Name Key

UNIVERSITY OF UTAH
ELECTRICAL AND ENGINEERING DEPARTMENT

ECE 5325

WIRELESS COMMUNICATION SYSTEMS

MIDTERM #1
Problem 1 = 20 points
Problem 2 = 40 points
Problem 3 = 20 points
Problem 4 = 20 points

YOU MAY USE A CALCULATOR & PORTFOLIO/NOTES but no textbook.

February 9, 2005

1. (20 points) A cellular telephone provider wants to provide service for 2 million residents, ensuring that their calls are blocked less than 1% of the time. Blocked calls are dropped. Each user makes an average of 4 calls per hour, each of which lasts 5 minutes. Each cell supports 30 channels of 10 kHz each. How many cells are needed?

GOS

H C λ

$\lambda = 4$ calls/hr $\quad H = \frac{5 \text{ min}}{60 \text{ min/Hr}} =$ length of call (hours)

$A_u = \lambda H = [redacted]33$ Erlang

$C = 30 \quad GOS = .01$

Read Erlang B chart $\quad A = 20$ Erlang

see attached chart

$u = A/A_u = 60$ users/cell

$\text{cells} = \frac{2 \times 10^6 \text{ users}}{60 \text{ users/cell}} = 33$K cells

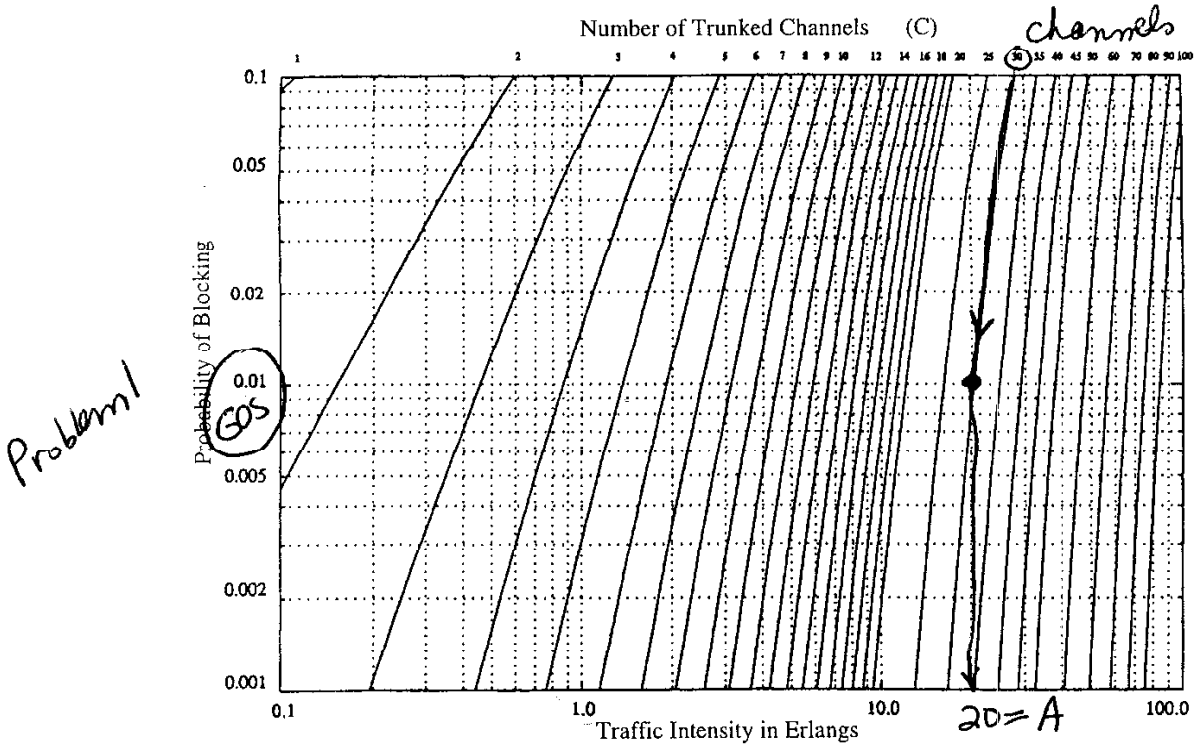

Fig. 3.6 The Erlang B chart showing the probability of blocking as functions of the number of channels and traffic intensity in Erlangs.

