UHF-TV BAND SHADOWING CHARACTERISTICS AFFECTED BY SURROUNDING BUILDINGS

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1. Introduction

Recently, in the mobile communication fields, the demand of broadband and high mobility has increased. To achieve the broadband capacity, the radio systems using higher frequency bands such as micro or millimeter bands have been mainly investigated and developed. However, the radio propagation performance deteriorates as the radio frequency becomes higher[1]. In order to easily realize the high mobility, the lower frequency band should be applied to mobile communication systems. On the other hand, the terrestrial TV broadcasting will be digitalized all over Japan after the year 2006[2]. The terrestrial digital TV systems will utilize the UHF band from 470 to 770 MHz. This frequency band has better performances in radio propagation compared with higher frequency bands.

Considering above situations, authors have proposed the new type of UHF band mobile platforms constructed with both digital communication and broadcasting systems in order to achieve high mobility of communication and broadcasting cooperated services[3]. Since the UHF-TV band has been mainly utilized for the fixed reception of TV broadcasting waves, it is necessary to newly investigate and clarify the mobile propagation characteristics of UHF-TV band radio wave for realizing the mobile reception of digital TV and for constructing the proposed mobile platforms.

One of the most important subjects should be investigated is the shadowing characteristics in the urban mobile environment, where there are many man-made buildings around the mobile terminal. In the past investigations, the effect of surrounding buildings on the shadowing has been studied by use of the ground cover factor (the percentage of the area covered by buildings)[4]. However, it has not been sufficiently investigated how large is the affection on the shadowing characteristics from the surrounding buildings near the mobile terminal. At the present, we can obtain the detail digital map from which we can calculate the ground cover factors even on 50 x 50 m^2 small area.

In this investigation, to study the shadowing characteristics affected by the surrounding buildings in UHF-TV band, we have measured the UHF-TV band radio wave with the mobile measurement system, using existent TV broadcasting wave and DGPS systems, in the urban environments with various ground cover factors. And we have analyzed the shadowing characteristics such as the mean received level and the standard deviation of the log-normal approximation. And we have newly investigated the shadowing characteristics as a function of 50 x 50 m^2 ground cover factors.

2. Measurement Method

Figure 1 shows the measurement system used in our investigation. In this measurement system, UHF band monopole antenna is fixed on the rooftop of the vehicle, and the receiving signal of TV broadcasting is detected in the UHF band receiver. The RSSI (Received Signal Strength Indicator) associated with the received level is transferred through an A/D converter to be recorded in a personal computer as digital data. This measurement system can also record the positioning data using DGPS system. By use of the DGPS systems, we can obtain the positioning data

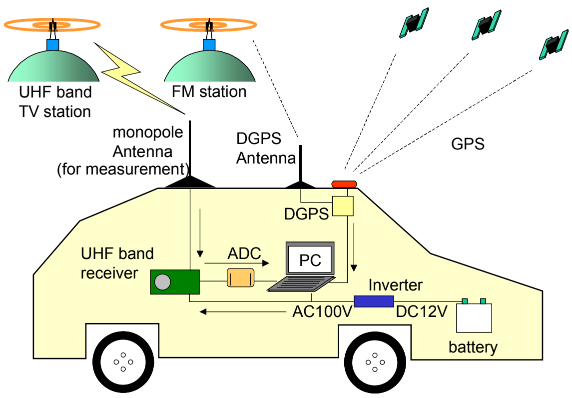

Figure 1: Measurement system

ISBN: 89-86522-77-2 94460©KEES

with the error less than a few meters. In this system, the existent UHF band TV station is utilized as a transmitter. And it is confirmed that the accurate measurement can be achieved by use of the voice carrier frequency in the existent NTSC TV signal as a measurement frequency.

Table 1 shows the parameters of the measurement system. The receiving antenna height is about 1.5 m and the length of antenna is 1/4 wavelength of measuring frequency. The 6 dB bandwidth of the receiver is about 200 kHz, and the measurement limitation is about -95 dBm in the received level. In this measurement, the received level data is recorded every 100 milliseconds.

