Introduction to Wireless and Mobile Networking

Homework 1 Report

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1. Consider the path loss only radio propagation (without shadowing and fading). Use Two-ray-ground model as the propagation model for your simulation.

   1-1. Please plot a figure with the received power of the mobile device (in dBm) as the y-axis and the distance (in meter) between the BS and the mobile device as the x-axis.

   The relationship between transmitted power P_T and received power P_R is given by

   $$P_R = P_T \times G_T \times g(d) \times 10^{x/10} \times G_R, \tag{1}$$

   where G_T is the transmitter gain, $g(d)$ is the path loss parameter, x is the shadowing variable, and G_R is the receiver gain.

   If we only consider path loss using the two-way-ground model, then $x = 0$ and

   $$g(d) = (h_t h_r)^2 / d^4, \tag{2}$$

   where h_t is the height of the transmitter from the ground, h_r is the height of the receiver from the ground, and d is the distance between the transmitter and receiver. Since we measure received power in dBm, by taking 10 times of logarithm on both sides, formula (1) becomes

   $$10 \log P_R = 10 \log P_T + 10 \log G_T + 10 \log g(d) + x + 10 \log G_R. \tag{3}$$

   Here $10 \log P_R$ and $10 \log P_T$ are all measured in dBm, while the rest of the terms are measured in dB. Figure 1 depicts the relationship between received power in dBm and distance, simulated for $d = 1 \sim 1000$ m.

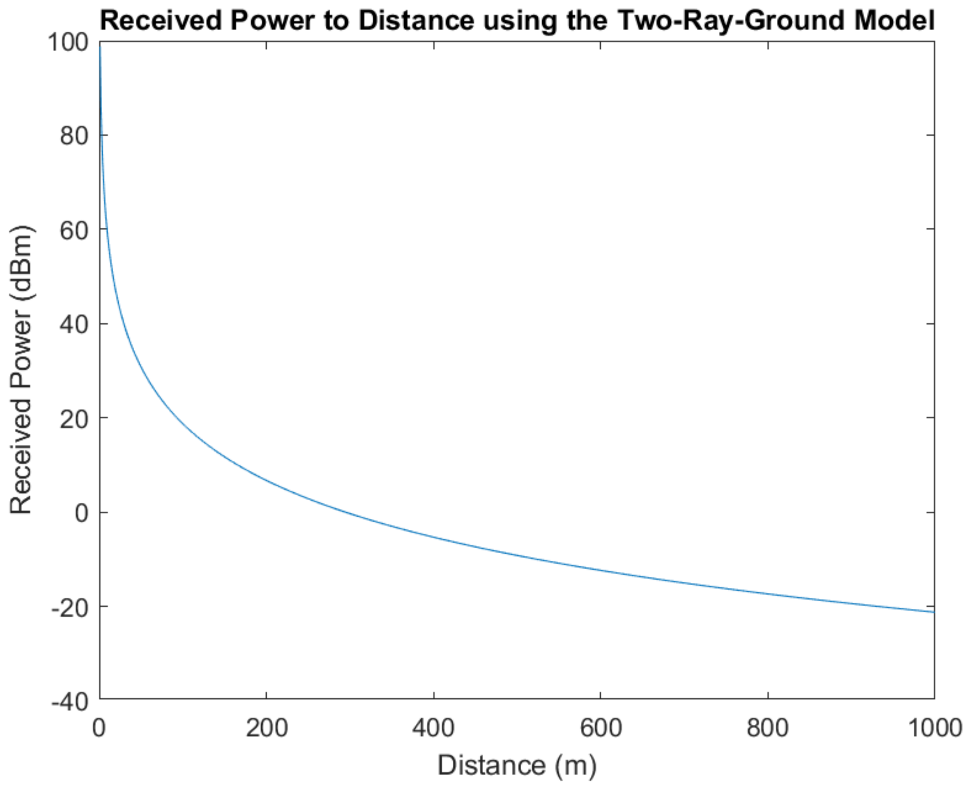

Figure 1. Received power to distance,
only path loss is considered

As shown from Figure 1, the received power decayed as the distance between the transmitter and receiver increased. This aligns with the two-ray-ground model. However, we need to be careful about the data for short distances. If there is no path loss, the maximum power received will be 33 + 14 + 14 = 61 dBm. However, when the distance between the transmitter and the receiver is very short (less than 10 meters), the two-way-model amplifies the power more than 10 times, which is not practical. Overall, two-way-ground model is suitable in normal distances.

1-2. According to 1-1, please plot a figure with **SINR** of the mobile device (in dBm) as the y-axis and the distance between the BS and the mobile device (in meter) as the x-axis.

