

行政院國家科學委員會專題研究計畫 期中進度報告

移動式分散無線網路之無線電通道量測與模型建構(1/2)

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計畫編號：NSC94-2213-E-009-070-

執行期間：94 年 08 月 01 日至 95 年 07 月 31 日

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計畫主持人：唐震寰

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行政院國家科學委員會補助專題研究計畫 ☐ 成果報告
☒ 期中進度報告

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計畫類別：☒ 個別型計畫 ☐ 整合型計畫

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共同主持人：

計畫參與人員：

成果報告類型(依經費核定清單規定繳交)：☒ 精簡報告 ☐ 完整報告

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執行單位：國立交通大學電信工程系

中 華 民 國 95 年 6 月 1 日

一、中文摘要

本計畫預期在兩年內探討 Vehicle-to-vehicle 無線電通道的特性，並建構相關模型。在本年度(第一年)，吾人已探討接收信號場強特性：大尺度—平均傳播損失；中尺度—遮蔽衰落，及小尺度衰落，並利用統計方法建構相關之模型。此外，吾人也探討遮蔽相關長度，以瞭解該通道之時變性。吾人所發展之模型，已利用 900MHz 及 1200MHz 的大量實驗數據驗證。我們發現：(1) Dual-slope 的經驗公式適合描述平均傳播損失；(2) Log-normal 分佈可用於遮蔽衰落；(3) 遮蔽相關長度隨著道路交通量或信號頻率增加而遞減；(4) 可用 Ricean 分佈描述小尺度衰落。**關鍵詞：**行動台-行動台之無線電通道，傳播損失，遮蔽衰落，小尺度衰落，遮蔽相關長度

Abstract

This is a two-year project to characterize and to model vehicle-to-vehicle radio channels. In the first year, the received signal strength is characterized and modeled in three aspects: averaged path loss, shadow fading, and small scale fading, which are basically explored using a statistical approach. In order to investigate the time-varying property of the radio channels, shadowing correlation length is characterized. Here, extensive measurements of vehicle-to-vehicle radio channels at 900 MHz and 1200 MHz have been conducted to validate the proposed models or characterize channel parameters. It is found that (1) The dual slope empirical path loss model is suitable to describe the averaged vehicle-to-vehicle path loss; (2) The lognormal distribution basically fits the shadow fading of the received signal well; (3) The shadowing correlation length decreases when road traffic or signal frequency increases; and (4) The small scale fading still follows a Ricean distribution.

Keywords: Vehicle-vehicle radio channels, path loss, shadow fading, small-scale fading, shadowing correlation length.

二、報告內容

I. Introduction

In recent years, mobile ad-hoc networks (MANETs) have received much attention due to their potential applications and proliferation of mobile devices [1, 2]. Specifically, MANETs mean wireless multi-hop networks formed by a set of mobile nodes without relying on a preexisting infrastructure. Although they are infrastructureless and have many benefits such as self-configuration and ease of deployment, their flexibility and convenience come at a price. The networks still inherit the traditional problems of wireless communications, such as bandwidth optimization, power control, and transmission quality enhancement. In addition, their mobility, multihop nature and the lack of infrastructure create a number of new

complexities and design constraints, which include dynamically changing network topologies, network robustness and reliability, hidden-terminal and exposed-terminal problems, variation in link and node capabilities, energy constrained operation and network security. Many of them are due to the time-varying radio channel characteristics since every node, including the source and the target, in the networks is in motion. In addition, low transmitting and receiving antenna heights lead to severe blockage effect, which may be different from that of macrocellular and microcellular radio systems with the base station antenna height being much larger than that of the mobile station.

A profound knowledge of the radio channel characteristics is a prerequisite for the development of efficient wireless transmission systems. To our knowledge, only few literatures explore vehicle-to-vehicle radio channel characteristics and models. In [3]~[4], the authors present a “double ring” model to simulate the mobile-to-mobile local scattering environment and use it to develop a sum-of-sinusoids based method for simulating small scale fading channels. In [5], analytical expressions of the time-autocorrelation function and the Doppler spectrum in a mobile radio channel are derived in the presence of three-dimensional (3-D) multipath scattering. In [6], fading statistical properties, such as the level-crossing rate and fade duration of the envelope, of mobile-to-mobile land communication channels have been investigated. In [7], the paper present results from vehicle to vehicle RF propagation measurements centered at 900 MHz. The authors focus on determining delay spread and path loss exponents measured by vector network analyzer.

