EE 483L/583L Antennas for Wireless Communications
Spring 2026 Laboratory 1- Antenna Pattern Plotting

<snip>

A small, thin-wire, circular loop antenna in free space, centered on origin on the *x*-*y* plane, has far-field electric and magnetic fields given by

$$\overline{E} = \hat{a}_\phi \, \eta_0 \frac{\pi S I_0 \sin(\theta)}{\lambda^2} \frac{e^{-jkr}}{r} \text{ and } \overline{H} = -\hat{a}_\theta \frac{\pi S I_0 \sin(\theta)}{\lambda^2} \frac{e^{-jkr}}{r}$$

where S is the surface area of the loop and I_0 is the input current. Assuming the loop is lossless, has an input current of $20\angle 0°$ A, and a radius of $a = \lambda/50$:

1) Find functions for $\overline{E}$ (V/m) and $\overline{H}$ (A/m) in terms of k, r, and θ.

$$\overline{E} = \hat{a}_\phi \, 376.7303 \frac{\pi[\pi(\lambda/50)^2](20\angle 0)\sin(\theta)}{\lambda^2} \frac{e^{-jkr}}{r} \quad \Rightarrow \quad \underline{\overline{E} = \hat{a}_\phi \, 29.74543\sin(\theta)\frac{e^{-jkr}}{r} \text{ (V/m)}}$$

$$\overline{H} = -\hat{a}_\theta \frac{\pi[\pi(\lambda/50)^2](20\angle 0)\sin(\theta)}{\lambda^2} \frac{e^{-jkr}}{r} \quad \Rightarrow \quad \underline{\overline{H} = -\hat{a}_\theta \, 0.0789568\sin(\theta)\frac{e^{-jkr}}{r} \text{ (A/m)}}$$

2) At $r = 10$ m, find a function for the magnitude of the electric field $|\overline{E}|$. Also, find maximum $|\overline{E}|$ (V/m <u>and</u> dBVm).

$$|\overline{E}| = \sqrt{\overline{E}\bullet\overline{E}^*} = \sqrt{\hat{a}_\phi \, 29.7454\sin(\theta)\frac{e^{-jk10}}{10} \bullet \hat{a}_\phi \, 29.7454\sin(\theta)\frac{e^{jk10}}{10}} \quad \Rightarrow \quad \underline{|\overline{E}| = 2.9745\sin(\theta) \text{ (V/m)}}$$

The maximum electric field occurs at $\theta = 90° = \pi/2 \Rightarrow \underline{|\overline{E}|_{max} = 2.9745 \text{ (V/m)} = 9.4684 \text{ dBVm}}$

3) Plot polar radiation patterns for $|\overline{E}|$ (V/m <u>and</u> dBVm w/ 10 to -20 dBVm scale) at $r = 10$ m.

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% EE483_583_Lab_01_Emag_rad_patts.m
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<snip>

