda_0} = \frac{C^2}{2\lambda_0}$

$$\lambda_0 = \frac{2.998\times10^8}{915\times10^6} = 0.32765\,m = 327.65\,mm$$

$$S = \frac{0.025^2}{2(0.32765)} \Rightarrow \underline{\underline{S = 0.95376\,mm = 0.002911\,\lambda_0}}$$

b) Per Fig 10.13, $L = NS = 7(0.95376\,m) = (7)0.002911\lambda_0$

$$\underline{\underline{L = 6.67633\,mm = 0.020376\,\lambda_0}}$$

c) Per Fig 10.13, $L_0 = \sqrt{S^2 + C^2} = \sqrt{0.95376^2 + 25^2}$

$$\underline{\underline{L_0 = 25.01819\,mm = 0.076356\,\lambda_0}}$$

d) $L_n = N L_0 = 7(25.01819\,mm) = (7)0.076356\,\lambda_0$

$$\underline{\underline{L_n = 175.1273\,mm = 0.5345\,\lambda_0}}$$

e) Per (10-24), $\alpha = \tan^{-1}\left(\frac{S}{C}\right) = \tan^{-1}\left(\frac{0.95376}{25}\right)$

$$\underline{\underline{\alpha = 2.1848^\circ}}$$

f) Per (10-25), a single short dipole radiates

$$E_\theta = j\eta \frac{k I_o S e^{-jkr}}{4\pi r} \sin\theta = j\eta \frac{I_o S e^{-jkr}}{2\lambda_o r} \sin 90^\circ$$

$$= j376.73 \frac{12(9.5376\times10^{-4}) e^{-j\left(\frac{2\pi}{0.32765}\right)6}}{2(0.32765)\,6}$$

$$E_\theta = 1.09663 \angle -22.3949^\circ \text{ V/m}$$

Per (10-26), a single loop radiates

$$E_\phi = \eta \frac{k^2 (D/2)^2 I_o e^{-jkr}}{4r} \sin\theta = \eta \frac{C^2 I_o e^{-jkr}}{4\lambda_o^2 r} \sin 90^\circ$$

$$= \frac{376.73 (2.5\times10^{-2})^2\, 12\, e^{-j\left(\frac{2\pi}{0.32765}\right)6}}{4(0.32765)^2\, 6}$$

$$E_\phi = 1.09663 \angle -112.3949^\circ \text{ V/m}$$

$$\bar{E}_{single} = \hat{a}_\theta E_\theta + \hat{a}_\phi E_\phi$$

$$\bar{E}_{Tot} = N \bar{E}_{single} = 7\left[\hat{a}_\theta 1.0966 \angle -22.3949^\circ + \hat{a}_\phi 1.0966 \angle -112.395^\circ\right]$$

$$\boxed{\begin{aligned} \bar{E}_{Tot} &= \hat{a}_\theta 7.6764 \angle -22.395^\circ + \hat{a}_\phi 7.6764 \angle -112.395^\circ \text{ V/m} \\ \bar{E}_{TOT} &= 7.6764 \angle -22.395^\circ \left(\hat{a}_\theta - j\,\hat{a}_\phi\right) \text{ V/m} \end{aligned}}$$

circularly polarized!