EM Propagation Measurements and Analysis

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***Abstract*—This document reports on electromagnetic propagation experiments. The received power has been measured for various distances and frequencies. The acquired data are fitted to simple propagation models, showing satisfactory results.**

***Index Terms*—Antennas, Electromagnetic propagation, Propagation losses**

I. Introduction

Our research addressess the propagation of electromagnetic signals in the frequency region 20 MHz-6 GHz. Measurements haven been performed at a countryside test site in the Netherlands. To analyze the data, some simple radio propagation models have been considered. Such models attempt to predict the received power at a receiver. Given the transmitted power and antenna gains, it is equivalent to determining the propagation loss. The simplest example is the well-known free space loss. However, in practice a large number of phenomena like ground reflections, surface waves, multipath, shadowing and diffraction are present. The environment plays a dominant role. A classic example of a propagation model is the one of Egli for rural environment [1]. More propagation models are discussed in, e.g., [2], [3], [4].

II. Simple EM propagation models

In free space the received electromagnetic power P_R for antenna separation distance d is given by

$$P_R = \left(\frac{\lambda}{4\pi d}\right)^2 G_T G_R P_T, \tag{1}$$

where P_T denotes the transmitted power, λ the wavelength and $G_{T,R}$ the transmitter/receiver antenna gains. Polarization and impedance matching factors [5] are taken to be one, *i.e.*, ideal matching.

The so-called R^n model has been presented in [2]; it effectively means that the factor d^2 in the denominator is replaced by d^n. Thus a different power fall-off in distance is allowed for. We convert to decibels and use the R^n model in the following form

$$P_R(\text{dBm}) = \eta - 10\, n \log d. \tag{2}$$

The parameter η depends on frequency and transmitted power. An alternative phenomenological model explicitly includes the frequency dependence as well:

$$P_R(\text{dBm}) = \alpha \log d + \beta \log f + \gamma, \tag{3}$$

with frequency f and parameters α, β, γ.

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III. Experiments and fits

Propagation measurements have been done for distances between transmitter and receiver antenna ranging from 5 to 100 meters. In each frequency band the power has been measured for 500 frequencies. We have also varied the polarization of the receiving antenna.

The measured data haven been analyzed using the proposed models. The first model, the R^n model (2), does fit these data quite well per frequency. This is confirmed by a preliminary statistical analysis. The second model (3) takes the frequency dependence into account by the use of the parameter β. It performs reasonably; in a few cases, however, it fails. No noticeable dependency on the polarization has been observed in the measurements.

As an example, we show results for fitting the R^n model to low-frequency data with horizontal antenna polarization. The left hand side shows the power as function of the distance at 250 MHz only; it is one of fitted subsets. Such a fit is done for each frequency. Herewith we can depict the power as a function of frequency at a fixed distance, here 20 m. The right hand side contains this collected result of the various fits.

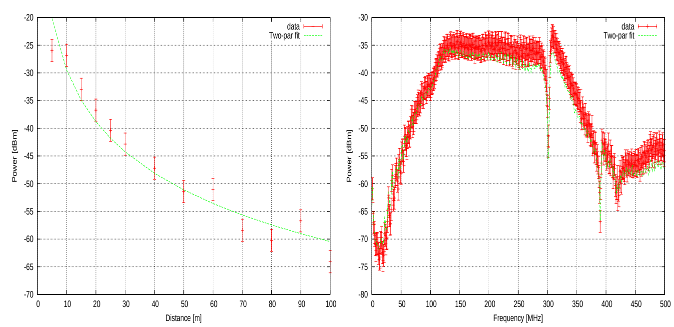

Fig. 1. L.h.s frequency 250 MHz, r.h.s. distance = 20 m

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