DETECTION RESULTS OF GUARD RAILS BURIED IN SNOW BY AN FM-CW RADAR MOUNTED ON A VAN

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Introduction

There is an urgent need to detect objects buried in snow in regions with heavy snowfall. The buried objects include a human body or objects encountered an avalanche, guard wires and rails on road shoulders by natural snow accumulation, etc. For snow plowing actions on road, it is highly important to detect guard wires/rails on road shoulders quickly and precisely, because it is vital for rapid shoveling of snow on road and hence for guarantee the life in these regions. There was no way to detect them except for snow-plow driver's intuition. The use of microwave subsurface radar seems to be well suited for the detection problems and may serve the purpose. We have been engaged in the research of detecting objects buried in snow. In this paper, we present the detection results of guard wires/rails by an explored real aperture FM-CW radar mounted on a van. In the following, the FM-CW radar system and the results of the field experiment are described, indicating that the explored system has a potential ability to detect guard wires/rails at real time operation.

FM-CW Imaging radar

The fundamental principle of FM-CW radar is the relation between target distance R from the radar and the beat frequency f_b.

$$R = \frac{c}{2\sqrt{\varepsilon_r}} \frac{\Delta t}{\Delta f} f_b$$

where, R: distance, c: 3×10^8 m/s, f_b: beat frequency, Δf: sweep frequency,

Δt: sweep time, ε_r : relative permittivity of intervening medium.

It is possible to determine R if the relative permittivity of the intervening medium (snow) and the beat frequency are known. It is known that the relative permittivity of snow ranges from 1.5 to 3 in the lower microwave frequency [1]. The error in the range R within 1 m according to ε_r is a few cm. On the other hand, in our system, the beat frequency is determined by Fourier transform of the time domain beat signal due to a target. By making use of amplitude information of the beat spectrum, it is also possible to image a target buried in snow by successive scanning of radar antenna[2]. The block diagram of the radar system is shown in Fig.1. The operating frequency is 1.1 - 2.1 GHz, and the sweep time is 5.2 ms, which result in the radar range accuracy of 6.1 cm in the air. The important factor for the radar mounted on a van is the processing time in order to accommodate real time operation. For this purpose, a digital signal processing board is newly equipped, which executes 512 point Fast Fourier Transform (FFT) at less than 5 ms. The total time needed for one radar display routine was approximately 100 ms.

Field Experiment

The field experiment to detect guard wires/rails buried in snowpack on road shoulders was carried out two times, one on Feb. 2, 1990 (case A), and the other on Mar. 5-8, 1991 (case B) at Yamakoshi Village, Niigata Prefecture, Japan. The radar system was mounted on a van. Fig.2 shows the conceptional feature of the experiment.

Case A

The target was 4 metallic wires (1 cmϕ) spanned along a road shoulder approximately 50 cm behind the snow surface (Photo 1). The snow was relatively wet (approximately snow wetness of 4%). The van moved at a speed of 5 km/h, and the radar echo from the snow surface was obtained. The result is shown in Fig.3, where the vertical axis represents the length of 50 m, and the horizontal axis represents the radar range. The reflection magnitude

is normalized to unity with black indicating strong reflection. The left most white line shows the antenna position, the most right line indicates the guard wires, and the faded in-between line is the echo from snow surface. One can see that the wires are well detected by this radar. The echo from the guard wires vanished at lower portion of the figure. This fact was confirmed, after the experiment, by the fact that the wire did not exist beyond that point.

Case B

The target was a guard rail (50 cm wide) spanned along a bridge covered with snow. The snow thickness was 70 cm. The speed of the van was 12 km. In this case, we tried three setup for the measurement: the first was fully covered(with snow) case, the second was partially covered, and the third was non-covered case. The echo for each case is shown in Fig.4.