In this report, vehicle-to-vehicle radio channels characteristics are explored and modeled. The models for average path loss, shadow and small scale fading are proposed or explored, which is validated by massive measured data at frequencies 900MHz and 1200MHz in open areas, roadways or streets with light or heavy traffic.

II. Measurement System and Sites

A. Measurement system

CW measurements at 900MHz and 1200MHz are conducted so as to enable the fast sampling required for the study of fading dynamics on the channels of interest. A schematic diagram of the measurement system is shown in Fig. 2.1. A 10-dBm CW signal is transmitted by a half-wavelength dipole antenna at a height 1.5 m above the ground. Both the instantaneous positions of the transmitter and the receiver are located by a GPS module and recorded by a notebook. The receiving antenna is a half-wavelength dipole antenna at a height 2 m above the ground. The receiver (Advantest R3261A) can instantaneously measure the signal strength between -10 to -85 dBm over a 300kHz interval. The received data is acquired automatically by a

notebook with a GPIB (General Purpose Instrument Bus) card. A GPS module is also used at the receiver to position the location of the transmitter.

During the measurement, two vehicles are carrying the transmitter and receiver systems separately and moving along roadways. Both the transmitting and receiving antennas are vertically polarized. As the both vehicles move, the received power versus the Tx-Rx distance is recorded.

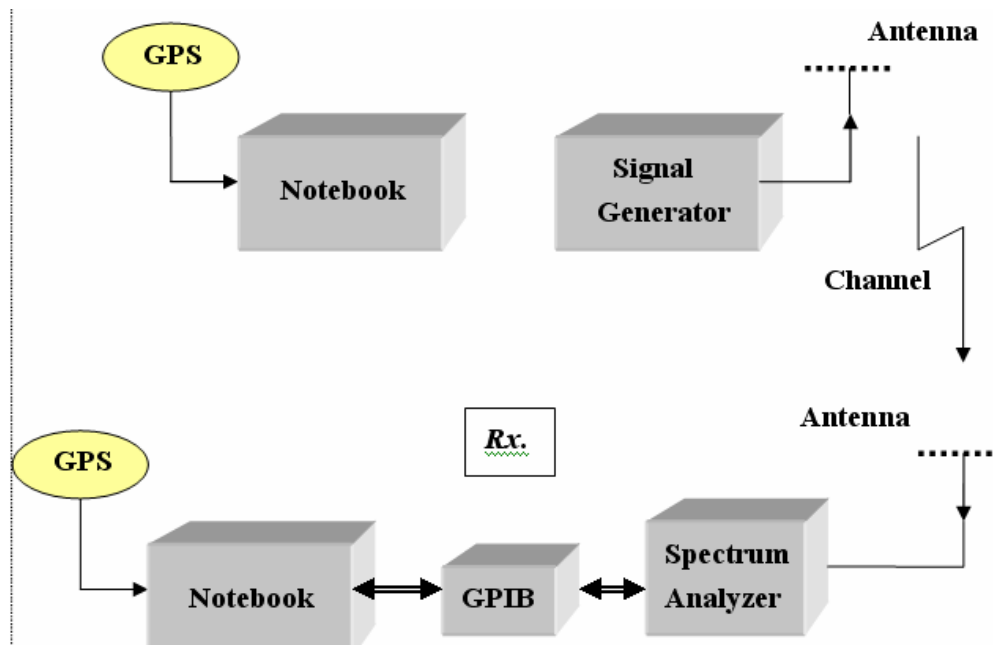


Figure 2.1 Block diagram of the vehicle-to-vehicle field strength measurement system.

B. Measurement sites

Narrow-band (CW) signal strength measurements are made at 900 MHz and 1200 MHz along roads and streets in Hsin-Chu city, Taiwan. The measurement is carried out at four measurement sites: Site A: roadways with light traffic located in an open area; Site B: Along a highway (highway 68 built in a rural area); and Sites C and D: Along the streets (Dong-Da road and Kuang-Fu road) located at urban areas with heavy traffic. In order to fully understand the time-varying property of the radio channels, measurements are repeated six times along each road.