MATLAB Command Window

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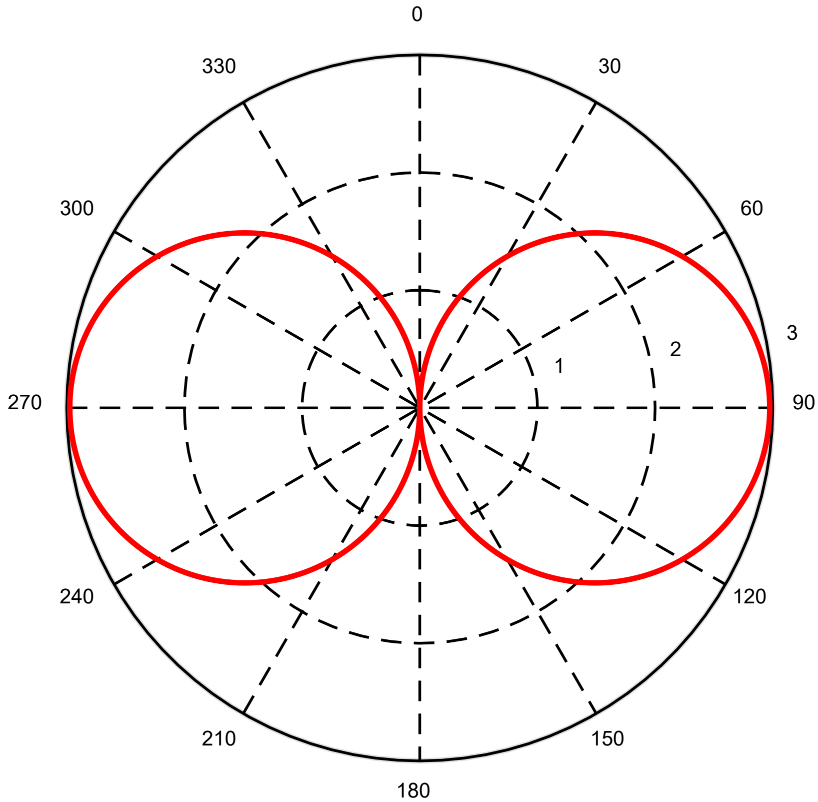
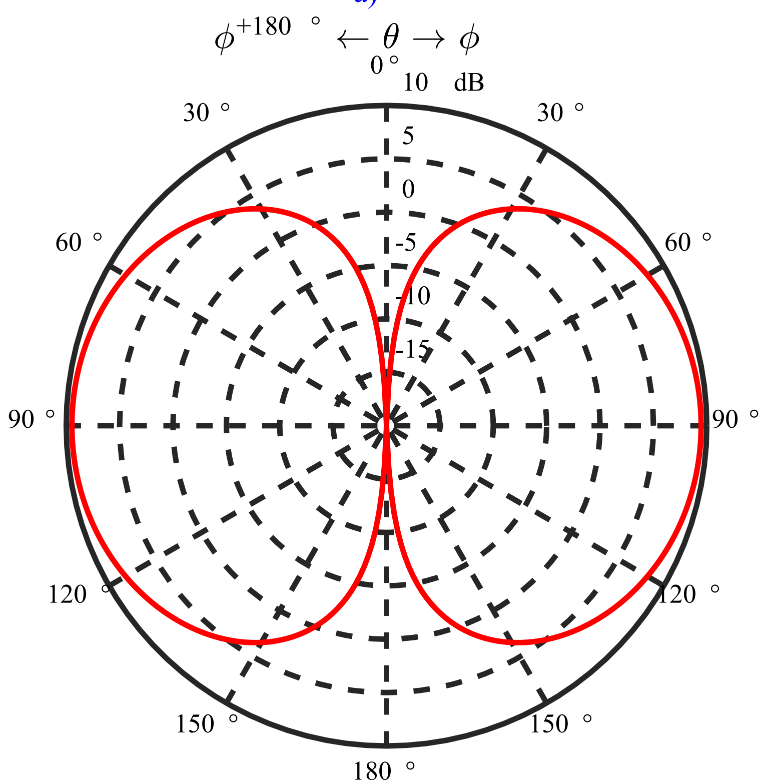


a)



b) (dBVm)

Figure 1 Polar radiation patterns for a) $|\overline{E}(r=10\,\mathrm{m})|$ (V/m) and b) $|\overline{E}(r=10\,\mathrm{m})|$ (dBVm).

4) Plot **normalized** polar radiation patterns for $|\overline{E}|$ (unitless and dB w/ 0 to -30 dB scale).

