S-96.3320 Radiowave Propagation

Exam 17-March-2014

Instructions

First answer the course first part Problems 1 and 2. (Problem 1 is voluntary: it can be used to compensate the summary essay written in the fall; the better of the two will be used for grading.) You may use the materials stated in Noppa, i.e., a hardcopy of Richards's book and a print of the first part lecture notes, and a calculator.

After finishing your answer to Problems 1 and 2, raise your hand to get the attention of the exam supervisor. **Give** your **answers to Problems 1 and 2 and the printed materials** to the supervisor, who will then hand you the second part Problems 3 and 4. You may still use a calculator but no other materials.

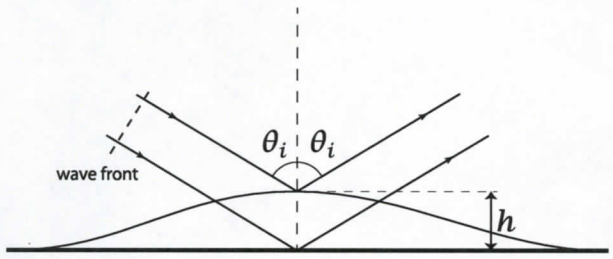
At the end of the exam, give your answers to Problems 3 and 4 to the exam supervisor, pick up your printed materials, sign the attendance list and leave the exam hall.

Open-book problems:

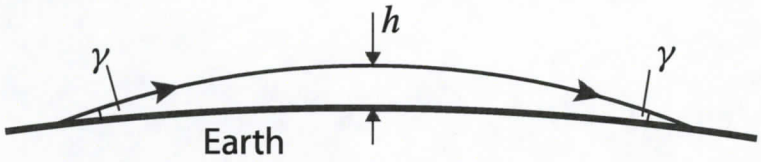
1. The textbook of this course (Radio Wave Propagation) defines a surface as smooth if its vertical height variation h obeys the criterion

$$h < \frac{\lambda}{8 \cos \theta_i}$$

where θ_i is the angle of incidence of the incoming plane wave and λ is the wavelength. Show that this criterion follows from the condition stating that the phase change $\Delta\phi$ of the field due to height variation is always smaller than 90° compared to a reflection from an ideally flat surface.



2. The value of the spherically symmetric refraction index $n(r)$ is $n(a) = n_0$ on the surface of the Earth. The refractive index diminishes linearly to value $n = 1$ which is obtained at the height $h = 5\,\text{km}$. What is the minimum value for n_0 if it is required that a ray sent at an elevation angle $\gamma = 1.5°$ from the Earth's surface is refracted back to the surface of the Earth.



[Closed-book problems]

3. We estimate energy reflected from a smooth and flat surface having a width x by illuminating the surface from a normal direction as illustrated in Fig. 1. We assume that the transmit and receive antennas are co-located at a location where the distance normal to the surface is d.
   A) Define Fresnel zones using mathematical expressions. Provide physical meaning of the Fresnel zones. We use a symbol λ to denote wavelength of a sinusoidal radio signal.
   B) We estimate the energy reflected from the surface using ray-optics approximation. Derive a maximum possible separation distance d_{max} between the surface and the antennas to obtain a valid estimate.
   C) Give grounds why the estimation may be invalid when $d > d_{max}$.
   D) For a radio frequency signal of 100 MHz and 1 GHz, estimate d_{max} for a surface with x = 2.0 m.

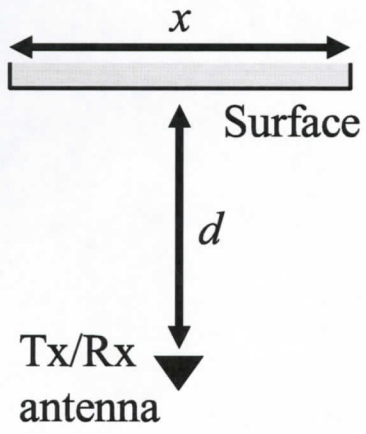


Figure 1: Geometrical setting to estimate energy reflected from a smooth and flat surface.

4. For the following statement, mention if you agree or disagree. Then provide detailed reasoning for the chosen side.
   A) In mobile communications, macrocell is the most effective way to provide service to mobile subscribers.
   B) When a mobile operates in a multipath fading channel with a small K factor, the mobile receives better quality of service than a mobile operating in a large K factor.