Spatial Correlation Property Derived from Radar Rain Map and Site-Diversity Effect Evaluation

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***Abstract* – Rain attenuation should be overcome for future high-speed satellite communication using higher frequencies above 20GHz even in rain-rich countries. Several countermeasure techniques has been proposed to maintain satellite link service. Site-diversity method has been used for that purpose. For quantitative evaluation of site-diversity effect, spatial correlation of rain may be quite valuable. We derived 2-dimensional space correlation property all over Japan and found region dependence, anisotropic property and distance dependence of the correlation. We derived relations between space correlation and site-diversity gain. This results is useful for efficient site-diversity strategy design.**

***Index Terms* — Rain attenuation, Site-Diversity, Rain space correlation**

I. Introduction

Rain attenuation mitigation methods are divided into (i)static methods, (ii)adaptive methods and (iii)diversity methods[1]. In category (iii), site-diversity method has been used such as feeder-link of satellite broadcasting system. The estimation procedure of diversity gain and cumulative time percentage improvement are available in ITU recommendation[2]. These procedures are based on empirical results mainly derived in middle latitudes countries. It is very useful for effective and efficient design of site-diversity system, if site-diversity effect can be evaluated quantitatively using rain spatial properties such as space correlation rather than empirical relation. Recently good quality rain map which has high resolution both in space and time can be obtained from Rain Radar network. Of course such rain information is quite useful to disaster prevention through quick grasping of intense rain dynamics, but also useful for analyzing such rain space correlation property over wide area.

II. Data Analysis

We used rain radar data all over Japan produced by Japan Meteorological Agency. The rain radar data are available every 5 minute interval time and about 1 km mesh point. Rainfall intensity is estimated from radar reception with adjustment by surface rain gauge observation data. This paper used 4 years data from July 2009. Fig.1 shows an example of snap-shot of rain pattern on the 1st Nov. 2009, 00:00. Areas of concern in this paper, Kanto, Kansai and Kyushu are also indicated in the figure. The parameters used in this work are given as follows;

- Rain radar data from July 2009 – June 2013 (4 years)
- Rain gauge data with 1min measuring interval in Kanto area from July 2009-June 2013 (4 years)
- Area of concern: Kanto, Kansai and Kyushu

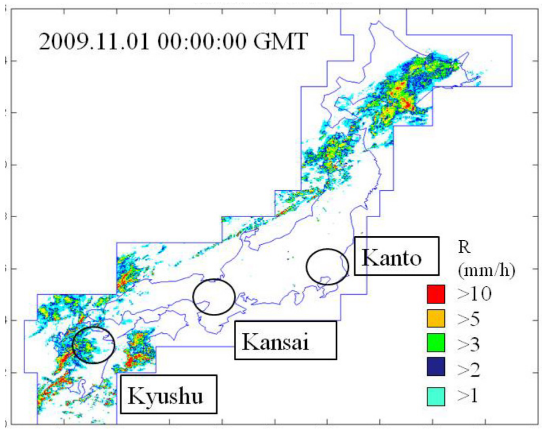

Fig.1 Sample of rain map and area of concern

Data analysis procedure is shown in Fig.2. Rain map data are transformed into equi-distance 0.5km mesh map for each area. The rain patterns in which rainfall rate larger than 1mm/h points number is larger than threshold percentage are used for 2 dimensional FFT analyses. The analyzed power spectrums are averaged over 4years and space correlation property is derived by 2 dimensional IFFT process. Fig.3 shows a sample of equi-distance rain pattern.

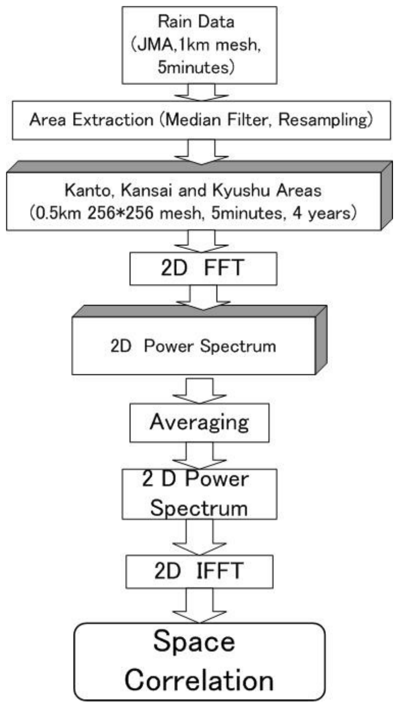

Fig.2 Data process procedure

III. Space Correlation Properties

A. 2 Dimensional space correlation

Fig.4 a) and b) show 2 dimensional space correlation of rain in Kanto and Kansai area. These patterns were derived from rain maps in which larger than 60% of points have rain larger than 1mm/h over 4years. It is observed that anisotropic property of correlation coefficient especially in lower correlation case. Because Kanto area is not mountainous and has wide almost flat terrain, correlation is relatively isotropic and high along distance. On the contrary, correlation in Kansai area has strong anisotropic property and quickly decreases as a function of distance.

