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DELAY SPREAD CHARACTERISTICS FOR OFDM TRANSMISSION IN TELEVISION STUDIOS

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1. INTRODUCTION

The authors have been developing a studio-use wireless television camera [1] which can transmit HDTV signals at up to 1.5 Gbps by utilizing a wide bandwidth of millimeter-wave bands.

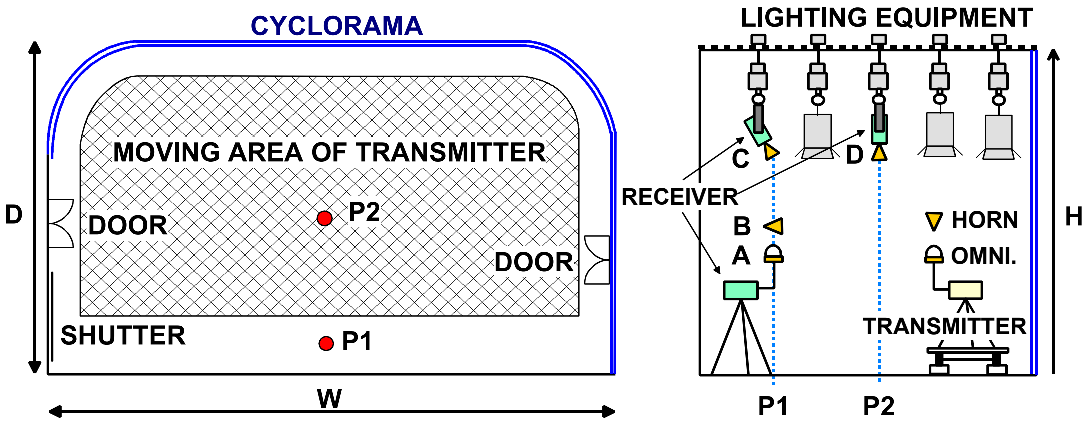
Orthogonal frequency division multiplexing (OFDM) is a major candidate for the wireless transmission scheme, because it is robust against multipath propagation. To determine OFDM parameters, we must consider radiowave propagation characteristics. For example, the guard interval should be greater than several times the r.m.s. (root-mean-square) delay spread; and the channel-estimation pilot carrier spacing should be less than the reciprocal of the r.m.s. delay spread [2]. Therefore, a solid knowledge of delay spread characteristics is essential when designing the system. However, there have been few reports on the delay spread characteristics of television (TV) studios [3]. We have therefore been investigating the delay spread characteristics of TV studios in the 42 GHz and 55 GHz bands which have been assigned for broadcast material transmission.

This report summarizes the delay spread characteristics obtained from our measurements and simulations, and provides predicting formulae for the average r.m.s. delay spread with respect to the studio floor area.

2. MEASUREMENT AND SIMULATION METHODS

Although each TV studio has a different structure, a typical structure is shown in Figure 1. The floor area ranges from 150 to 600 m^2 for almost studios, although there is an exceptional class of 1000 m^2.

To obtain power delay profiles, we performed measurements in 155 m^2 and 296 m^2 floor area studios[4], and also performed ray-tracing simulations with 150 m^2, 300 m^2, and 600 m^2 floor area studio models [5]. The dimensions of the simulation model are listed in Table 1. The studio condition was such that the lighting equipment was raised to the highest level, and the technical equipment and the scenery were removed from the studio. The transmitting conditions were as follows: the radiation frequency was 54.77 GHz; the bandwidth was 1 GHz; the modulation scheme was BPSK with m-sequence signal; the transmitted power was about +15 dBm; and the polarization was vertical.