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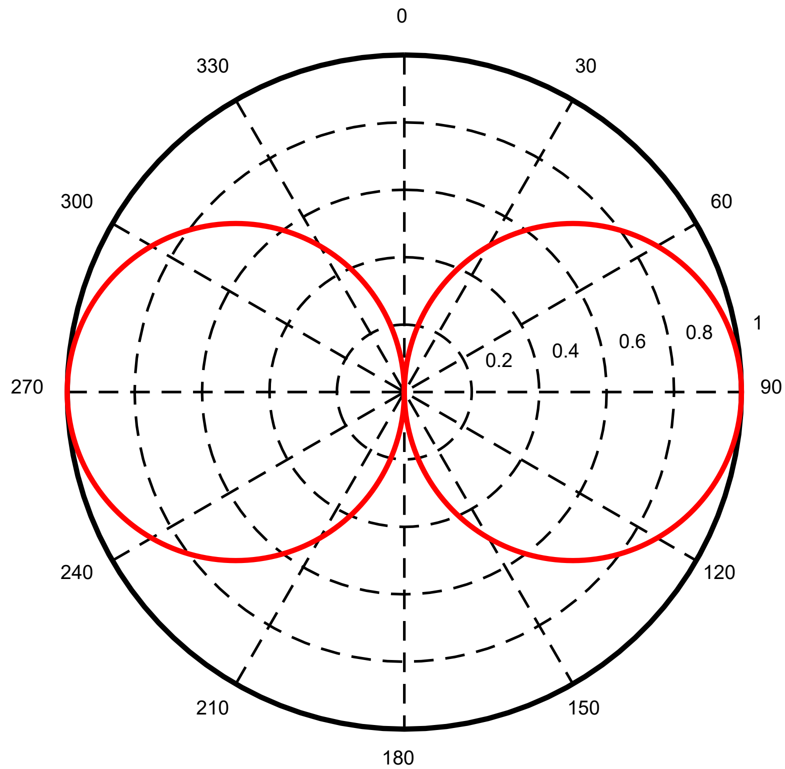
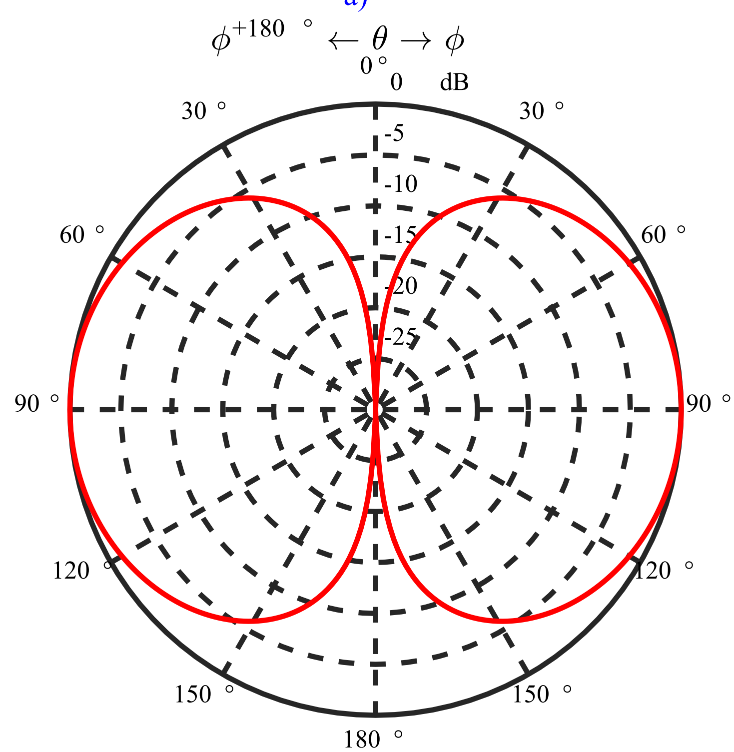


a)



b)

Figure 2 Normalized polar radiation patterns for a) $|\overline{E}(r=10\,\text{m})|$ and b) $|\overline{E}(r=10\,\text{m})|$ (dB).

5) Find function for the time-average Poynting vector $\overline{W}_{\text{rad}}$ (W/m^2). Find time-average power P_{loop} radiated by this antenna.

$$\overline{W}_{\text{rad}} = 0.5\,\text{Re}(\overline{E}\times\overline{H}^*) = 0.5\,\text{Re}\left(\hat{a}_\phi\, 29.74543\sin(\theta)\frac{e^{-jkr}}{r}\times -\hat{a}_\theta\, 0.0789568\sin(\theta)\frac{e^{jkr}}{r}\right)$$

$$= 0.5\,\text{Re}\left(\hat{a}_r\, 29.74543(0.0789568)\sin^2(\theta)\frac{e^{-jkr}e^{jkr}}{r^2}\right)$$

$$\Rightarrow \underline{\overline{W}_{\text{rad}} = \hat{a}_r \frac{1.174302\sin^2(\theta)}{r^2}\ (\text{W/m}^2)}$$

