Preliminary Results from the Study of Raindrop Size Distribution and Rainfall Rate in Indonesia for the Development of Millimetre-Wave Systems in Tropical Regions

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1. Introduction

Increasing demand on broadband access to multimedia services has spurred interests in the use of millimetre-wave wireless access technologies. However, stringent requirements of propagation condition for sufficient radio link performance in this frequency band has limited the extent of its application. Rain attenuation is one of the natural factors that put severe limitation on the range of millimetre-wave radio propagation. In tropical countries like Indonesia, for instance, rain can induce as large as 85 dB attenuation on a 5-km 30-GHz link [1]. To devise techniques to combat this deleterious impact of rain attenuation, a comprehension of the random behaviour of rain events is compulsory. In this paper we report preliminary results from a measurement campaign aiming at characterization of raindrop size distribution (DSD) and space-time variation of rainfall rate and attenuation [2].

The DSD examination is inspired by the large differences found in the DSD shapes previously found in tropical countries, e.g. Singapore [3], compared to models empirically derived in higher-latitude regions, such as the Marshall and Palmer's (MP) [4]. These differences indicate that the MP-based ITU-R method for attenuation prediction [5] might be misleading when applied to tropical regions. Aside from that, it is considered interesting to compare the DSD shapes found in various parts of the tropical belt. Investigation of temporal variation of rainfall rate is stimulated by the desire to understand the variation of rain attenuation in tropical regions. For sufficiently short links, point rain rates approximately translate into attenuation following a power-law relation. In addition, from the knowledge of temporal variation, synthesis of random numbers representing a time series of rain rate or attenuation can be made on computer ([6], [7]).

Details of the measurement are briefly explained after this introductory section. It is followed successively by discussions on the measured DSD and rainfall rate variation. At the end of this paper, conclusions are drawn on these preliminary findings and subsequent steps.

2. Measurement Details

The DSD and rainfall rate have been measured using a disdrometer mounted on a rooftop in the campus area of Institut Teknologi Sepuluh Nopember in Surabaya since December 2006 [2].

ISBN: 978-4-88552-223-9 C3055©IEICE

The instrument comprises of an optical-based hardware called Parsivel, which detects falling drops that cross a laser beam, and an accompanying software that counts the number of crossing drops categorized into a number of diameters and fall velocities and translates them into rainfall rates. Two different settings of measurement have been tried, with one-minute integration time being adopted for the first month of operation and 10-second integration adopted afterward. The change in setting corresponds to upgrading of the acquisition software, from HYDRAS that can only measure rainfall rate to the more advanced ASDO that is also capable of measuring DSD. The change in sampling period can also be useful in studying the effect of averaging window upon the measured variation of both DSD and rainfall rate. That is, average rain rate and DSD with 60-second integration time can be computed from the recorded 10-second values by averaging six successive measurements.

Since the start of the disdrometer operation, as many as 28 rain events have been detected, excluding the unrecorded events during power failures (see Table 1). Grouping of the events into stratiform and convective classes has been done by applying a simple criterion on the rain intensity [8]. Specifically, a rain event is considered of stratiform type if the intensity is below 25 mm/h at all times during the whole event. Otherwise, it is considered convective. Sometimes, an event is started by a brief convective period followed later by a longer stratiform tail. In this case, these sub-events are considered as separate events. In the preliminary study reported herein, however, classification into the two groups was not applied yet. The 2006/2007 rainy season in East Java is atypically characterized by relatively dry weather. Downpours of high intensity accompanied by very strong wind occurred during a one-month period covering the last half of January and the first half of February. This extreme condition only implies that longer period of measurement is necessary, especially to capture annual variation of the precipitation.

