

MEASUREMENT OF UHF BAND RADIO PROPAGATION AFFECTED BY HUMAN MOTION BY USE OF EXISTENT TV BROADCASTING WAVE

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1. Introduction

Recently, in the development of wireless access technologies, there is a trend to investigate higher frequency bands, such as micro or sub-millimeter wave bands, in order to realize the user demands for broadband communications. However, the radio propagation performance deteriorates as the radio frequency becomes high in both outdoor and indoor environment [1]-[3]. In order to easily achieve high mobility that will be also demanded by user in the futures, the lower frequency band should be applied to the transmission media.

On the other hands, in Japan, the analog terrestrial TV broadcasting system have utilized from 470 MHz to 770 MHz in UHF band, that is lower than the frequency bands assigned for 2nd and 3rd generation mobile communication systems. And the TV broadcasting system will be digitalized after 2006 all over Japan [4]. As a result of the digitalization of the terrestrial TV broadcasting, communication and broadcasting services will fuse together in the future using both digital medias.

Therefore, authors have proposed the new type of information service platforms by use of both communications and broadcasting medias as shown in Fig. 1. In our proposed information service platforms, the UHF band of the terrestrial digital broadcasting will be utilized as a broadband information download media, and the higher frequency bands of the existent mobile communications systems will be utilized as a upload media, that will be mainly used for user requests [5].

Since the UHF band has been mainly utilized for a fixed and outside receiving of TV broadcasting, the propagation performance of UHF band in the mobile environments has not been investigated enough up to now. Moreover, in order to realize the seamless connectivity between outdoor and indoor environment and to achieve the stress-free mobile access, it is necessary to investigate the propagation performance of UHF band when the radio wave goes from outside to inside. In our previous study, we have performed a basic measurement of the UHF radio propagation by use of existent TV broadcasting wave and clarified that the propagation performance depends on the circumstance around the receiving antenna [5].

This paper newly investigates the UHF band radio propagation affected by the motion of humans that is one of the biggest factors of the propagation degradations. The variation of received level of the existent TV broadcasting is measured in both outdoor and indoor environments, and the probability distribution of the variation is also analyzed based on the measurement results.

2. Measurement Environment

In order to easily and quickly measure the UHF band radio wave propagation at low cost, the existent terrestrial TV broadcasting waves are utilized in our measurement method. The broadcasting stations that have been installed in several thousand sites in Japan can act as the transmitter. Since these radio waves are used for the TV broadcasting services, the level of transmitted wave is kept to a

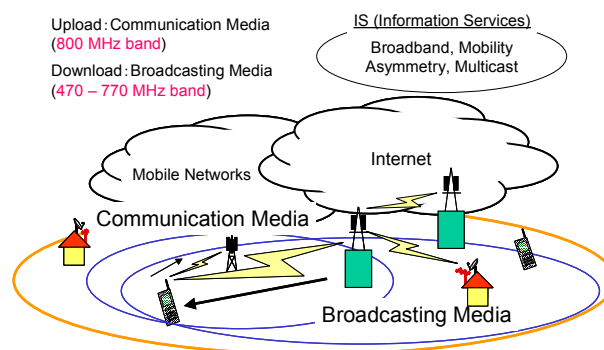


Fig. 1: The concept of new information service platforms

real steady level, and the accurate measurement can be easily achieved only by preparing a receiver.

Fig.2 shows the measurement environments to investigate the UHF band radio propagation affected by the motion of humans. The received level is measured at Hiroshima City University using the existent terrestrial TV broadcasting wave that is transmitted by the broadcasting station located 1.8 km apart from the university in the south direction. In this measurement experiments, there are some humans (from 0 to 4 humans) around the receiver in three environments as shown below.

