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Performance Evaluation Method for Wideband Wireless Communication Systems Using Instantaneous Frequency Characteristics

#Kenya Yonezawa Takashi Inoue Shinichi Nomoto
KDDI R&D Laboratories
Hikarinooka 7-1, Yokosuka, Kanagawa, 239-0847, Japan

1. Introduction

Future mobile communication systems, such as IMT-Advanced, are expected to use more wide-band signals than current 3G systems to realize high speed and broad band data communications. Designing the wide-band system, not only the signal strength but also multi-path propagation characteristics are important.

Generally, the delay spread is used as an indicator for multi-path propagation characteristics. However, there are the cases where the communication qualities are different where the delay spread is almost same. Though the delay spread can determine the performance of wireless systems if the symbol length is in the specific range [1], the symbol length of the wideband systems being studied recently is not always correspond the range. For example, 3GPP [2] and 3GPP2 [3] use different delay profile models for the system evaluation. Furthermore, to estimate the delay profile of the real propagation channel, special equipments are required. Thus, mobile communication operators need a simple method and an indicator with inexpensive equipments to design and maintain the wireless communication systems.

In this paper, we focused on the frequency spectra of the received signals, which we can measure easily with a spectrum analyzer. The performance of the wireless communication system was estimated by using measured spectra. In Section 2, the details of the measurement and measured data are introduced. In Section 3, we estimated the system performance using the measured spectra. Finally Section 4 concludes the paper.

2. Measurement description

Spectra data were measured in a suburban area assuming a cellular environment, using 40 MHz wideband signal in the 4 GHz band which is one of the candidate bands for IMT-Advanced. (In Japan, 3.4 - 4.9 GHz band is expected to be assigned to the next generation mobile system.) Table 1 summarizes the specification of the measurement system. The transmission system consisted of a signal generator (SG), power amplifier, and transmitting antenna. We employed an orthogonal frequency division multiplex (OFDM) signal with the bandwidth of 40 MHz for transmitting signal because the rectangular spectrum is required. An omni-directional antenna was used for the transmitter and the receiver, and the gain was 10 dBi and 5 dBi, respectively. The transmitted signal was received by a real-time spectrum analyzer via a receiving antenna and a low noise amplifier.

The transmission system was set on the roof of a building at a height of 30 m. The receiving antenna was set on the roof of a measurement van at a height of 2.5 m. The measurement van travelled within the measurement area, which was within about a 2 km radius from the transmission point, at the usual speed, and the spectrum of the transmitted signal was recorded at a rate of 1 data per second. The time length for spectrum data was about 0.02 ms, and was sufficiently shorter than the inverse of the Doppler frequency.

Figure 1 shows examples of the measured data. The left side of Figure 1 is a three-dimensional expression of the spectra by the water fall and the right side is a sample of spectrum data.

ISBN: 978-4-88552-223-9 C3055©IEICE

3. System evaluation and analysis

3.1 Assumed system and evaluation method

An OFDM/OFDMA system was assumed in this evaluation. The sub-carriers were bundled to some sub-bands. These sub-bands meant the frequency interleave blocks in the OFDM system or assigned sub-carriers per users in the OFDMA system.

In the evaluation, first, each spectrum data was moving averaged in the frequency domain, the size of the window for averaging was set to 20 kHz, which corresponded to the bandwidth of a sub-carrier in OFDM/ OFDMA signal. The averaged spectrum was normalized by the median. That is, the effects of long-term and short-term fading were eliminated assuming that the type of fading was flat fading. Setting the frequency window, the survival rate was calculated in each window, which is defined by the rate of the spectral densities higher than a threshold. The rate was how many sub-carriers can meet with the threshold. The cumulative probability of the sub-carrier survival rates was derived by moving the window. 1 / 3/ 5 MHz was selected as the size of the window. Here, the threshold was set to -5 dB.

3.2 Evaluation result and analysis

Figure 2 shows two examples of normalized spectra (Case 1 and 2). These data were selected from the different locations but the CNR (carrier to noise ratio) was almost the same. Figure 3 shows the results of calculating the cumulative probability of sub-carrier survival rates from the spectra data in Figures 2(a) and (b). Because the degradation due to a notch observed in the spectrum is mitigated when the sub-carrier block size (window size) becomes large, the gradient of the cumulative probability depends on the block size. The dependence on block size in Case 2 would be stronger than that in Case 1. The cumulative probabilities in Figure 3 are discrete; this is because the identical values are obtained when the notch lies within the window.