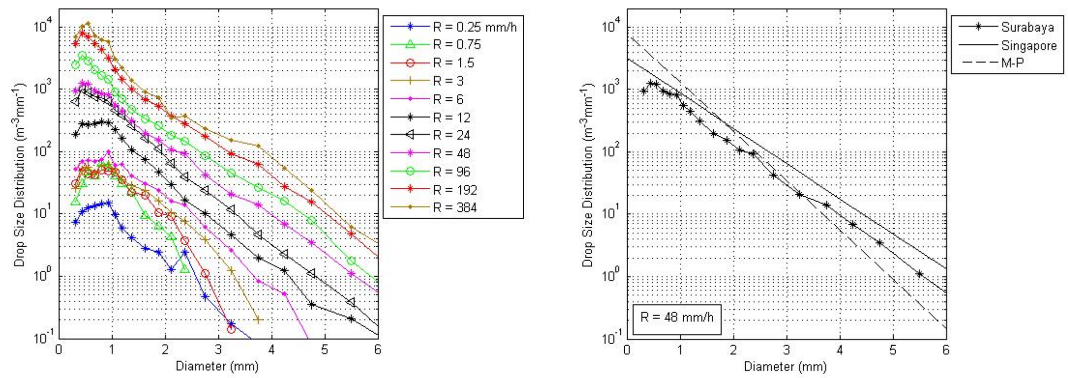
Table 1: Recorded rain events as of February 10, 2007

No	Date	Time	Type (S/C)	Sampling (sec)	No	Date	Time	Type (S/C)	Sampling (sec)
1	12/8/2006	02:09:00-3:08:00	S	60	15	1/17/2007	22:25:00-23:43:00	C, S	60
2	12/8/2006	19:59:00-20:33:00	C	60	16	1/22/2007	12:58:30-13:23:20	C	10
3	12/26/2006	10:09:00-10:48:00	S	60	17	1/22/2007	14:35:50-14:38:30	S	10
4	12/28/2006	20:34:00-22:33:00	C, S	60	18	1/22/2007	21:30:30-21:53:40	S	10
5	12/28/2006	22:49:00-23:13:00	S	60	19	1/23/2007	13:27:50-13:45:50	C	10
6	12/29/2006	14:38:00-03:17:00	C, S	60	20	1/23/2007	15:29:30-16:12:50	C, S	10
7	12/31/2006	14:08:00-14:22:00	S	60	21	1/30/2007	13:44:50-14:03:10	C	10
8	1/1/2007	16:57:00-23:26:00	C, S	60	22	1/30/2007	16:39:50-19:01:20	S	10
9	1/5/2007	20:39:00-21:13:00	S	60	23	2/1/2007	16:10:10-17:31:40	C	10
10	1/6/2007	20:18:00-20:24:00	C	60	24	2/1/2007	18:22:40-18:57:30	S	10
11	1/10/2007	17:26:00-17:39:00	S	60	25	2/2/2007	22:29:00-22:35:30	S	10
12	1/12/2007	15:29:00-18:39:00	C, S	60	26	2/3/2007	16:47:20-21:14:30	C, S	10
13	1/14/2007	16:46:00-18:46:00	C	60	27	2/9/2007	13:37:50-16:49:20	C, S	10
14	1/15/2007	16:09:00-17:28:00	C, S	60	28	2/10/2007	12:44:10-14:40:40	C, S	10
S: stratiform; C: convective									

3. Drop Size Distribution

Fig. 1(a) shows averages of 60-second DSDs, respectively, obtained for various intervals of rain rate measured during a single event of high intensity. The values given in the legend of the figure are medians of the rain rate intervals, namely 0-0.5, 0.5-1, 1-2, 2-4, …, 256-512 mm/h. Nothing as yet can be concluded from this presentation statistically as it is obtained from a single event, but the curves clearly indicate a tendency to follow a negative exponential form. The same form has been reported for DSDs measured in various places in the world, including North America (i.e., the MP model) [4] and Singapore [3], with different parameter values.

