AN UNDER SNOW RADAR
USING MICROWAVE HOLOGRAPHY

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1. Introduction

An under snow radar is needed in many field to detect the objects covered by snow. The radar needs to use wave which can penetrate snow, and has high resolution in short range. One solution is to use a microwave holography.

In this paper, we report an experiment of the under snow radar using microwave holography. The result of experiment shows that the radar has a capability to detect metallic objects covered by snow.

2. Principles of multi-frequency holography

Conventional microwave holography which uses single frequency, is poor at range resolution comparing with the lateral one. The reconstructed image suffers from a interference of unwanted scattering from a surface due to the air-snow interface, underlaying ground and boundaries of the snow layers. Therefore, it is difficult to find the objects. To improve the range resolution, we can use multi-frequency holography. By this method, the image is reconstructed by holograms recorded with each frequency.

The formation geometry of multi-frequency hologram is shown in Fig.1. Suppose that the object reflecting function is \( g(x_0, z_0) \), where \( x_0 \) is a constant, the returned signal can be obtained by

\[
U(\omega) = \int_{-\infty}^{\infty} g(x, z_0) \exp(-j2\omega x/V) \, dz_0
\]

(1)

Fig.1 The formation geometry of multi frequency holography

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Fig.2 A schematic of an under snow radar system
where the transmitted frequency is \( \omega \), and \( v \) is velocity of wave. The above integral represents a Fourier transform of \( g(X_0, Z_0) \) with respect to \( Z_0 \), hence processing the distance direction can be achieved by an inverse Fourier transform. The resolution of range direction can be given by

\[
1/\Delta Y = \Delta \omega / 2V
\]

(2)

where \( \Delta \omega \) is band width. The maximum distance is

\[
Z_{\text{max}} = \Delta Y \cdot N
\]

(3)

where \( N \) is the number of frequency steps.

On the other hand, if \( Z_0 \) is constant, the wavefield produced by object at the \( X \)-axis within the Fresnel approximation can be given by

\[
u' (x) = \int_{-\infty}^{\infty} \omega '(X_0) \exp(-j (X-X_0) \omega / V Z_0) \, dX_0
\]

(4)

Eq.4 called Fresnel transform can be solved by Fourier transform.

3. Experiment

(1) System

Fig. 2 shows a schematic of an under snow radar system by using multi-frequency holography. The holograms are recorded using a scanning transmitter, receiver which is controlled by a microprocessor. Image reconstruction and processing are achieved by the same processor, and the image is shown on color graphic display.

(2) Experimental results

Using this system, we have tried to find the object under the snow in February 1984 at Hokkaido. The antenna was scanned 1.5m sampling at 128 points, and transmitted signal was swept from 8.4GHz to 10.7GHz in microwave sampling at 128 points.

We carried out experiments by both of horizontal and virtual radiation against the layers of the snow. The location of the targets were three metallic cylinders shown in Fig.3-(a). An image of hologram which uses sweep frequency is shown in Fig.3-(b), and longitudinal dimension of the image is frequency. Reconstructed images are shown in Fig.3-(c) and snow coverd targets are clearly visualized. There is another backscatter from a surface of the snow.

The distance of objects in reconstructed image are further than the true one, because wave velocity in the snow is different from one in the air. To estimate that the permittivity is 1.7, we can get the distance more accurately.

4. Conclusions

The result shows that the radar system using multi-frequency holography has a potentiality to find the object covered by snow or ice, and surface of snow and underlaying ground as well. Thus, the radar system can be applied to detect objects which are buried under a snowslide, and to measure the depth of snow.
On the other hand, microwaves easily transmit through the layers of snow, permittivity and conductivity are different in each layer of snow. Therefore it is necessary to find these parameters.

Fig. 3-(a) Location of targets

Fig. 3-(b) Hologram data

Fig. 3-(c) Reconstructed image