In this question, we are not able to know the power of interference, so we only consider the thermal noise. The thermal noise power is given by

$$P_N = kTB, \tag{4}$$

where $k = 1.38 \times 10^{-23}$ J/K is Boltzmann's constant, T is absolute temperature of the environment (in Kelvin), and B is the bandwidth of the channel. By using $T = 300.15$ K and $B = 10$ MHz, we know that $P_N = 4.14 \times 10^{-14}$ W. The formula for SINR is

$$\text{SINR} = P_R/(P_I + P_N), \tag{5}$$

where P_R is the power of signal and P_I is the power of interference. We assume the latter to be zero in this question. Figure 2 shows the relationship between SINR and distance. Similar to Figure 1, as the distance increases, the received power declines, therefore SINR decreases.

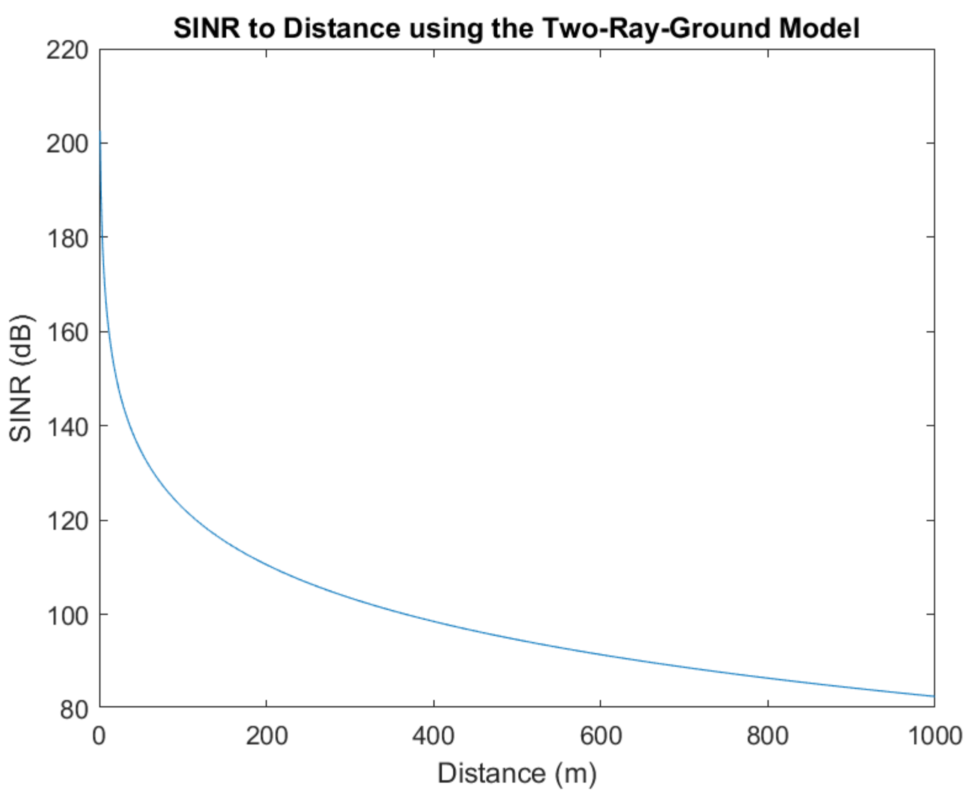

Figure 2. SINR to distance, only path loss is considered

2. Consider both the **path loss** and **shadowing** (without fading). Apply log-normal shadowing to model the shadowing effect. The path loss model should be the same as 1. Please set $\sigma = 6$ dB in the simulation.

   2-1. Please plot a figure with the received power of the mobile device (in dB) as the y-axis and the distance (in meter) between the BS and the mobile device as the x-axis.

   In this question, x is a Gaussian(0, 6) random variable, which is not necessarily zero. When the signal propagates in the space, more energy will be lost due to different environmental conditions. Therefore, in each iteration of the for loop (Line 47 ~ 51 in the file), x is chosen randomly in order to simulate the effect of the environment. The result is illustrated in Figure 3.