Fig. 1(b) compares the average DSD curve measured in Surabaya for rain rates in the range of 32 – 64 mm/h (i.e., 48 mm/h median rain rate) with the corresponding DSD curves for 48 mm/h rain rate based on the Singapore and MP models. Similarity in curve slope of the Surabaya DSD to that of Singapore is striking, but again no conclusion can be made at this point due to the limitation of the number of evaluated events. Nevertheless, it can be clearly seen that more in-depth investigation is necessary to characterize the DSD in tropical regions. As mentioned in the introductory section, the difference between the tropical and MP DSDs implies that ITU-R method of rain attenuation prediction must be applied with great care in tropical regions or even be replaced by a more appropriate one.



(a) (b)

Figure 1: DSD measurements in Surabaya: (a) Average DSDs for various median rainfall rates, (b) Comparison with Singaporean and M-P models for median rain rate of 48 mm/h.

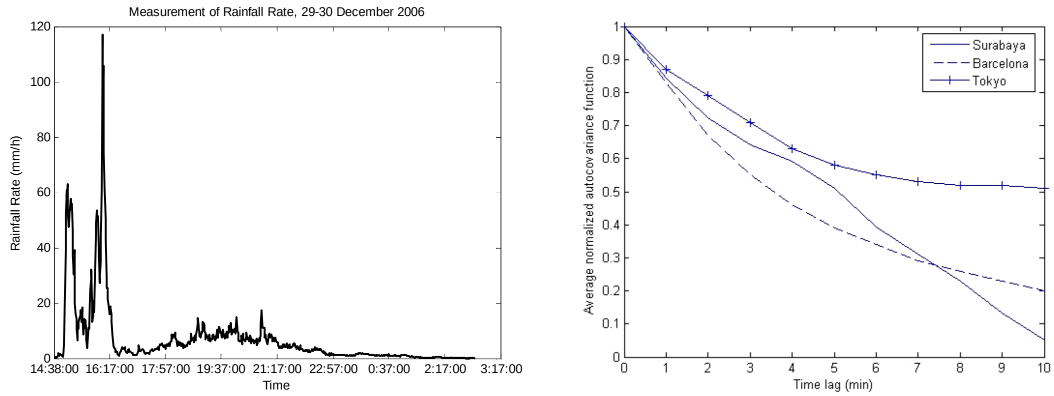
4. Temporal Variation of Rainfall Rate

The rainfall rate measurements considered herein are those from the measurement phase that used one-minute integration. In the evaluation reported below, stratiform and convective events are not yet separated. Fig. 2(a) exemplifies a recorded series of rain events comprising of a shorter convective segment (approximately from 14:38 to 16:17 on December 29, 2006) with higher intensity and variation followed later by a stratiform segment characterized by longer duration, lower and more stable intensity, until its fade at about 02:17 the next day.

Fig. 2(b) shows normalized autocovariance functions of the rainfall rate in Surabaya obtained during this rainy season (i.e., all events listed in Table 1 recorded with 60-second sampling) with those of Barcelona obtained from 49 years of measurement and Tokyo [9]. As with the DSD results, no statistically firm conclusion can be made thus far, except that there is a possible difference that can be observed in the shape of the autocovariance function obtained in Surabaya compared to those obtained in Barcelona and Tokyo. Examination of more rain events is required to investigate this issue.

5. Conclusions

Preliminary results from the measurement of DSD and rain rate variation in Indonesia has been presented. Due to the limited number of rain events evaluated, no conclusion can be made at this point. However, the presented results indicate that further study into the DSD shape as well as the temporal variation of rain rate is necessary. Consequently, our next step is to gather more rain events and include them in the subsequent analysis by applying classification of the type of the event, i.e. stratiform against convective. More results from this on-going study will be presented in the conference as they become available.



(a) (b)

Figure 2: Rain rate variation: (a) A long event recorded on 29-30 December 2006; (b) Average normalized autocovariance function of rainfall rate

Acknowledgments

The reported work is funded by Japan International Cooperation Agency (JICA) through a joint research grant within the PREDICT-ITS project and by Institut Teknologi Sepuluh Nopember through a DIKS research grant.

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