1. (25 pts total) The total length of the direct path would be $\sqrt{200^2 + 29^2} = 202$ m. Because of the symmetry, the two distances to the knife edge are $d_1 = d_2 = 101$ m, and the height $h = 29/2 = 14.5$ m. Since $f_c = 450 \times 10^6$ Hz, $\lambda = 3 \times 10^8 / 4.50 \times 10^8 = 2 / 3$ m. So

$$\nu = h \sqrt{\frac{2(d_1 + d_2)}{\lambda d_1 d_2}} = 14.5 \sqrt{\frac{2 (202)}{(2/3)(101)^2}} = 3.53.$$ 

If you used the graph in Rappaport Figure 4.14, I read about $G = -23.5$. Using Lee’s approximation, $G = 20 \log_{10} \frac{0.225}{3.33} = -23.9$.

The received power due the diffracted path is

$$P_r = P_t + G_{\text{Gains}} - G_{\text{Losses}}$$

where $P_t = 10$ dBW. There are antenna gains of 10 dB and a diffraction gain of -23.9 dB, for a total of -13.9 dB. The free space loss on the line-of-sight is $20 \log_{10} \frac{4 \pi 202}{2/3} = 71.6$ dB. So

$$P_r = 10 \text{ dBW} - 13.9 \text{ dB} - 71.6 \text{ dB} = -75.5 \text{ dBW} = -45.5 \text{ dBm}$$

2. (20 pts total) 5325-only short answer question: For a given speed, what direction of travel results in the maximum Doppler frequency? Define any variables, if used.

Answer: If the an arriving multipath wave arrives at angle $\theta_0$, then the direction of motion that will result in maximum Doppler shift is $\theta_{\text{move}} = \theta_0 + 180^\circ$. If you stated that you assume that the multipath are arriving in the line-of-sight path from a base station, then travelling towards the BS will result in the maximum Doppler shift. If you answered that maximum Doppler frequency is $\theta_{\text{move}} = \theta_0$, then this is actually the minimum Doppler frequency, since you are moving away from the arriving multipath wave.

(20 pts total) 6325-only short answer: Compare Rician ($K > 0$) and Rayleigh fading: (a) What assumptions are made about multipath in Rician channels? What assumptions are made about multipath in Rayleigh channels? (Two sentences max); (b) Which, the Rician or the Raleigh channel, requires a larger fade margin? (Two sentences max).

Answer: (a) Rician channels are assumed to have a single specular component and diffuse multipath power. Rayleigh channels have only diffuse multipath power. It is not necessary to assume anything about the angle-of-arrival of the diffuse power. (b) The Rayleigh channel requires a larger fade margin than the Rician ($K > 0$) channel.
3. (40 pts total)

(a) (15 pts) For QAM methods, \( R_b = R_s \log_2 M = \frac{B \log_2 M}{1 + \alpha} \), and we are given \( B = 30 \times 10^3 \) Hz and \( \alpha = 0.30 \). So for OQPSK, \( R_b = \frac{30 \times 10^3(2)}{1.3} = 46.1 \) kbps; for 64 QAM, \( R_b = \frac{30 \times 10^3(6)}{1.3} = 138.5 \) kbps. For binary coherent FSK, \( R_s = \frac{B}{2 + \alpha} \) so \( R_b = \frac{30 \times 10^3(1)}{2.3} = 13.0 \) kbps.

(b) (25 pts) OQPSK has the same \( P[\text{error}] \) as QPSK, so

\[
3 \times 10^{-4} = \frac{E_b}{N_0} = 0.5 \left[ Q^{-1} \left( 3 \times 10^{-4} \right) \right]^2 = 5.9
\]  

(1)

Then

\[
\frac{S}{N} = \frac{E_b R_b}{N_0 B} = 5.9 \frac{46.1}{30} = 9.05 = 9.56 \text{ dB}
\]

For binary coherent FSK (2-co-FSK in the table in Lecture 12),

\[
3 \times 10^{-4} = \frac{E_b}{N_0} = \left[ Q^{-1} \left( 3 \times 10^{-4} \right) \right]^2 = 11.8
\]  

(2)

Then

\[
\frac{S}{N} = \frac{E_b R_b}{N_0 B} = 11.8 \frac{13.0}{30} = 5.10 = 7.1 \text{ dB}
\]

For 64-QAM

\[
3 \times 10^{-4} = \frac{4}{\log_2 M} \frac{\sqrt{M - 1}}{\sqrt{M}} Q \left( \sqrt{\frac{3 \log_2 M E_b}{M - 1 N_0}} \right) = \frac{7}{12} Q \left( \sqrt{\frac{2 E_b}{7 N_0}} \right)
\]

\[
\frac{E_b}{N_0} = 3.5 \left[ Q^{-1} \left( 5.14 \times 10^{-4} \right) \right]^2 = 37.7
\]  

(3)

Then

\[
\frac{S}{N} = \frac{E_b R_b}{N_0 B} = 37.7 \frac{138.5}{30} = 174.1 = 22.4 \text{ dB}
\]

4. (15 pts) Short answer: What is the benefit of OQPSK compared to QPSK? (Two sentences max)

Answer: OQPSK is a constant-envelope modulation, which allows a transmitter to use a more efficient amplifier, such as a Class C amplifier, and thus save energy.