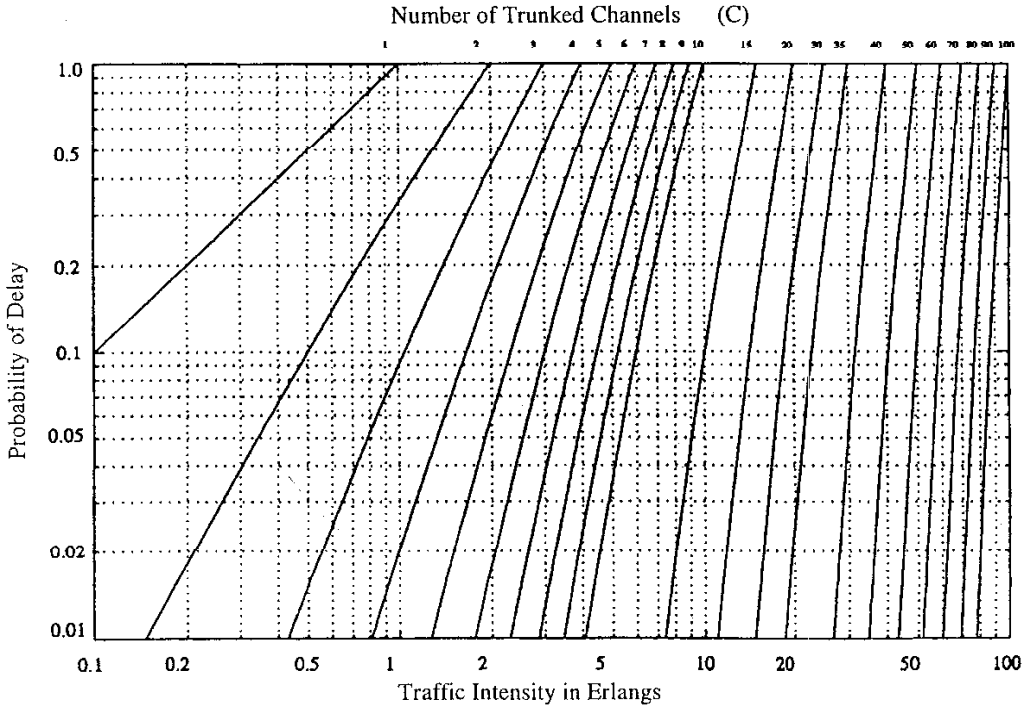

Fig. 3.7 The Erlang C chart showing the probability of a call being delayed as a function of the number of channels and traffic intensity in Erlangs.

2. (40 points) A person is talking on a cell phone. Given:

Bandwidth = 0.2 MHz $B = 0.2 \times 10^6$ Hz

Temperature = 294°K $= T$

Noise figure of amplifier = 3 dB $= NF_{dB}$

Required S/N = 15 dB

Power lost in head = 50% $= 3dB = L_{Head}$

Voltage Reflection coefficient at mobile (applies to RX and TX) = 1/20

Mobile antenna is a PIFA antenna with a gain of 3 dBi. $= G_{mobile}$

Mobile antenna is 80% power efficient (20% of the power is lost).

Base station antenna measurements:

Measurement 1:

Two identical dipole antennas (RX and TX) are placed 1 m apart.

Power received is 0.4W.

Measurement 2:

One of the dipoles (TX) and the base station antenna are placed 1m apart.

Power received is 0.8W.

The same source and receiver electronics are used in both measurements.

Mobile can transmit 0.6 W of power

Show all of your work.

(a) Determine how many **dBm** of power should be transmitted by the base station.

(b) Determine the allowable path loss.

(c) Determine how far apart the mobile and base station can be in an urban environment.

