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.

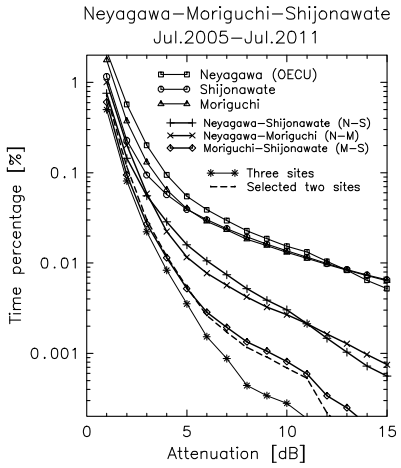

Fig. 2 Cumulative time percentages at Neyagawa, Shijonawate, and Moriguchi, together with joint probabilities between these sites.

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 recommendations [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.

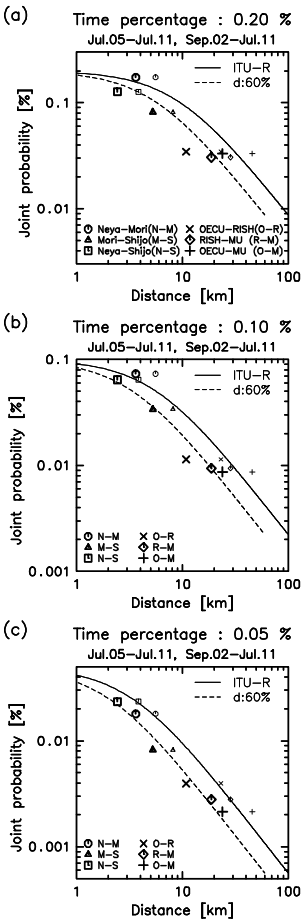

Fig. 3. Diversity effects for all rain events obtained in the range of 3-50 km.

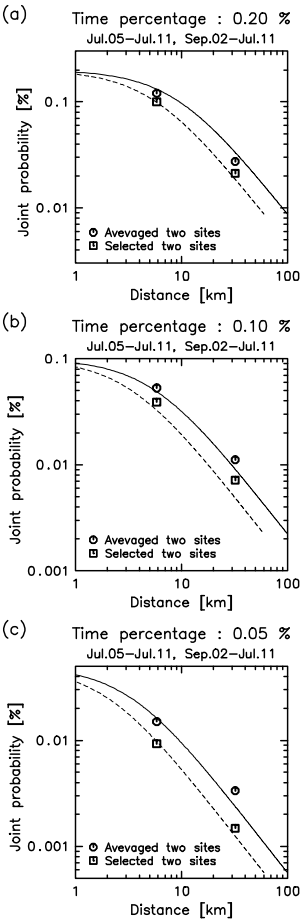

Fig. 4. Diversity effects for the two sites with the shortest length against the rain area motion.

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.

[2] ITU-R, P.618-8, "Propagation data and prediction methods required for the design of Earth-space telecommunication systems," ITU-R Recommendations, Geneva, 2006.

[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.