EE 4382/5306 – Antenna Engineering

Test # 1 Sep. 25, 2017

Instructions:

a. **Please keep your cell phone stored in your bag or pocket. No cellphone access during the exam. If you are found using your cellphone, you will be asked to leave the room and will receive a grade of 0 in the test.**

b. **You cannot talk to your classmates during the exam. If you talk to your classmates during the exam, you will be asked to leave the room and will receive a grade of 0 in the test.**

c. **This is a closed book, closed notes, no computer exam. The formula sheet is one page, double-sided, written by you and will be handed at the end along with the test. DO NOT TEAR ANY PAGES FROM THE TEST.**

d. **Put the proper units and prefixes with your answers and use the appropriate sign conventions.**

e. **Show all work, including intermediate steps. Failure to do so will be penalized.**

f. **Write clearly the answer(s) to each question and highlight them or box them. Do all your work on the pages provided. No scrap paper is permitted. You may use the back of the paper if you run out of space.**

g. **No bathroom breaks during the exam.**

By signing this exam, you agree that the work presented here represents only your effort.

Name: KEY **Signature:** KEY

UTEP ID: KEY

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1.– Antenna Parameters – Theory (5 points each)

Fill in the blanks for the following statements.

1. For electromagnetic radiation to occur, you need to have a/an AC source and/or acceleration of charge.
   displacement
2. An antenna that has perfect electromagnetic radiation in all directions and uniform power is called isotropic radiator.
3. It describes the power properties of an antenna far away from its origin. It is usually a spatial function or a 3d surface: Far Field Pattern
   Radiation Pattern
4. A parameter that describes how much an antenna radiates in a specific direction. It is usually over isotropic: Directivity
5. Takes into account the physical losses of the antenna such as metal and dielectric losses: Antenna Efficiency
6. It is the antenna parameter that takes into account the directivity, efficiency, and mismatches into one number: Gain
7. The equation used in telecommunications engineering, that calculates the power received into an antenna as a product of power of many different parameters is called Friis Transmission Equation
8. It is the range of frequencies in which an antenna has acceptable performance relative to some metric or parameter: Bandwidth
9. Sometimes an antenna is connected to a generator and/or transmission line to which the impedance is not optimized for full power transmission. This loss is called Mismatch
10. It is the range of angles in which the power pattern for an antenna ranges or surpasses ½: HPBW

2.– Antenna Communications (30 points)

In a space radio operations base, a 30-dB gain antenna radiates (in the positive z-direction) 5 W of power at 2 GHz. It has an impedance of 40 Ω, and is connected to a transmission line with characteristic impedance of 75 Ω. The field pattern is at the beam maximum, given by $\boldsymbol{E}_t = (\hat{\boldsymbol{a}}_x + j\hat{\boldsymbol{a}}_y)F_t(\theta, \phi)$.

A satellite antenna is placed in Medium Earth Orbit, roughly 4,500 km away from the first antenna, and is used to receive waves from the transmitting antenna, placing its beam maximum along the negative z-direction. This antenna has an efficiency of 95% and its field pattern is given by $\boldsymbol{E}_r = (2\hat{\boldsymbol{a}}_x + j\hat{\boldsymbol{a}}_y)F_r(\theta, \phi)$.

As shown in the field patterns for both antennas, they are not perfectly matched in polarization.

The received power from the transmitting antenna needs to be at least 1 Femtowatt (10^{-15} W) when reaching the satellite antenna for the signal to be picked up and decoded. Determine the minimum directivity (both dB and dimensionless) that the receiving antenna needs to have that will enable it to decode the signal. Assume perfect conditions in all other unmentioned parameters.

Use Friis Transmission Formula

$$\frac{P_r}{P_t} = e_{cdt}\, e_{cdr} (1-|\Gamma_t|^2)(1-|\Gamma_r|^2)\left(\frac{\lambda}{4\pi R}\right)^2 D_t D_r |\hat{\rho}_t \cdot \hat{\rho}_r|^2$$

$P_r = 1\times10^{-15}$

$P_t = 5$

$e_{cdr} = 0.95$

$e_{cdt} = 1$

$\lambda = \frac{3\times10^8}{2\times10^9} = 0.15$

$R = 4.5\times10^6$

$\left(\frac{\lambda}{4\pi R}\right)^2 = \left(\frac{0.15}{4\pi(4.5\times10^6)}\right)^2 = 7.0362\times10^{-18}$

$D_t = 30\text{ dB} = 1000$

$D_r = \text{unknown}$

$1-|\Gamma_t|^2 = 1 - \left(\frac{Z_{in}-Z_0}{Z_{in}+Z_0}\right)^2$

$= 1 - \left(\frac{40-75}{40+75}\right)^2$

$1-|\Gamma_t|^2 = 0.9074$

$1-|\Gamma_r|^2 = 1$

$|\hat{\rho}_t \cdot \hat{\rho}_r|^2 = \left(\frac{1}{\sqrt{2}}\frac{1}{\sqrt{5}}[(1)(2)-(1)(1)]\right)^2 = \left(\frac{1}{3.1622}\right)^2 =$

$\hat{\rho}_t = \frac{1}{\sqrt{2}}(\hat{a}_x + j\hat{a}_y)$

$\hat{\rho}_r = \frac{1}{\sqrt{5}}(2\hat{a}_x + j\hat{a}_y)$

$|\hat{\rho}_t \cdot \hat{\rho}_r|^2 = 0.1$

Putting all values together we get

$$\frac{1\times10^{-15}}{5} = (1)(0.95)(0.9074)(1)(7.0362\times10^{-18})(1000)(D_r)(0.1)$$

$$2\times10^{-16} = (D_r)(6.0654\times10^{-16})$$

$$D_r = \frac{2\times10^{-16}}{6.0654\times10^{-16}} = 0.3297$$

$$\boxed{D_r = 0.3297 = -4.8183\ dB}$$

So antenna is good, no additional gain is needed, communication link is OK

3.- Radiation Pattern (20 points)

Plot in polar form the following radiation pattern. You can help yourself with the diagram provided below.

$$U(\theta) = \sin(\pi \sin\theta), \quad 0 < \theta < 2\pi$$