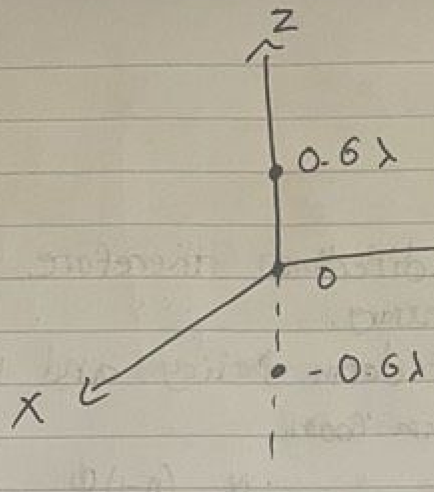
①



$$AF = 1 + e^{jkd\cos\theta} - e^{jkd\cos\theta}$$

$$AF = 1 + 2\cos(kd\cos\theta)$$

$$kd = \frac{2\pi}{\lambda}\cdot\frac{6\lambda}{10} = 1.2\pi$$

$$AF = 1 + 2\cos(1.2\pi\cos\theta)$$

$$E_\theta \approx \underbrace{j\eta\frac{kI_0Le^{-jkr}}{8\pi r}}_{C_1}\sin\theta \quad \text{(small dipole)} \rightarrow E_\theta = C_1\sin\theta$$

HPBW $\approx 105^\circ - 75^\circ \approx 30^\circ$
(from plot)

$$\cancel{U = r^2 W_{rad} = \frac{-\eta^2k^2I_0^2L^2 \cdot 2\pi \cdot 4}{64\pi^2 \cdot 2\eta \quad 3}}$$

$$W_{rad} = \hat{r}\frac{C_1^2}{2\eta}\sin^2\theta$$

$$\cancel{U = \frac{-j\eta k^2 I_0^2 L^2}{64\pi^2 \cdot 2}\sin^2\theta}$$

$$\cancel{P_{rad} = \frac{C_1^2 \cdot 2\pi}{2\eta}\int_0^\pi \sin^3\theta\, d\theta}$$

$$\cancel{P_{rad} = \frac{8\pi}{8\eta} = \frac{4\pi C_1^2}{3\eta}}$$

$$W_{rad} = \cancel{E_t} \approx (AF \cdot E_\theta)^2 = \frac{(1+2\cos(1.2\pi\cos\theta))^2\sin^2\theta)}{2\eta}\cdot C_1^2$$

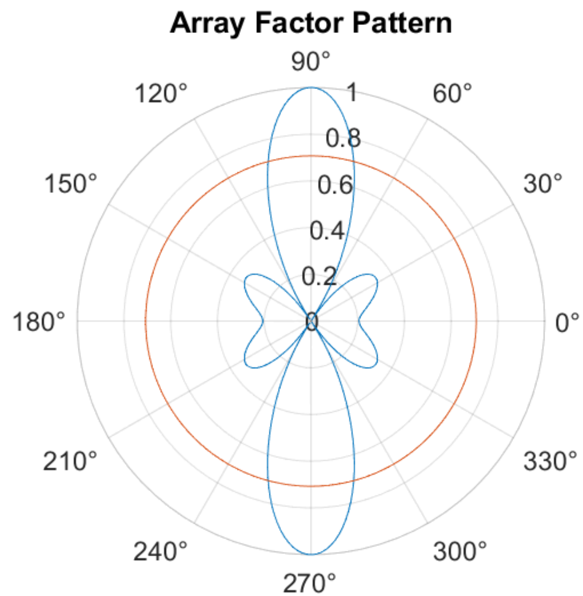
$U(\theta) = r^2 W_{rad}$ $\quad U_{max} = 9\, C_1^2/2\eta$ $\quad P_{rad} \approx 29.59$ (matlab)

