Measurement of Radio Propagation Path Loss over the Sea for Wireless Multimedia

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Abstract. In order to estimate the signal parameters accurately for wireless multimedia services, it is necessary to estimate a system's propagation characteristics through a medium. Propagation analysis provides a good initial estimate of the signal characteristics. The ability to accurately predict radio propagation behavior for wireless multimedia services is becoming crucial to system design. Since site measurements are costly, propagation models have been developed as a suitable, low cost, and convenient alternative [1]. A number of studies have been conducted to quantitatively predict the characteristics of propagation in inhabited areas on land having many wireless multimedia service users, resulting in a number propagation prediction models being proposed. However, since very few such studies have been conducted for the sea, which has a different physical layer structure from land, the propagation prediction model for free space has been commonly used. Thus, in this study, I measured the propagation path loss of a 1950 MHz band signal over the sea surface, and analyzed the results by comparing them with the path loss data of a propagation prediction model in free space, which is frequently used to predict the propagation path loss over the sea surface.

1 Introduction

The commercial success of wireless communication, since its initial implementation in the early 1980s, has led to there being an intense interest among wireless engineers in understanding and predicting the radio propagation characteristics in various urban and suburban areas, and even within buildings. Given that the explosive growth of wireless multimedia service is continuing unabated, it would be very useful to have the capability of determining the optimum base-station location, obtaining suitable data rates, and estimating their coverage, without having to conduct extensive propagation measurements, which are very expensive and time consuming [1].

Whereas many studies have been conducted to predict the characteristics of propagation quantitatively land, including the development of many propagation prediction models, few such efforts have been conducted for the sea. In fact, there are many difficulties involved in providing wireless multimedia services over the sea, viz. the lack of economic viability associated with long and short distance services, the absence of good locations for new base-stations, and the difficulties associated with these locations. To solve these problems, facility investment and maintenance expenses need to be reduced by optimizing the service area per base-station the precise prediction of the propagation path loss over the sea surface.

Accordingly, in this study, I measured the propagation path loss of a 1950 MHz band signal over the sea surface, and analyzed the results by comparing them with the predicted propagation path loss in free space, which is frequently used to predict the propagation path loss over the sea surface.

2 Propagation environment and propagation path loss

The radio propagation over the sea surface is different from the land propagation prediction model. In other words, the total received power of a mobile unit situated over the sea is the sum of the direct wave, the reflected wave from the sea surface, and the reflected wave from the ground. As a result, it gives more intense interference to other base-stations and mobile units, as compared with land propagation, and so special attention and care is needed. The received power over the sea surface is given by Eq. (1) [2].

$$\begin{aligned} P_r &= P_t \times \left(\frac{\lambda}{4\pi d} \right)^2 \left| 1 - e^{jd_{\theta 1}} - e^{jd_{\theta 2}} \right|^2 \\ &= P_t \times \left(\frac{\lambda}{4\pi d} \right)^2 \left| 1 - (\cos d_{\theta 1} + \cos d_{\theta 2}) - j(\sin d_{\theta 1} + \sin d_{\theta 2}) \right|^2 \end{aligned} \tag{1}$$

where d is the path length, λ is the wavelength, $d_{\theta 1}$ is the difference in the propagation path between the direct wave and the reflected wave from the ground, $d_{\theta 2}$ is the difference in the propagation path between the direct wave and the reflected wave from the sea surface, p_t is the transmitting power, and p_r is the received power in free space.

However, in Eq. (1), the difference in the propagation path between the two reflected waves, $d_{\theta 1}$ and $d_{\theta 2}$, is sufficiently small for propagation path loss over the sea surface to be replaced by the predicted value of the propagation path loss in free space, if a limiting value, 0, is adopted in both $d_{\theta 1}$ and $d_{\theta 2}$, as shown in Eq. (2).

$$\begin{aligned} P_r &\approx \lim_{d_{\theta 1}, d_{\theta 2} \to 0} \left[\left\{ P_t \times \left(\frac{\lambda}{4\pi d} \right)^2 \right\} \left| 1 - e^{jd_{\theta 1}} - e^{jd_{\theta 2}} \right|^2 \right] \\ &\approx P_t \times \left(\frac{\lambda}{4\pi d} \right)^2 \end{aligned} \tag{2}$$

In general, the propagation path loss in a downtown environment is known to be about 20 ~ 50dB/dec, based on empirical measurements, depending on the environment, and an approximate value of 20dB/dec is generally use for the propagation path loss over the sea surface [1, 3, 4].

3 Experimental setup and measurement procedure

The propagation path loss over the sea surface was measured in the vicinity of the islands situated off the coast of in Latin America.