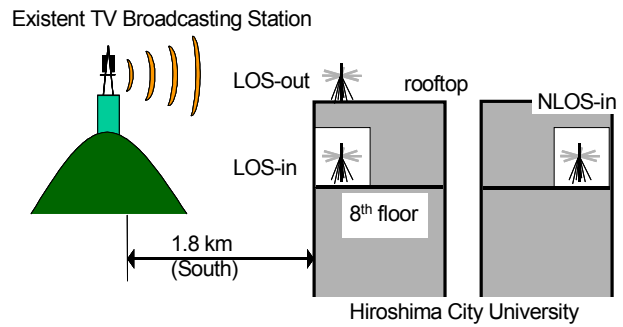


Fig. 2: The measurement environments

- (1) LOS-out (Line-of-Site, Outdoor environment): The rooftop is the measurement area. There are a line-of-site path between the transmitter and the receiver, and the direct wave from the transmitter can be received in this environment. The floor of this rooftop is covered by the water-protected sheet asphalt as shown in Table 1.
- (2) LOS-in (Line-of-Site, Indoor environment): The radio wave is measured in the room on the 8th floor of our university, and there are line-of-site path between the transmitter and receiver through a window. As shown in Table 1, Hiroshima City University is the steel-frame building, and the wall of room is made by the plaster board and the floor is covered by the vinyl sheet. As shown in Fig. 3, the depth, width and height of this room are 6.9 m, 3.5 m and 3 m, respectively. There are steal racks at the both side of the room and one desk.
- (3) NLOS-in (Non Line-of-Site, Indoor environment): Although the radio wave is also measured in the room on the 8th floor of our university, the room is faced on the opposite direction to the station and there are no line-of-site paths. The materials are as well as those of LOS-in room as shown in Table 1. As shown in Fig. 3, the depth, width and height of this room are 6.9 m, 7 m and 3 m, respectively. In this room, there are 8 desks as shown in Fig. 3. Compared with LOS-in environment, there are a few reflectors of radio wave in NLOS-in environment.

	LOS-out	LOS-in	NLOS-out
LOS path	O	O	X
Materials	Floor: water-protected sheet asphalt	Frame: steel-frame Wall: plaster board Floor: vinyl sheet	
Fixtures		Desk (1), Steal rack (both side)	Desk (8)

Table 1: The characteristics of environments

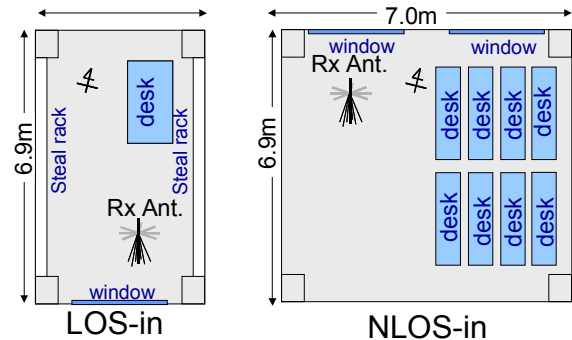


Fig. 3: The indoor environments

3. Measurement System

In order to measure only the affect of human motion, the receiving antenna is fixed in the measurement periods. The receiving antenna is the modified monopole antenna of disc-corn shape, and has the non-directivity characteristics. In our measurement system, the receiving signals are detected by the receiver through the coaxial cable. The detected voltage level associated with the received level is transferred through an A/D converter and is saved as digital data in a PC.

Fig. 4 shows the relationship between the received power level and the detected voltage level in the temperature of 16 and 25 degree centigrade. It is necessary to calibrate from the detected level to the received level for evaluating the accurate received level. In our measurement, the approximation of 5-th order polynomial is used to calibrate the received level. The calibration error is within about 1 dB in the normal temperature, and the measurement limitation of this receiver is about -105 dBm.

