ECEN 5533 DESIGN PROJECT #1 (70 Points)

In order to better respond to future emergencies, the Oregon Emergency Response Team (OERT) has decided to build a secure analog Cellular Telephone Network to cover the State of Oregon, and has recently requested bids.

Your employer, MegaMoron Communications Inc., the world's premier communications design company, has decided to submit a proposal. As an esteemed member of the technical staff, you have been requested to determine the specifications for a portion of the system.

Specific tasks include:

-**Design** a one way **analog RF link** from a user's mobile handset to an antenna atop a radio base station tower.

-Move the signal from the top of each base station tower to a junction box at the bottom of each tower. **Specify receiver and cable configuration** to accomplish this.

-**Specify** recommended **number, location, and height of cellular towers.**

Preliminary analysis has revealed the following:

-Use analog Free Space Link Equation (#9 of handout) to estimate received power.

-Use 'cue ball' earth model to estimate communication distance as a function of antenna heights, i.e. Radio Horizon (Km) = $4(h_t \text{ meters})^{0.5} + 4(h_r \text{ meters})^{0.5}$

-Transmitter antenna height = 2 meters

-Receiver antenna height depends on the size of the towers built.

-Maximum distance depends on the number of towers you chose to erect and where you place them. The area that must be covered consists of the State of Oregon, which we will approximate as a vertically flat rectangle. This state is 595 Km long in the east-west direction, and 485 Km long in the north-south direction. *Use the worst case antenna-to-relay tower distance in your design calculations.*

-All tower configurations should be identical.

-All towers must be physically located in the state of Oregon.

-Signal noise bandwidth: 20 KHz (narrow band FM voice signal)

-Minimum acceptable signal-to-noise ratio out at the BASE of a tower: 23 dB

-Minimum acceptable receiver signal power out at the BASE of a tower: 1.2 watts

-Modulation, polarization, and other losses: 2.8 dB

-Allowable transmission center frequencies: 2.4 - 5.0 GHz

-Maximum RF power out: 25 watts (FCC Limits & battery constraints)

-The ACME antenna company has given MegaMoron a good deal on omni-directional transmitting and receiving monopole antennas. These antennas have a gain of 1.6 at 2.4 GHz, and a gain of 5.0 at 5.0 GHz. The gain increases linearly between these two frequencies. Receiver antenna gains = transmitter antenna gains.

-RF Receiver Antenna Temperature: $(293 + 6.1|\text{fc in GHz} - 3.4|^{0.83}$ degrees K. For example, a system transmitting at a center frequency of 5.0 GHz would have a receiver antenna temperature of 302.0 degrees Kelvin.

-The signal picked up by a receiving antenna at the top of a tower must be delivered to a junction box at the base of every tower. This junction box is installed in a small enclosed hut with power. The hut has room for several amplifiers if you decide to install some there. You can get the signal from the top of the tower to the base by installing a long antenna cabling run.

-Coaxial Cable Losses: L=1.19 dB per 100 meters if you move IF or base band energy over the cable. Cable loss L = 3.28 + 0.90(RF Center Frequency in GHz)$^{0.50}$ dB per 100 meters if you move RF energy over the cable. For example, if RF energy at 2.9 GHz is moved over the cable, the loss will be 4.813 dB per 100 meters.

-Amplifiers available...

...GaAs HEMT, F = 1.4 dB, G = 0-40 dB, Input Frequency = 2.4 - 5.0 GHz GHz, Output Frequency = IF or Baseband

...IC F = 12.9 dB, G=0-50 dB, Input and Output Frequencies = IF or Baseband

Remarks: The first amplifier in any receiver must be a High Electron Mobility Transistor, which will down convert the RF center frequency of the transmitted signal to a lower frequency IF or Baseband signal more suitable for inexpensive amplification. IC amps may be used thereafter.

COSTS

Base Station Receiver amplifiers

HEMT: $116*(center frequency in GHz). For example, a receiver amp with a center frequency of 2.0 GHz would cost $232.