The measured route at site A as shown in Figure 2.2(a) is located in an open area and has one kilometer long with planted trees. The measurement road of Site B shown in Figure 2.2(b) is along a highway, highway 68, which is an overpass way with very few buildings along the road. Figures 2.2(c) and 2.2(d) show the pictures of the measurement roads of Site C and Site D, respectively, which are along Dong-Da road and Kuang-Fu road. Usually, the traffic along the each road is quite heavy. The roadwidth of Site C is double of that at Site D and the building height along the street at Site C is not as uniform as that at Site D.

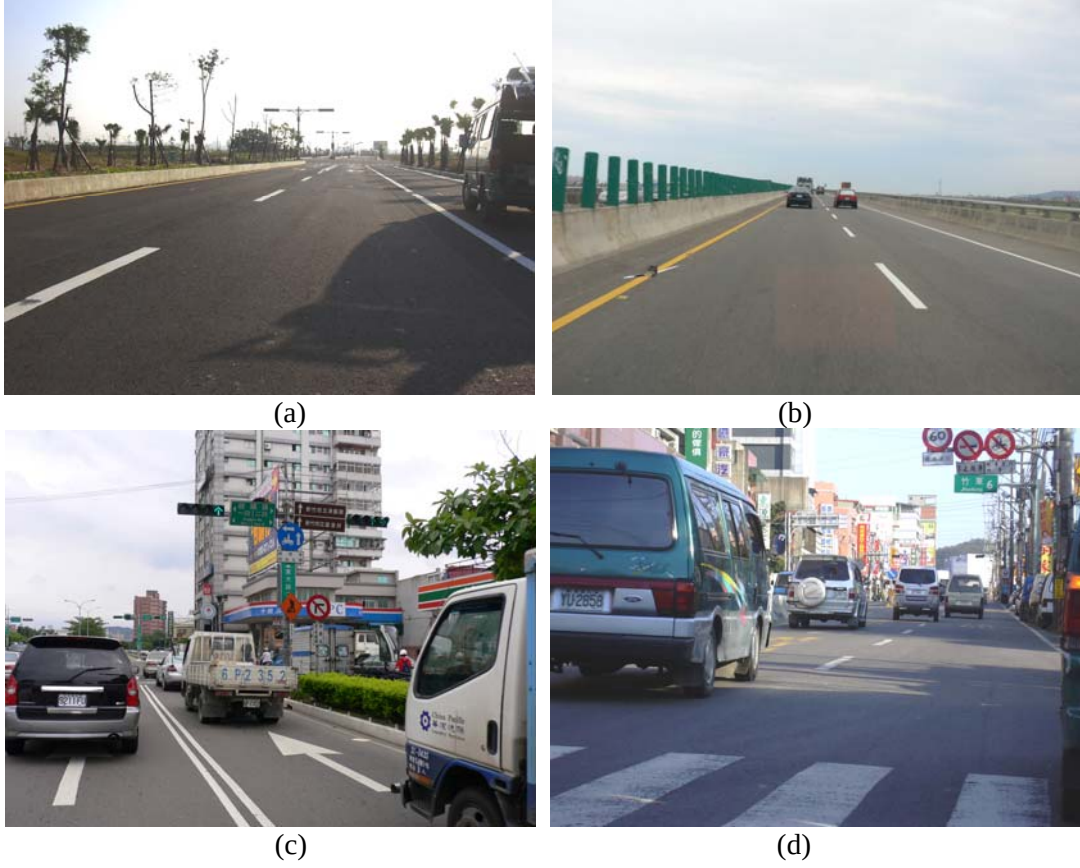


Figure 2.2 The photograph of each measurement site: (a)Site A; (b)Site B; (c)Site C; and (d)Site D.

III. Measurement Results

3.1 Site A

Figure 3.1(a) and Figure 3.1(b) show the measured path loss versus Tx-Rx distance at frequency 900 MHz and 1200 MHz respectively at site A. It can be observed obviously that the path loss increases with Tx.-Rx. distance. Similar result is also observed at site B.

