Topic 5: Radio wave propagation and radiation safety

Problem 5.1: Fresnel zones and obstruction losses

A 10-km link system, see Figures 1(a) and 1(c) below, operates at 6 GHz.

a) Figure 1(b) shows the relative electric field strength at the RX E_B when there is an infinitesimally large absorbing screen deployed in the middle of the link. The absorbing screen has a hole of radius r, where the center of the circle coincides with the line between the TX and RX. The value E_B is normalized with respect to that of $r = \infty$, i.e., when hole radius is infinitesimally large meaning that the screen does not exist. Explain why the curve has very low values at small r and then converges to 0 dB with small fluctuation as r increases.

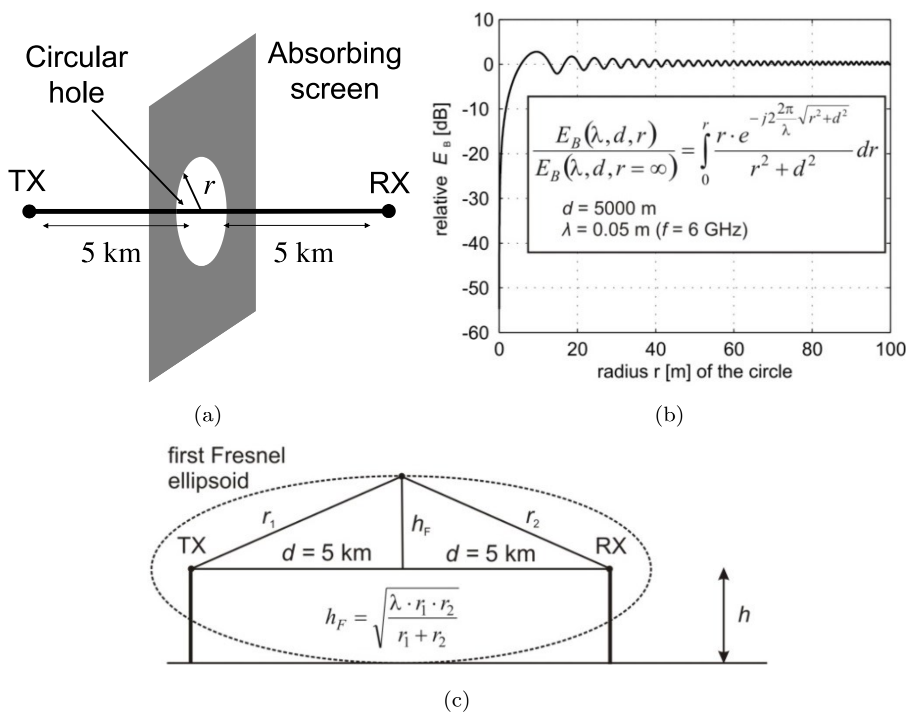

Figure 1: (a) 10 km link, (b) Relative field strength at the RX and (c) First Fresnel ellipsoid.

b) Based on the curve for the relative E_B in Figure 1(c) estimate roughly the needed radius r for the space that should be kept free of obstacles so that the radio wave propagates without any extra loss caused by the obstacles.

c) Estimate the same radius as in b) based on the first Fresnel ellipsoid. Refer to Figure 1(c), i.e., calculate h_F. Compare and discuss h_F and the value r chosen in b).

d) Based on b) and c), what should be the height h of the antenna towers when the radio wave propagates without any extra loss? Neglect the ground reflection and the radius of the Earth.

Topic 5: Radio wave propagation and radiation safety

Problem 5.2: Radiation safety

Let us assume that you live in a suburb area. A local mobile operator is planning to build a new base station in the area. A person, who is "very concerned" about the health risks of the radio waves transmitted by the base station, collects names to a petition in order to prevent the building of the base station. Write a short (e.g., half A4) opinion to a local newspaper in order to clarify the health effects of the radio waves. Write understandable way! Choose your perspective freely, but your opinion is based on scientific research results. Pay attention to the legibility of your text and use good linguistic form. You can, for instance, use the following article.

> Reference: Säteilyturvakeskus (STUK) – Radiation and Nuclear Safety Authority of Finland, "Radio waves and our environment," https://www.stuk.fi/documents/88234/148243/radio-waves-and-our-environment-2009.pdf

Topic 5: Radio wave propagation and radiation safety

EXTRA Problem 5.3: Two-path model of ground reflection

You can get extra three (3) points maximum as a bonus by solving this problem.

