Receive Power and C/I Characteristics of DSRC Systems under Heavy Snowy Conditions

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1. ABSTRACT

In order to evaluate the influence of snow on the radio propagation of Dedicated Short Range Communication (DSRC) systems, received power and Carrier-to-interference (C/I) power ratio characteristics were analyzed with the ray trace method by changing the height of roadside walls and materials for road surfaces and roadside walls into concrete, wet snow and dry snow. The reflection coefficient was a crucial parameter to this analysis. The result of analysis was also compared with the experimental data. It was clarified that though dry snow hardly affects the radio propagation, wet snow affects the received power characteristic near the desired BS, and wet snow reduces the communication area where the C/I performance exceeds the required threshold level of the DSRC systems.

2. Introduction

Snow on a highway has serious impacts on safety, e.g. traffic accidents and jams, in cold, snowy areas like Hokkaido. It is expected that a cruise assist system realized by Intelligent Transport Systems (ITS)[1] could reduce such traffic accidents and jams. Dedicated Short Range Communication (DSRC) systems play an important role in the cruise assist system to convey traffic and vehicle information between fixed roadside base stations (BSs) and mobile stations (MSs) in moving vehicles. In the DSRC systems, the signal power received is extremely attenuated periodically between a BS and an MS, because a direct wave is interfered with by waves reflected from road surfaces and roadside walls. The received signal is also interfered with by co-channel interference signals transmitted by other base stations. Heavy snow affects radio propagation environments of the DSRC systems, which should be taken into account in evaluating the received power characteristics of the DSRC systems so that the threshold performance of the DSRC systems are always achieved. However, no discussion has been made on the radio propagation of the DSRC systems in cold, snowy areas. In this study, stability of communication in a single BS against multi-path waves was investigated by analyzing received power characteristics. Interference from an adjacent BS was estimated by analyzing the channel-to-interference ratio (C/I).

3. DSRC Systems

The DSRC systems are expected as a roadside-to-vehicle communications system in the ITS. The

DSRC systems for ETC (Electronic Toll Collection) are standardized as Association of Radio Industries and Businesses (ARIB) STD T-55[2] in Japan. They provide roadside-to-vehicle communications in a spot beam with a diameter of 10 to 30 meters. In order to provide the cruise assist system, the DSRC systems need to have continuous communication over several BSs.

In the DSRC systems, two or three frequency channels are assigned for each zone repeatedly to avoid co-channel interference between adjacent zones. The DSRC systems configuration is shown in Fig. 1. In Fig. 1, several BSs with a zone range of approximately 30 meters are arranged 30 meters apart along a road to form a communication area. Communication with radio cells of the DSRC systems is based on direct wave. In the DSRC systems, however, signal power received is interfered with by both multi-paths and co-channel interference power.

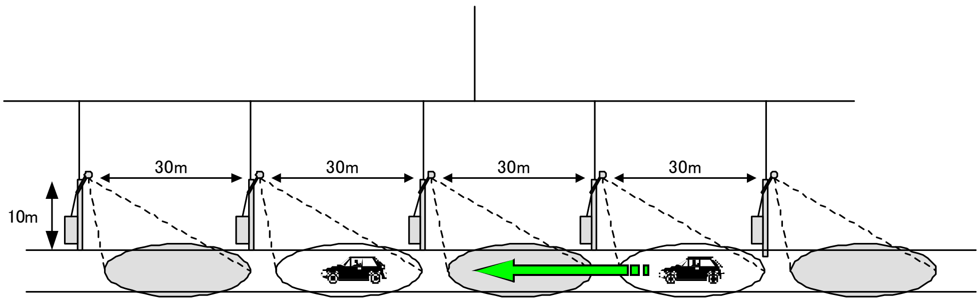

Fig. 1 DSRC systems

4. Reflection coefficient

In this study, the propagation was analyzed with the ray trace method. As a propagation model between a BS and an MS, a four paths model consisting of a direct path and three reflected paths was assumed. In order to obtain the reflection coefficient of 1) concrete, 2) wet snow and 3) dry snow, the following expression (Fresnel's formula)[3] was used.