To find the time-average power radiated by the loop, integrate the time-average Poynting vector through a sphere enclosing the antenna

$$P_{\text{loop}} = \oiint_s \overline{W}_{\text{rad}} \bullet d\overline{s}_r = \int_{\phi=0}^{2\pi}\int_{\theta=0}^{\pi} \hat{a}_r \frac{1.174302\sin^2(\theta)}{r^2} \bullet \hat{a}_r\, r^2 \sin(\theta)\, d\theta\, d\phi \qquad \Rightarrow \underline{\mathbf{P_{loop} = 9.83781\ W}}$$

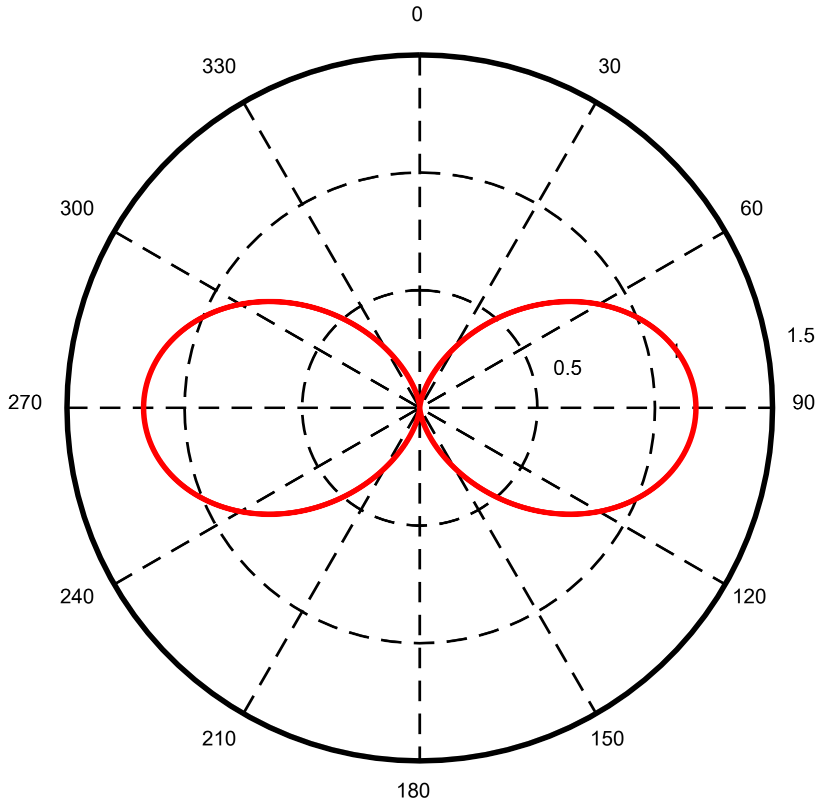
6) Find function for the radiation intensity U_{loop} of the antenna. Also, find maximum radiation intensity $U_{\text{loop,max}}$ (W/Sr <u>and</u> dBW).

$$U_{\text{loop}} = r^2 W_{\text{rad}} = r^2 \frac{1.174302\sin^2(\theta)}{r^2} \qquad \Rightarrow \underline{\mathbf{U_{loop} = 1.174302\ \sin^2\theta\ \ W/sr}}$$

