Sample midterm #3

EE 276 Midterm, Spring 1996

(60 points total)

State any approximations you use and note why they are justified for your application.

Note attached table of Q( ) function.

1\. 10 pts

A mobile communications set is moving in a multipath environment having many propagation paths restricted to a horizontal plane and uniformly distributed in angle-of-arrival around omnidirectional receiving antennas. The set has two receivers connected to two dipole antennas oriented vertically. The receivers each have a threshold sensitivity at their inputs due to thermal noise of -110 dBm at a specified minimum BER with no fading, i.e. an input signal power of -110 dBm into the front end of each receiver will produce the specified BER at the output of each receiver with no fading. Assume no interference. The receiver outputs are connected to a two branch selection diversity combiner. The dipole receiving antennas are spaced 0.88 wavelengths horizontally.

If the fading signal received by each receiver (i.e. each branch) over many wavelengths of travel has a median of -102 dBm, what is the probability of outage of the output of the two branch diversity combiner over the many wavelengths of travel. Outage occurs when the received signal is below the thermal noise threshold sensitivity value. Explain in a few sentences how you arrived at your answer.

2\. 15 pts

Consider a 900 MHz personal communications receiver connected to a half-wave length dipole antenna in an inside room within a large multi-story building. Assume antenna and receiver input impedances are matched. The receiver front end amplifier has a noise figure of 6 dB and uses a synchronous detector and matched filter to demodulate a 4-QAM digital received signal having a bit rate, r_b, of 20 kilobits/sec. Assume perfect carrier and bit timing recovery. Assume no co-channel interference, no multipath delay spread (ISI), and no signal level variation.

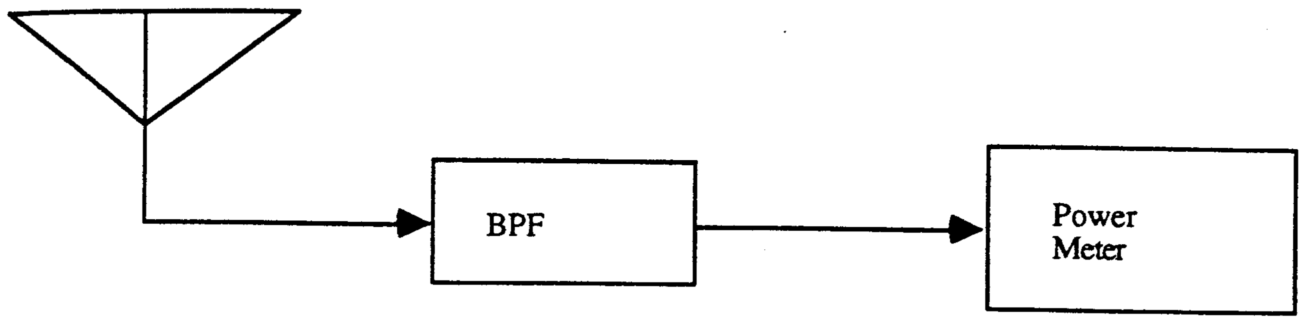
What total received signal power in dBm at the input to the receiver front end amplifier will yield a bit error ratio (BER) of 1.1×10^{-4}?

3 Consider an arrangement of base stations at the center of hexagons in an idealized hexagonal cell pattern. The base station antennas have omnidirectional patterns in the horizontal plane containing the hexagons. The point of interest is at the corner of a hexagon at maximum distance from three base stations. At the point of interest, the downlink signal power received from the serving base station is proportional to R^{-n} where R is the distance from the corner point to the base station at the center of the hexagon. The co-channel interference is proportional to D^{-n} where D is the average distance from the point to the 6 nearest co-channel base stations. You are considering two different systems. One system has no forward error correction (FEC) coding and requires a signal-to-interference ratio (S/I) of 12 dB for the radio links to provide acceptable operation. (Assume no small scale multipath fading or shadow fading.) The second system includes FEC coding that requires twice the radio link bandwidth of the uncoded system, but only requires a S/I of 6 dB for acceptable operation. Which system makes the most efficient use of the radio spectrum in terms of number of channels per base station, i.e. per cell, if the propagation exponent n=4? Show your calculations and explain the result in a few sentences.

