Blast From the Past!

Final Exam

Spring 2012

Problem 5 (20 pts)

Suppose we wish to communicate between a base-station antenna and a cell-phone antenna that is located on a user's cell phone. Assume that the cell-phone antenna is modeled as a simple resonant dipole antenna. The cell phone operates at 2.0 [GHz]. The base station antenna is radiating a total power of 60 [W]. Assume that the base-station antenna is modeled as a (lossless) vertical resonant dipole antenna. The person is at a distance of $r = 2.0$ [km] from the base station.

a) Determine how much power the cell-phone antenna will deliver to a 50 [Ω] load, which models the receiver circuit inside the phone. Assume that user holds the phone so that the cell-phone antenna is vertical.

b) How would the answer change if the user holds the phone so that the cell-phone antenna is now at an angle of 45° with respect to vertical?

c) How would the answer change if the user holds the phone so that the cell-phone antenna is now horizontal?

d) How would the answer change if the cell-phone antenna is horizontal, but the base-station now radiates 60 [W] using circular polarization instead of vertical polarization? Assume that the directivity of the CP base-station antenna is still the same as it was for the vertical base-station antenna.

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$$f = 2 \ [\text{GHz}]$$

$$\left(\lambda_0 = 0.149896 \ [\text{m}]\right)$$

$$P_{\text{rad}} = 60 \ [\text{W}]$$

$$r = 2 \ [\text{km}]$$

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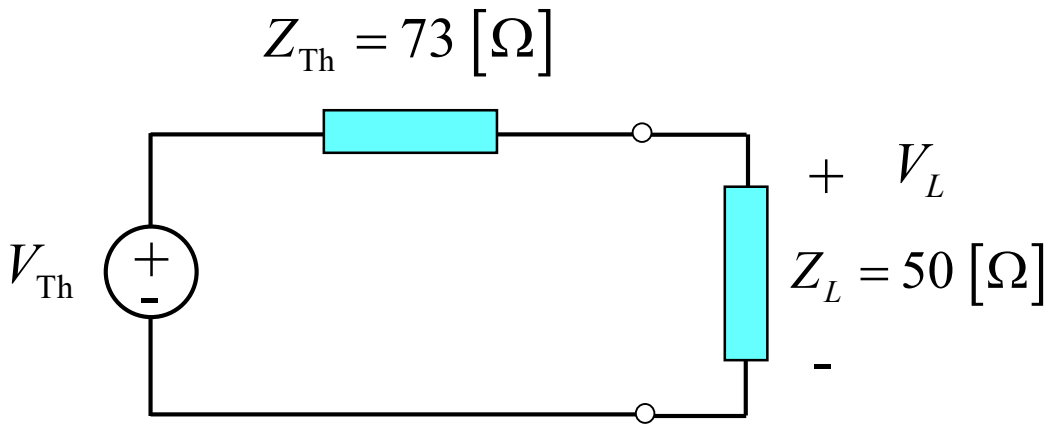
Equivalent Circuit



$P_{\text{rec}} = P_L =$ power absorbed by load

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a) Determine how much power the cell-phone antenna will deliver to a 50 [Ω] load, which models the receiver circuit inside the phone. Assume that user holds the phone so that the cell-phone antenna is vertical.

$$P_{\text{rec}} = \frac{1}{2}\frac{|V_L|^2}{R_L} = \frac{1}{2}\frac{|V_L|^2}{50}$$

where

$$V_L = V_{\text{Th}}\left(\frac{R_L}{R_L + Z_{\text{Th}}}\right) = V_{\text{Th}}\left(\frac{50}{50+73}\right)$$

$$P_{\text{rec}} = 5.56\times10^{-9}\ [\text{W}]$$

If we have a conjugate matched load ($Z_L = 73\ [\Omega]$):

$$P_L^{\text{matched}} = \frac{1}{2}\frac{|V_{\text{Th}}/2|^2}{73} = \left[\left(\frac{P_{\text{in}}}{4\pi r^2}\right)(1.643)\right]\left[1.643\frac{\lambda_0^2}{4\pi}\right]$$

G_{TX} ↓ G_{RX} ↓

$(P_{\text{in}} = P_{\text{rad}})$ ↑ P_d^{inc} ↑ A_{eff}

$$|V_{\text{Th}}| = \frac{2(1.643)\sqrt{2(73)}}{4\pi r}\lambda_0\sqrt{P_{\text{rad}}}$$

$$|V_{\text{Th}}| = 1.835\times10^{-3}\ [\text{V}]$$

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b) How would the answer change if the user holds the phone so that the cell-phone antenna is now at an angle of 45° with respect to vertical?

The received voltage changes by a factor of $\cos\left(45^{\circ}\right) = 1/\sqrt{2}$

The received power thus changes by a factor of $1/2$

$$P_{\text{rec}} = \frac{1}{2}\left(5.56\times10^{-9}\right)\ [\text{W}]$$

$$\Rightarrow \quad P_{\text{rec}} = 2.78\times10^{-9}\ [\text{W}]$$

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c) How would the answer change if the user holds the phone so that the cell-phone antenna is now horizontal?

The received voltage changes by a factor of $\cos\left(90^{o}\right)=0$

The received power thus changes by a factor of 0

$$P_{\text{rec}}=0\left(5.56\times10^{-9}\right)\ [\text{W}]$$

$$\Rightarrow \quad P_{\text{rec}}=0\ [\text{W}]$$

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d) How would the answer change if the cell-phone antenna is horizontal, but the base-station now radiates 60 [W] using circular polarization instead of vertical polarization? Assume that the directivity of the CP base-station antenna is still the same as it was for the vertical base-station antenna.

For the incident power density, we now consider only the componet of the incident wave that is horizontally polarized. This carries $1/2$ of the total incident power density.

$$P_{\text{rec}} = \frac{1}{2}\left(5.56\times10^{-9}\right)\ [\text{W}]$$

$$\Rightarrow \quad P_{\text{rec}} = 2.78\times10^{-9}\ [\text{W}]$$