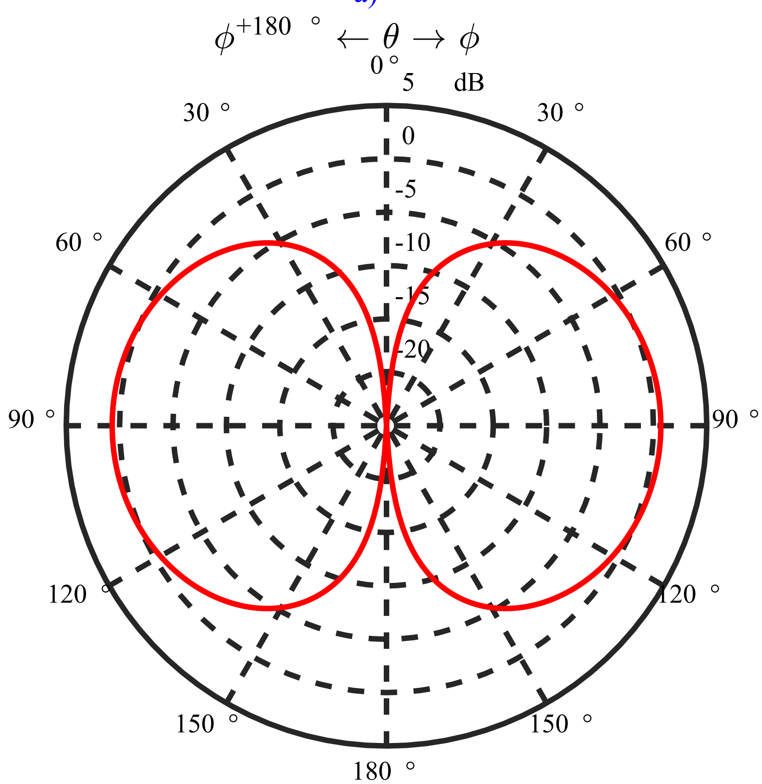
Maximum radiation intensity occurs @ $\theta = 90° = \pi/2 \Rightarrow$ **$\underline{U_{loop,max} = 1.1743\ W/sr = 0.6978\ dBW}$**

7) Plot polar radiation patterns for U_{loop} (W/Sr <u>and</u> dBW w/ 5 to -25 dBW scale).

<snip>



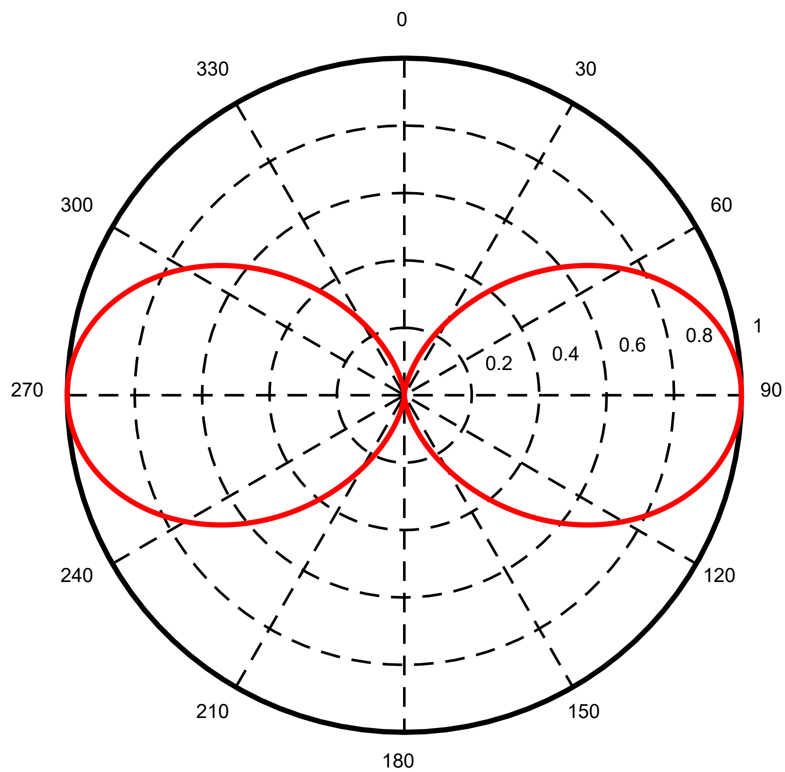
a)



