SPACIAL CORRELATION OF RAINFALL RATE IN URBAN AREAS OF JAPAN

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1.Introduction

Characteristics of spatial correlation of rainfall at the range of several kilometers are necessary to evaluate signal degradation on radio access systems using millimeter wave.[(1),(2)] In this paper, a relationship of the spatial correlation between rain gauge measurement and radar AMEDAS(Automated Meteorological Data Acquisition System) data in urban areas of Tokyo is obtained. Using this result, spatial correlations of rainfall rate in major cities in Japan are estimated.

2. Calculation of spatial correlation coefficient of rainfall rate using radar AMEDAS data.

Radar AMEDAS data are recorded as the national rainfall rate distribution in Japan at about 5km intervals in every one hour and these data are also available at 2.5km intervals since March 2001. Figure 1 shows characteristics of the spatial correlation in the region of about 30km near Tokyo station through 5 years. It is the feature that the correlation coefficient is large in the direction from north-west to south-east in Tokyo. Especially, this feature has appeared every year in Osaka.

Next, Figure 2 shows the spatial correlation of Nagano where the annual amount of rainfall is rather small. In this city, decrease rate of the correlation coefficient by distance is considerably larger than Tokyo and Osaka. Table 1 shows the change of spatial correlation by distance and azimuth in Tokyo,Osaka,Nagano,Fukuoka and Sapporo.

Table1. Spatial correlation in Tokyo,Osaka,Nagano,Fukuoka and Sapporo (Period: 1995~2000)

Distance [km]	Maximum	Minimum	Distance [km]	Maximum	Minimum	Distance [km]	Maximum	Minimum
Tokyo			Osaka			Nagano		
5	0.78	0.76	5	0.74	0.72	5	0.69	0.66
10	0.67	0.62	10	0.62	0.54	10	0.56	0.49
20	0.52	0.42	20	0.46	0.30	20	0.41	0.30
Fukuoka			Sapporo					
5	0.68	0.67	5	0.68	0.64			
10	0.53	0.50	10	0.56	0.48			
20	0.35	0.30	20	0.42	0.30			

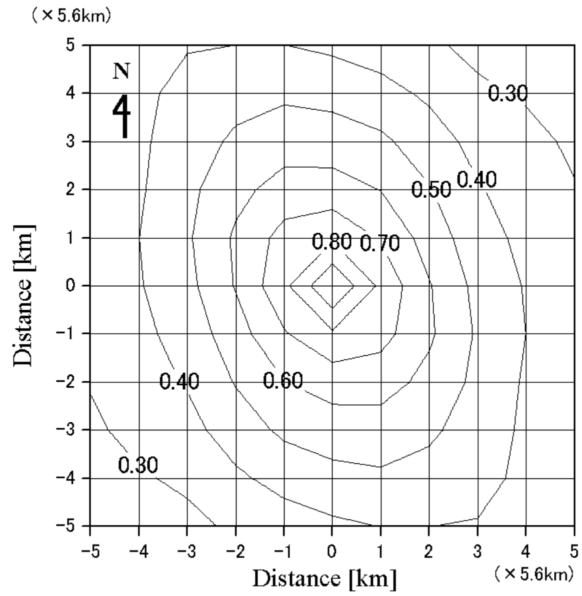

Fig.1 Spatial correlation contour in the area of Tokyo
(Data: Radar AMEDAS, Period: 1995~2000)

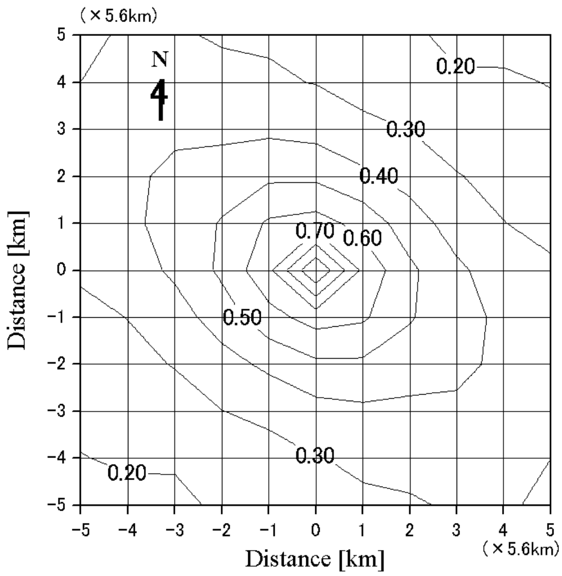

Fig.2 Spatial correlation contour in the area of Nagano
(Data: Radar AMEDAS, Period: 1995~2000)

3. Comparison of special correlation between rainfall rate of the radar AMEDAS and that of rain gauge measurement

Spatial correlation derived from the rainfall rate measured by rain gauge carried out by the KDDI laboratories in one year, 2001, are compared with that calculated from the radar AMEDAS data in almost the same period and place. Correlation coefficients were calculated for raining period including the case that no rain was observed at one point of the two.

