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A VERY SHORT PULSE C-BAND RADAR FOR CREVASSE DETECTION

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Abstract: A very short pulse C-band radar system to detect hidden crevasses in Antarctica has been developed. The characteristics of the new radar system are shown. A preliminary experiment to measure the distances of four targets made of plywood board was done in a laboratory to confirm the fundamental characteristics of the radar. Another preliminary experiment to detect the walls of a pit dug in a snow pile was performed by the radar to determine the usefulness of this radar for crevasse detection.

1. Introduction

Hidden crevasses have posed a very significant problem for the safe movement of snowmobiles in Antarctica, especially under blizzard conditions. Available techniques to detect hidden crevasses have not been successful and the development of a crevasse detection system using radio waves, which can penetrate into snow and ice, is highly desirable. Such a radio wave system must be able to both penetrate and detect within the snow and ice and have high resolution at close range. Although recently, radar observations of snow-covered terrain in winter have been made by several groups using holography techniques (SAKAMOTO and AOKI, 1985), wide band frequency-modulated radar (FUJINO *et al.*, 1985) and short pulse S-band radar (COOPER *et al.*, 1976), these radars were not for crevasse detection purposes.

Since 1987, the Communications Research Laboratory has been developing a new radar system in conjunction with the National Institute of Polar Research. The purpose is to detect hidden crevasses in front of a snowmobile by transmitting a short radar pulse to the snow surface and analyzing the echo signals with range-gate methods.

2. Instruments

The new radar system employs a very short C-band pulse together with a pencil beam antenna which can be scanned over the snow surface by changing the azimuth and elevation (or incidence) angles. Figure 1 shows a conceptual diagram of the angular relationships. The antenna is mounted on top of a snowmobile. The trans-

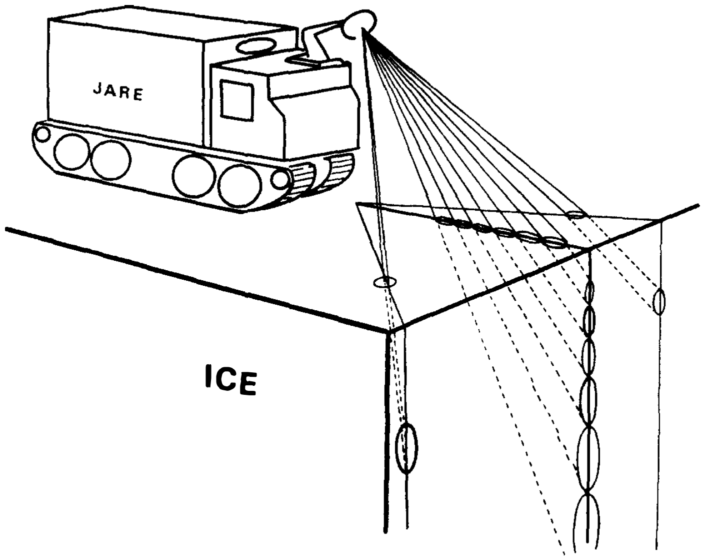

Fig. 1. Conceptual figure of a crevasse detection radar on a snowmobile which detects hidden crevasses by transmitting a short pulse to the snow surface and analyzing the echo signals with range-gate methods.

Table 1. Major characteristics of the radar system for crevasse detection. The heart of the system is a 1-nanosecond pulse generator together with a pencil beam antenna.

Type	
C-band short pulse	
Transmitter	
Frequency:	4.3 GHz
Power:	20 dBm
Pulse-width:	1 nS
P.R.F.:	1.25, 12.5 kHz
Receiver	
Band width:	1.2 GHz
S_{min}:	−85 dBm
Dynamic range:	105 dB
Antenna	
Type:	90 cmΦ Parabolic
Gain:	28.3 dB (at 4.3 GHz)
Beam-width:	5.6 degrees
Scan angle	0 to 60 degrees (depression angle)
	±90 degrees (azimuth angle)

mitter, receiver and signal processor are placed inside the snowmobile. Table 1 shows some key characteristics of the radar system. The frequency of 4.3 GHz was selected because C-band showed rather good propagation characteristics through dry snow during preliminary experiments with a multi band FM-CW scatterometer. Although it is advantageous to use a much lower frequency from the point of view of penetration depth into the snow, it is operationally inconvenient to mount a large aperture antenna, required for the lower frequency, on the snowmobile. With an effective pulse width of 1–2 ns, the expected resolution will be 15–30 cm in air and smaller in snow