In the case of transverse magnetic (TM) wave,

$$R_H = \frac{\cos\theta - \sqrt{n^2 - \sin^2\theta}}{\cos\theta + \sqrt{n^2 - \sin^2\theta}}$$

In the case of transverse electric (TE) wave,

$$R_V = \frac{n^2\cos\theta - \sqrt{n^2 - \sin^2\theta}}{n^2\cos\theta + \sqrt{n^2 - \sin^2\theta}}$$

where θ is the incidence angle, and n is the refraction index. Fig. 2 shows the reflection coefficients of concrete, wet snow and dry snow. When the incident angle is lower than 90 degrees (in the case of a short distance between the BS and the MS), reflection coefficients depend on materials, i.e. concrete (0.45 at 0 degrees), wet snow (0.36 at 0 degrees) and (0.1 at 0 degrees)[4]. When the incident angle is approximately 90 degrees (in the case of a long distance between the BS and the MS), the reflection coefficient of each material becomes 1. This value means that the transmitted signal is reflected on the road or roadside completely. In this study, it is assumed that the height of the BS and the MS are 10 m and 1.5 m, respectively. Therefore, in the case of the short distance, e.g. a distance between a desired BS and a MS, the reflection coefficients varied according to materials. In the case of the long distance e.g. a distance between an adjacent BS and the MS, the reflection coefficients of each material were almost 1.

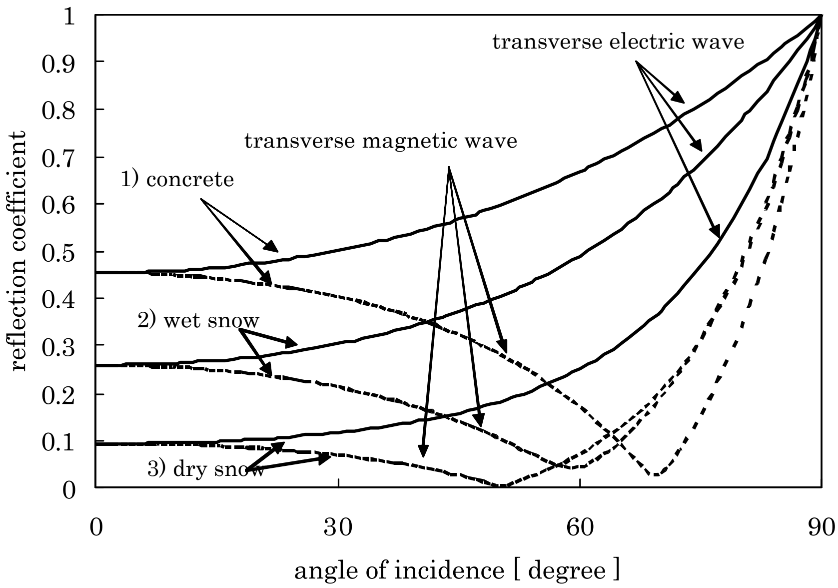

Fig. 2 Reflection coefficients of 1) concrete, 2) wet snow and 3) dry snow

5. Analysis model

Fig. 3 shows the analysis model assumed in this study. BSs are arranged at intervals of thirty meters. The same frequency is used at every other BS. So, the separation of BSs using the same frequency was 60 m. The received power characteristic was calculated as a function of the distance between a BS and a MS. The C/I characteristic was calculated as a ratio of the signal power received from a desired BS (BS 1 in Fig. 3) versus the interfering signal power from the adjacent BS (BS 3 in Fig. 3) at 60 m in front of the desired BS. Analyses were done by changing the height of walls and the material for road surfaces and roadside walls into concrete, wet snow and dry snow. The simulation parameter is summarized in Table 1. 0 m and 11 m were assumed as the height of roadside walls, because 10 m was assumed as the height of a BS antenna. When the height of walls was 0 m, this was the best condition as a calculation model, because there was no interfering wave reflected by a roadside wall. When the height of walls was 11 m, two waves were reflected by roadside walls and interfered with by the direct wave, because there were the two reflecting paths due to the walls being higher than the height of the BS antenna. It should be the worst case in the whole calculation models. The free space loss was used as the propagation loss. In this study, the received power of -65 dBm, prescribed by ARIB STD T-55, was applied to the threshold of the required sensitivity of the received power. The C/I power ratio of 18 dB, which satisfies the required bit error rate (BER) of 1×10^{-5}, was applied to the threshold level.