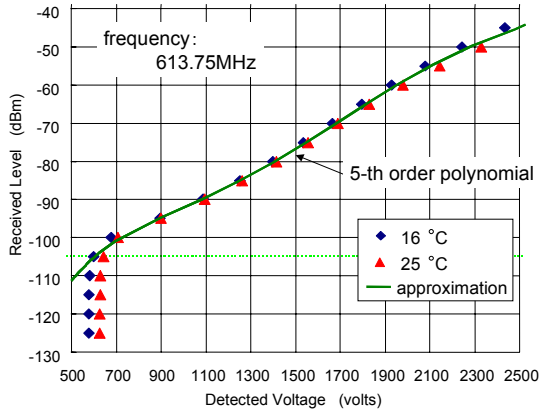


Fig. 4: Received level versus detected voltage

Receiving antenna	Modified monopole antenna
Receiver bandwidth	250 kHz / 3dB
Quantization level	13 bit
Sampling interval	1 sec
Transmitter	Koi broadcasting station
Measurement freq.	625.75 MHz (Voice carrier of NTSC-TV Ch. 38)
Transmission power	2.5 W (ERP 7.25 W)

Table 2: The specifications of measurements

Table 2 shows the specifications of the UHF band radio propagation measurement. The 3 dB cut off bandwidth of the receiver is about 250 KHz. The quantization level of A/D converter is 13 bit and the sampling period is 1 sec. The transmission power is 2.5 W and the effective radiated power (ERP) is 7.25 W. The measurement frequency is 625.75 MHz that is the frequency of voice carrier in the NTSC (National Television Standards Committee) TV signal of Ch.38. In the NTSC signal, the voice signal is FM modulated, and the fluctuation of its amplitude is almost stable. By monitoring this voice carrier, the stable and accurate measurements can be achieved.

4. Measurement Results and Discussion

4.1 The variation of the received level

In each environments described above, the received level were continuously measured in 10 minutes under condition that each human were moving at random around the receiving antenna.

Fig.5 shows the time variation of the received level in each measurement environment in case of different number of moving persons. From this figure, it is clarified that the average level without moving persons of LOS-out, LOS-in and NLOS-in are about -62 dBm, -67 dBm and -83 dBm, respectively. Because there are no line-of-site paths in NLOS-in and surrounding environments outside the room are changing time to time, the received level without moving persons of NLOS-in is fluctuating within 2 dB, while those of other environments are almost stable. Moreover, it is clarified that the fluctuation of received level in each environment becomes large as the number of moving persons increases. But the average level of each number of persons is almost equal to that of no persons. So the average received level does not depend on the number of persons.