15 pts

4. A mobile user is moving in an environment in which signal energy arrives uniformly distributed in angle-of-arrival in a horizontal plane at an omnidirectional antenna having unity gain in the horizontal plane. The following receiver is used to measure power received from a sinusoidal transmission (unmodulated carrier) of 900 MHz.

20 pts

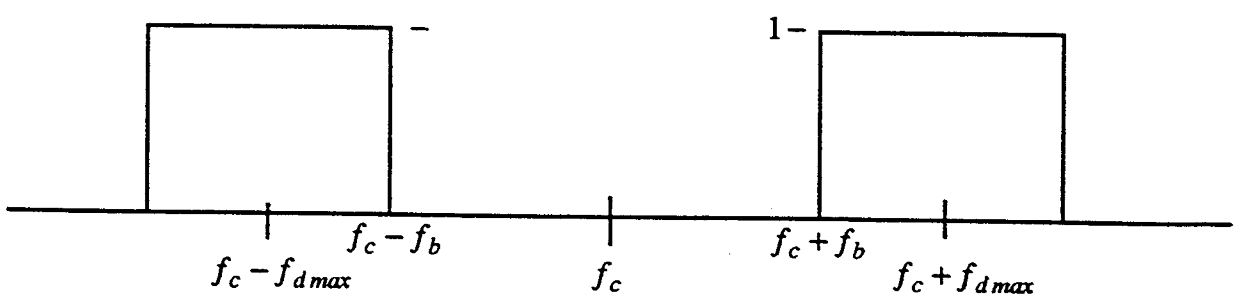


For parts a) and b) below, the unity gain ideal rectangular BPF is centered at f_c=900 MHz and passes frequencies $f_c - f_a < f < f_c + f_a$. The cutoff frequency, f_a, is chosen so that when the user is moving at speed v_0, the maximum Doppler shift, f_{dmax}, is $\frac{1}{2} f_a$. The power received at the antenna output before the BPF is P.

a) If the user is moving at a speed $2v_0$, what is the average power at the output of the BPF in terms of P?

b) If the user is moving at a speed of $4v_0$, what is the average power at the output of the BPF in terms of P?

c) Replace the BPF with a filter having the following $|H(f)|$ for f>0



where $f_{d\,max}$ is the maximum Doppler shift for motion at speed $4v_0$. Find f_b in terms of $f_{d\,max}$ such that the average power at the output of the BPF is the same as in part b).

Table D.1 Tabulation of the *Q*-function

z	$Q(z)$	z	$Q(z)$
0.0	0.50000	2.0	0.02275
0.1	0.46017	2.1	0.01786
0.2	0.42074	2.2	0.01390
0.3	0.38209	2.3	0.01072
0.4	0.34458	2.4	0.00820
0.5	0.30854	2.5	0.00621
0.6	0.27425	2.6	0.00466
0.7	0.24196	2.7	0.00347
0.8	0.21186	2.8	0.00256
0.9	0.18406	2.9	0.00187
1.0	0.15866	3.0	0.00135
1.1	0.13567	3.1	0.00097
1.2	0.11507	3.2	0.00069
1.3	0.09680	3.3	0.00048
1.4	0.08076	3.4	0.00034
1.5	0.06681	3.5	0.00023
1.6	0.05480	3.6	0.00016
1.7	0.04457	3.7	0.00011
1.8	0.03593	3.8	0.00007
1.9	0.02872	3.9	0.00005

0.00011

$$Q(z) = \frac{1}{2}\left[1 - erf\left(\frac{z}{\sqrt{2}}\right)\right] = \frac{1}{2}erfc\left(\frac{z}{\sqrt{2}}\right) \tag{D.11}$$

$$erfc(z) = 2Q(\sqrt{2}z) \tag{D.12}$$

$$erf(z) = 1 - 2Q(\sqrt{2}z) \tag{D.13}$$

The relationships in equations (D.11) - (D.13) are widely used in error probability computations.

$$Q(z) \triangleq \frac{1}{\sqrt{2\pi}}\int_z^{\infty} e^{-x^2/2}\,dx$$