



Indoor Radio Propagation

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Purpose

This experiment examines the characteristics of indoor radio propagation. It explores the influence of the number and the type of walls on signal attenuation as a function of frequency.

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 behavior of radio signals in buildings (indoor propagation) depends on the working frequency, number of walls, ceilings, and other obstacles existing in a building. The indoor radio channel differs from the traditional mobile radio channel in two aspects:

- a) Distances covered are smaller
- b) Variability of the environment is much greater.

The propagation within buildings is strongly influenced by the building layout, the construction materials and the building type. Walls and obstacles made of different materials obstruct the signal differently. Indoor radio propagation is characterized with the same effects as outdoor propagation: reflection, diffraction, and scattering. But the influence of each parameter is much greater for indoor propagation. The position and type of antenna mounting strongly influence the propagation (e.g. antennas mounted at the desk level, on the ceiling, or on the wall).

In general, indoor radio propagation may be classified as:

- Line of sight or
- Obstructed.

When predicting the signal level inside the building, different parameters should be considered:

1. *Building penetration* (caused by the signal entering the building) applies only for the transmitters that are outside the building. It has two main factors: wall penetration and window area. It is found that the wall penetration for 900 MHz signals can be in the range 15 – 27 dB, depending on building construction. The building penetration in the window area is approximately 6 dB.
2. *Floor attenuation* depends on the number of floors between the transmitter and receiver, the type of the material, and the working frequency. It is found that for the carrier frequency of 900 MHz, the attenuation in the first 13 floors is nearly the same, about 2.7 dB/floor. Above 13 floors the attenuation is approximately 7 dB/oct.



A detailed description on signal attenuation inside buildings can be found in Tables 3.3, 3.4 and 3.5 of “Wireless Communications – Principles & Practice”, by Rappaport. In this literature indoor losses are divided into partition losses at the same floor and between floors.

Furthermore, the indoor path loss obeys the distance power law (similar to the class model):

$$P=P(d_0) + 10n\log(d/d_0) + X_\sigma$$

Where $P(d_0)$ is the power at a reference distance d_0 , n depends on the surroundings and building type, d is the transmitter and receiver separation and X_σ represents a normal random variable having a standard deviation of σ dB.

The values for n and σ for different building types are given in Table 3.6 of Rappaport.

PRE-STUDY

Exercise 1

Using the tables 3.2 – 3.6 in the Rappaport estimate the path loss through several specific walls in the lab for a 900MHz signal, example from the telecom lab to the outer hallway.

LAB PROCEDURES

The influence of working frequency

For the signal source set the power to 0 dBm, attach a matched antenna, and transmit an unmodulated sine-wave. Connect a second antenna to the spectrum analyzer and measure the signal level at 10 points along a line within the same room at increasing distance. Record the distance and signal level. At each point make 3-5 measurements separated by $\approx 1\lambda$.

Carry out all measurements for two frequencies: one between 100 kHz and 450 MHz and the other between 800 MHz and 1.5 GHz (suggested is 900 MHz).

Influence of antenna height

Repeat the previous measurements for different transmitting and receiving antennas near the ceiling and near the floor.

Influence of wall characteristics

1. For different walls, measure the signal levels on both sides of the same wall. Calculate the wall attenuation and note down the value and determine wall characteristics.
2. For a distant transmitter measure the level of the signal passing through several walls. It is very important to choose a distant transmitter (e.g. some of the public broadcasting stations), in order to avoid the effect of the distance between the walls being comparable to the distance between the transmitter and receiver.

Carry out all the measurements for two frequencies: one between 100 kHz and 450 MHz and the other between 800 MHz and 1.5 GHz.

Influence of floors

Place the signal generator on the top floor of the Engineering building. Set the power to 0 dBm, connect a matched antenna and transmit an unmodulated sine-wave. Connect a second antenna to the spectrum analyzer and measure the signal level at the same position on every floor under the first antenna. Record the number of floors between them and signal level. Do not forget that the increase of distance between the transmitter and receiver should not be neglected for the first few floors. Carry out all the



measurements for two frequencies: one between 100 kHz and 450 MHz and the other between 800 MHz and 1.5 GHz.

Fast fading measurements

Divide a square having sides of length 2 to 3 wavelengths into 16 or 25 points. With the transmitter at least 10λ from the square measure the signal level at all marked points.

POST-LAB (GROUP) EXERCISE

Exercise 2

Draw a diagram for the indoor attenuation caused by different obstacles for different frequencies. Compare the measured values obtained for 900 MHz with the values from the literature and discuss the results.

Exercise 3

Graph measured signal values as a function of distance and frequency for the indoor measurements.

Exercise 4

Graph measured signal values as a function of distance and antenna height and frequency.

Exercise 5

Find the attenuation caused by the walls and ceilings for different frequencies.

Exercise 6

Arrange fast fading measurements from the smallest to the largest. Divide them into 4 groups, the smallest 25%, higher 25% and so on. Plot the average of each group as a bar chart. Discuss the range of values.

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