IC: $0.52*(power gain in dB)

ANY AMPLIFIER NOT INSTALLED IN THE HUT AT THE END OF THE LONG CABLE RUN IS CONSIDERED TO BE INSTALLED OUTSIDE IN THE ELEMENTS AND COSTS THREE TIMES THE ABOVE PRICE.

Base Station Tower Cost: $114,000 + (height in meters)$^{1.77}$ x $1.65.

For example a 100 meter tower would cost $119,721.16. This cost includes the price of a receiving antenna, cabling, power, and the cost of leasing the required property. It DOES NOT include the cost of any receiver amplifiers, which must be installed at each tower location. MegaMoron mechanical engineers have assured you they can build a tower to any height $\leq$ 3,000 meters.

Mobile Transmitter Electronics Costs:

The Oregon Emergency Response Term expects an initial manufacturing run of 9,000 mobile transmitters. The cost of one transmitter can be calculated via the following equation.

$398(center frequency in GHz).

For example, a transmitter using a 2.0 GHz center frequency would cost $796. This price includes the cost of antennas.

Transmitter Battery Costs:

$43.30*(transmitter power out watts). For example, if the power out is 10 watts, the projected battery cost over the life of the project *for each transmitter* is $433

Reliability Cost:

System M (margins): Lower margins result in increased outages due to fading, weather, and/or equipment problems. A real-world system with a low initial cost and low margin would tend to be unusable more often than a system with a higher margin and more expensive initial cost. This term penalizes low margin designs that might hinder OERT's response times.

Margin Cost = $7.76M/ |Margin in dB|

For example, if the worst case Margin is 5 dB, the Margin Cost is $1,552,000.00.

Using the provided information, design a communications link from a SINGLE mobile user terminal to the nearest fixed relay tower, *using the worst case distance*. Insure your system meets specifications. You may work in two person teams if you so desire.

The low bid will be that design with the lowest cost over the life of the system. The low bid designer(s) will receive 20 extra credit points. The 2nd lowest bid designer(s) will receive 15 points, and the 3rd lowest bid designer(s) will receive 10 points. All remaining designs with cost < the average class cost will receive 5 points extra credit. Only working bids will be considered for the above. The instructor reserves the right to modify these rules in the event of a tie, and to deduct points for gross over-designs.

Each team's documentation should include

*A link analysis form such as the one below

*A block diagram of your base station tower configuration

*A map showing the locations of your base stations

*A cost form such as the one below.

Your report should clearly indicate the number and height of your towers, tower configuration, and the location of towers in the state. **Make your final report short and sweet**. *DO NOT GIVE ME A RUNNING COMMENTARY OF YOUR DERIVATION* . I will dock you points if you do so. Just show the minimum information necessary for me to understand and confirm your final design.

Treat your project as if it were proprietary corporate information, i.e. do not disseminate your design in any manner to the competition. Doing so, and getting caught, will likely get anyone involved "fired" (i.e. an F for the course).

<<<<< Link Analysis Form >>>>>

	dB	Remarks
1) Transmitter Power Out (watts)		
2) Transmitter Antenna Gain		
3) Path Loss		
4) Receiver Antenna Gain		
5) Other Losses	-2.8	
6) Margin		
7) Receiver Cabling Losses		
8) Receiver Amplifier Gain		

9) TOTAL RECEIVER SIGNAL POWER OUT *(MUST BE ≥ 1.2 dBW)*
(sum of lines 1 thru 8)

10) TOTAL RECEIVER NOISE POWER OUT

11) RECEIVER SNR AT THE OUTPUT *(MUST BE ≥ 23 dB)*

$ COST

1) Receiver amp & electronics cost

2) Receiver tower cost

3) SUBTOTAL- Cost per Receiver Tower
(Line 1 + Line 2)

4) Transmitter unit cost

5) Transmitter battery cost

6) SUBTOTAL- Cost per Transmitter
(Line 4 + Line 5)

7) Safety Margin cost

GRAND TOTAL
((number of towers)*line 3 + 9,000*(line 6)

Additional Information

Transmission Center Frequency:

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