As seen in Fig.4, the reflection magnitude is dependent on position. The fluctuation is due to the roughness of snow surface and due to snow type. For the case B, as the snow had undergone melting cycle repeatedly, it had become wet Depth Hoar snow which caused strong variation of the reflection magnitude. For partially covered case, one can see that the guard rails appears close to the snow surface in the interval of 1 m where the snow cover was removed. This is due to the difference in the permittivity of snow and of the air.

Concluding Remarks

It was possible to detect guard wires/rails embedded in snow by the explored FM-CW radar. The very first requirement for snow shoveling is to find guard rails or wires at real time operation. The radar has the ability of displaying 10 snapshot scenes per second, which will serve the snow shoveling requirement. The radar can obtain images at the vehicle speed up to 30 km/h and hence is suitable for snow-plow machines. Since the radar is still a prototype, further modifications such as size, time, etc, will be needed for actual operation.

References

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[2] Y.Yamaguchi, Y.Maruyama, A.Kawakami, M.Sengoku, and T.Abe, "Detection of objects buried in snowpack by an FM-CW radar", *IEEE Trans. Geosci. Remote Sensing*, vol.29, no.2, Mar. 1991

[3] Y.Yamaguchi, M. Mitsumoto, T.Kawakami, M.Sengoku, and T.Abe, "Detection of guard rails buried in snowpack by an FM-CW radar mounted on a van", *Technical Report of IEICE*, A·P91-33, May 1991.