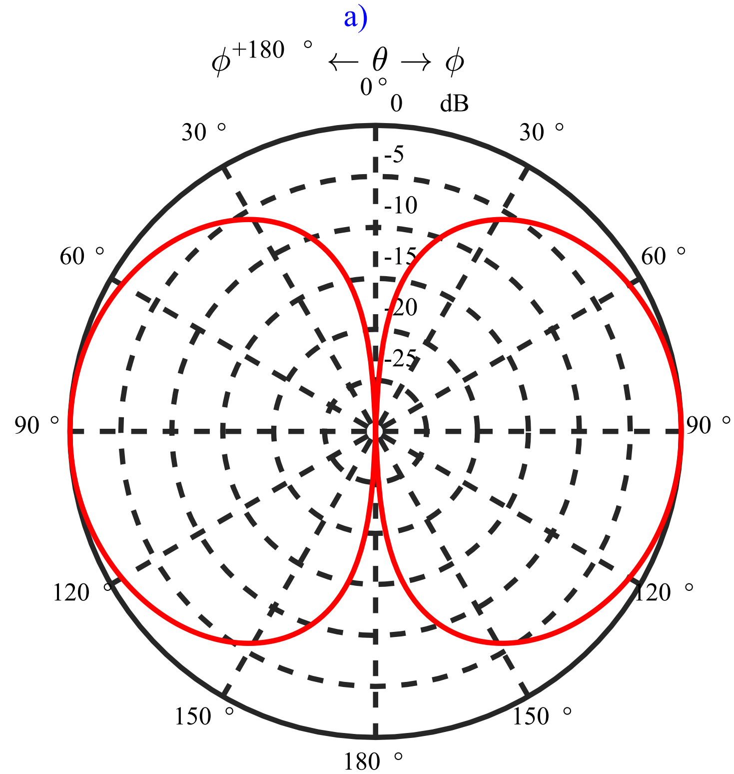
b)

Figure 3 Polar radiation patterns for a) U_{loop} (W/sr) and b) U_{loop} (dBW)

8) Plot **normalized** polar radiation patterns for the U_{loop} (unitless and dB w/ 0 to -30 dB scale).
<snip>



a)



b)

Figure 4 Normalized polar radiation patterns for a) U_{loop} and b) U_{loop} (dB)

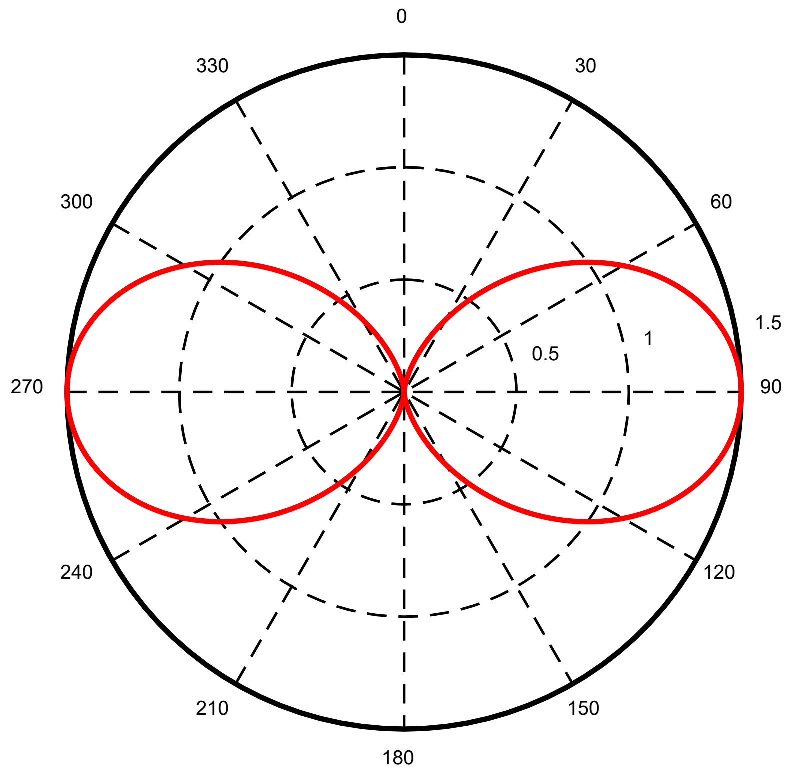
9) Find function for the directivity D_{loop} of the antenna. Also, find maximum directivity $D_{\text{loop,max}}$ (unitless and dBi).

$$D_{\text{loop}} = \frac{4\pi U_{\text{loop}}}{P_{\text{rad}}} = \frac{(4\pi)1.174302\sin^2(\theta)}{9.83781} \quad \Rightarrow \quad \mathbf{D_{loop} = 1.5\ sin^2\theta}$$