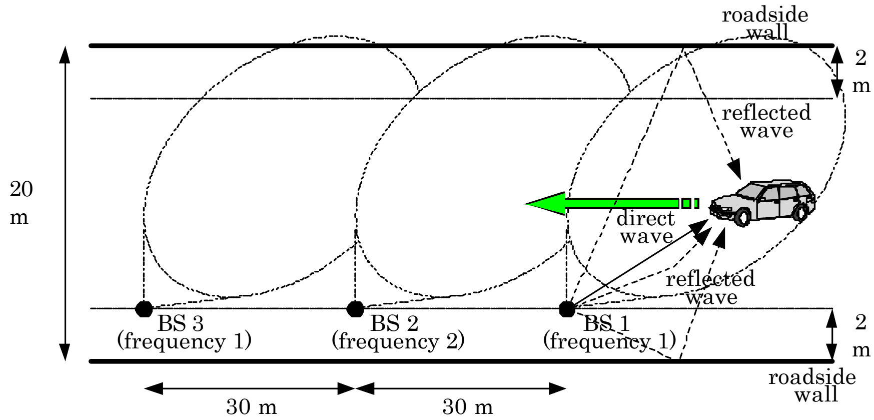

Fig. 3 Model of analysis

Table 1
Simulation parameter

BS	Frequency	5.8 GHz
	Transmission power	10 dBm
	Antenna gain	12 dBi
	Antenna Height	10 m
	Antenna direction	Depression: 30 degrees Azimuth: 45 degrees
	Polarization	Vertical polarization
MS	Antenna gain	8 dBi
	Antenna direction	Elevation: 45 degrees Azimuth: 0 degrees
	Received power sensitivity	-65 dBm
	Required C/I	18 dB
	Road width	20 m
	Wall height	0 m, 11 m

6. Calculation results

A. Case of concrete road without roadside wall

In this section, the propagation characteristic on the concrete road was calculated in order to investigate the received power and C/I performance in the DSRC systems. Fig. 4 shows the received power on a concrete road without roadside wall as a function of the distance between a BS and an MS. A Two-path model consisting of a direct wave and a wave reflected by the road surface was used, because there was no wave reflected on a roadside wall. It was shown that a transmission power was reached at a distance of more than 60 m.

In order to evaluate the precision in calculation, the experimental data measured in the field test is shown in Fig. 5. This received power characteristic was obtained on the concrete road without roadside wall by transmitting the 4.096 Mbit/s QPSK signal from a BS and measuring the signal power at an antenna installed on the dashboard in the car. The experimental condition was the same as the analysis assuming a concrete road without roadside wall, though there were losses in the experiment e.g. cable loss and so on. The received power of the experimental data near the BS was lower than that of the simulation data, because the decrease in permeability of the front-glass in the car reduces the signal power near the BS where the incident angle into the glass is almost 90 degrees. Because there was little difference between Fig. 4 and Fig. 5, the propagation characteristic of the DSRC systems was obtained by calculation with computer simulation with the propagation model assumed as a two-path model consisting of a direct path and the reflection path from the road surface.

Fig. 6 shows the C/I performance as a function of the distance between a BS and an MS when the surface of the road is covered by concrete and there is no roadside wall. From the results of Figures 4 and 6, it could be concluded that the communication link would be stable in an area over 30 m, because the received power and C/I performance exceed the threshold level of the DSRC systems.