Table 1: Parameters of the measurement system

Receiving antenna height	1.5 m
Length of antenna	1/4 wavelength
Receiving bandwidth	200 kHz (6 dB)
Measurement limitation	-95 dBm
Sampling rate	100 msec.
Calibration error	Max. 1 dB

3. Measurement Environments

Using above measurement system, we have measured the received level of UHF-TV band radio wave in Hiroshima city. Figure 2 shows the measurement area A, B and the transmitter (TV station) site. Both measurement area A and B are 500 x 500 m^2 areas. The distance between the measurement area and the TV station is about 10 km as shown in Figure 2. There are not any obstacles such as small mountains between the measurement area and the TV station. Figure 2 also shows the road angle in the measurement area A and B. In this investigation, we have also studied the shadowing characteristics affected by the road angle. As shown in Figure 2, the road angle is defined as the acute angle between the road direction and the radio propagation direction. In the area A, the main road angles are 17 degrees and 13 degrees. In the area B, the main road angles are 36 degrees and 54 degrees.

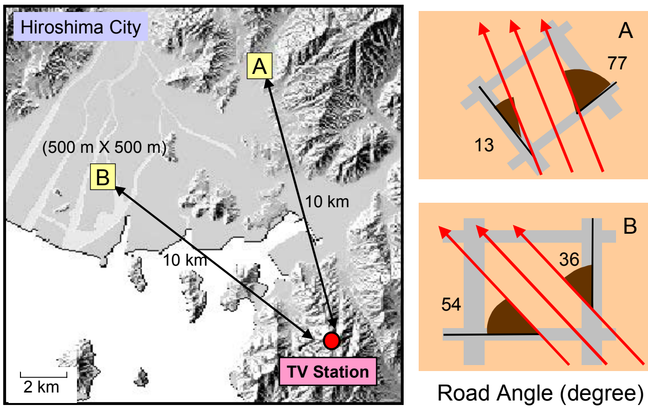

Figure 2: Measurement environments

Table 2: Parameters of TV station

TV station altitude	620 m
Frequency	607.75 MHz
Transmission power (ERP)	100 kW

Table 2 shows the parameters of the TV station used in the measurement. The altitude of the TV station is about 620 m, And measurement frequencies is voice carrier frequencies of Ch. 35. The effective radiation transmission power (ERP) is about 100 kW (80 dBm).

4. Measurement Results

From the measurements results of the received level and DGPS positioning data, we can construct the received level contour map in the measurement area. Figure 3 shows the received level contour map in the area A and B. The received level is shown from the red color (-40 dBm) to the blue color (-80 dBm) according to the level strength. From this figure, we can see that the received level is changed about 20 or 30 dB associated with surrounding buildings. There is a tendency that the received level becomes large as the density of the building around the mobile terminal becomes small.

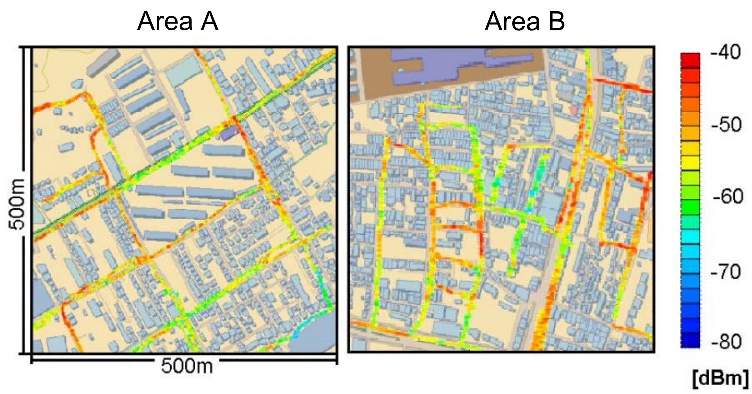

Figure 3: Received level contour map

Figure 4 shows the probability density function (PDF) of the received level in the whole area A and B with different road angles. The log-normal approximations are also shown in this figure. In general, the shadowing characteristic (probability density function of the received level *x*) is modeled with log-normal distribution given as next equation[5].