B. Distance dependence of correlation coefficient

Fig.5 shows correlation coefficient as a function of North-South distance for each area, Kanto, Kansai and Kyushu. It is noticed that the results depends on areas. From site-diversity point of view, it is preferable that the correlation decreases rapidly along the distance then it is expected that Kyushu area may have benefit in site-diversity effect. As previously mentioned correlation coefficient depends not only area and distance but also depends on direction. We propose the following modeling equation for relation between correlation coefficient, rho, and distance, D. Dependence on area and direction, theta, are included in the coefficients alpha and beta. We also discovered the coefficients also depends on distance. By approximating such a way, correlation coefficient in short distance area can be well approximated.

$$\rho = \exp[-\alpha(D,\theta) D^{\beta(D,\theta)}]$$

IV. Conclusion

We analyze rain radar data all over Japan for 4 years with 5 minute of time interval in order to evaluate space correlation property and its relation on site-diversity effect. We found precise approximation of correlation coefficient as a function of area, direction and distance. This property may be useful for site-diversity effect evaluation and design of site-diversity system.

Acknowledgment

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References

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[2] Recommendation ITU R P.618-11, "Propagation data and prediction methods required for the design of Earth-space telecommunication systems," 2013.

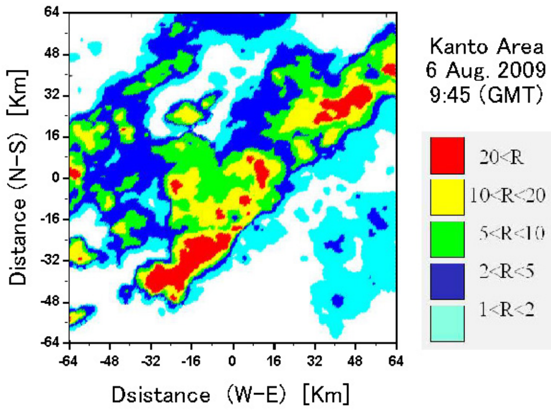

Fig.3 Re-sampled rain pattern example

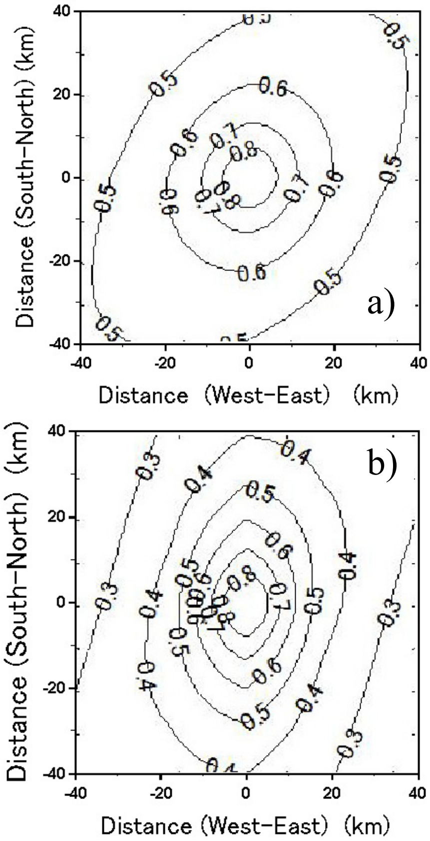

Fig.4 2 D correlation a) Kanto b)Kansai

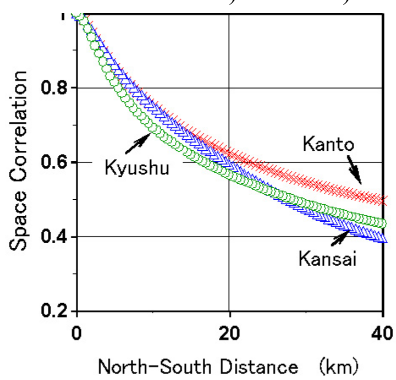

Fig.5 Distance dependence of correlation