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Rain Front and Rain Area Motions related to Ku Band Satellite Signal Attenuation

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Abstract - **Speeds and directions of the motion of rain areas that cause the attenuation of Ku-band satellite signals are estimated from the broadcast satellite (BS) signal levels simultaneously obtained at three locations of Osaka Electro-Communication University (Neyagawa, Osaka), Research Institute of Sustainable Humanosphere of Kyoto University (Uji, Kyoto), and Shigaraki MU Observatory (Koga, Shiga). The speeds and directions of rain area motion are compared with those of rain fronts obtained from image analyses of real time weather charts and rain cloud images recently published in the website by Japan Meteorological Agency. The speeds and directions of rain area motions estimated from the BS signals are in fairly good agreement with those estimated from these images of rain fronts and rain clouds down loaded from the websites, although the speeds tend to be faster in the BS signal measurements than in the images in the websites. So, the information on the rain area motions expected to be useful for site diversity techniques will be easily obtained by the image analysis methods presented by this study.**

Index Terms — **Satellite Signal, Site Diversity, Rain Attenuation, Ku Band, Rain Area Motion, Image Analysis.**

1. Introduction

Rain attenuation of radio wave signals is significant in satellite communications links using frequency of higher than 10 GHz. Site diversity techniques are often used to mitigate rain attenuation effects when the attenuation of the signal levels is not negligible in the operations of satellite communications links [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 at three locations of Osaka Electro-Communication University (OECU) in Neyagawa (Osaka), Kyoto University in Uji (Kyoto), and Shigaraki MU Observatory in Koga (Shiga). Speeds and directions of the motion of rain area that causes the attenuation of the BS signals and may affect the operation of site diversity techniques are estimated from the BS signal level observations conducted at these three locations. The results are compared with those directly obtained from image analyses of real time weather charts [3] and rain cloud images [4] recently published in the website by Japan Meteorological Agency.

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. Also, 1 min rainfall rate has been continuously recorded at these stations. 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.

The images of real time weather charts are obtained from the websites published by Japan Meteorological Agency (JMA) at three hour intervals [3]. The shape of rain fronts such as warm, cold, and stationary fronts is extracted by the image analysis techniques, and 112 examples of rainfall events are recorded during the period from 2007 and 2011. Recently, the images of rain clouds are also obtained from the websites of "radar now cast" by JMA at 10 min intervals [4]. The speeds and directions of the rain areas are directly estimated by two-dimensional cross-correlation analysis between the two successive rain cloud images separated by 10 min, and 15 examples of rainfall events are collected during the period from 2011 to 2012.

3. BS Signal Measurements and Rain Front Image Analyses

Figure 1 depicts an example of speed and direction of the rain area motion estimated from the three-location BS signal measurements at 3-6 LT on March 30, 2007. On this day, the peak of the rain attenuation is detected 3 min and 22 min later at RISH and MU, respectively, than at OECU by cross-correlation analyses, so the speed and the direction are estimated to be 22.3 m/s and 123.1 deg, respectively, where the direction is indicated in clockwise from the north.

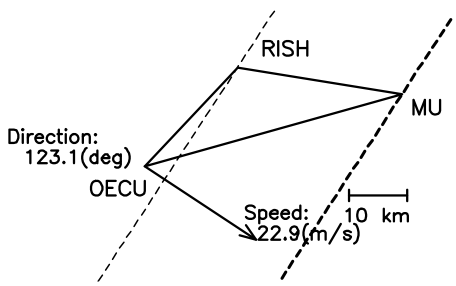

Fig.1. Example of the rain area motion estimated from the BS signal measurements on March 30, 2007.

On the other hand, Fig.2 shows the rain fronts extracted from the weather charts cited in the websites at three hour intervals, which are obtained at 3 and 6 LT on the same day. During this period, the cold front is found to pass over Osaka area toward south-east direction. The speed and the direction are estimated to be 21.5 m/s and 130.8 deg, respectively, from the reduction rate of the weather chart, being in good agreement with those obtained from the BS signal measurements.