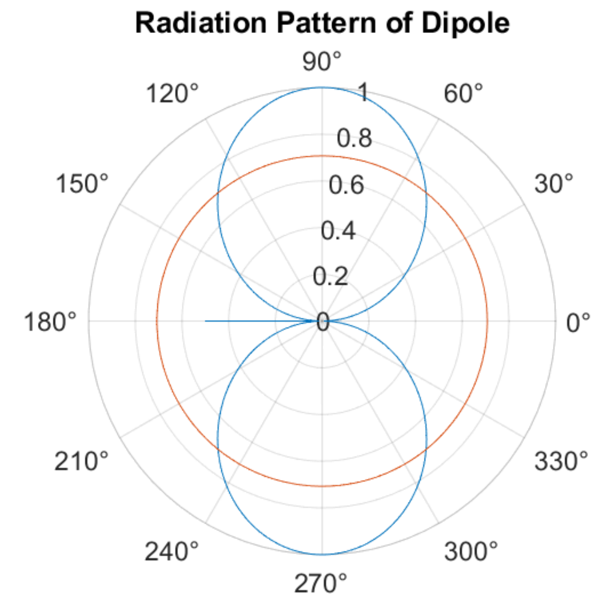
$$D_0 = \frac{4\pi U_{max}}{P_{rad}} = 3.822$$

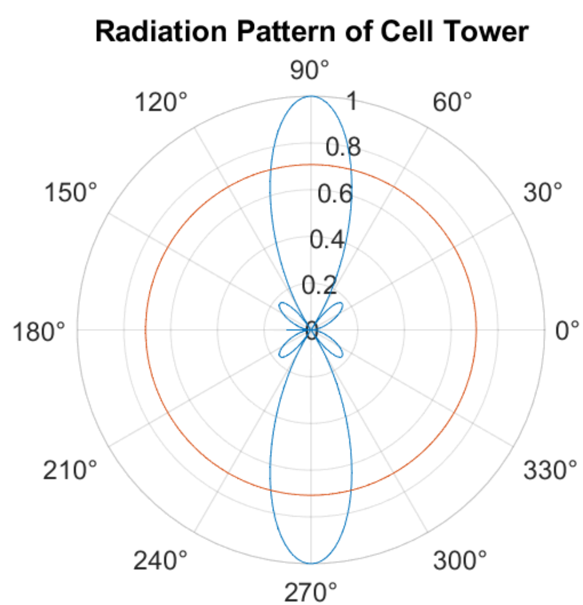
D_0 (dB) $\approx$ ~~.13~~ .13.4079

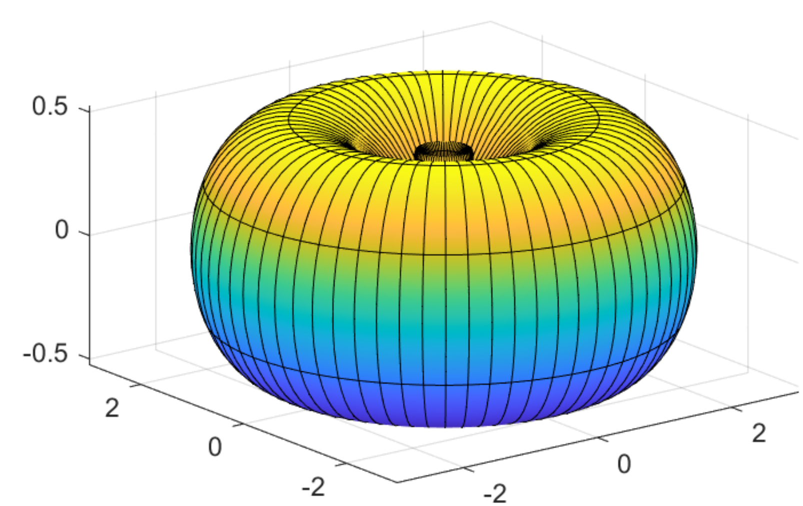
The designers choose 3 elements because they wanted higher directivity and better power handling, and to avoid interference with sky objects, since all cell users are on the ground. Five elements would have a lower HPBW which may cause cell user to have a bad signal based on their elevation. ~~and if th~~

$$E_t = \frac{\cos(\pi/2\cos(\theta))}{\sin\theta}\left[1 + 2\cos(1.2\pi\cos(\theta))\right]$$