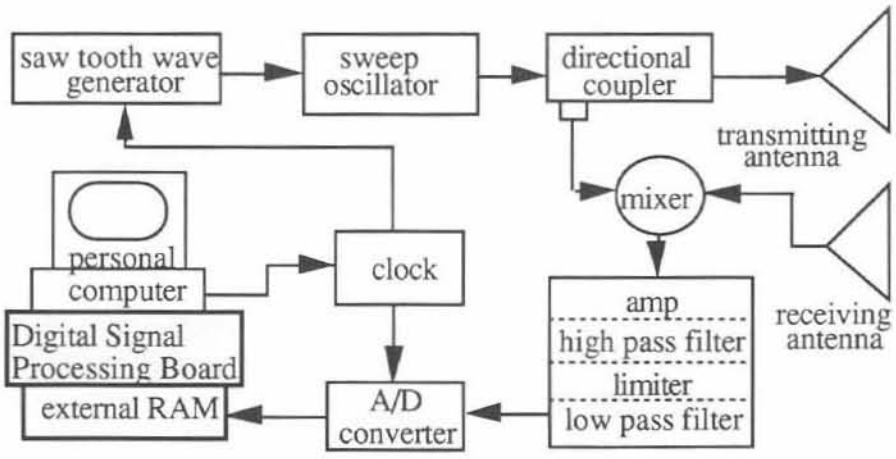

Fig.1 Block diagram of FM-CW radar

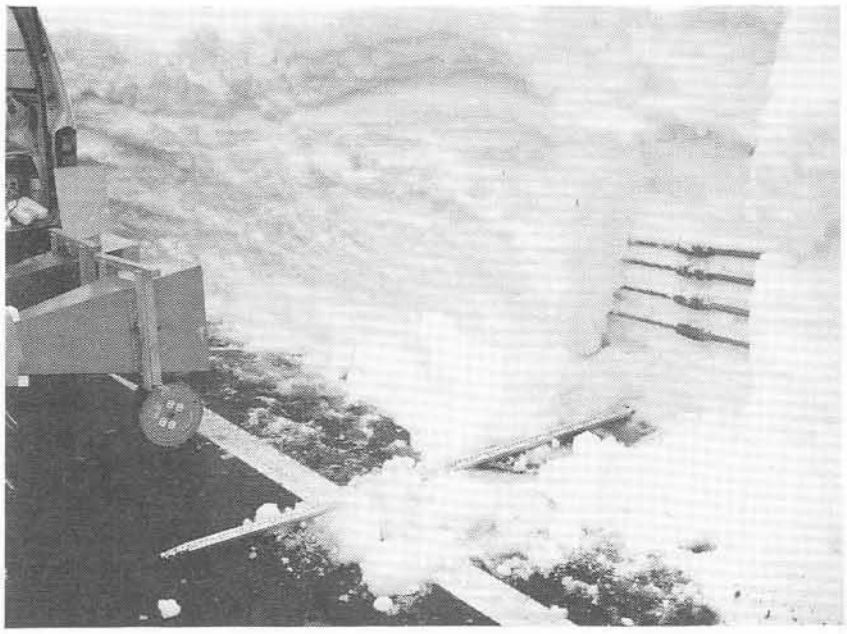

Photo 1. Four guard wires buried in snow
(approximately 50 cm deep from the surface)