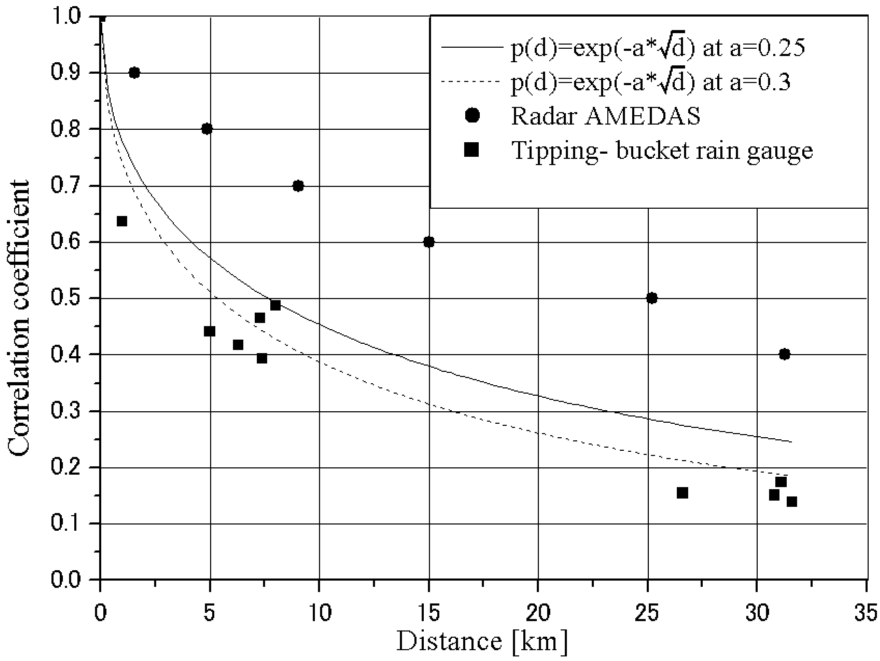

Fig.3 Spatial correlation coefficient in urban areas of Tokyo
(Period of tipping-bucket rain gauge data: 2001 June ~ 2002 March)
(Period of radar AMEDAS data: April~December 2001)

Figure 3 shows comparison of correlation coefficients between radar AMEDAS data in the period of April ~ December 2001 and rain gauge in almost the same period in Tokyo. Correlation coefficients of radar AMEDAS in this figure are average of the maximum and minimum value in the whole direction. Two curves in this figure are spatial correlation coefficient ρ given in Ref. (3) as follows,

$$\rho = \exp(-\alpha\sqrt{d}) \quad (\alpha=0.3 \text{ or } 0.25, \text{ d: distance}) \qquad (1)$$

The result derived from measurement by KDDI is well approximated by equation (1) (α=0.3) at the short distance from 1km to 8km.

The radar AMEDAS data shows larger value of 0.1～0.3 than that of rainfall rate measured by rain gauge and also than the curves of estimated using equation (1). This may be caused by some integration effect over fixed intervals of radar rainfall rate measurement.

4. Estimation of spatial correlation characteristics in major cities

There are some estimation schemes about rain attenuation available now and these schemes are based on one-minute rainfall rate measured at surface by tipping-bucket or drop counting type rain gauges.[4] However, number of observation points are not enough to obtain spatial correlation data at various places within the distance of several 10kms. Hence we have tried to estimate spatial correlation in major cities of rainfall rate using the relationship of spatial correlation between rain gauge measurement and radar AMEDAS data.

Spatial correlation coefficient using radar AMEDAS data is approximated by following equation.

$$\rho_{Radar} = \exp(-\beta \times d^{\gamma}) \qquad (2)$$

We have approximated the spatial correlation (period: April ~ December, 2001) using the radar AMEDAS data in the cities, Tokyo, Osaka, Nagano, Fukuoka and Sapporo by equation (2). Table 2 shows the parameters of β and γ for these cities.