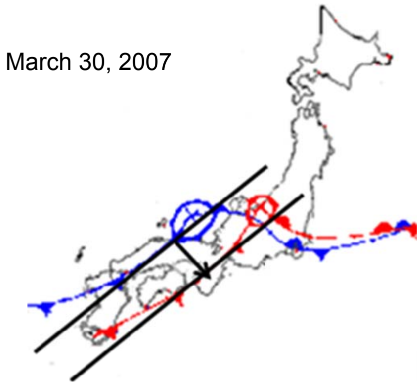

Fig.2. Images of rain fronts extracted from the weather charts in the website at 3 and 6 LT on March 30, 2007.

4. BS Signal Measurements and Rain Cloud Image Analyses

Figure 3 depicts an example of speed and direction of the rain area motion estimate from the BS signal measurements at 16-19 on April 11, 2012. On this day, the peak of the rain attenuation is detected 15 min and 36 min later at RISH and MU, respectively, than at OECU by cross-correlation analyses, so the speed and the direction are estimated to be 21.2 m/s and 78.3 deg, respectively, where the direction is indicated in clockwise from the north.

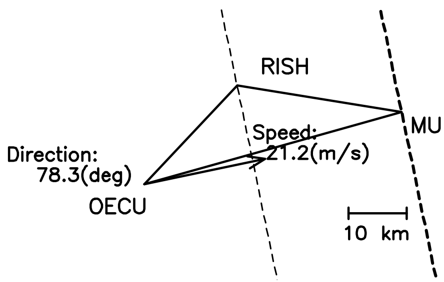

Fig.3. Example of the rain area motion estimated from the BS signal measurements on April 11, 2012.

Next, Fig.4 shows the pictures of rain cloud images extracted from the "radar now cast" cited in the websites at 10 min intervals, which are obtained at 17:00 and 17:10 LT on the same day. During this period, the rain area associated with the cold front is found to pass over Osaka area toward east direction by the two-dimensional cross-correlation analysis between the two pictures. The speed and the direction are estimated to be 18.5 m/s and 78.6 deg, respectively, from the reduction rate of the map, and agree well with those obtained from the BS signal measurements.

(a) (b)

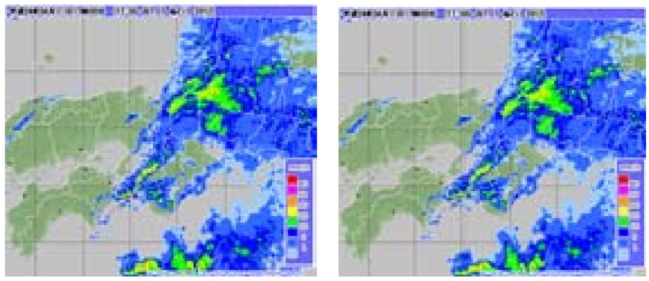

Fig.4. Images of rain areas extracted from the rain cloud images in the website at (a) 17:00 and (b) 17:10 LT on April 11, 2012.

Finally, cross-correlation coefficients between the speeds and directions of rain area motions estimated from the BS signal measurements and the two kinds of image analyses are summarized in Table 3 for all observed rainfall events. The comparison with the rain front images of the weather charts uses 117 examples obtained from 2007 to 2012, while that with the rain area images has 15 examples from 2011 to 2012. It should be here noted that in the both kinds of image analyses, higher correlations are obtained for the direction of rain area motions, which is important to choose two sites with the shortest distance against rain area motions for the site diversity techniques [2].

Table 1. Cross-correlation coefficients between the BS signal measurements and image analyses of rain areas.

	Rain fronts (117)	Rain clouds (15)
Speed	0.530	0.543
Direction	0.865	0.671

5. Conclusions

The rain area motions estimated from the three location BS signal measurements are compared with those directly obtained from the images of rain fronts and rain clouds recently published in the websites by Japan Meteorological Agency. The estimated rain area motion agrees fairly well with the real time information on rain fronts and rain areas, which is easily retrieved by the websites. It is thus suggested that this information can be applied to actual operations of satellite communications links and networks using site diversity techniques.

References

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