PROBLEM SET 2
ECE 5010 Autumn 2013

Problem 1

A radio astronomy system observes a quasar with brightness temperature $10^{18}$ K. The quasar has a radius of $1.5 \times 10^{9}$ km and is $5 \times 10^{21}$ 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) Find the specific attenuation for vertical polarization at this frequency and elevation angle for rain rate 40 mm/hr.
(d) Using the ITU-R model, how many hours per year would the system be expected to fail (vertical polarization) in Columbus, OH? In Miami, FL?