Assuming that the sub-carrier block (sub-band) can be demodulated when 50 % of the sub-carriers achieve CNR, the block error rates were found using Figure 2. We calculated the block error rates for 100 samples (100 seconds) around the locations where the spectra in Case 1 and 2 were measured. Figure 4 shows the time fluctuations in the small area around the locations of Case 1 and 2. In whole, the block error rates in Case 1 were worse than in Case 2. This indicated that the location in Cases 1 and 2 were not special cases but the small areas around Cases 1 and 2 had almost the same characteristics, respectively. The cumulative probabilities in each small area (around the locations of Cases 1 and 2) and the whole measurement area are shown in Figures 5(a), (b), and (c), respectively. To achieve a block error rate of 0 % with a probability greater than 90 %, a block size of 5 MHz is needed in a small area in Case 1; on the other hand, a block size of 3 MHz achieves 98% probability and a block size of 5 MHz achieves 100% probability in Case 2. The achievement rates for no block error rate in each case are shown in Table 2. It is believed that the wireless communication quality around Case 2 is lower and Case 1 is higher than that for the whole area.

4. Conclusion

In this paper, we studied an evaluation of a wireless communication system using normalized frequency characteristics. Spectra data were acquired by field measurements in a suburban area, and the block error rate characteristics in the measurement area and cases in two small areas were obtained. The system parameters assumed in this evaluation do not depend on the specific systems. Therefore, it is considered that the general trend would be almost the same although the evaluation results would change quantitatively.

In the future, we will try to establish simple methods for system design, area design, and area evaluation with simple measurement systems.

Acknowledgments

The authors are grateful for the continued guidance from Drs Akiba and Matsumoto, President and Vice President of KDDI R&D Labs., respectively.

Table 1: Specifications of measurement system

Transmitting power	40 dBm
Centre frequency	4.535 GHz
Bandwidth	40 MHz
Transmitting signal	OFDM (based on WiMAX)
Transmitting antenna	Omni-directional 10 dBi
Receiving antenna	Omni-directional 5 dBi

Table 2: Achievement rate of 0 block error

	Block Size		
	1 MHz	3 MHz	5 MHz
Case 1	52%	85%	96%
Case 2	76%	98%	100%
Whole area	59%	92%	97%