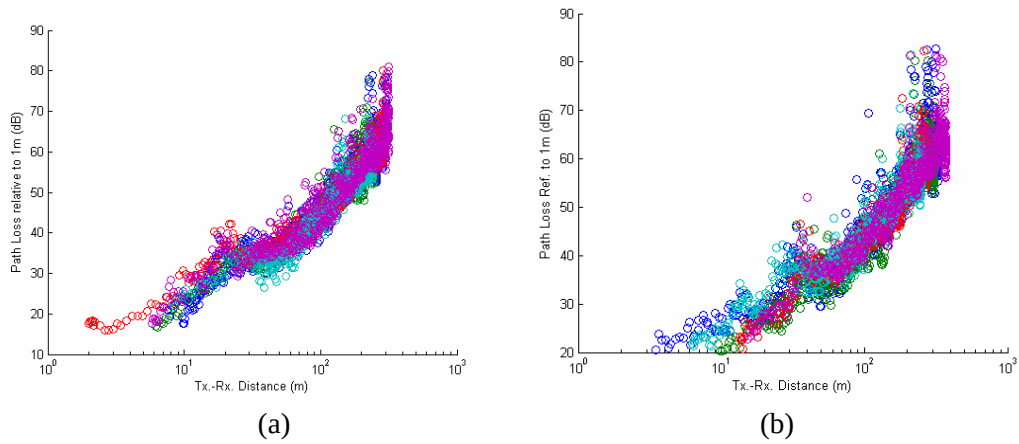


Figure 3.1 Path loss versus Tx-Rx distance of measured data at site A (a) 900MHz ; and (b) 1200MHz.

3.2 Site D

Figure 3.2(a) and Figure 3.2(b) show the measured path loss versus the Tx-Rx distance at 900 MHz and 1200 MHz, respectively, at site D. Similar result is also observed at site C.

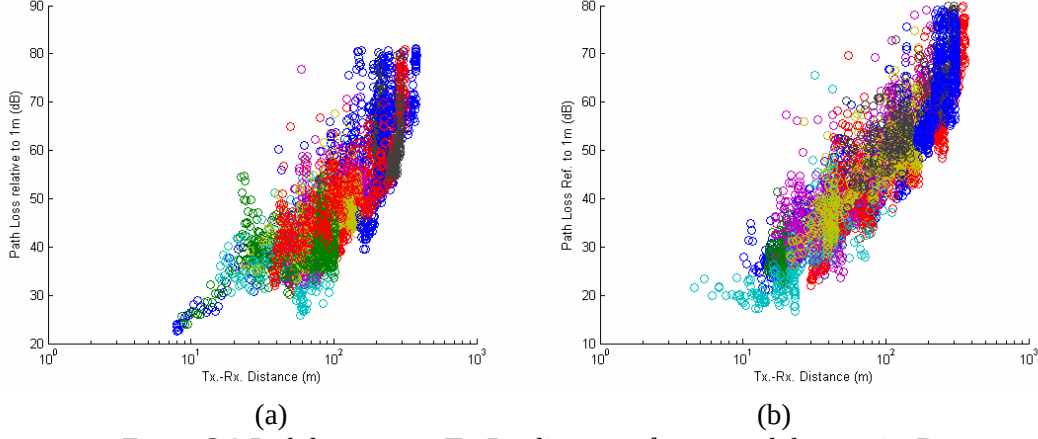


Figure 3.2 Path loss versus Tx-Rx distance of measured data at site D
(a) 900MHz ; and (b) 1200MHz.

It is found that the measurement at the site with heavy traffic (many scatterers or reflectors existed) such as at Site D, severe fading is found to compare with that at the sites with light or no traffic at Sites A, which is due to local scattering effects.

