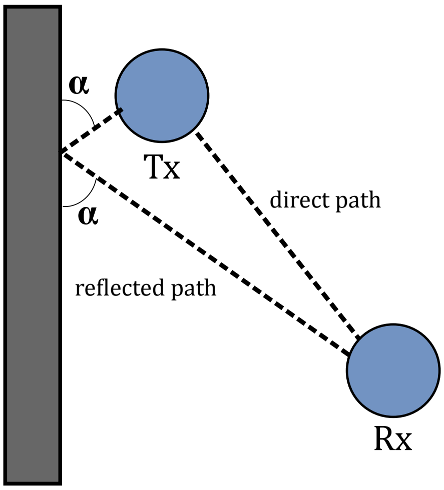
The University of Queensland
School of Information Technology & Electrical Engineering

COMS3100/7100 Introduction to Communications
Semester 1, 2011

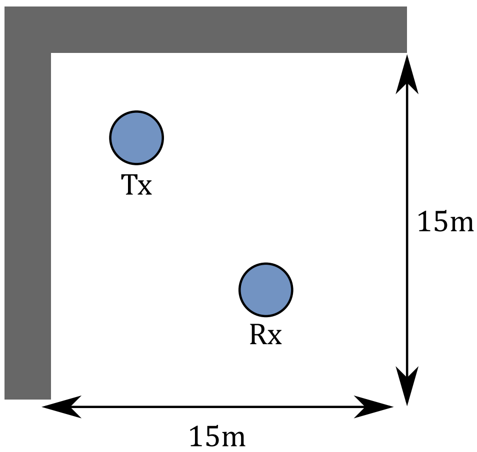
Assignment 1

Due date: 5pm, Thursday, 24th March.
Where to submit: through the Faculty of EAIT (Hawken Building 50) assignment chute.
Note: All assignments require a cover sheet (available from http://www.eng.uq.edu.au/courses.asp)

This assignment counts 5% towards your final mark for COMS3100/7100.



(a) Single reflection



(b) Full scenario

Figure 1: Illustration of multipath for this assignment.

Question 1: Multipath and Mobility in Wireless Communications (6 marks)

In wireless communications, it is common that the signal experiences *multipath distortion* between transmitter (Tx) and receiver (Rx). As illustrated in Fig. 1(a), the signal may travel not only in a direct path ('line of sight') between Tx and Rx, but also may take an indirect path, for example, by reflection off other objects in the environment. In the scenario depicted in Fig. 1(a), if the transmitter transmits the signal $x(t)$ then the receiver receives

$$y(t) = L(d_1)x\left(t - \frac{d_1}{c}\right) - \frac{1}{2}L(d_2)x\left(t - \frac{d_2}{c}\right) \qquad (1)$$

where d_1 and d_2 are the path lengths of the direct and indirect paths, respectively, and c is the speed of light. Here, we assume that reflections cause both a 50% loss in signal, and a polarity inversion. Additionally, the signal is attenuated due to distance, with the function $L(d) = \frac{1}{d}$.[1]

(a) Complete the equation in (1), by substituting the path lengths.

(b) Obtain the impulse response $h(t)$ of this wireless channel depicted in Fig. 1(a) (as a system).

(c) Derive the frequency response, $H(f)$.

(d) Write a program (eg MATLAB) to plot the magnitude response in decibels for given positions of Tx and Rx over the frequency range from DC to 3 GHz. *Plot* this output.

(e) Consider a transmitter fixed at the position x=2 m, y=2 m, and a receiver moving along a line from x=2 m, y=4 m towards the transmitter to x=2 m, y=3 m. *Plot* the magnitude response $H(f)$ for a frequency of your choice (between DC and 3 GHz), for each position of the receiver.

(f) Comment on what happens to the received signal strength relative to frequency and relate this to the wavelength (NOTE: $f = \frac{c}{\lambda}$).

Question 2: More complex multi-path environments (4 marks)

Now consider the scenario in Fig. 1(b). The transmitter and receiver are located in a 15 m × 15 m square which has reflecting walls on two adjacent sides.

(a) Draw a diagram that illustrates the four paths that exist in this scenario.

(b) Write the equation corresponding to (1), relating it to your diagram.

(c) Using the same transmitter location, and receiver path as in Question 1, generate the magnitude response $H(f)$ for the same frequency as previously but with the improved channel model.

Question 3: Equalization and Capacity (5 marks)

In communication systems, if a single carrier is used, frequency flat channel responses are preferred. To do this, a channel equalizer is used.

(a) Based on the frequency response in Q1 and Q2, extend the program designed in Q1(d) to design an equalizer for the channel response.

(b) Plot the magnitude response of the received signal before and after the equalizer.

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[1] We are using a very simple model for wireless propagation here (no noise), but taking into account the most important aspects of time delay and attenuation due to distance.

(c) Considering the system in Q2(c) with the receiver fixed at x=2 m, y=4 m, a signal of bandwidth 20 MHz, centre frequency of 2420 MHz, and signal power 10 dBm is sent through the channel. Assuming a fixed noise power of -20 dBm, work out the capacity of this system. Calculate the maximum theoretical capacity of this system (using Shannon's Limit). (HINT: work out the power spectral density of the signal first).

(d) The designed equalizer could be placed at the receiver or transmitter (pre-coding). Assuming the channel response is known at both the Tx and Rx, where would it be better to implement it (in the presence of noise)? What limitations are present in both? (discuss power, capacity).