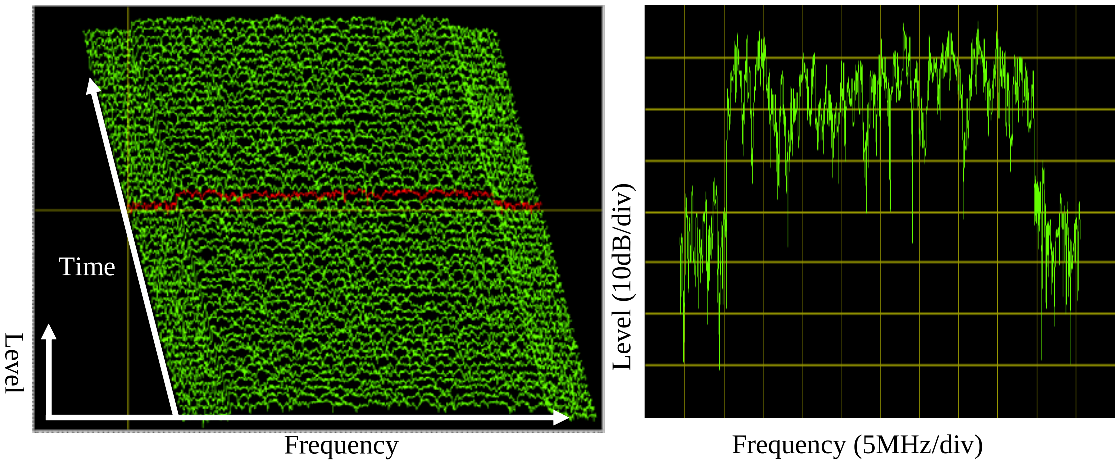


Figure 1: Examples of acquired spectra and spectrum data

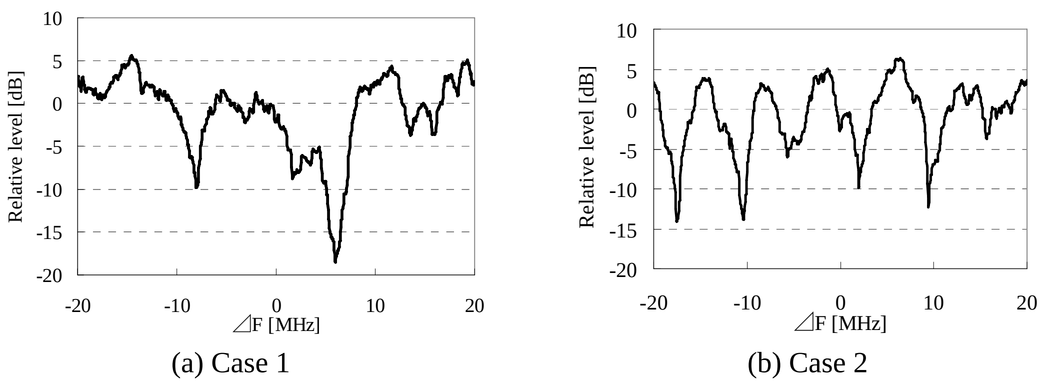
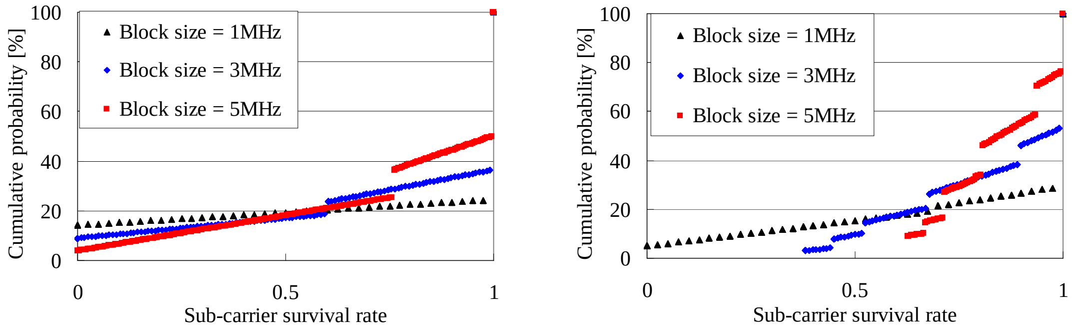
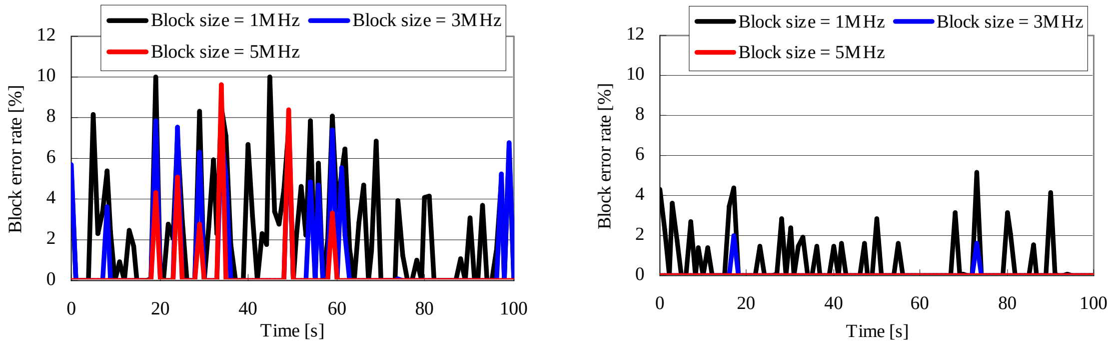


Figure 2 Example of spectra normalized by median



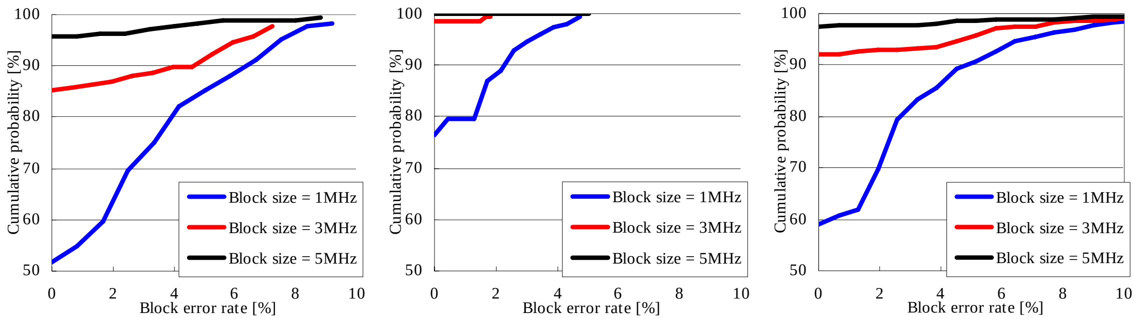
(a) Case 1 (b) Case 2

Figure 3 Block error rate



(a) Case 1 (b) Case 2

Figure 4 Time fluctuations of block error rate characteristics



(a) Case 1 (b) Case 2 (c) Whole area

Figure 5 Cumulative probability of block error rate

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