PROBLEM SET 2
ECE 713 Spring Quarter 2008

Assigned: April 7th
Quiz: April 16th

Instructor: Joel Johnson

Problem 1

A radio astronomy system observes a quasar with brightness temperature 10^{18} K. The quasar has a radius of 1.5×10^9 km and is 5×10^{21} km away, so that it appears to be a very small circular source to our observing antenna. Our 1 GHz antenna has a 35 dBi directivity, and is oriented so that the quasar is at the pattern maximum.

(a) Find the amount of solid angle subtended by the quasar when observed from our antenna.
(b) Calculate the antenna temperature due to the quasar assuming a lossless antenna and that the brightness temperature everywhere else is zero.
(c) If our system has a bandwidth of 10 kHz, how much noise power is delivered to the receiver from the quasar?
(d) Calculate the noise power delivered if the antenna has a 99% efficiency and a physical temperature of 290 K.
(e) Suggest a few ways for improving our system's ability to observe this quasar.

Problem 2

Given all the recent excitement about satellite PCS (personal communication systems), you and some fellow students decide to start a company. Knowing that your satellite can have higher gain antennas if the frequency is higher, you decide to design your system for 94 GHz. To try and minimize all expenses, you make the satellite transmitter power small (10 Watts), the satellite and personal antenna maximum gains small for this frequency (64 dBi and 10 dBi respectively), operate your satellites in an equatorial geostationary orbit (35,900 km high) above 60 degrees W longitude, and use a relatively low performance receiver (F=10). Let's assume we use circular polarization, a 20 kHz bandwidth for one channel (audio plus maybe some control information), and our signal processing methods require a 10 dB signal to noise ratio to function.

(a) Find the look angles to the satellite from Columbus, OH (approx 40 deg N latitude, 82 deg W longitude).

(b) Assuming an impedance and polarization matched system and properly oriented antennas, and neglecting atmospheric and rain losses, calculate the power received at the Earth station.

(c) Is our 10 dB S/N ratio met in part (b)? Assume the receiver operates at 290 K, and neglect any external noise or interference effects.

(d) Now include the effects of atmospheric gas attenuation at 94 GHz from sea level on the slant path angle you found in part (a). Do we still meet the S/N ratio requirements?

(e) Discuss rain attenuation for this system. How practical is 94 GHz for satellite PCS?

Problem 3

Use the same parameters as problem 2 for a satellite communications system, but change the frequency to 15 GHz (Ku band).

(a) Calculate the power received neglecting atmospheric and rain losses as in problem 2 (b).
(b) Calculate the power received including atmospheric losses as in problem 2 (d).
(c) Assuming a rain rate of 40 mm/hr, find the total attenuation using the Crane and Lin models. Do we still meet S/N ratio requirements?
(d) How many hours per year should we expect to observe the fade of part (c)? Compare results using the Rice-Holmberg model with beta=0.125 and M=1000 and region D2 in the Crane model.

Problem 4

A plane wave with $\underline{\bar{E}}^{inc} = (2\hat{x} + \hat{y} + 2\hat{z})e^{-j2\pi(x-z)}$ V/m is incident from a lossless, non-magnetic medium with $\varepsilon = 5\varepsilon_0$ onto a planar boundary in the xy plane with free space.

(a) Find θ_i and the frequency.

(b) Find $\underline{k}_z^{trans}$.

(c) Write the reflected electric field, $\underline{\bar{E}}^{ref}$, including numerical values for field amplitude.

(d) Write the transmitted magnetic field, $\underline{\bar{H}}^{trans}$, including numerical values for field amplitude.

(e) If a receiver in the free space region receives all the transmitted power in a 1 square meter area and requires 10^{-6} Watts in order to function, how far away from the boundary can the receiver be moved and still function? Assume that $\langle \bar{S}(t) \rangle = \hat{x}\frac{10}{\eta_0}e^{-2Im\{\underline{k}_z^{trans}\}z}$ W/m^2 in the transmitted region.

Problem 5

The references we have been using in our study of rain attenuation are somewhat dated. Try to find at least one more recent journal paper on the subject of rain attenuation and provide the bibliographical reference. Journals you may want to search include Radio Science, IEEE Trans. on Communication Technology, and the IEEE Trans. on Geoscience and Remote Sensing, among many others. You may also want to try using the Science Citation Index, which is an index of authors with articles which reference their work. Bibliographical references for our papers are:

Rice, P. L and Holmberg, N. R, “Cumulative time statistics of surface point-rainfall rates,” IEEE Trans. Commun. Technol., vol. COM-21, no. 10, Oct. 1973
Crane, R. K., “Prediction of attenuation by rain,” IEEE Trans. Comm. Technol., 1980.
Lin, S. H., “Empirical rain attenuation model for Earth-satellite paths,” IEEE Trans. Comm. Technol., vol. 27,1979.
Yamada et al, “A prediction method for rain attenuation,” Radio Science, vol. 22, no. 6, 1987.