Radio transmitter (TX) and receiver (RX) are deployed on a flat smooth ground as illustrated in Figure 2. The TX and RX are equipped with idealistic omni-directional lossless antennas with heights of $h_1 = 300$ and $h_2 = 10$ m operating at $f = 500$ MHz. The TX feeds a unit power to the antenna, which emits a horizontally polarized wave to the ground. The RX antenna receives the same polarization.

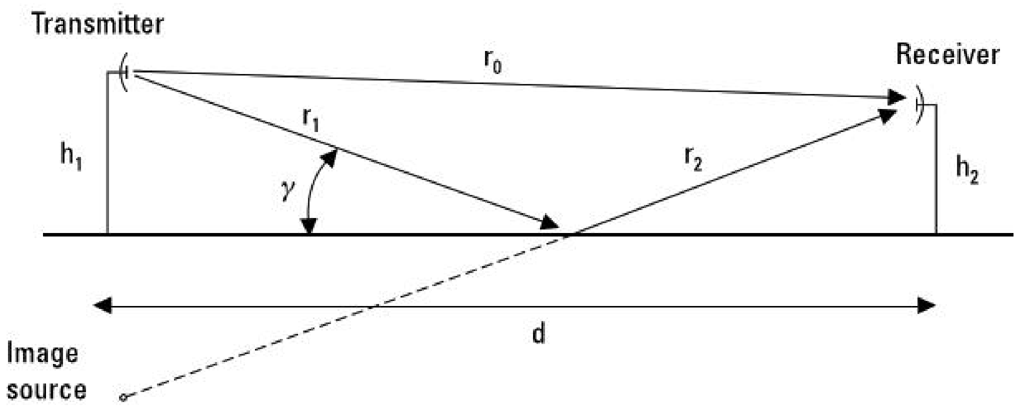

Figure 2: Radio propagation involving direct wave and reflection from the ground; $h_1 = 300$ m, $h_2 = 10$ m and $f = 500$ MHz.

a) Given the separation distance between the TX and RX d, derive a formula of complex voltage at the RX antenna port, E.

   Hint: the Friis' formula we covered in Problem 4.4 provides the complex voltage at the RX antenna port for a unit TX power as

   $$E = \frac{\lambda}{4\pi d} e^{-j\beta d}, \tag{3.1}$$

   when the separation distance between the TX and RX antennas is d and there is no reflection from the surrounding environment; λ is wavelength of a radio wave and β is a wavenumber.

b) Reproduce Figure 3, which corresponds to Figure 10.11(a) of Räisänen and Lehto, using the formula obtained in a). In the figure E_0 denotes a magnitude of the voltage at the RX antenna for the direct wave propagating from the TX to RX.

   Hint: for a horizontally polarized wave, the reflection coefficient on the ground approaches -1 when the wave incidence is close to *glazing*, i.e., the wave incident direction is close to parallel of the ground.

c) What are implications of variations of the received field strength, illustrated in Figure 3, on the quality of cellular mobile radios? Assume that a base station is serving as a TX for your mobile phone as an RX. Is the quality of mobile data connection always ensured across all distances from the TX?

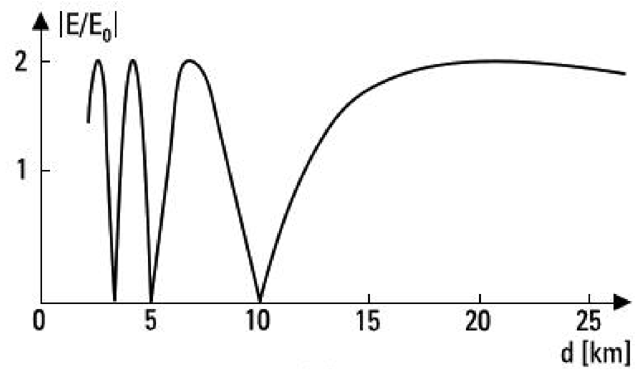

Figure 3: Normalized field strength at the RX antenna for varying TX-RX separation distance; $h_1 = 300$ m, $h_2 = 10$ m and $f = 500$ MHz.