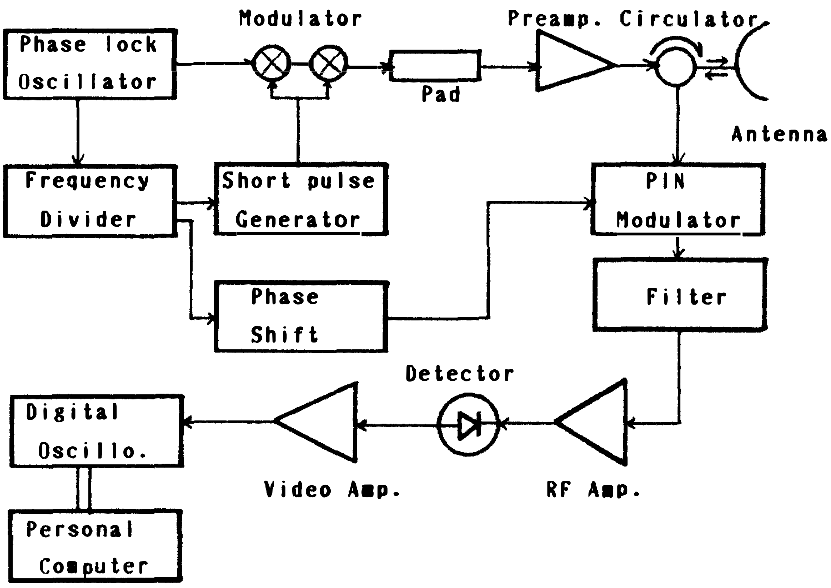

Fig. 2. Block diagram of a C-band radar for hidden crevasse detection with a very short pulse length.

or ice because of their larger dielectric constants. In spite of the rather wide band width of 1.2 GHz, a rather good minimum detectable power of −85 dBm is attained. The depression and azimuth angles can be changed between 0 to 60 degrees, and ±90 degrees, respectively. A conceptual diagram of the radar system is shown in Fig. 2. The heart of the radar is a 1-nanosecond C-band pulse generator. For this purpose, a dual mixer system is employed to decrease feedthrough from each double balanced microwave mixer. A 12.5-gigahertz digital sampling oscilloscope is used for the radar A-scope. The digitized data of A-scope echoes from the antenna area are to be analyzed using a personal computer and displayed as a two-dimensional image on a CRT.

3. Preliminary Experiments

Figure 3 shows results from a sampling oscilloscope obtained by a preliminary experiment performed in a laboratory to examine the basic characteristics of the radar. As it is indicated in the figure, four targets made of plywood board with a size of $45 \times 25 \times 0.3$ cm were placed on a line in front of the radar. The abscissa shows the time delay after transmission. One division represents 20 ns. The ordinate shows the strength of the return echo on a linear scale. The large echo at the antenna position is caused by the reflection of the antenna itself. The succeeding four echoes which correspond to the four plywood boards are clearly detected by this radar. A resolution of about 30 cm is attained in air. This is mainly limited by the characteristics of the wide band detector. However, this resolution is more than adequate for crevasse detection because a dangerous crevasse size for a snowmobile is more than 80 cm.

A preliminary field experiment to detect the walls of a pit dug in the snow pile was performed by this radar at Tazawa-ko Kogen in Akita Prefecture. The upper