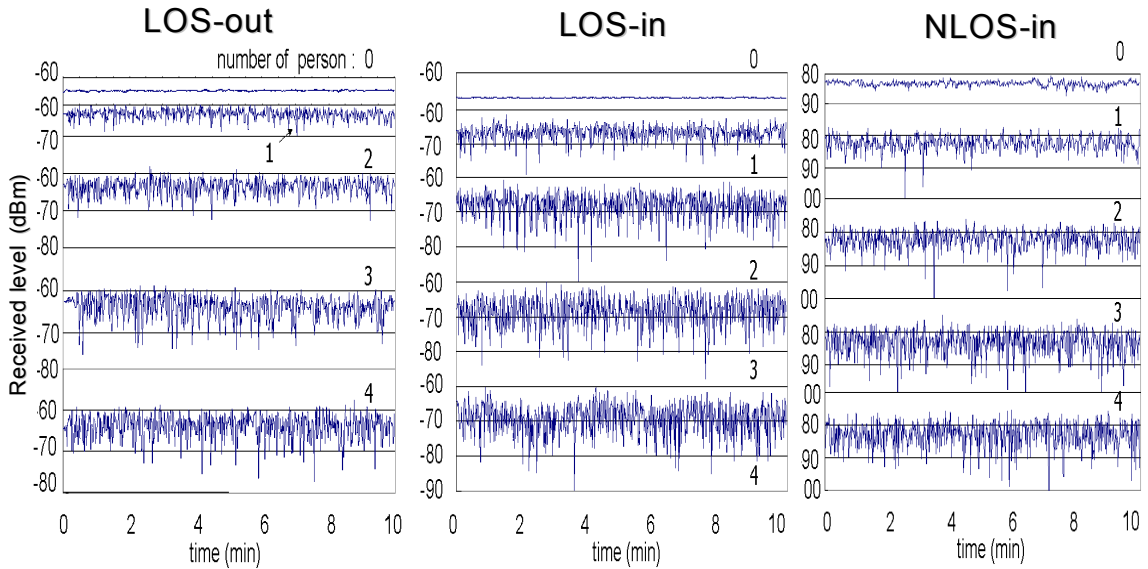


Fig. 5: Time variation of received level in each environment

4.2 The cumulative probability of the received level

To statistically analyze the fluctuation of the received level, the cumulative probability of the received level is compared with the distribution functions in case that the electromagnetic intensity depends on Rayleigh and Rice distribution functions as well as previous other investigations [3][6].

Fig. 6 shows the cumulative probability exceeding abscissa of the received level in each measurement environments. In this figure, the number of moving persons is 2 or 4. From this figure, it is clarified that the cumulative probability of the received power corresponds to the curve of cumulative functions of Rayleigh and Rice distribution. In the LOS-out, the probability functions of 2 or 4 persons correspond to those of Rice distribution with the Rice parameter K of 9 or 6 dB, respectively. The shadowing of the direct-path radio wave causes the fluctuation. In the LOS-in, the probability function of 2 persons corresponds to that of Rice distribution with K of 4 dB and probability function of 4 persons corresponds to that of Rayleigh distribution. The received level of LOS-in is more fluctuated than that of LOS-out. This is caused by a lot of reflections exist in the LOS-in room due to steel racks installed in both sides. And these reflected radio waves are largely affected by the human motion and are received with multi-path fading, consequently, the fluctuation of received level becomes large. In the NLOS-in, the probability functions of 2 or 4 persons correspond to those of Rice distribution with K of 7 or 3 dB, respectively. The received level of NLOS-in is less fluctuated than that of LOS-in. This reason is that there are few reflections in the NLOS-in room, and only principal radio waves through the window are affected.

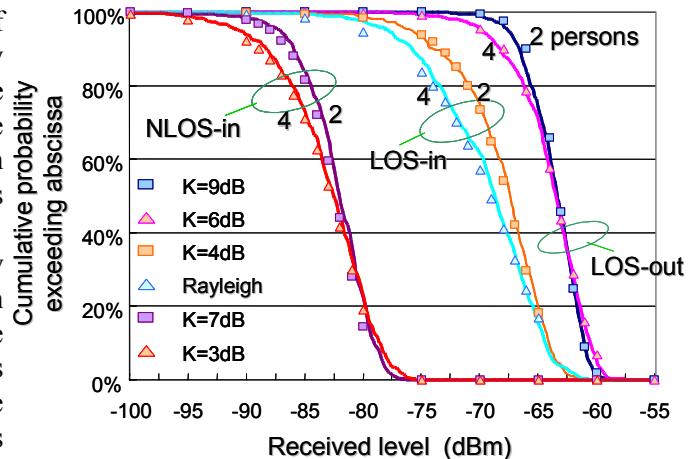


Fig. 6: Cumulative probability of received level

5. Conclusions

This paper has described the necessity of investigation of the UHF band radio wave propagation characteristics in order to construct our proposed information service platforms that can effectively make use of both broadcasting and communication media. Base on the measurement of the received level affected by human motions by use of the existent terrestrial UHF band TV broadcasting wave in LOS-out, LOS-in and NLOS-in environments, following subjects were newly clarified.

- The fluctuation of received level in each environment becomes large as the number of moving persons increases. However the average of received level doesn't depend on the number of moving persons. The average level of LOS-out, LOS-in and NLOS-in are about -62 dBm, -67 dBm and -83 dBm, respectively.
- The cumulative probability of the received power corresponds to the cumulative functions of Rayleigh or Rice distribution. In case that there are 4 moving person around the receiver, the probability functions of LOS-out, LOS-in and NLOS-in correspond to those of Rice distribution with K of 6 dB, Rayleigh distribution and Rice distribution with K of 3 dB.

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