Lab Assignment #6

Outdoor Radio Propagation

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Purpose

This experiment examines the characteristics of outdoor radio propagation. It explores radio propagation in three path loss zones: near field, free space, and far field. It also provides basic knowledge on fast and slow fading.

Equipment

- Spectrum Analyzer Agilent ESA–L1500A: 9 kHz-1.5 GHz
- Signal Generator Agilent E4400B: 250 kHz – 1 GHz
- Antennas made in the second experiment

Introduction

The received signal power from a radio transmitter depends on many factors. In general, those factors can be divided into:

- Transmitter and receiver geometry
- Intervening terrain and obstacles.

Transmitter and receiver geometry embodies transmit power, antenna gains, cable losses, antenna heights, working frequency, and the distance between the transmitter and receiver. These factors depend on the transmitter, receiver. Although the two systems working on different terrain can have the same parameters, yet the received signal could be different because of the differences in other factors.

Intervening terrain and obstacles take into consideration terrain profiles on the path between the transmitter and receiver and obstructions (sometimes called clutter) such as: woods, bridges, urban areas, hills, water, or high buildings.

In this lab we focus on the factor known as *path loss*. The path loss models all effects between the transmitting and receiving antennas.

The signal from a transmitter passes through three regimes - zones:

- Near field zone,
- Free space path loss zone, and
- Excess path loss zone.

Near field zone has the length of approximately:

$$d_1 = \frac{2D^2}{\lambda} ,$$

where D is the largest dimension of the antenna.

The signal attenuation in this zone is the highest, but this zone is relatively short. When doing the experiments all measurements should be distinguished whether they have been done in the near field zone or in other zones.

In the *free space path loss zone* the signal is proportional to $1/r^2$, or the signal longitudinal attenuation is approximately 20 dB/decade. This zone extends from d_1 to:

$$d_2 = \frac{4h_t h_r}{\lambda} \quad ,$$

where h_t and h_r are the heights of the transmit and receive antennas, respectively.

This zone is called the free space path loss zone, because as long as the signal has no significant interaction with the ground the attenuation is equal to the free space path loss. The higher the antennas, the less interaction with the ground and so the free space path loss zone (i.e. d_2) extends further.

Excess path loss zone, theoretically, has an infinite length. In this zone the transmitted radio wave interacts with the ground. Ideally the loss in this zone is 40 dB/dec, but in practice it varies from one type of terrain to another in the range 20-50 dB/decade. Increasing the antenna heights improve the signal.

The near field behavior is complex and is usually not modeled for typical applications. But the signal strength outside of the near field zone can be easily calculated relative to a certain reference point. A reference point has to be chosen at some distance d_0 outside of the near field and signal strength is relative to the power at this point:

$$P_R = P(d_0) \cdot PathLoss \ ,$$

where $P(d_0)$ embodies the transmit power, antenna characteristics, etc. and P_R is the received power.

The signal is strongest when the receiver has a Line of Site (LOS) to the transmitter. LOS means the straight line connecting the transmitter and the receiver has no obstructions. But, objects near the LOS can cause significant intereference, which depends upon the Tx-Rx distance and its location along the LOS. The volume that must be clear is denoted as the first 'Fresnel Zone'. It is an ellipsoid, where the radius changes with the distance between the transmitter

and the receiver. If the separation is *'d'*, at a distance *'d_x'* from the transmitter the radius of the first Fresnel zone is:

$$r_x \approx \sqrt{\frac{\lambda \cdot d_x (d - d_x)}{d}}$$

Where (d, $d_x >> r_x$)

PRE-STUDY

Exercise 1

For an ideal plane terrain, carrier frequency 900 MHz, height of the transmitter 30 m, height of the receiver 1.5 m, and quarter-wave dipole compute d_1 and d_2.

Exercise 2

Study the topographic map of Boulder, and plan a drive test (plan 10 to 15 points where you will measure the signal strength). The transmitter will be on the engineering center tower. Measure and calculate the transmitter-receiver distance. Make sure that you have distances more and less than d_2, add one point close to the engineering center (this will be the reference point with P_{d0} – reference level of a signal).

LAB PROCEDURES

Outdoor propagation and slow fading

Use one of the continually transmitting cellular transmitters on the known position as a reference signal. If you cannot determine the continual transmitter, place a signal generator with the matched antenna on the roof of the ECE building and use the transmitted signal as the measuring signal. Using your drive test plan, measure received signal strength with the portable spectrum analyzer at your test points. So as not to include the fast fading effects at each test location, move the antenna over several wavelengths and find the maximum signal and record this. Maximum signal could be measured using TRACE MAX-HOLD function of the spectrum analyzer.

Note: The high-gain onmidirectional antennas usually have narrow vertical beam angles. Thus for smaller distances the receiving antenna could be outside the main lobe under the transmitting antenna.

Also note that the road orientation, in-line or perpendicular, close to the cell site can cause a big difference in signal reception levels.

Fast fading

Measure the fast fading over a small area in the excess path loss zone. The measurement area can be a square with sides up to 2 or 3 signal wavelengths.

Using a chalk draw a rectangle of sides 2 to 3 wavelengths. Mark 16 or 25 measuring points inside the square (4×4 or 5×5).

First determine the maximum and minimum signals in the measuring area. Set the spectrum analyzer to TRACE MAX-HOLD for the maximum or TRACE MIN-HOLD for the minimum signal. Move the receiving antenna over a measuring area. Be sure to keep the antenna at the same position, and, if possible, above the head. In that way the reflection of the waves caused by the operator's body will be reduced to a minimum.

Second measurement has to be done in each marked measuring point. Measure the maximum of a signal at each point and draw a graph.

Suggested additional measurement: Use one of the drawn lines. Mark along a line about 10 points separated approximately by 5 cm (2 inches). Measure the maximum signal along the line at the marked points.

POST-LAB (GROUP) EXERCISE

Exercise 1

Graph the measured signal values as a function of distance for outdoor measurements.

Exercise 2

For the outdoor measurements find the distance at which attenuation changes (“knee” point), and compare it with the value calculated from the literature.

Exercise 3

In the excess path loss zone fit a straight line to the data. Give a rough estimate of the signal variation around your curve. Find the signal variation.

Exercise 4

Arrange the fast fading measurements from the smallest to the largest. Divide them into four groups, the smallest 25%, higher 25% and so on. Plot the average of each group as a bar chart.

REFERENCES

Books

1. T.Rappaport, *Wireless Communications: Principles and Practice*, Prentice Hall, 1996
2. W.C.Y.Lee, *Mobile Cellular Telecommunications*
3. Y.Okumura et al., “Field strength and its Variability in VHF and UHF Land-Mobile Radio Service”, *Review of the Electrical Communication Laboratories*, Vol.16, Nos.9 and 10, 1968, pp. 825-873