$N = 10\log_{10} kTB + 30 + NF$ (dB to dBm)

$= -118$ dBm

$L_r = \left(1 - \left|\frac{1}{20}\right|^2\right) = .011$ dB

$L_\varepsilon = 10\log(.2) = -7$ dB

this describes measurement of antenna gain relative to a dipole

$G_{Base} = 10\log\frac{0.8}{0.4} = 3$ dBd

$G_{Base} = 3$ dBd $+ 2.15$ dB $= 5.15$ dBi

$= 10\log 600 = 27.8$ dBm $= P_{T\,mobile}$

$N = NF_{dB} + 10\log_{10}(kTB) + 30$ ($\uparrow$ dB to dBm)

$= -118$ dBm

$k = 1.38 \times 10^{-23}$

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Mid I Problem 2 ECE 5325 Sp05

RX Path

Base Up	
N	−118 dBm
L_r	.01 dB
L_ε	7 dB
G_{Base}	5.15 dB
SNR	15 dB

$P_{in\ min} = SNR - G_{Base} + L + N$

$= -101$ dBm

Mobile Up	
	−118 dBm
L_{Body}	3
L_r	.01
L_ε	7
G_{mobile}	3

$P_{in\ min} = SNR - G + L + N = -95.9$ dBm

TX Path

Mobile DN

P_T	27.8 dBm
L_{Body}	3 dB
L_r	.01 dB
L_ε	7 dB
G_{mobile}	3 dB

$P_{T\,eff} = P_T - L + G$

$= 20.8$ dBm

TX Path

Base DN

$P_T = P_{in\ min} + PL - G + L$

$P_{T\,Base} = 27.8$ dBm

L_r	.01
L_ε	7
G_{Base}	5.15 dB

$PL = (P_{in\ min} - P_{T\,eff})$ ③

$= +122$ dB → **+122 dB = Path Loss**

$PL = 10n \log d$ simplest model

$d = 10^{\frac{122}{10 \cdot 3}}$ $n \sim 3$ (p139)

$d = 11.6$ km

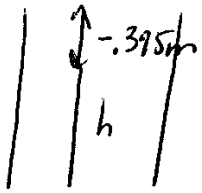
3. (20 points) Given two cell phones on either side of a 10m tall building. One phone is 1 m from the building, and the other is 2m away from the other side of the building.

(a) Compute the diffraction loss if both cell phones are on the sidewalk.
(b) What height of knife edge diffractor between the two transmitters would result in maximum power at the receiver?
(c) Sketch or describe a possible physical scenario that could represent the physical location of phones and the building in (b).

(a) $v = h\sqrt{\frac{2(d_1+d_2)}{d_1 d_2}} = 31.62$

$G_d(dB) = 20 \log\left(\frac{.225}{v}\right) = -42.96\ dB$

(b) $v = -1.25$ so $h = -0.395\ m$



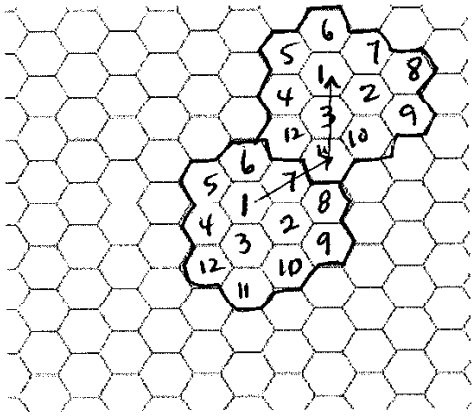
4. (20 points) Design a hexagonal cell system for a TDMA system that requires S/I of 15 dB and has a path loss coefficient is 3.

(a) Find the frequency reuse factor N = 11

(b) Can the system be built with a LARGER or SMALLER N and still work?

(c) Choose an N with integer values for i and j that will still work (depending on your answer to (b)) and sketch the frequency reuse pattern on the grid below. Clearly show your work.

(d) Your colleague suggests several ways of improving the signal to interference ratio for the system including sectoring the cells, using larger cells, splitting the cells into smaller cells, amplifying the transmitted power, using a larger frequency reuse factor N, allowing blocked calls to be dropped, and using antennas with higher gain on the mobiles. Circle all methods that will increase S/I.



$$\frac{S}{I} = \frac{\left(\frac{D}{R}\right)^n}{i_o} \qquad n = 3$$

Guess $i_o = 6$

$$D/R = \sqrt[n]{\frac{S}{I} i_o} = 5.74$$

(a) $$N = \frac{\left(\frac{D}{R}\right)^2}{3} = 11.0064$$

(b) Go up to nearest convenient integer

$N = 12$ → Same as Homework

Check is $i_o = 6$ OK? yes

$i = j = 2$

(c) To improve $\frac{S}{I}$

either reduce i_o

or increase D/R