Name Key
Name

UNIVERSITY OF UTAH
ELECTRICAL AND ENGINEERING DEPARTMENT

ECE 5960

WIRELESS TRANSMISSION SYSTEMS

MIDTERM #1

YOU MAY USE A CALCULATOR & PORTFOLIO

February 7, 2003

1. (33 points)

A hexagonal cell within a seven-cell cluster has a radius of 1 km. The cluster is allocated a frequency band of 100 MHz, and each channel is 1 MHz wide. The average user makes one 10-minute call per hour.

a. What is the load per user?

$\mu = 1$ call/60min

$H = 10$ min/call

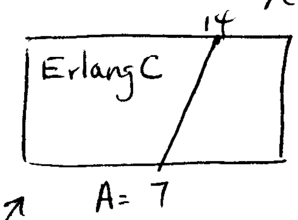
$A_\mu = \mu H = 1/6$ Erlang

.1667

b. How many users can the <u>cluster</u> support while having a 1% probability of delay?

channels/cluster = 100 mHz / 1mHz = 100

channels /cell = 100/7 = 14.28 → 14 = C



1% → .01

This must be per <u>cell</u> not per <u>cluste</u>.

$$\mu = \frac{A}{A_\mu} = \frac{7}{1/6} = 42 \text{ users/cell}$$

μ_c = 7 cells/cluster × 42 user/cell

μ_c = 294 users/cluster

c. What is the probability the call will be delayed more than 10 seconds?

$$P_r[\text{delay} > 10s] = P_r[\text{delay} > 0] \exp\left[\frac{-(C-A)t}{H}\right]$$

$$= (.01) \exp\left[-\frac{(14-7)(10\text{sec})\left(\frac{\text{min}}{60\text{sec}}\right)}{10 \text{ min/call}}\right]$$

= .008898 = 0.8898%

2. (33 points) A person is sitting inside a car talking on a cell phone. Determine how many **watts** of power that should be transmitted by the base station given:

Bandwidth = 0.5 MHz
Temperature = 294°K
Noise figure of amplifier = 2 dB
Required S/N = 10 dB
Power lost in body = 50%
Reflection coefficient at car roof = 1/3
Mobile antenna is a dipole.
Base station antenna has a gain of 6 dBd
Loss in base station cable = 2 dB
Mobile can transmit 0.6 W of power

Show all of your work.

Power = ________________ Watts

PROBLEM 2

	RX Path			
	Base up	**Mobile dn**		
Noise				
Channel BW	500	500	kHz(IS136)	
Temperature	294	294	kelvin	
Boltzman	1.38E-23	1.38E-23		
Noise	2.03E-15	2.03E-15	kTB (linear)	
Noise	-1.47E+02	-1.47E+02	dB	
Noise Figure	2	2	dB	
Noise	-1.15E+02	-1.15E+02	dBm	NOISE
Losses				
Cable Length	0		ft	
Cable Loss per 100 ft	0.8		dB	
Cable Loss	2	0	dB	
Body		3	dB	
Vehicle		9.542425094	dB	
Building		0	dB	
Total Losses	2	12.54242509	dB	LOSS
Gains				
Receiver Antenna Gain	6	0	dBd	
Dipole Gain	1.64	1.64	Linear	
Receiver Antenna Gain	8.1484385	2.14843848	dB	
Receiver Diversity Gain	0			
Total Gains	8.1484385	2.14843848		GAIN
Hardware				
SNR (required for 3% BER)	10	10	dB	SNR IS136
Min Input Power	-1.11E+02	-9.45E+01	dBm	P=SNR-Gain+Loss+N
	Transmit P:ath			
	Mobile Up	**Base Dn**		
Hardware				
Transmit Power	0.6	6.00E-01	W	
Transmit Power	27.781513	2.78E+01	dBm	Pt=Pin-PL-GAIN+LOS
Losses				
Cable Length		0	ft	
Cable Loss per 100 ft		0.8	dB	
Cable Loss		2	dB	
Transmit Combiner		0		
Body	3		dB	
Vehicle	9.5424251		dB	
Building	0		dB	
Slow Fade Margin	0	0	dB	
Total Losses	12.542425	2	dB	LOSS
Gains				
Receiver Antenna Gain	0	6	dBd	
Dipole Gain	1.64	1.64	Linear	
Receiver Antenna Gain	2.1484385	8.14843848	dB	GAIN
Effective Transmitted Power	17.387526	10.75074391	dBm	Pt-LOSS+GAIN
PATH BALANCE				
Min Input Power	-1.11E+02	-9.45E+01		dBm (from above)
Max Path Loss (PL)	-1.28E+02	-1.28E+02		dB =Pin - Pt

3. (33 points)

A 0.6 W cell phone transmitter is located 1 km from the base station. The frequency is 915 MHz, and the bandwidth is 1 MHz.

$\lambda = c/f = 0.33m$

a. How much power does the base station receive according to the Friis transmission equation assuming no additional losses or gains?

$$P_r = P_t \left(\frac{\lambda}{4\pi d}\right)^2 = .408 \times 10^{-10} \; W$$

$$= -93.9 \; dB$$

$$= -63.9 \; dBm$$

b. How much power does the base station receive according to the Okumura model in a suburban area where the mobile is 1.5 m high, and the base station is 10 m high?

$$G_{hte} = 20 \log \frac{h_{te}}{200} \qquad 1000m > h_{te} > 30m$$

oops

$$= 20 \log\left(\frac{10}{2000}\right) = -26 \; dB$$

$$G_{hre} = 10 \log\left(\frac{h_{re}}{3}\right) \qquad h_{re} \leq 3m$$

$$= 10 \log\left(\frac{1.5}{3}\right) = -3 \; dB$$

$d = 1 \; km \qquad F = 915 \; MHz \qquad$ Fig 4.23

$A(f, d) \sim 18 \; dB$

Suburban

$G_{AREA} \sim 9 \; dB$

$$L_F = -10 \log\left(\frac{\lambda}{4\pi d}\right)^2 = +93.9 \; dB$$

$$L_{50} = L_F + A(f,d) - G(h_{te}) - G(h_{re}) - G_{AREA}$$

$$= +93.9 + 18 + 26 + 3 - 9 = 131.9$$

$$P_r = P_t - L_{50} = 10 \log_{10} .6 - 131.9 = \qquad 130 \; dB$$