Array Factor Pattern
90°
120°
60°
150°
30°
180°
0°
210°
330°
240°
300°
270°
1
0.8
0.6
0.4
0.2
0


Radiation Pattern of Dipole
90°
120°
60°
150°
30°
180°
0°
210°
330°
240°
300°
270°
1
0.8
0.6
0.4
0.2
0

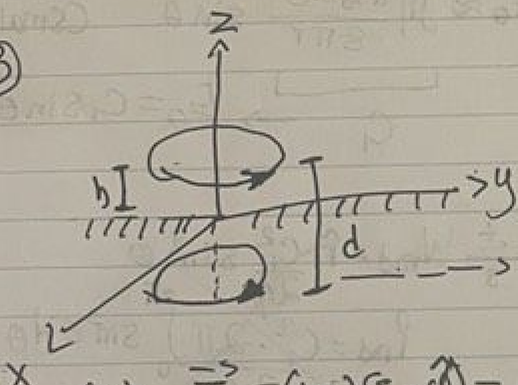

Radiation Pattern of Cell Tower
90°
120°
60°
150°
30°
180°
0°
210°
330°
240°
300°
270°
1
0.8
0.6
0.4
0.2
0


0.5
0
-0.5
2
0
-2
2
0
-2

② Rabbit ear because

- Cheaper
- OTA channels are omnidirectional therefore a high gain anttena is not neccessary.
- Could be aganist UCF dorm Policy and will occupy more space in limited dorm room.

③



$$AF = \sum_{n=1}^{N} e^{(n-1)\psi} \qquad \psi = kd\cos\theta$$

$$AF = 1 + (-1)e^{jkd\cos\theta} \qquad kd = \frac{2\pi}{\lambda} \cdot 2h\cos\theta$$

$$\psi = 2kh\cos\theta$$

$$E_\phi = j\frac{kI_m l\sin\theta}{4\pi r}\left[1+\frac{1}{jkr}\right]e^{-jkr}$$

(a) $\vec{E}_t = (AF)(E_\phi\hat{\phi}) = (1 - e^{2jkh\cos\theta})\left(\frac{jI_m l\sin\theta}{4\pi r}\right)\left[1+\frac{1}{jkr}\right]e^{-jkr}$

(b) $AF = 1 - \cos(4\pi(\cos\theta)) - j\sin(4\pi(\cos\theta))$

$AF = 0$ when $\theta = 0, \pi/3, \pi/2, 2\pi/3, \pi$

(Plotted on desmos) $\theta = 0°, 60°, 90°, ~~270~~°, 120°, 180°$

(c) $\vec{E}_t = \left[1 - e^{jkd\cos\theta}\right]\left[\cancel{1+\frac{1}{jkr}}\right]\left[\cancel{j\frac{kI_m l\sin\theta}{4\pi r}}\right]\cancel{e^{-jkr}}$

$\theta = \pi/3$

$$1 - e^{-jkd\cos(\pi/3)} \Rightarrow 1 - \exp(-j\,1/2 \cdot \frac{2\pi}{\lambda} \cdot 2h) \quad h = \alpha\lambda$$

$$\Rightarrow 1 = \exp(-j2\pi\alpha) = \cos(2\pi\alpha) + j\sin(2\pi\alpha)$$

$$2\pi\alpha = \pi \Rightarrow \alpha = 1/2 \rightarrow h = 2\alpha\lambda$$

$$\alpha = 1, 2, 3, \ldots, n$$

$e_{cd} = \frac{R_r}{R_r + R_L}$

④ $R_{series} = \frac{Na}{b} R_s$ (1 MHz, 100 turns)

