Effects of Rain Area Motions on Site Diversity Techniques in Ku Band Satellite Signal Attenuation

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***Abstract* - The effects of site diversity techniques on Ku-band rain attenuation are investigated using two sets of simultaneous satellite signal observations, which have been conducted among Osaka Electro-Communication University (OECU) in Neyagawa, Kyoto University in Uji, and Shigaraki MU Observatory in Koga for about past nine years, and among the headquarters of OECU in Neyagawa and their other facilities in Shijonawate and Moriguchi for about past six years. The site diversity effects are found to be largely affected by the passing direction of rain areas. The diversity effects primarily depends on the distance between the sites projected to the rain area motions, and the time percentages of rain attenuation can be reduced down to about 60 % of the ITU-R predictions between the fixed two sites, by choosing a pair of the two sites out of the three, which is aligned nearest to the rain area motion in each rainfall event.**

***Index Terms* — Satellite Communications, Site Diversity, Rain attenuation, Ku band, Rain area motion.**

1. Introduction

Site diversity techniques are often used to mitigate rain attenuation effects that are significant in satellite communications using frequency of higher than 10 GHz [1], [2]. In this study, the effects of site diversity techniques on Ku-band rain attenuation are investigated using the simultaneous satellite signal observations, which have been conducted among Osaka Electro-Communication University (OECU) in Neyagawa (Osaka), Kyoto University in Uji (Kyoto), and Shigaraki MU Observatory in Koga (Shiga) from September 2002 to July 2011, and among the headquarters of OECU in Neyagawa and their other facilities in Shijonawate and Moriguchi from July 2005 to July 2011. Based on these two observations, the site diversity effects related to the rain area motions of various rain types are investigated between OECU (Neyagawa) and the other two locations in the ranges of several tens km and 3-8 km, respectively. The effects of the rain area motions are evaluated in the distances from 3 to 50 km in terms of the site diversity performance.

2. Observation Methods

At the three locations of OECU, RISH and MU, the Ku-band broadcasting satellite (BS) signals (11.8GHz, RHCP, EL=41.4°) have been continuously observed. Similarly at the two nearby locations in Moriguchi and Shijonawate, BS signals have been continuously measured. Also, 1 min rainfall rate has been continuously recorded at these stations. At RISH in Uji, however, the Ku-band signal (12.7GHz, HP, EL=48.9°) of Superbird C had been observed up to July 2005 [3]. These signal levels are recorded every second by personal computers equipped with 16 bit AD converters, and averaged over 1 min for further analyses. RISH in Uji, Kyoto is located 23.3 km northwest (16.0 km, 16.9 km) from OECU in Neyagawa, Osaka, while MU in Koga, Shiga is located 45.9 km east northeast (44.2 km, 12.4 km) from OECU. On the other hand, the sites at Moriguchi and Shijonawate facilities are located 5.6 km west southwest (-5.0 km, -3.7 km) and 3.9 km southeast (3.2km, -2.1km) from OECU in Neyagawa, respectively.

3. Site Diversity Effects

Figure 1 depicts the results of site diversity effects that are numerically calculated for the three locations 20-50 km away from each other, together with the cumulative time percentages of the rain attenuation obtained at OECU (square), RISH (circle), and MU (triangle), for the past nine years from 2002 to 2011. Their effects are evaluated for any two of the three sites, being switched between OECU and MU (plus, O-M), OECU and RISH (cross, O-R), and RISH and MU (diamond, R-M), respectively, as well as among the three sites (asterisk). Also, a dashed line indicates the results switched between two optimal sites, which have been selected for all rainfall events such that their alignment is the nearest to each rain area motion.

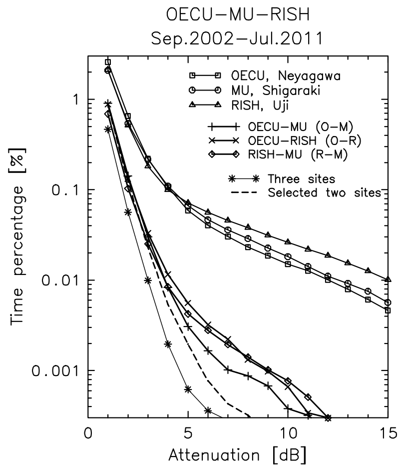

Fig. 1 Cumulative time percentages at OECU, MU, and RISH, together with joint probabilities between these sites.

Figure 2 similarly depicts the diversity effects calculated for the nearby three sites 3-8 km away from each other, together with the cumulative time percentages of Neyagawa (square, OECU), Shijonawate (circle), and Moriguchi (triangle), for the past six years from 2005 to 2011. The results are presented for the numerical evaluations switched between any two of the three sites (N-S, N-M, M-S), among the three sites (asterisk), and between two optimal sites compared to each rain area motion in every rainfall event, respectively, in the same way. Note that in both Figs.1 and 2, the site diversity effects are further increased between two sites when their alignments are always chosen nearer to the rain area motions.