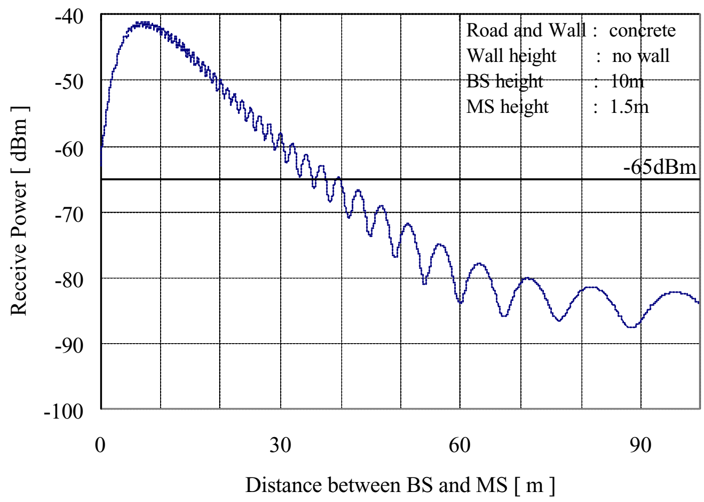

Fig. 4 Received Power characteristic on the concrete road without roadside wall

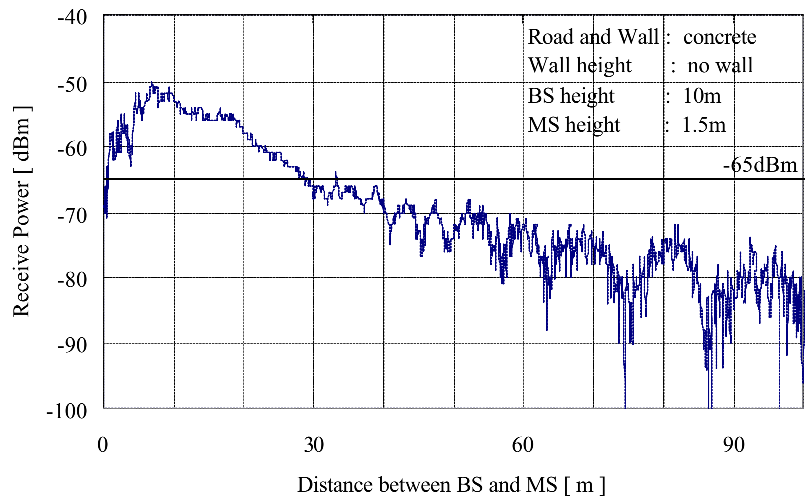

Fig. 5 Experimental data measured in the field test

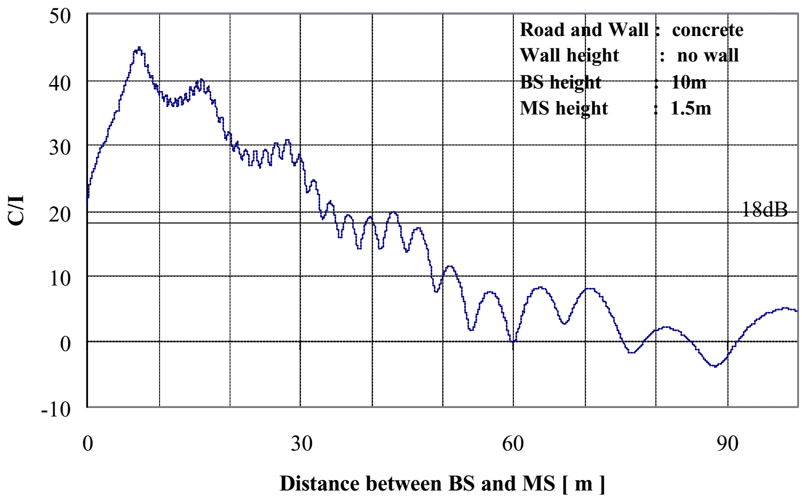

Fig. 6 C/I performance on concrete road without roadside wall

B. Case of concrete road with concrete wall

Fig. 7 shows the received power as a function of the distance between a BS and an MS when the surface of the road is covered with concrete and roadside walls are continued along the road. In this figure, the received signal power is periodically attenuated even within the range of a 30-m distance from the BS. Furthermore, the interference power was reached, e.g. –73 dBm at a 90-m point, stronger than that in the case without roadside wall, because the direct wave is synthesized with reflected waves. Fig. 8 shows the C/I performance when the analysis condition is the same as Fig. 7. As a result, the area where the received signal power and C/I performance exceed the required threshold level of the DSRC systems was reduced from 30 m to 20 m in comparison with Fig. 4.