$R_s = \sqrt{\frac{2\pi f \mu_0}{2\sigma}} = \sqrt{\frac{2\pi \times 10^6 \times 4\pi \times 10^{-7}}{2 \times 5.8 \times 10^7}} \doteq 260\,\mu\Omega$

a: loop radius = 1/2 cm

b: wire radius = 100 µm

$R_{ohmic} \approx 1.3044\,\Omega$

$R_f \approx 20\pi^2 \left(\frac{C}{\lambda}\right)^4 N^2 \mu_{cer}^2 = 20\pi^2 \left(\frac{2\pi \cdot 1/2 \cdot 1/100}{3\times10^8/10^6}\right) 100^2 \cdot 100^2$

$R_f = 2\times10^9 \cdot \pi^2 \left(\frac{\pi/100}{300}\right)^4 = 2.37\,\mu\Omega$

$e_{cd} = \frac{2.37\,\mu\Omega}{2.37\,\mu\Omega + 1.3044\,\Omega} = 1.8 \times 10^{-4}\,\% \approx 0$

(dipole)

$R_r = 80\pi^2 \left(\frac{l}{\lambda}\right)^2$

$\lambda_{1\,MHz} = \frac{3\times10^8}{10^6} = 300\,m$

$R_r \approx 80(10)\left(\frac{3/4}{300}\right)^2 (2)$

$R_r \approx 5.13\,m\Omega \cdot 2 \approx 10\,m\Omega$ $\quad \lambda_{98\,MHz} = \frac{3\times10^8}{98\times10^6} = \frac{300\,m}{98} = 3.06\,m$

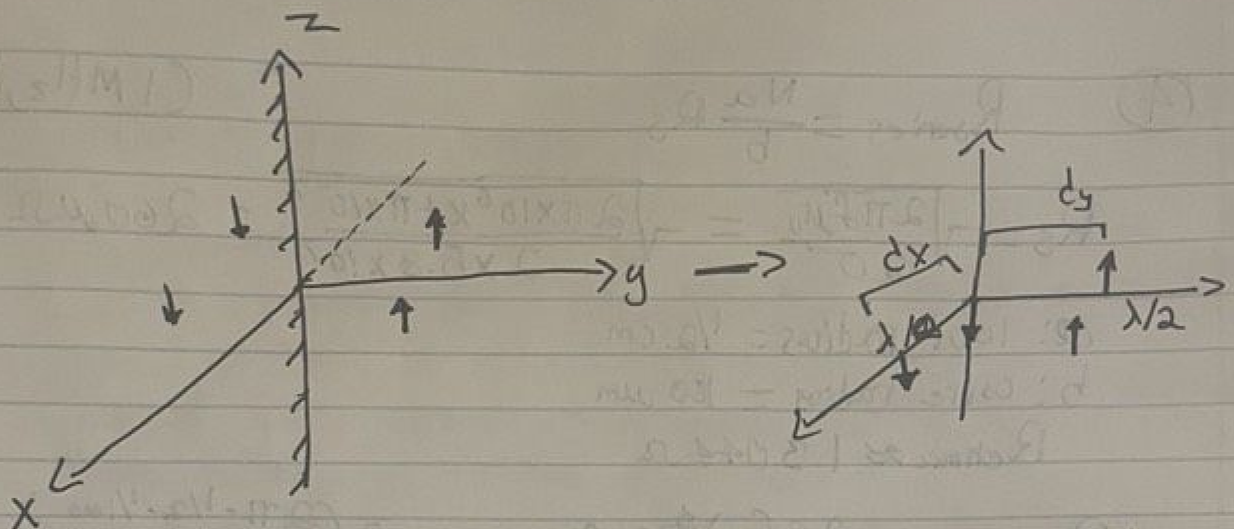
$R_{loss} = \frac{l}{2\pi a}\sqrt{\frac{2\pi f \mu_0}{2\sigma}} = \frac{0.75}{2\pi \times 10^{-3}}\sqrt{\frac{4\pi^2 \cdot 10^6 \cdot 10^{-7}}{2 \cdot 5.8 \times 10^7}} = 0.75\sqrt{\frac{1}{12 \cdot 10^8}}$