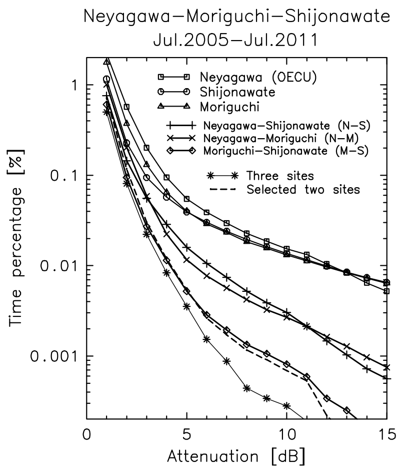

Fig. 2 Cumulative time percentages at Neyagawa, Shijo-nawate, and Moriguchi, together with joint probabilities between these sites.

Next, these features of the diversity effects are depicted in terms of distance dependence. In Fig.3, the joint cumulative time percentages obtained for all pairs of the locations (N-S: square, N-M: circular, M-S: triangle, O-R: cross, R-M: diamond, O-M: plus) are plotted against their geographical distances (small symbols) and average lengths projected to the direction of rain area motions (large symbols). The results obtained in all rainfall events are presented for the yearly single-site time percentages of (a) 0.2, (b) 0.1, and (c) 0.05%, respectively. Thin lines indicate joint time percentages predicted by the ITU-R recom-mendations [2] for the corresponding time percentages. As was shown in our previous study [3], the average distances between the sites projected to the rain area motions are found to be reduced down to about 60 % of the ITU-R predictions as indicated by dashed lines including the case of the nearby sites (N-S, N-M, M-S).

Finally, Figure 4 presents the distance dependence of the site diversity effects in the case that the two sites which have the shortest length projected to the rain area motion are selected in each rainfall event. The results are depicted for two sets of the three sites in the same time percentages, and their distances are averaged over the three sites. As compared with the ITU-R predictions, we can similarly find the improvement of the diversity effects of about 60% in terms of the distance.

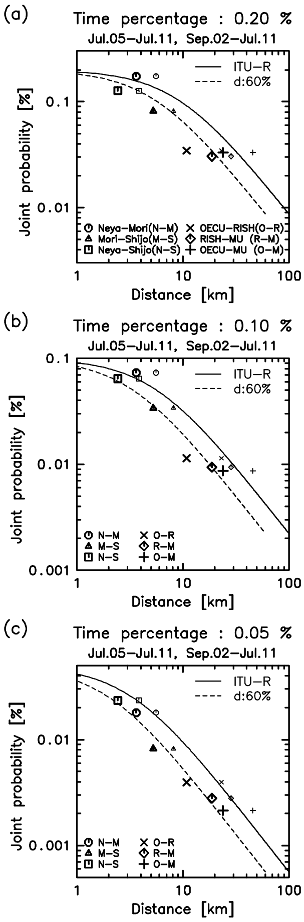

Fig. 3. Diversity effects for all rain events obtained in the range of 3-50 km.

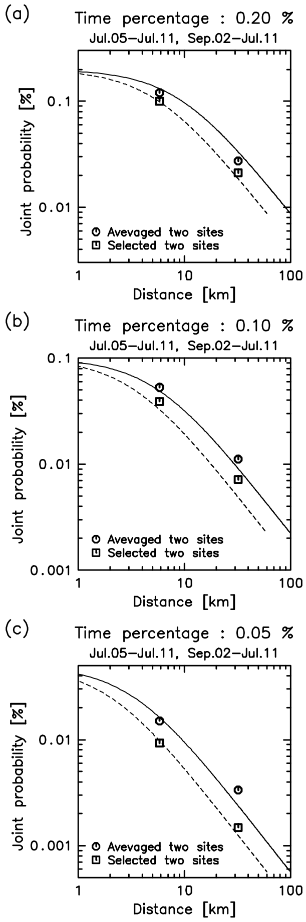

Fig. 4. Diversity effects for the two sites with the shortest length against the rain area motion.

4. Conclusions

The improvement of the site diversity effects is discussed in relation to the rain area motions, using the rain attenuation data of the Ku-band satellite radio wave signals observed at OECU and the nearby two sites 3-8 km away from OECU, as well as those obtained in Kyoto and Shiga 20-50 km away from OECU in Osaka. Considering average lengths projected to the rain area motions, the distance required to achieve the same diversity effects are found to be reduced down to about 60%, in the range from 3 to 50 km. Also, this improvement is shown to be realized by choosing two sites with the shortest length against rain area motion in each rainfall event.

References

[1] T. Iida, *Satellite Communications* (*in Japanese*), Ohmusha, 427p. 1997.

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[3] Y. Maekawa, T. Nakatani, Y.Shibagaki, T. Hatsuda, "A Study on Site Diversity Techniques related to Rain Area Motion using Ku-Band Satellite Signals," *IEICE Tran. Commun.* Vol.E91-B, No.6, pp.1812-1818, Jun. 2008.