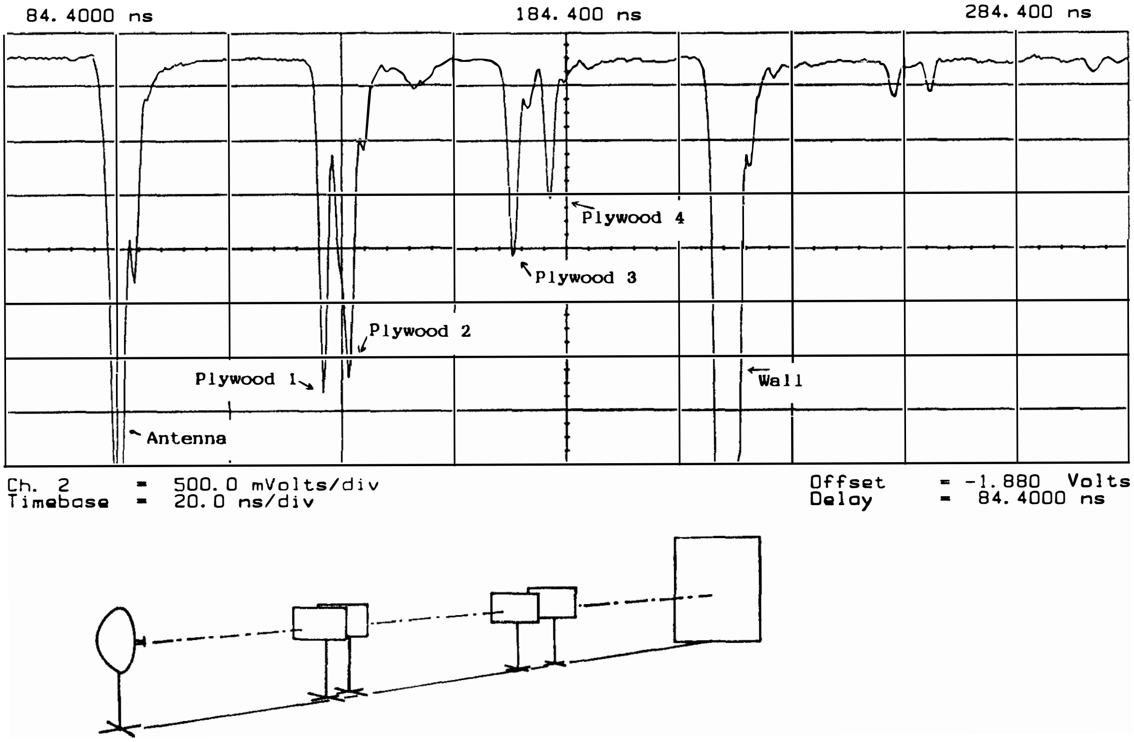

Fig. 3. Results of a preliminary experiment in a laboratory. Echoes of four targets made of plywood board are clearly detected.

part of Fig. 4 shows results from a sampling oscilloscope obtained in the experiment, and the lower part shows the vertical cross section of the pit and the snow pile at the experiment. The abscissa of the upper figure corresponds to the distance along the line of sight of the antenna, and the ordinate shows return echoes on a linear scale. The snow was wet during the experiment. Two peaks which correspond to echoes originating from the snow walls were clearly found in the experiment.

4. Concluding Remarks

It is now planned to perform a basic experiment to examine scattering characteristics of an actual crevasse whose location is well known in Antarctica. Actual operational use of the crevasse detection radar system will be proposed after analyzing data from this experiment. It is anticipated that the following problems will have to be solved to realize an operational crevasse detection radar.

(1) Attenuation of the radio wave as it propagates through intervening snow and ice.
(2) The effect of inhomogeneities in the dielectric constant of the snow and ice as the radio wave propagates.
(3) The effect of clutter from the antenna sidelobe area.
(4) The development of data analysis techniques to identify the crevasse area on the two dimensional CRT image.

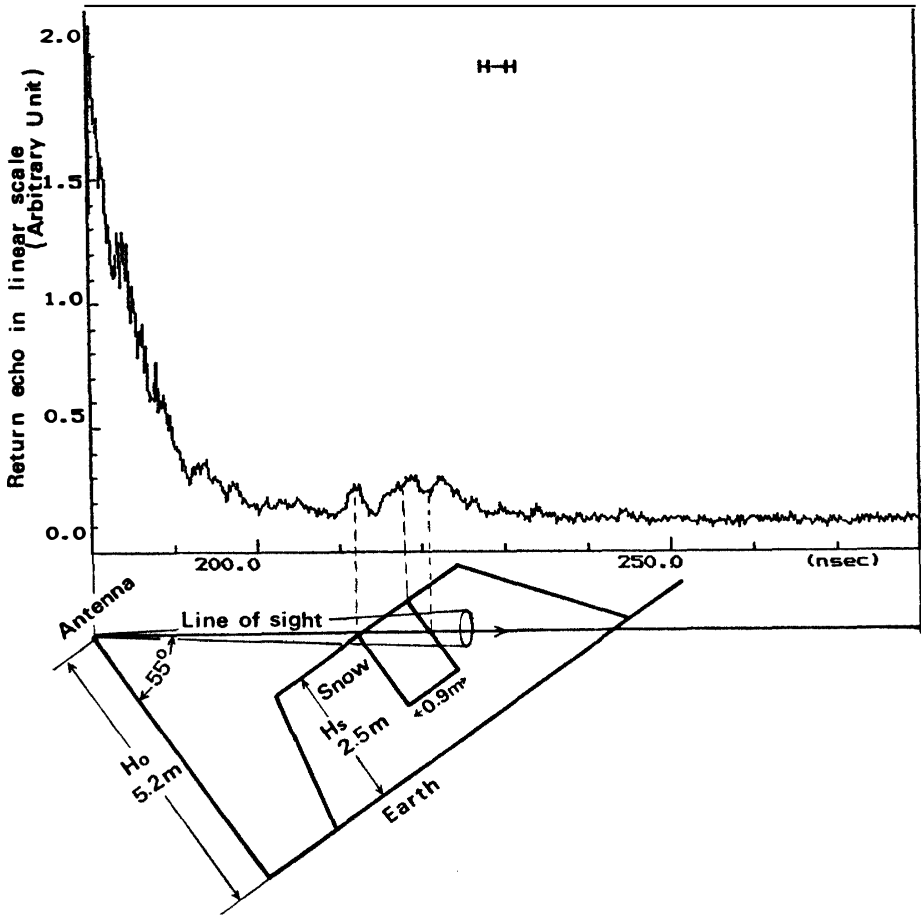

Fig. 4. Results of preliminary experiment to detect the walls of a pit dug in a snow pile. Two peaks which correspond to echoes originating from edges of the snow walls are detected.

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