Fig. 1. Sample areal photograph. (a) Test antenna (b) East (c) West (d) South (e) North

Table 1. Location information

	Latitude	Longitude
Test site	17-55-9.7	(-)87-57-40.6
UTM coordinate	1981526.786	398186.5393

Table 2. Measured parameters

Tx power	Cable loss	Tx ant. gain	Tx ant. height	Rx ant. height
20W (43dBm)	2dB	6dB	22m (Ant. 2m + Building 20m)	2.5m

The transmitting signal (1950 MHz) was generated using a signal generator installed in the steel tower of an existing base-station in Latin America.

The signal sent from the base-station was processed on a real-time basis using HP RF Coverage Measurement equipment manufactured by Agilent. The location information was obtained using a GPS (Global Positioning System) embedded in the receiving set and Mercator projection [4, 5]. To measure the propagation path loss over the sea surface, a boat with a speed of 40 ~ 60km/h was used.

4 Results

Fig. 2 shows the path loss slope from the measured data. The measured data in Fig. 2 represent the mean values of tens ~ hundreds of data collected when the mobile unit's location was changed by 0.001 degrees in latitude or longitude.

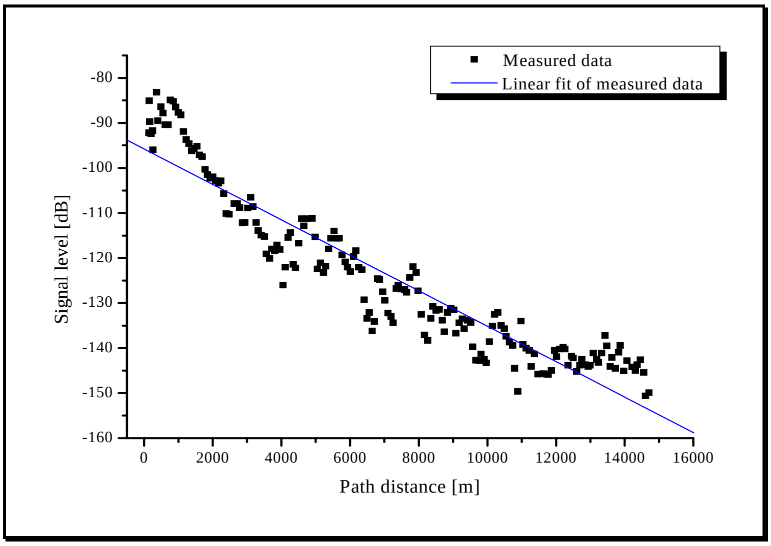

Fig. 2. Path loss slope from measured data

Fig. 3 shows the results calculated using Eq. (2) for the predicted data of the propagation path loss in free space, which is frequently used to predict the propagation path loss over the sea. The propagation path loss and regression analysis according to distance are also presented using the measured data.

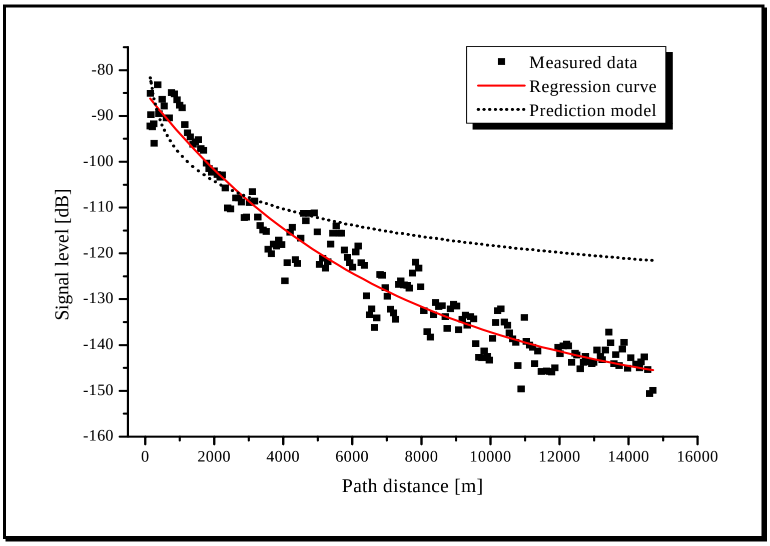

Fig. 3. Propagation path loss according to distance

Fig. 4 shows the difference of the regression of measured data against predicted data of propagation path loss in free space.