$R_{loss} \approx \cancel{22.02\,m\Omega}$ $31\,m\Omega$

~~$e_{cd} = \frac{5.13}{22.02 + 5.13} \approx 19\,\%$ efficiency~~

$e_{cd} = \frac{10}{31+10} = \frac{10}{41} \approx 24.4\,\%$ efficiency

⑤



$$AF = \cancel{e} + (-1) - e^{jkd_x \sin\theta \cos\phi} + e^{jkd_y \sin\theta \sin\phi}$$

$$+ e^{jkd_x \sin\theta\cos\phi} e^{jkd_y \sin\theta \sin\phi}$$

$kd_x = \frac{2\pi}{\lambda} \cdot \frac{\lambda}{2}$

$= \pi$

$kd_y = \pi$

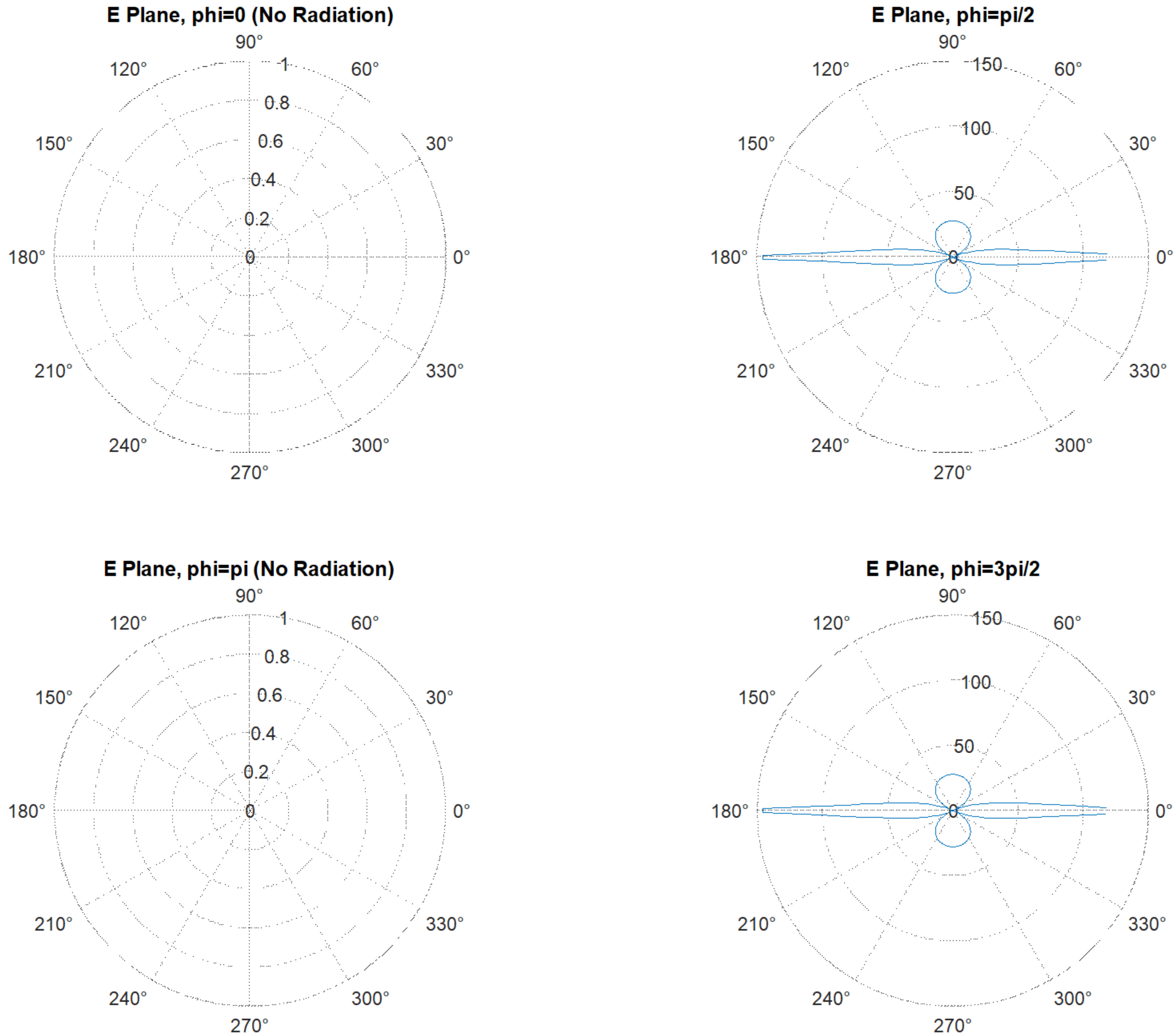
$$AF = -1 - e^{j\pi \sin\theta\cos\phi} + e^{j\frac{\pi}{} \sin\theta \sin\phi} + e^{j\pi(\sin\theta\cos\phi + \sin\theta\sin\phi)}$$