IV. Characterization and Modeling of Vehicle-to-Vehicle Path Loss

4.1 Averaged path loss

Since both the transmitting and receiving antenna heights are lower than street building heights, which is the same as that of microcellular environments, the dual slope empirical model is adopted to describe the averaged path loss. The model is given by

$$PL(d) = PL(d_0) + 10n_1 \log(d) + 10(n_2 - n_1) \log\left(1 + \frac{d}{d_b}\right) \quad (4.1)$$

where n_1 and n_2 are unknown parameters and $PL(d_0)$ is the path loss in decibels at the reference distance of $d_0 = 1m$. Again, n_1 and n_2 are the path loss exponents for the model. d_b is the break distance. These two unknowns can be determined in closed form based on the MMSE criterion [10], where the variance or mean squared error σ^2 is the quantity to be minimized. For a total of N measurement locations, the mean squared error is

$$\sigma^2 = \frac{1}{N} \sum_{i=1}^N (PL_i - PL(d_i))^2 \quad (4.2)$$

where PL_i is the measured path loss in decibels for the i th path loss measurement and $PL(d_i)$ in decibels is evaluated by using Eq.(4.1). σ represent the standard deviation of the medium scale variation.

Table 4.1 shows the best-fitting results with the dual slope path loss model at four measurement sites at frequency 900MHz and 1200MHz. An important result shown in Table 3.1 is that the path loss exponents for these four sites are all in the ranges of $1.9 \leq n_1 \leq 2.1$ and $4.0 \leq n_2 \leq 4.2$. These results indicate that the two-ray or three-ray model may accurately predict the averaged path loss of vehicle-to-vehicle propagation. From the table it can be seen that the rms error (σ in decibels) increases when the local scatterers increases at the measurement sites.

4.2 Shadow fading distribution

The shadowing contribution to the medium-scale attenuation is extracted [8]. The small-scale fading is easily discarded by computing local means of the received field using a 10λ sliding window. Figures 4.1 and 4.2 illustrate the measured path loss versus Tx-Rx distance after moving average for frequencies 900 MHz and 1200 MHz, respectively. Figure 4.3 shows the histogram of the moving-averaged path loss for 900 MHz. It is found that it can be well fitted by a log-normal curve. It is the same at other sites.

Table 4.1 Dual slope path loss exponents and the standard deviation of the shadow fading for 900MHz and 1200MHz of the four sites

Measurement sites	900MHz			1200MHz		
	n_1	n_2	$\sigma(dB)$	n_1	n_2	$\sigma(dB)$
Site A	2	4.1	3.26	1.9	4.1	3.62
Site B	1.9	4.0	4.03	1.9	4.1	5.29
Site C	1.9	4.0	4.74	2	4.0	5.93
Site D	2.1	4.2	5.57	2.1	4.1	3.7

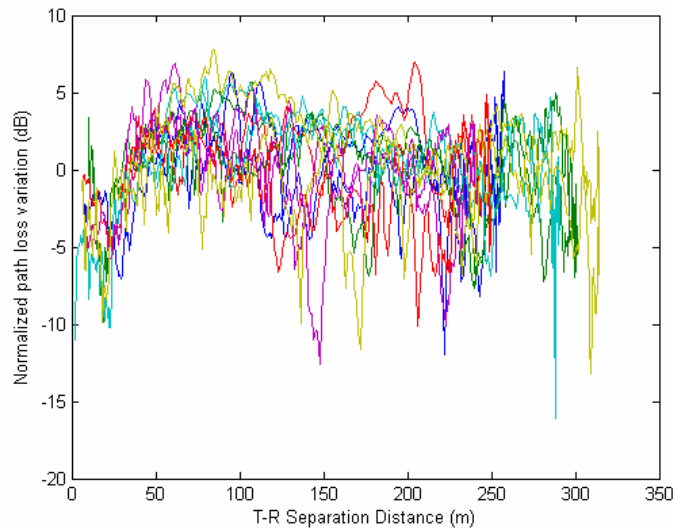


Figure 4.1 The moving-averaged measured path loss vs. T-R separation at site A for 900MHz.