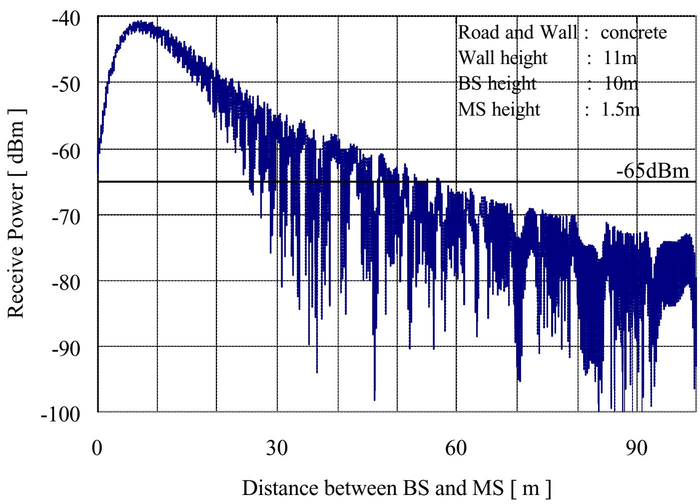

Fig. 7 Received power on concrete road with roadside wall

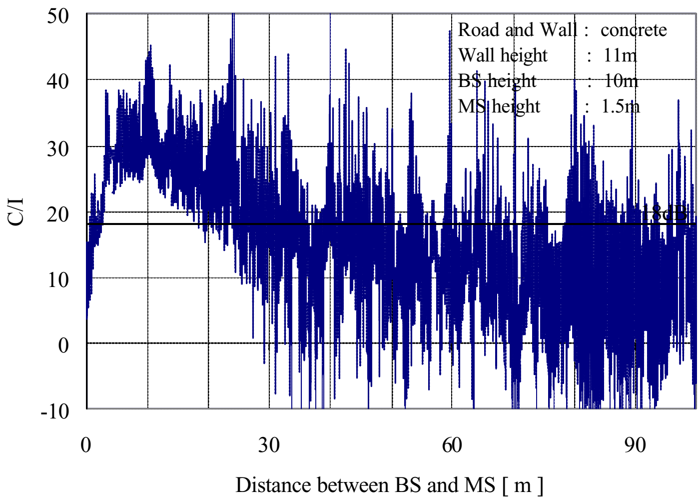

Fig. 8 C/I performance on concrete road with roadside wall

C. Case of dry snow road and wall

In order to investigate the influence of snow just after snowfall, the propagation of dry snow was calculated. Fig. 9 shows the received power when the surfaces of the road and roadside walls were covered with dry snow. In a distance of less than 30 m, the characteristic was stable, because the reflection coefficient of dry snow was smaller at a low angle of incident than that of concrete. Fig. 10. shows the C/I performance when the simulation condition was the same as Fig. 9. When the MS locates near the desired BS at a distance of less than 30 m, the C/I performance is higher than that in the case of concrete because the reflection coefficient is small in these areas and the signal power reached from the adjacent BS is lower than that in the case of concrete. So, the C/I performance was relatively similar to that in the case of a concrete road without roadside wall. It could be concluded that dry snow hardly affects the radio propagation environment.