Table 2. Values of β and γ for radar AMEDAS

	Tokyo	Osaka	Nagano	Fukuoka	Sapporo
β	0.073	0.093	0.13	0.12	0.15
γ	0.77	0.75	0.70	0.76	0.64

Under the assumption that relationship of spatial correlation between rain gauge measurement and radar AMEDAS in Tokyo is also applicable to the other cities, in other words, the difference between the value derived from equation (1) and the correlation coefficient calculated using the radar AMEDAS data in Tokyo are the same in the other places, estimated value of the spatial correlation of one-minute rainfall rate using rain gauge measurement is obtained from the radar AMEDAS data as given in Figure 4. This figure shows spatial correlations calculated directly from radar AMEDAS and results estimated in 5 cities during the period of 1996 - 2000 using the above method. Table 3 gives values of β and γ for estimated curves in these cities. It is found from this figure that the spatial correlation of rainfall rate in Sapporo and Nagano have large decrease of the correlation coefficient with increase of distance.

Table 3. Value of β and γ for estimated curves

	Tokyo	Osaka	Nagano	Fukuoka	Sapporo
β	0.29	0.30	0.34	0.31	0.37
γ	0.55	0.62	0.64	0.71	0.60

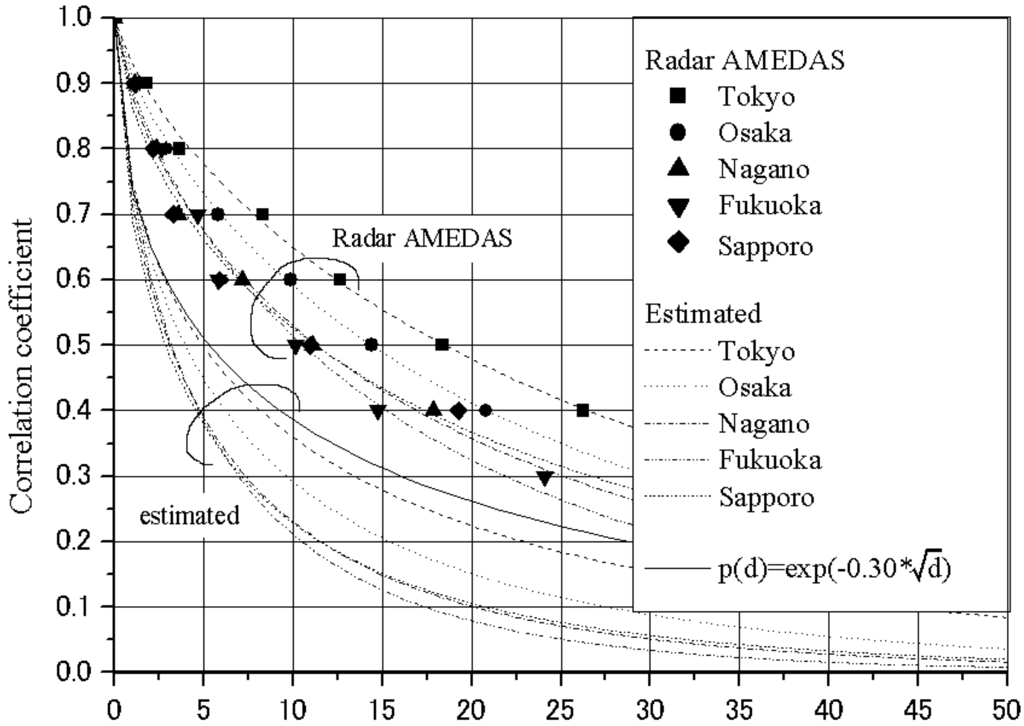

Fig.4 Correlation coefficient for 5 major cities
(Data: Radar AMEDAS, Period: 1995~2000)

Moreover, in Sapporo and Nagano it seems both rainfall rate and rain area are smaller than Tokyo and Osaka considering that Ref. (5) shows the spatial correlation is changed by rainfall rate, and it decreases when rainfall rate increases.

5. Conclusions

In this paper, we have obtained the relationship of spatial correlation between tipping-bucket rain gauge and radar AMEDAS data in urban areas of Tokyo, and using this result, we have obtained spatial correlations of rainfall rate in major cities. It will be necessary for estimating link parameters as diversity effect etc. using spatial correlation coefficient to consider local varieties of spatial correlation. As further work, we will clarify the relation between results estimated and diversity effects as basic data of millimeter wave access link design.

Reference

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