# Midterm Exam

(Open Book)

**Problem 1 (50 points)**

For a user location in a wireless personal communications environment, the impulse response of the signal received from a base station is found to be representable as

$$h(t) = v_0 \sum_{j=1}^{N} c_j \, \delta(t - \tau_j)$$

and the signal received at the location can be represented as $f(t) \cos \omega t * h(t)$.

If $N = 2$; $c_1 = c_2 = 1$; $\tau_1 = 1\ \mu\text{sec}$; and $\tau_2 = 2\ \mu\text{sec}$,

a) Find the frequency transfer function, $H(j\omega)$ for a fixed user location $z_0$.

b) What is the spacing between nulls (i.e., between minima) in $H(j\omega)$?

c) Assume that a transmitted signal, $f(t) \cos \omega t$, can separate the path with delay $\tau_1$ from the path with delay $\tau_2$, i.e., $f(t)$ can resolve the two paths. At the user location, motion in a particular straight line, $z$, from $z_0$ results in a phase shift with respect to distance moved (i.e., a "Doppler" shift) of +1 cycle per wavelength (i.e., for $f = \frac{\omega}{2\pi} = 2$ GHz, this is 6.67 cycle/meter) for the path with $\tau_1 = 1\ \mu\text{sec}$, and a phase shift of -1 cycle per wavelength for the path with $\tau_2 = 2\ \mu\text{sec}$. What are the arrival angles, $\alpha_1$ and $\alpha_2$, with respect to the direction of motion, for the paths with delay $\tau_1$ and $\tau_2$.

d) For the condition in c) above, what is the change in the position of the nulls in $H(j\omega)$ when the user moves between two locations separated by $\lambda/4$.

e) Does this approximate a possible real personal communications environment? If so, briefly describe (less than 1 page) a situation that could yield such an impulse response and phase variation with distance.

**Problem 2 (15 points)**

A mobile radio set is driven along the circumference of a circle at a constant radius, R, from a base station in a region covered by only that one base station. From previous measurements it is known that in the environment being driven through:

a) the large scale signal variation (large scale fading) is log-normally distributed, and

b) the correlation of the large scale signal variation between two locations at a distance R from the base station becomes zero when locations are separated by 300 feet, and remains zero for greater separations.

The radio link margin provides a probability, $P[s \geq T] = 0.9$, of the signal, s, being above the threshold of acceptability, T, at any location at a distance R from the base station. Estimate the probability that the user will experience an unacceptable circuit at some time while driving a distance of 3000 feet along the circumference of the circle at a constant radius R from the base station.

**Problem 3 (35 points)**

The attached figure is a plot of 815 MHz experimental data taken in a building. Each data point represents the median of the small scale signal variations for a small area (4 ft x 4 ft). For locations where the medians are represented by the solid and open squares and circles, the small scale signal variations were approximately Rayleigh distributed. The dotted line represents free space propagation relative to the experimental data points.

You are to determine the transmitter power for an 815 MHz personal communications system to work in the building represented by the figure. From laboratory measurements you have determined that a) the receiver requires – 107 dBm to provide acceptable performance when provided with a steady signal, i.e. with no multipath fading, and b) with two branch selection diversity the performance in Rayleigh distributed multipath fading is acceptable if 98% of the time the signal level exceeds the median of the Rayleigh process.

There will be a base station on each floor (i.e., one on the 1 st floor and one on the 2 nd floor) in the center of the building so that the maximum distance from a base station is 200 feet. You are to provide complete coverage of the building based on the data in the figure.

As further requirements, the antennas will have 0 dB gain relative to isotropic antennas.