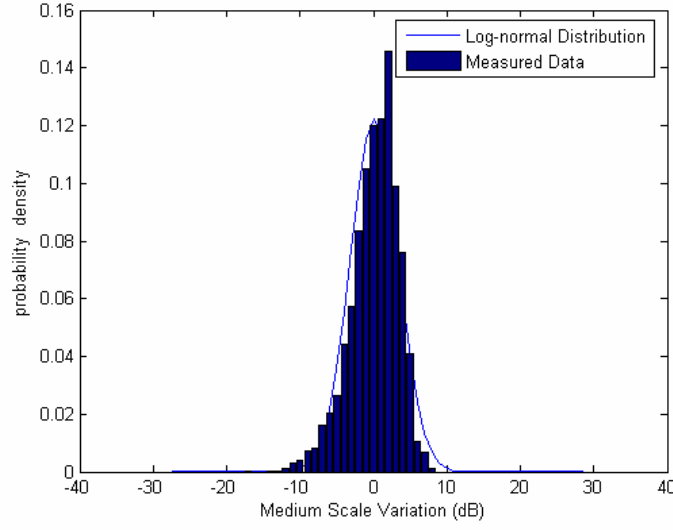


Figure 4.3 Probability density histogram with log-normal fitting curve ($\sigma = 3.26$ dB) at site A for 900MHz.

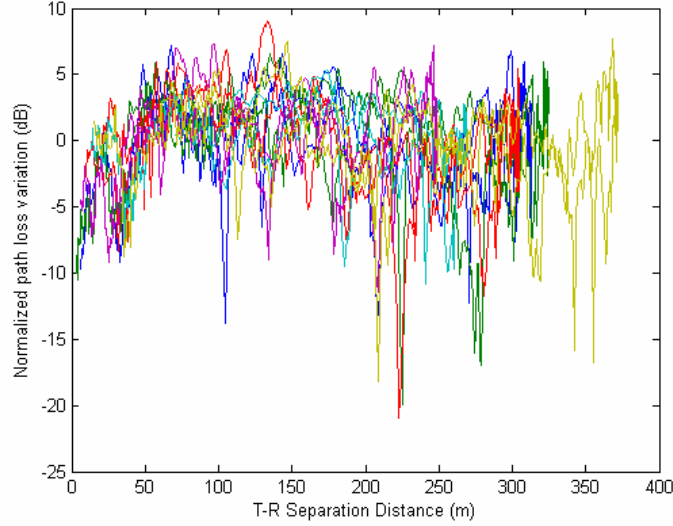


Figure 4.2 The moving-averaged measured path loss versus T-R separation at site A for 1200MHz.

In order to further discuss the time-varying property of the propagation channels, we consider the parameter of the shadowing correlation length. The autocorrelation of the shadow fading process over a range of traveled distance [11] is computed by using the following equation (4.3).

$$\begin{aligned}\tilde{x}_i &= x_i - \frac{1}{n} \sum_{i=1}^n x_i \\ \rho_k &= \frac{\frac{1}{n-k} \sum_{i=k+1}^n \tilde{x}_i \tilde{x}_{i-k}}{\frac{1}{n} \sum_{i=1}^n \tilde{x}_i^2}\end{aligned}\tag{4.3}$$

where x_i represents the path loss variation of T-R distance, d_i . Here, ρ_k represents the autocorrelation of k th lag (length).

Measurements of the shadowing autocorrelation process suggest that a simple exponential model of the process is appropriate, characterized by the shadowing correlation length, r_c , which is taken for the normalized autocorrelation to fall to $1/e$ of its value. In macrocells, the correlation length is a few tens or hundreds of meters, and corresponds to the widths of the buildings and other obstructions that are found closest to the mobile. In our research, it is found that the correlation length is smaller than ten meters in mobile-to-mobile channels and much smaller than that of the macrocellular cases. It is because that both the transmitter and receiver are surrounded by local scatterers, which yield many independently random received paths at both sites and decrease the correlation distance. Table 4.2 shows the correlation distances at four sites for 900MHz and 1200MHz. It is found that the shadowing correlation length decreases when road traffic or signal frequency increases.

