ATMO 489/689
Radar Meteorology

Laboratory #2

Problem set - radar design and electromagnetic wave propagation

09/19/05 (Monday section) and 09/20/05 (Tuesday section)
Due: By beginning of next lab session

Note: Be sure to show all of your work!

Questions (75 points):

1. (6 points) *Dynamic Range of a Receiver*: Radar receivers are designed to function over a range of powers. The minimum detectable signal (MDS) is the smallest power that can be detectable above the noise produced by the radar system itself. As the power going into a receiver increases, the output power increases, up to a point. If the input power is increased above some level, the receiver cannot put out any more power and it is said to be saturated.

a. (3 points) The MDS of a radar receiver is -115 dBm. What is the minimum received power (p) in mW?

b. (3 points) If the saturation power (P_{sat}) of the same radar is -25 dBm, then what is the dynamic range of the receiver?

2. (19 points) *Radar Antenna Design*:

a. (3 points) Calculate the gain (g) and logarithmic gain (G) of a circular parabolic reflector with a 1.5° beamwidth. How much does G increase or decrease if you change the beamwidth to 0.9°?

b. (6 points) Create a plot of the relative gain of the main lobe of a circular parabolic reflector that is approximated by a Gaussian shape as a function of angular distance (°) from the main lobe axis for a beamwidth of 1°, 1.5°, and 2°. For each beamwidth, what is the relative gain at 0.5° from the main lobe axis? What about at 2° from the axis?

c. (6 points) Create a plot of the beamwidth (θ, °) of a circular parabolic reflector as a function of reflector diameter (D) for K_u-band (1.8 cm), X-band (3 cm), C-band (5.5 cm), and S-band (10.7 cm) wavelengths for $0.3 \text{ m} \leq D \leq 9 \text{ m}$. You are designing a truck-based mobile radar that can support a maximum reflector diameter of 8-ft. If you wish to use the largest possible wavelength and still achieve a beamwidth close to 1° for mesoscale studies, what radar band would you utilize? What if your scientific application only required a 3° beamwidth?

d. (4 points) You wish to study tornadic circulations with radar. What is the beamwidth (°) and minimum reflector dish diameter (m) required to attain an azimuthal (and elevational) beam size of 7 m at 2 km in range from a W-band (3 mm) radar? What about a K_a-band (8.6 mm) radar?

3. (25 points) *Refractivity in the real atmosphere*

Using all mandatory- and significant-level rawinsonde data from any recent early morning (12 UTC) atmospheric sounding* with good data up to at least 6 km,

a. (3 points) Graph temperature and dewpoint temperature with respect to height (km).

b. (10 points) Calculate and graph the height dependence of the refractivity, N, both with and without the effects of water vapor. Compare and discuss.

c. (4 points) Determine the best fit exponential curve for your profile of N(h) (water vapor included). Plot the exponential fit over the data and provide the best-fit equation.

d. (4 points) A reference atmosphere has been described by the following exponential equation for the refractivity: $N(h) = 313 \exp(-0.1439h)$, where h is height. Explain any significant departures of your N profile and best-fit exponential equation from the exponential reference profile, if there are any.

e. (4 points) Using the actual profile of N(h) (with water vapor), determine a mean gradient of *n* in the lower atmosphere (i.e., first few hundred meters) and compute the effective earth's radius. How close is your value to the conventional 4/3R assumption?

4. (25 points) *Refractivity, $4/3^{rd}$ Earth radius, and beam height:*

In the late evening, you are scanning a storm at 60 km range with 10 cm radar. The beam axis is pointed at 0.5° elevation angle. Rawinsonde data show a strong surface-based inversion layer in which both the dry-bulb and dew point temperatures vary nearly linearly between the two data levels shown in Table 1.

Table 1.

	P (mb)	h (m) MSL	T (°C)	T_d (°C)	e or P_w (mb)	N
Surface	970	450	26	20		
	900	1000	28	11		

a. (8 points) Calculate e, the vapor pressure of moist air and then the refractivity, N, for each level.

b. (5 points) Determine the actual height of the beam axis above the earth at the storm.

c. (6 points) Compare the height calculated in (b) to the height calculated by assuming a 4/3-earth radius model. Briefly discuss your result.

d. (6 points) Compare the height calculated in (b) and (c) to the height calculated by making no correction for refractive index effects. Again, briefly discuss.