(a) Top view (b) Side view

Figure 1 Typical studio structure and antenna locations

ISBN: 4-88552-206-4 C3055©IEICE

Table 1 Studio dimensions

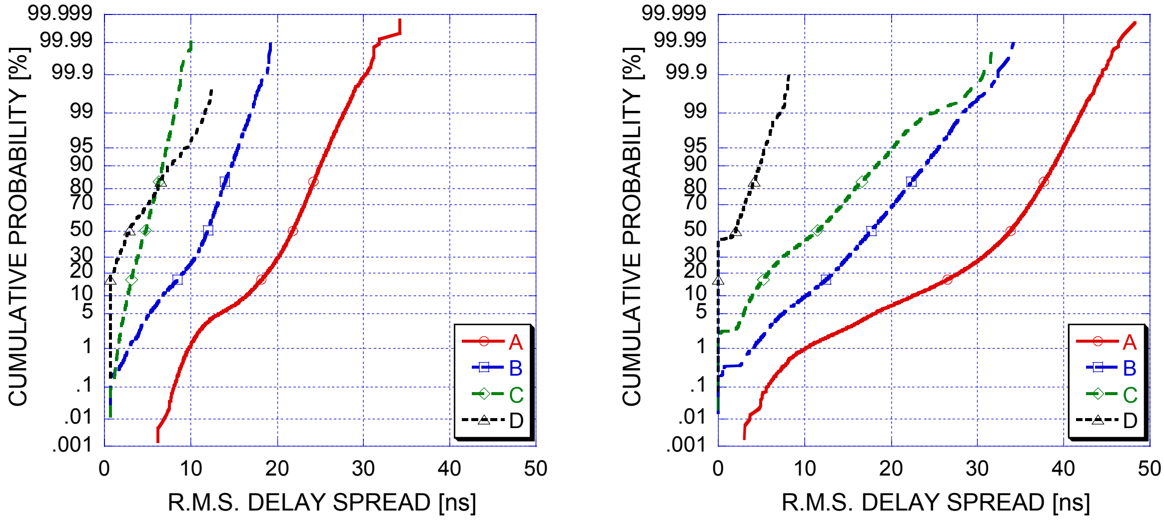
Floor area	Width W [m]	Depth D [m]	Height H [m]
150 m^2	15	10	5
300 m^2	21	14	8
600 m^2	30	20	8

Table 2 Antenna configurations

Case	Transmitter		Receiver	
	Antenna	Position	Antenna	Position
A	OMNI.*	Meshed area of Fig. 1(a), 1.8 m	OMNI.*	P1, 1.8 m
B			HORN**	
C				P1, 4 m
D	HORN**			P2, 4 m

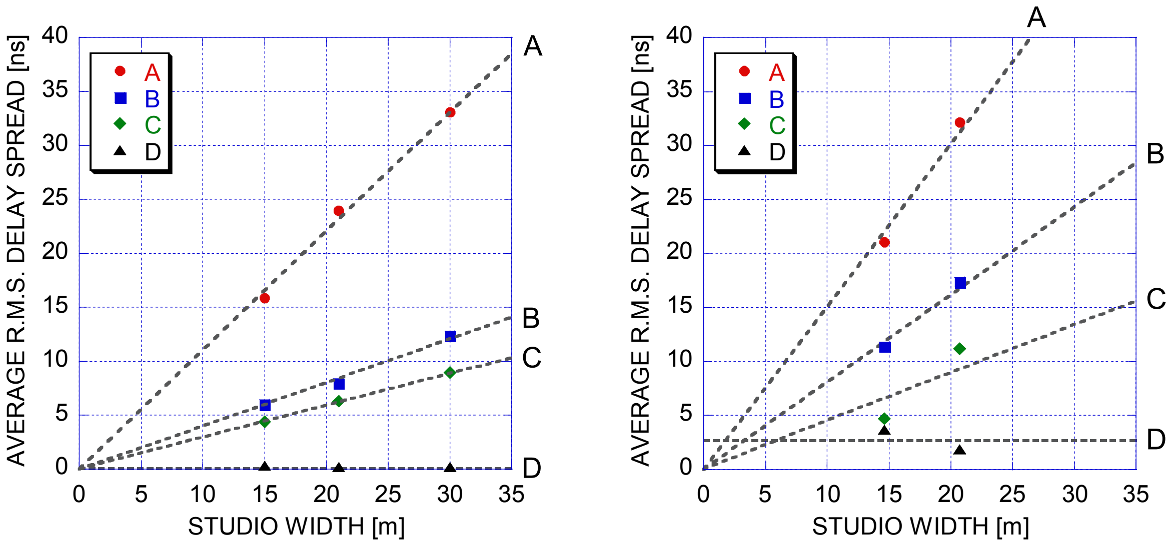
* OMNI.: (horizontally) omni-directional antenna, gain of 1 dBi

** HORN: horn antenna, gain of 10 dBi, 3 dB beamwidth of 50 deg.



(a) Floor area: 155 m^2 (b) Floor area: 296 m^2

Figure 2 Cumulative probability of the measured r.m.s. delay spread



(a) Simulation values (b) Measurement values

Figure 3 Average r.m.s. delay spread versus studio width

The antenna configuration was classified as A, B, C, and D according to the type and position of the antenna, as shown in Table 2. The antenna direction was fixed. The measurements were carried out with the transmitter moving in the meshed area shown in Figure 1(a). All of the transmitter positions were in a line of sight (LOS).