$$p(x) = \frac{1}{\sigma_0\sqrt{2\pi}} \exp\left(-\frac{(x-M_0)^2}{2\sigma_0{}^2}\right) \quad , (1)$$

where M_0 is the mean value of the received level and σ_0 is the standard deviation of the received level. From Figure 4, we can see that the received levels in this measurement almost follow the log-normal distribution. The mean received level is varied as the road angle is changed. When the road angles are 13, 36, 54, and 77 degrees, the mean received levels are about -58, -57, -57 and -55 dBm, respectively. On the other hand, the standard deviation is not varied even if the road angle is changed. The standard deviation of each road angle is about 4.5 dB.

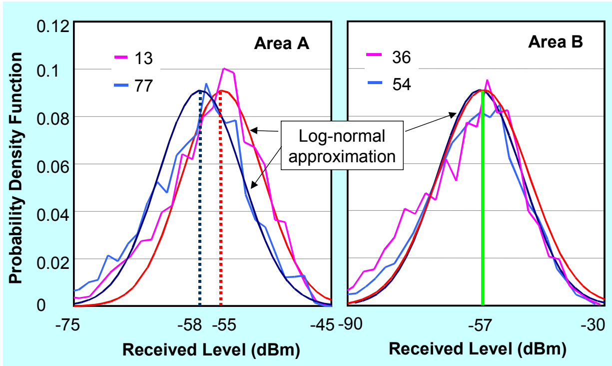

Figure 4: Probability density function of the received level

5. Shadowing Characteristics Analysis

From the measurement results, it is found that the buildings located near the mobile terminal largely affect the shadowing characteristics of the received level. In this investigation, in order to study the detail of the affection of the buildings to the shadowing characteristics, we compute the ground cover factor α on the small area (50 x 50 m^2) at first. In this paper, the 50 x 50 m^2 small area is defined as "segment". Figure 5 shows the ground cover factor α in the area A. This ground cover factor can be calculated by use of the digital map as a result of the image processing. From this ground cover factor, we have investigated how large the surrounding buildings influences the shadowing characteristics, considering various directions in the surrounding segments.

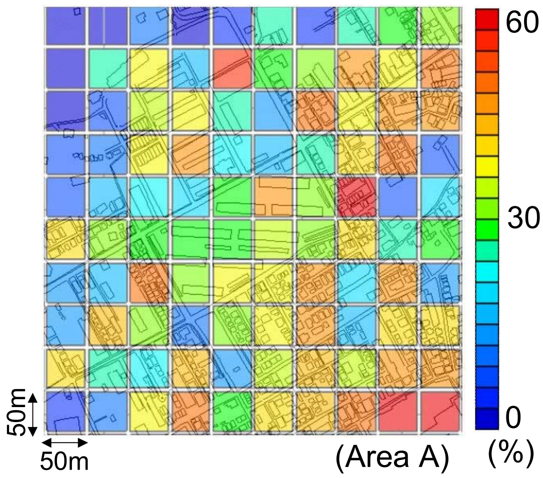

Figure 5: 50 x 50 m^2 ground cover factor α

Figure 6 shows the analysis method. In this method, we have considered five directions in which there are buildings that may affect the shadowing. These directions are "ALL", "S-E", "S-W", "N-W", and "N-W", respectively. At first, the mean received level in each segment M is analyzed. Next, the average ground cover factor α is calculated on the surrounding segments including the central segment in each direction. Finally, the relationship between the mean received level M and the ground cover factor α is approximated with log function given by