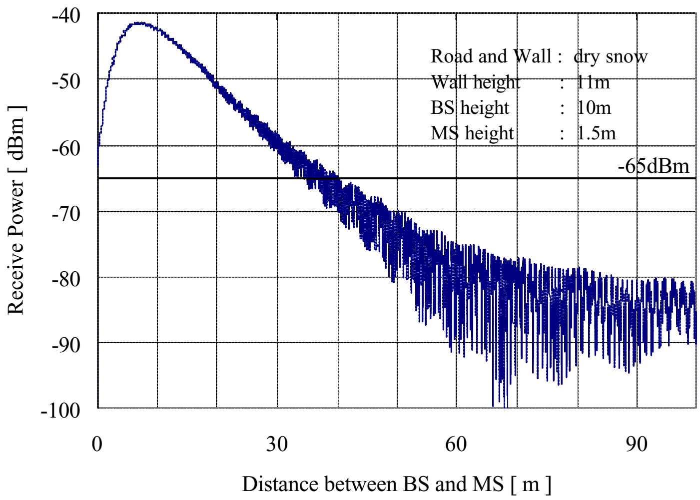

Fig. 9 Received power on dry snow road with roadside wall

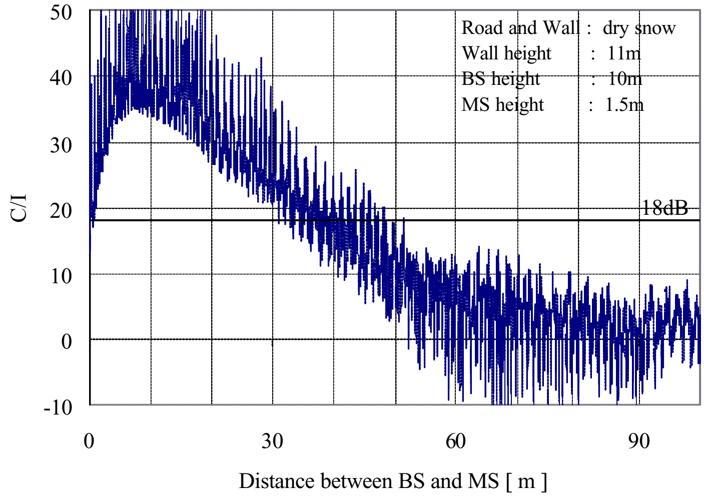

Fig. 10 C/I performance on dry snow road with roadside wall

D. Case of wet snow road and wall

The propagation of wet snow was calculated in order to investigate the influence of snow a long time after snowfall. Fig. 11 shows received power when the road and wall are covered with wet snow. As in the case of dry snow, the area where the received power exceeds the required threshold level is larger than that in the case of concrete, because the reflection coefficient of wet snow is lower at a low angle of incident than that of concrete. The interference power, which reaches further than 60 m, is stronger than that in the case of dry snow. Fig. 12 shows the C/I performance in the same condition as in Fig. 11. This figure shows that the communication area is smaller than that in the case of dry snow. This is because the signal power received from the adjacent BS at 60 m in front of the desired BS is stronger than dry snow. So, it could be concluded that wet snow affects the radio propagation environment.

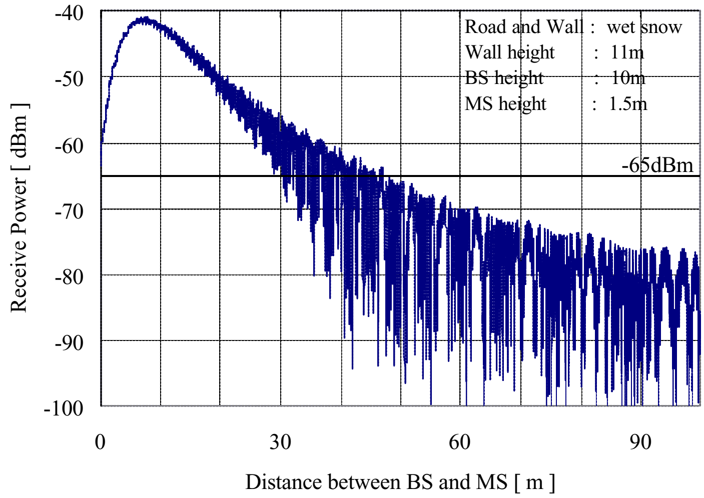

Fig. 11 Received power on wet snow road with roadside wall

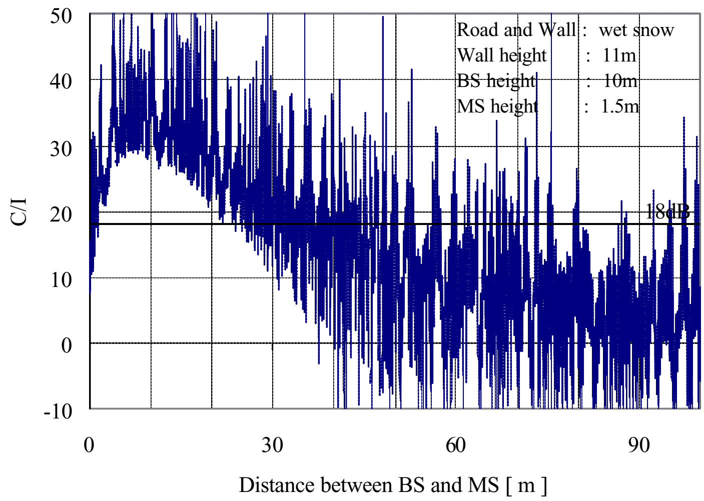

Fig. 12 C/I performance on wet snow road with roadside wall

7. Conclusion

The following conclusion was drawn from our study of the effect of snow on radio propagation assuming the DSRC systems by calculating the received power and C/I performance.

1) Dry snow affects the radio propagation slightly
2) Wet snow affects the received power characteristic near the desired BS
3) Wet snow reduces the communication area with sufficient C/I

Although dry snow just after snowfall hardly affects the radio propagation, wet snow a long time after the snowfall affects the propagation drastically. The influence of wet snow should be taken into account when multiple radio cells are constructed.

8. Acknowledgement

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9. Reference

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