The r.m.s. delay spread was calculated as the power weighted standard deviation of the excess delays [6]. For the calculation, we included the direct wave and set a cut-off level of 30 dB below the direct wave's power. We evaluated the data obtained only at the positions within the 3 dB beamwidth of the transmitter (Tx) and receiver (Rx) antennas for each antenna configuration.

3. RESULT AND ANALYSIS

Figure 2 shows the cumulative probability of the measured r.m.s. delay spread, revealing that the use of a directional antenna and reception at a higher position reduce the r.m.s. delay spread. Figure 3 shows the average r.m.s. delay spread versus studio width for both simulation and measurement values. Here we assume that the average r.m.s. delay spread is approximated by a first-order equation of the studio width for cases A to C and by a constant for case D, which is illustrated by dotted lines. This approximation closely agrees with the simulation values and almost agrees with the measurement values. From the above assumption, we propose predicting formulae (1)-(3) for the average r.m.s. delay spread S [ns] with respect to the studio width W [m] or the floor area Fa [m^2] for each antenna configuration as follows:

For cases A to C : $S = a \cdot W$ (1)

or $S = b \cdot Fa^{0.5}$ (2)

For case D : $S = c$ (3)

Equation (2) is a modified version of equation (1) by using the relation that W is proportional to the square root of Fa in almost all studios. A close correlation between the r.m.s. delay spread and the room size is reported in the literature (e.g., [7], [8]). In reference [9] the r.m.s. delay spread is described as equation (4) and in reference [10] as equation (5):

$$10 \cdot \log S = 3.6 \cdot \log(Fa) + 8.7 \tag{4}$$

$$10 \cdot \log S = 2.3 \cdot \log(Fa) + 11.0 \tag{5}$$

However, equations (4) and (5) are based on measurements in the 2 GHz band for several room types such as office, lobby, corridor, and gymnasium. Hence, we regard equation (2) as a specific equation for TV studios under the classified antenna configuration in the millimeter-wave band.

We employ equation (3) because it is obvious in case D that the reflection from the side wall (which is related to the studio width or the floor area) does not play a significant role since the directional antennas for both Tx and Rx confine the radiowave propagation to the vertical direction.

We estimated the parameters (a, b, and c) by the least squares method using the measurement values. The estimated parameters are listed in Table 3. Figure 4 shows curves of the predicting formulae (2) and (3) with the estimated parameters applied.

Table 3 Estimated parameters

Case	*a*	*b*	*c*
A	1.52	1.81	-
B	0.821	0.978	-
C	0.468	0.557	-
D	-	-	2.8

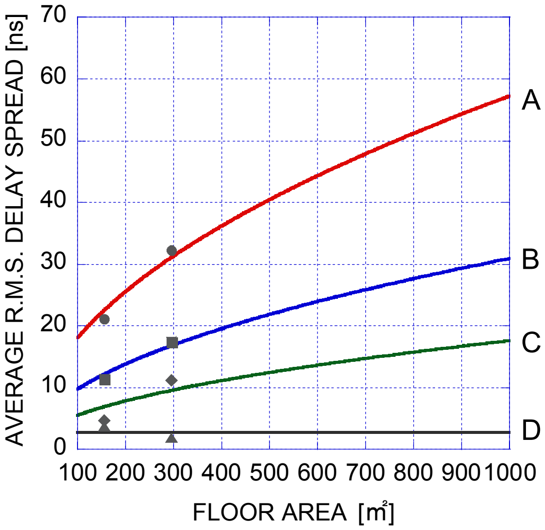


Figure 4 Curves of the predicting formulae for the average r.m.s. delay spread

4. CONCLUSION

We have been developing an OFDM based studio-use wireless television camera. In order to design an effective system, a good knowledge of radiowave propagation characteristics, especially r.m.s. delay spread characteristics, of TV studios is required. Therefore, we measured and analyzed the delay spread characteristics of TV studios in the 55 GHz band. As a result, we obtained a meaningful relationship between the average r.m.s. delay spread and studio floor area, and hence proposed equations for estimating the average r.m.s. delay spread with respect to the floor area under the classified antenna configuration.

We are going to design a studio-use wireless television camera system based on our propagation study and evaluate its transmission performance in the near future.

ACKNOWLEDGMENT

We wish to thank Dr. Nomoto in NHK Science and Technical Research Laboratories, for his encouragement throughout this research.

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