$$M = C\log_{10}(a) + D \quad . \qquad (2)$$

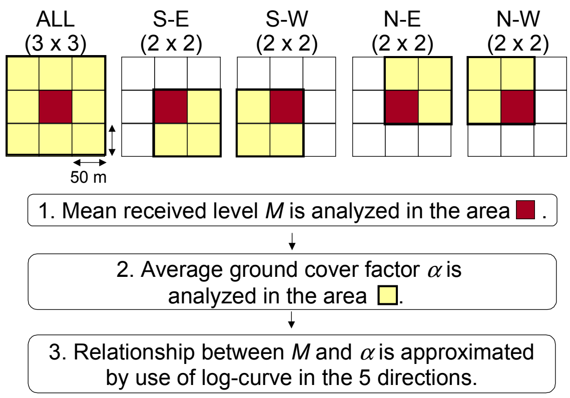

Figure 6: Analysis method

In this study, the log coefficient C has been evaluated as the degree of surrounding buildings affection to the shadowing characteristics, in the five directions with the different road angles.

6 Analysis Results

Figure 7 shows the mean received level in the segment as a function of the ground cover factor considering the direction S-E in the area A. In this case, the received level is focused in the 13 degrees road angle. From this figure, we can see that the mean received level in the segment has a high minus correlation to the 50 x 50 m^2 ground cover factor in the S-E direction. This figure also shows the log approximation. From this approximation, the log coefficient C is -15.5 in this case.

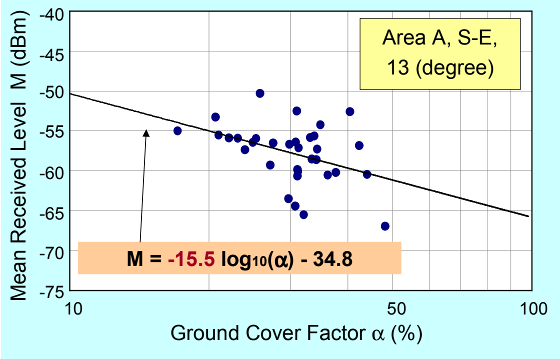

Figure 7: Mean received level as a function of the ground cover factor

Table 3 shows the analysis results of the log coefficient derived from the approximation of the mean received level in the five directions with the different road angles. From this table, we can see that the log coefficient of ALL direction becomes large in any area with any road angle. These results indicate that the surrounding buildings in the all directions (not a certain direction) largely affect the mean received level. The log coefficient of ALL direction is about -13. The log coefficient of S-E direction in the area A with 13 degrees road angle is -15.5 that is the largest value of all results. It can be considered as this reason that the buildings in the radio propagation direction can largely affect the radio wave when the road angle becomes small, and in this case, the propagation direction is almost equal to the S-E direction.

Table 3: Log coefficient in the approximation of the mean received level

Area (Road Angle)	A (13)	A (77)	B (36)	B (54)
ALL	-11.7	-14.7	-13.0	-13.0
S-E	-15.5	-11.6	-7.4	-10.1
S-W	-1.52	-7.41	-0.30	-6.40
N-W	-0.35	-8.24	-7.83	-8.06
N-E	-4.90	-8.45	-8.24	-3.57

5. Conclusions

In this paper, the UHF-TV band shadowing characteristics considering the surrounding buildings were studied on the basis of measurement in the urban environments with various ground cover factors. Consequently, following results were obtained.

(1) The fluctuation of received level in the UHF-TV band due to shadowing follows the log-normal, distribution. And the mean received level depends on the road angle. On the other hand, the standard deviation of the received level is about 4.5 dB, not depending on the road angle.

(2) The mean received level has a high correlation to the 50 x 50 m^2 ground cover factors on the surrounding area. And the surrounding buildings in the all directions largely affect the mean received level in the mobile environments with any road angle.

We have also analyzed the affection of the surrounding buildings to the standard deviation of the shadowing received level. Consequently, it was founded that the standard deviation did not depend on the 50 x 50 m^2 ground cover factors.

In the future, we have to accumulate many measurement results to develop the estimation method of the shadowing characteristics in UHF-TV band, and we would like to predict the shadowing characteristics from the developed estimation method using the digital map.

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