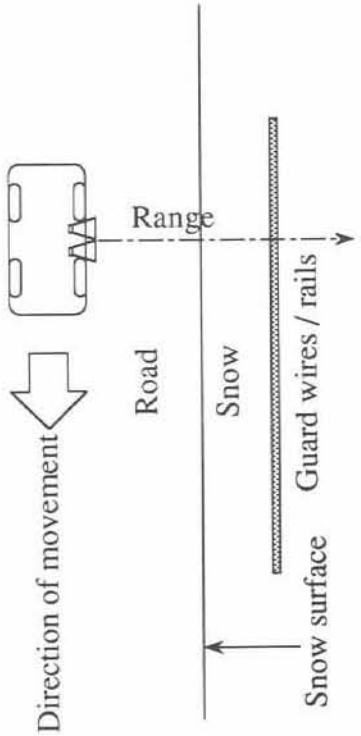

Fig.2 Conceptional feature of the experiment

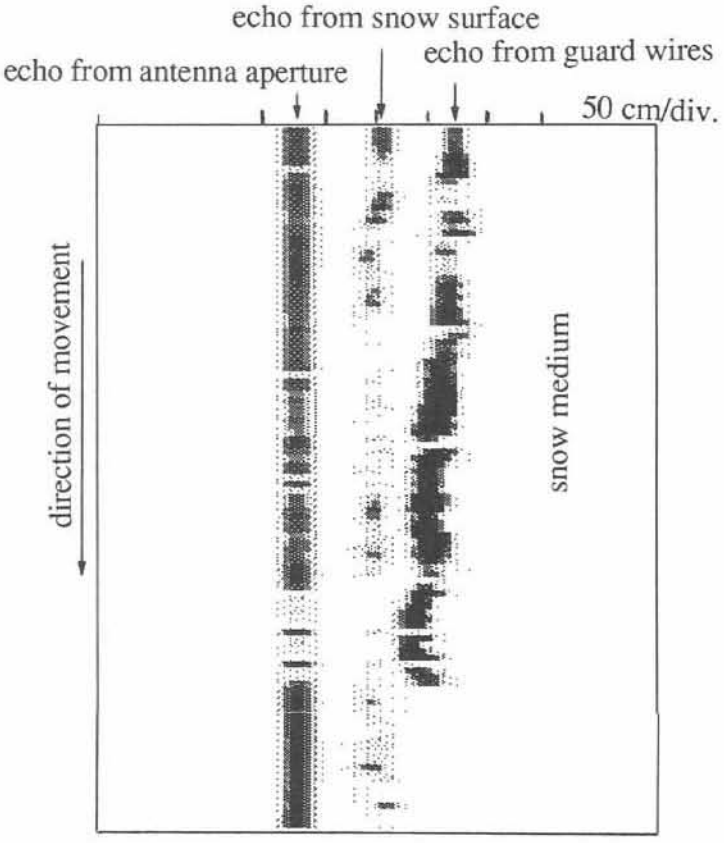

Fig.3 The detection result of guard wires

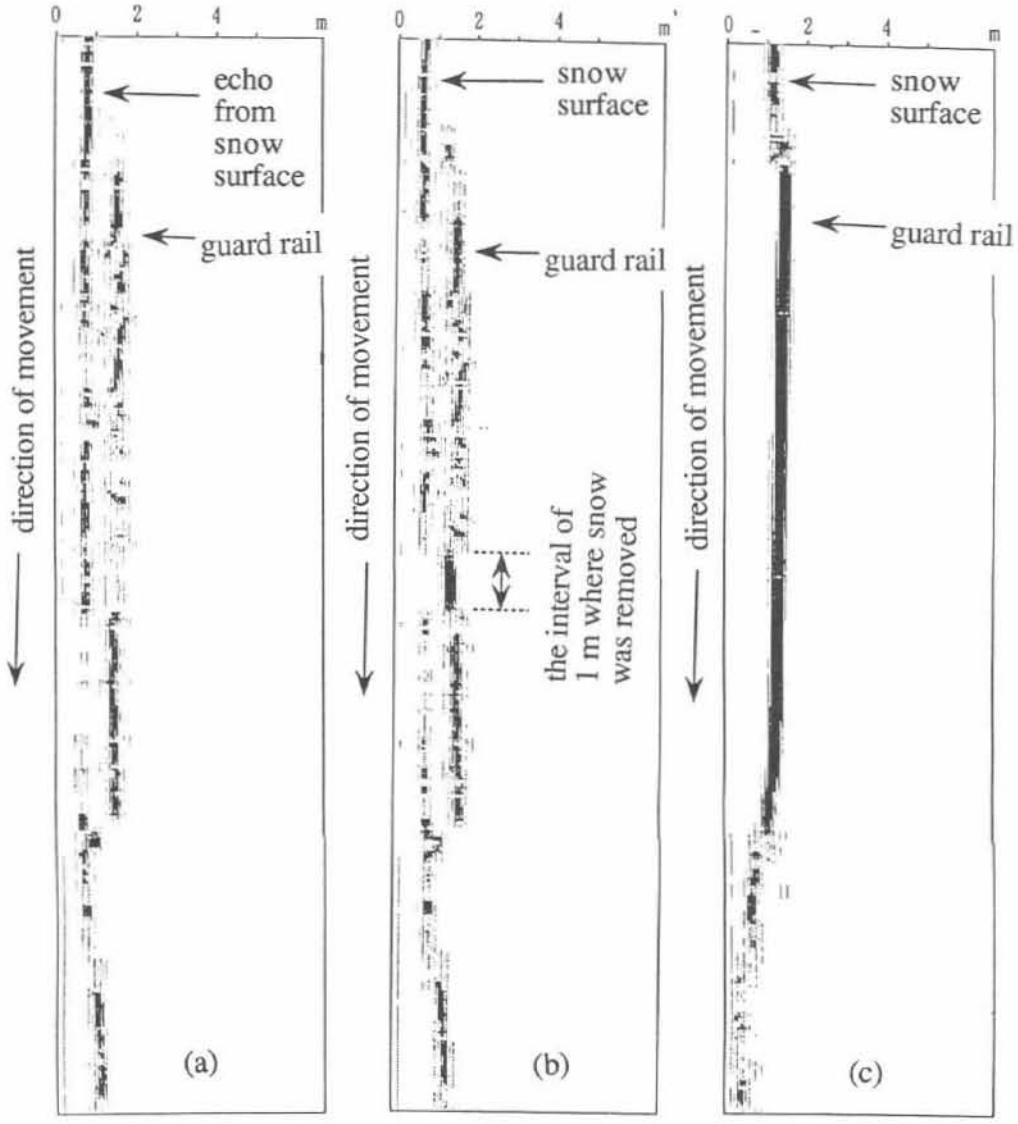

Fig.4 Detection results of guard rail
(a) fully covered with snow, (b) partially covered, (c) non-covered

Photo 2. Radar mounted on a van and a snow-covered guard rail on a bridge.