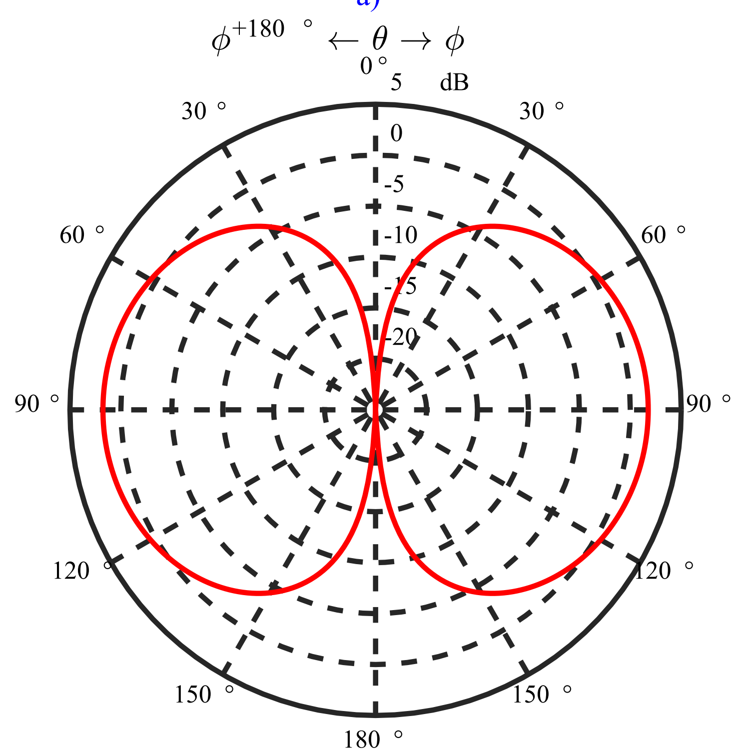
The maximum directivity occurs at $\theta = 90° = \pi/2$ $\Rightarrow$ $\mathbf{D_{loop,max} = 1.5 = 1.7609\ dBi}$

10) Plot polar radiation patterns for the D_{loop} (unitless and dBi w/ 5 to -25 dB scale).

<snip>



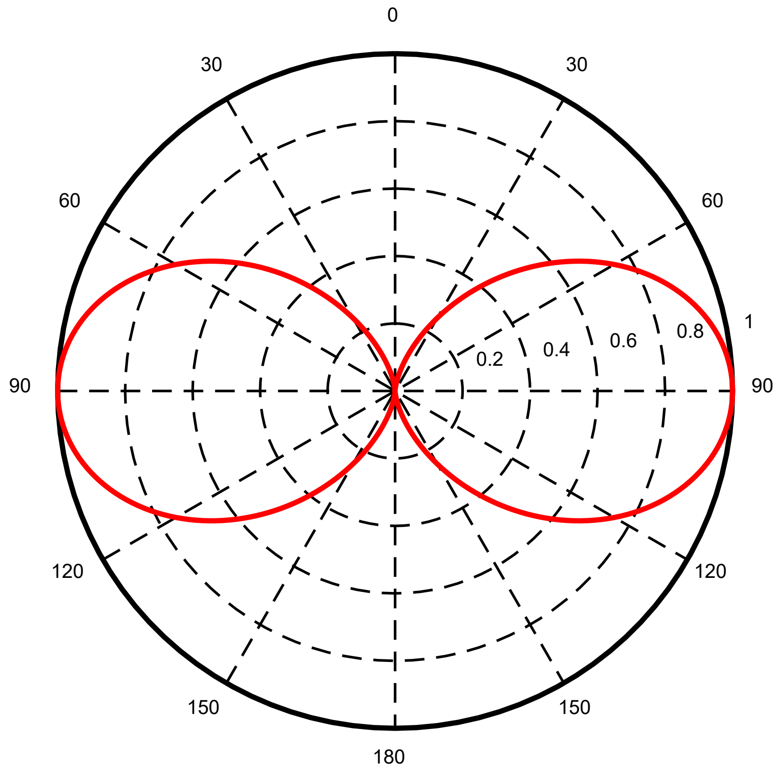
a)