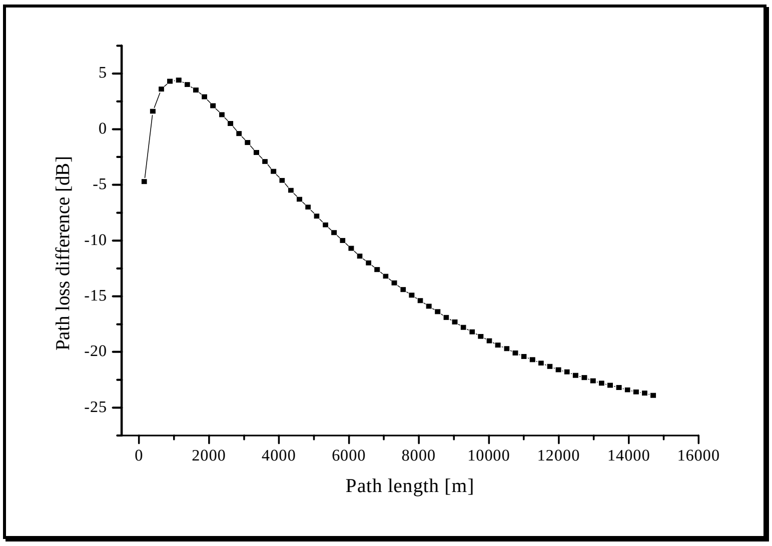

Fig. 4. Path loss difference according to distance

The results in Fig. 2, 3 and 4 suggest that the measured data of the propagation path loss over the sea surface were smaller than the predicted data of the propagation path loss in free space up to 2,200m, but bigger at a distance above 2,200m. As the path length was increased, the measured data were greatly increased compared to the path loss of predicted data. The smaller of the measured propagation path loss up to 2,200m, as compared to the predicted ones, may result from the absence of obstacles in the area, leading to a strong radio strength and large radio filed strength of the reflected radio signal. More specifically, the propagation path loss over the sea surface was about 40dB/dec, which is 20dB/dec bigger than the propagation path loss in free space of 20dB/dec.

Table 3 and 4 show the difference and the standard deviations of the predicted data of the propagation path loss in free space.

Table 3. Difference between predicted and measured data according to distance

Path length [m]	Difference range [dB]	Min. difference [dB]	Max. difference [dB]
0 ~ 2000	-10.7 ~ +11.6	0.7	11.6
2001 ~ 4000	-10.6 ~ +2.3	0.1	10.6
4001 ~ 6000	-15.6 ~ +0.8	0.2	15.6
6001 ~ 8000	-21.5 ~ -4.4	4.4	21.5
8001 ~ 10000	-25.1 ~ -13.9	13.9	25.1
10001 ~ 12000	-30.6 ~ -13.6	13.6	30.6
12001 ~ 14000	-24.9 ~ -16.4	16.4	24.9
14001 ~ 14700	-29.1 ~ -21.2	21.2	29.1

Table 4. Standard deviation of predicted and measured data according to distance

Path length [m]	Measured data & predicted data	Regression data & predicted data
0 ~ 2000	6.3	3.0
2001 ~ 4000	3.9	1.8
4001 ~ 6000	4.5	1.9
6001 ~ 8000	4.8	1.5
8001 ~ 10000	3.9	1.2
10001 ~ 12000	4.6	0.9
12001 ~ 14000	2.0	0.6
14001 ~ 14700	3.0	0.2
Total	**10.3**	**9.3**

From the experimental data, we know that one standard deviation of data spread on any radio path length is about 8dB. This spread is due to the various terrain conditions from which the data are collected at the same radio path length [7, 8, 9]. However, the standard deviation of the measured data for the propagation path loss over the sea surface is 10.3dB and the regression is 9.3dB, as compared to the predicted data for the propagation path loss in free space.

5 Conclusions

It is common practice to use the predicted model of the propagation path loss in free space to predict the propagation path loss over the sea. Thus, in this study, we measured the propagation path loss of a 1950 MHz band signal over the sea, and compared the results to the predicted data of the propagation path loss in free space. The principal results of this comparison are as follows.

- The propagation path loss over the sea surface was about 40dB/dec, which was 20dB/dec bigger than the propagation path loss in free space (20dB/dec).
- The Standard deviation of the predicted and measured data for the propagation path loss over the sea surface is 10.3dB, which is bigger than the standard deviation of the propagation loss land (8dB).
- As path length was increased, the differences were greatly increased.

The measured results reported in this paper are very valuable in that they provided a means of determining the optimum base-station locations, suitable data rates and estimating their coverage, without having to conduct extensive propagation measurements, which are very expensive and time consuming. Further studies are needed to develop the propagation prediction model for above the sea, by measuring the propagation path loss over the sea surface for various frequency bands.

Acknowledgment: I would like thank Dea-sick Choi, Jin-man Kim, Kyung-Jae Kim (RF Engineering Dept. R&D Center LGE) for useful discussions and valuable data.

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