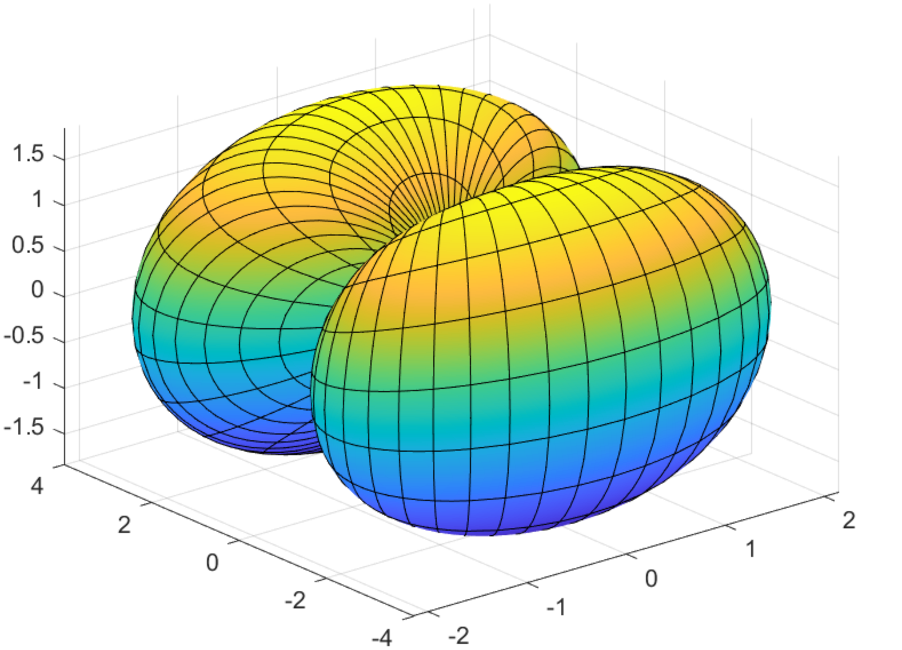
~~$AF = -1 - e^{j\pi(}$~~

$$E_t \approx (C_1 \sin\theta) AF$$

$$C_1 = j\eta \frac{kI_0 l e^{-jkr}}{8\pi r}$$

$$E_t = \frac{\cos(\pi/2 \cos(\theta))}{\sin\theta} \cdot AF$$


E Plane, phi=0 (No Radiation)
E Plane, phi=pi/2
E Plane, phi=pi (No Radiation)
E Plane, phi=3pi/2
90°
120°
60°
150°
30°
180°
0°
210°
330°
240°
300°
270°
0
0.2
0.4
0.6
0.8
1
50
100
150


1.5
1
0.5
0
-0.5
-1
-1.5
4
2
0
-2
-4
-2
-1
0
1
2