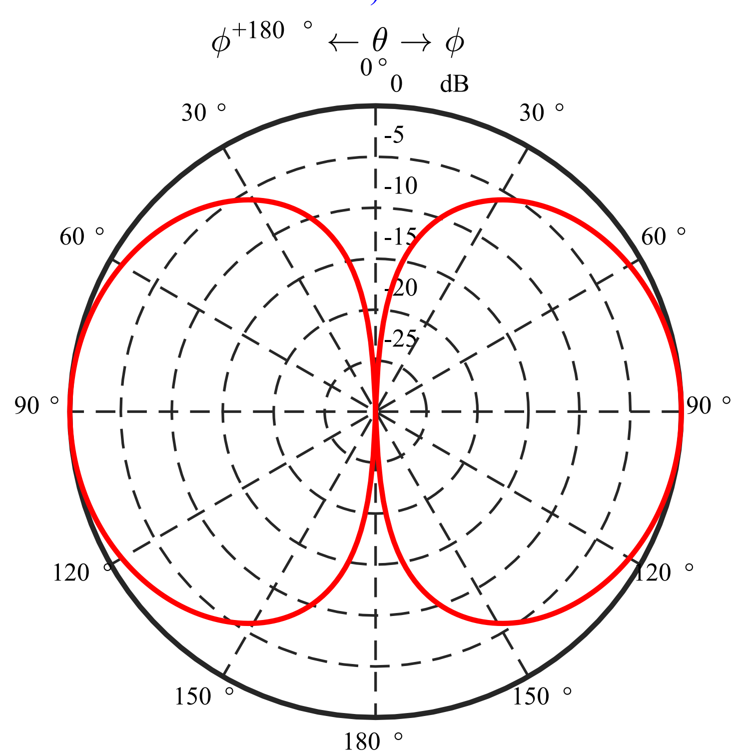
b)

Figure 5 Polar radiation patterns for a) D_{loop} (unitless) and b) D_{loop} (dBi)

11) Plot **normalized** polar radiation patterns for D_{loop} (unitless and dB w/ 0 to -30 dB scale).
<snip>



a)



b)

Figure 6 Normalized polar radiation patterns for a) D_{loop} (unitless) and b) D_{loop} (dB)

Conclusions

Compare and discuss the different radiation patterns. Which are similar? Which are identical?

- The electric field radiation patterns (Figs. 1 & 2) have the same shapes [compare a) to a) and b) to b)], adjusted to scale, as each other.
- The radiation intensity *U* radiation patterns have the same shapes [compare a) to a) and b) to b)], adjusted to scale, as each other.
- The directivity radiation *D* patterns have the same shapes [compare a) to a) and b) to b)], adjusted to scale, as each other.
- The general shape of the radiation intensity *U* (Figs. 3 & 4) and directivity *D* (Figs. 5 & 6) radiation patterns [compare a) to a) and b) to b)] are the same as they both are proportional to power.
- The normalized radiation intensity *U* and directivity *D* radiation patterns (unitless, Figs. 4a & 6a) are identical. However, the normalized electric field radiation patterns (unitless, Fig. 2a) is shaped differently.
- **All** the normalized radiation patterns in dB (Figs. 2b, 4b & 6b) are identical.

Short report is due Monday, February 2, 2026 at class.

Notes: Put all pairs of like quantity plots on a single page. All polar radiation patterns are in the elevation plane coinciding with *x-z* plane, i.e., plot with respect to θ when $\phi = 0$ and 180° (want plots to be symmetric about $\theta = 0$ or *z*-axis). Orient all polar plots to **put $\theta = 0$ at top**.

Hints:

- Consider what the MATLAB command '`view([90 -90])`' does to a polar() plot.
- U(dBW) = $10 \log_{10}[\,U/(1\text{ W})]$. $|E|$(dBVm) = $20 \log_{10}[\,|E|/(1\text{ V/m})]$.
- To normalize a quantity not in dB, find maximum value. Then, divide all values of quantity by maximum, e.g., $Q_{norm}(x) = Q(x) / Q_{max}$. Therefore, $Q_{norm}(x) \leq 1$ (unitless) & $Q_{norm}(x)$ (dB) ≤ 0.