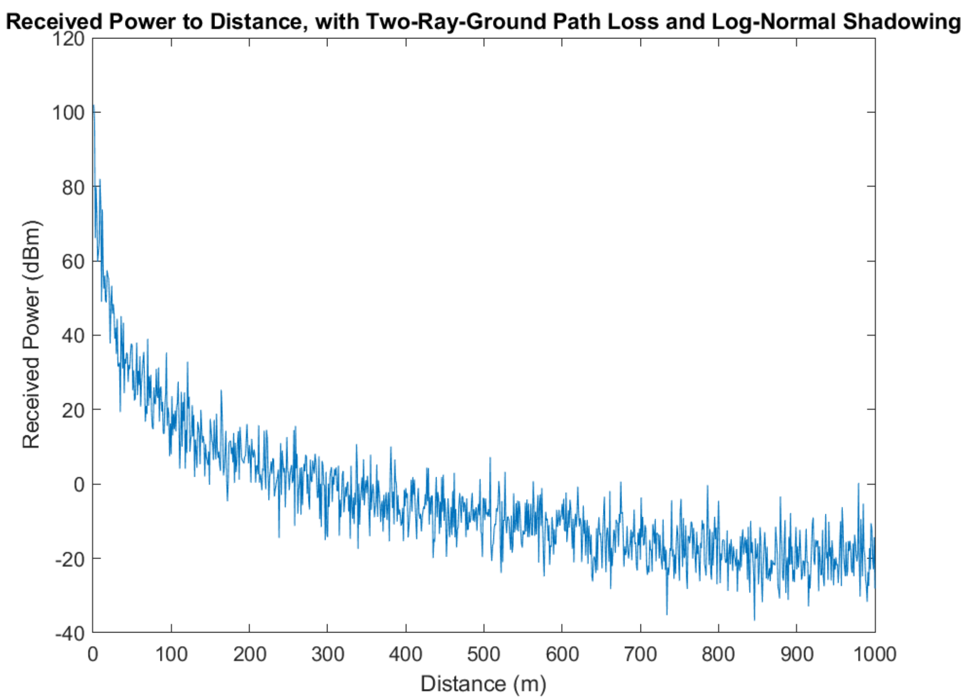

Figure 3. Received power to distance, both path loss and shadowing considered

   Overall, the received power decreases with increasing distance, but there are more spindles in the plot. The signal is sometimes stronger, sometimes weaker. We use probability to cover the complex mechanisms in the environment, and this curve is the result of randomness.

2-2. According to 2-1, please plot a figure with SINR of the mobile device (in dB) as the y-axis and the distance between the BS and the mobile device (in meter) as the x-axis.

The result is similar in 1-2. The only difference is that the curve is not smooth. Figure 4 shows the relationship between SINR and distance.

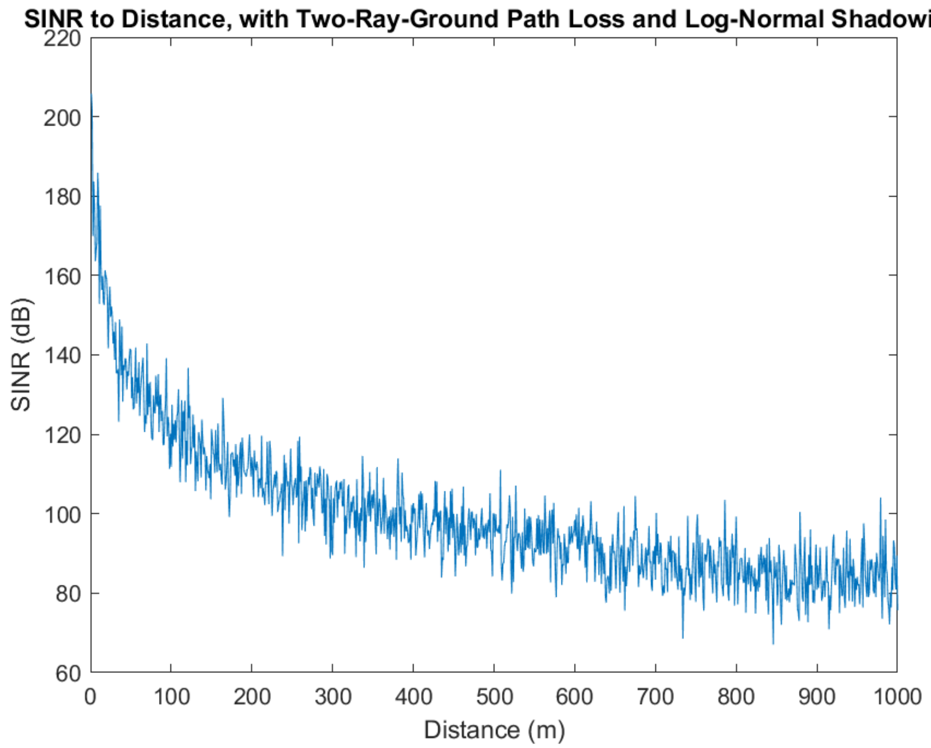

Figure 4. SINR to distance, both path loss and shadowing considered

As Figure 4 shows, the SINR decreases with distance because the received power drops.