Table 4.2 Correlation length at four sites for 900MHz and 1200MHz

Measurement sites	$r_c(m)$ (900MHz)	$r_c(m)$ (1200MHz)
Site A	7.9	7.7
Site B	7.1	7
Site C	5.7	4.7
Site D	5	4.18

4.3 Small scale fading

Small scale fading is mainly due to the scattering effect of local scatterers, which yield severe signal strength and phase variations in a short range of wavelengths order. Here, we propose that the amplitude statistics of received signal is described by a Ricean distribution [12]. Figure 4.4 illustrates the normalized small scale fading measured signal variation versus Tx-Rx distance at site A for 900MHz. Its cumulative distribution is shown by the dots in Figure 4.5 and it is found that it is well described by a Ricean distribution. Table 4.3 shows the Ricean factors of four measurement sites at 900MHz and 1200MHz. From the table it can be seen that the Ricean factor (K) decreases when the measurement site has more scatterers and/or reflectors; it is the smallest at site D (street has heavy traffic and builds along the road) and largest at site A (open area).

Table 4.3 Measured Ricean factors (K) at four sites for 900MHz and 1200MHz

Measurement sites	K (900MHz)	K (1200MHz)
Site A	13	12.5
Site B	6	5.8
Site C	3	2
Site D	2.7	2.5

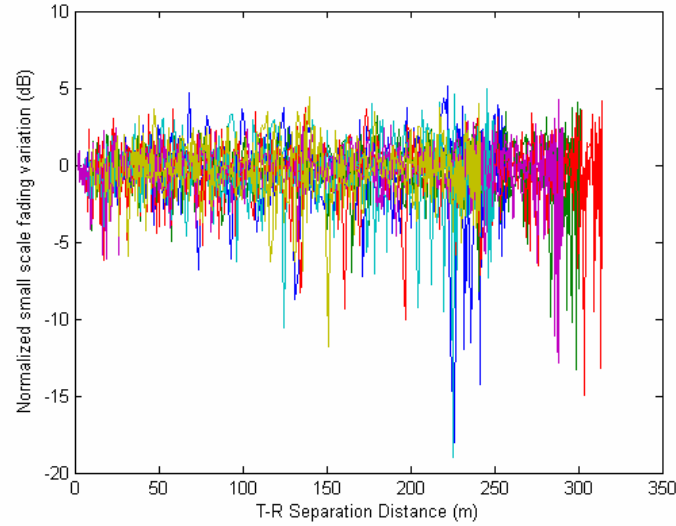


Figure 4.4 The small scale fading variation versus Tx-Rx distance at site A for 900MHz.

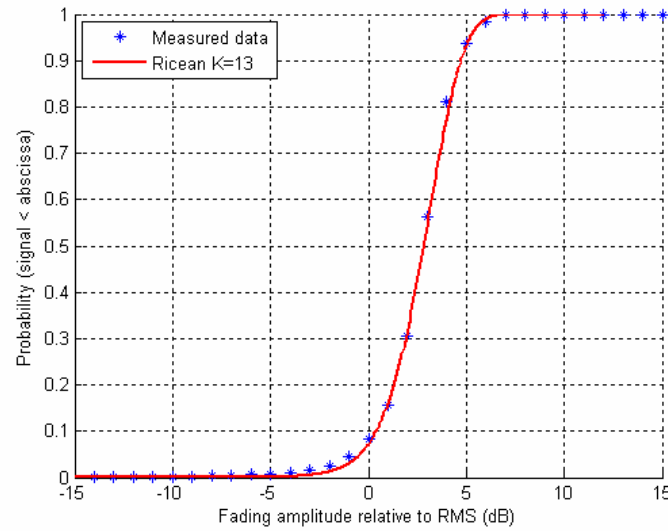


Figure 4.5 Cumulative distribution of small scale fading with Ricean fitting curve ($K=13$) at site A for 900MHz.

V. Conclusions

To compare with the measurement data, the dual slope path loss model for large scale path loss, provide good accuracy with path loss exponents of $n_1 \cong 2, n_2 \cong 4$. It is also observed that as the measurement environment becomes more complicated, the

standard deviation of shadowing increases and the correlation distances decrease. Also, it is found that the correlation distances at higher frequency (1200MHz) are always smaller than lower frequency (900MHz). The Ricean factor, K , is found in the range 2~13 and it has the maximum value at clear site and the minimum value on the roadway with heavy traffic. Also, the Ricean factor, K , at 1200MHz are always smaller than 900MHz.

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