Discrimination of Buried Objects Using GPR Responses

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***Abstract* – This paper describes experimental result of discrimination of buried objects using ground penetrating radar (GPR) data. As a target object, an anti-personnel landmine is considered. Two signal processing techniques are applied to extract a target response from raw GPR data. As a measure for target discrimination, the cross-correlation between waveforms of the extracted target response and a target template that is prepared by prior measurement is employed. Discrimination performance is checked by using a plastic landmine model and six confusing clutter objects that have approximately the same size as the landmine model. The result shows that the cross-correlation is one of the effective measures for this purpose. It, however, also indicates that using only the cross-correlation is not sufficient for accurate discrimination and thus other types of measures (features) for target identification should be added.**

***Index Terms* — Ground Penetrating Radar, Discrimination, Subsurface sensing.**

I. INTRODUCTION

Since ground penetrating radar (GPR) can detect shallowly buried objects, GPR systems are recognized as the effective sensors that can detect plastic or low metal content landmines [1]. However, because of the high incidence of false alarms, the potential of the GPR systems applied to landmine detection is not sufficiently utilized yet. In order to improve landmine detection capability, target identification which allows GPR systems to discriminate between landmines and other objects is important. In our previous study, we have introduces data preprocessing techniques for GPR data in order to improve target identification performance [2]-[4].

In this paper, we describe experimental result of landmine discrimination using GPR responses. As a measure for discrimination, the cross-correlation between waveforms of the extracted target response and a target template that is prepared by prior measurement is employed. Discrimination performance is checked by using a plastic landmine model and six confusing clutter objects that have approximately the same size as the landmine model.

II. GPR DATA PROCESSING

The GPR measurement system using in this study is shown in Fig. 1. Since the location of the buried object is already specified by a preliminary search process, the GPR data that is measured just above the buried object is obtained by using the GPR system. Our problem is to discriminate between the landmine and clutter objects using the measured GPR data. In order to improve landmine discrimination performance, data preprocessing for measured GPR data is required. In our previous study, we proposed two kinds of signal processing techniques for this purpose [2]-[4]. One is the calibration procedure of GPR responses for removing undesirable waveform distortion caused by frequency characteristics of GPR antennas. This procedure is based on an inverse filtering operation. The other is the method for removing strong ground clutter that hides a weak target signal. These signal processing techniques are significant and essential for landmine discrimination using the GPR systems. By applying them to the measured GPR data, the target response with no distortion is successfully extracted from the GPR data [4][5]. Fig. 2 shows the calibrated GPR response by the data preprocessing as an example. The target is a plastic dummy of a Type-72 anti-personnel landmine [3]. As an incident pulse, a monocycle pulse given by differentiation of Gaussian pulse is used. We can see from this result that a monocycle pulse shape of ground clutter is well reconstructed by the waveform calibration and the target response is clearly extracted.

III. EVALUATION OF DISCRIMINATION PERFORMANCE

A. Template and Clutter Objects

A template that is a reference waveform of the landmine is generated by averaging ten response waveforms from the landmine model buried at the depth of 5cm (see Fig. 3). As the confusing clutter objects, we employ six objects with approximately the same size, a plastic (PVC) cylinder, an expandable polystyrene (EPS) cylinder, three stones, and a metal rod with $0°$ and $90°$ orientation.

B. Discrimination Result

As the measure for landmine discrimination, the following cross-correlation coefficient between the target waveform $x(t)$ and the template $s(t)$ is used:

$$R_{\max} = \max_t \frac{1}{\| x \| \| s \|} \int x(\tau) s(\tau + t) d\tau \, . \qquad (1)$$

where $\| \; \|$ is the L_2 norm of the function. Since it is difficult to collect sufficient data samples for full statistical performance evaluation, we here show the result obtained from forty measurements (five measurements for each object). Table 1 shows averages of five correlation coefficients for each object. It can be seen that the correlation coefficient is close to 1 for the landmine and are low values for the PVC cylinder and stones. Although the number of data samples is insufficient, the result indicates that the cross-correlation is one of the effective measures for landmine discrimination. It, however, also suggests that using only the cross-correlation is not sufficient for accurate discrimination because the cross-correlation gives comparatively high values for the EPS cylinder and the metal rod with 90° orientation. In order to improve discrimination performance more, other types of measures (features) for target identification should be added.

IV. CONCLUSION

In this paper, we have described experimental result of landmine discrimination using the GPR responses. The cross-correlation between waveforms of the extracted target response and a target template is employed as a measure. Discrimination performance has been checked by using measured data and result demonstrates that the cross-correlation is one of the effective measures for landmine discrimination. However, it also suggests that using only the cross-correlation is not sufficient for accurate discrimination and other types of features for target identification should be added for improving discrimination performance.

ACKNOWLEDGMENT

This work was supported by JSPS KAKENHI Grant Number 25420335.

REFERENCES

[1] D. J. Daniels (Ed.), *Ground Penetrating Radar* (2nd Ed.), Institution of Engineering and Technology (IET) Radar, Sonar, Navigation and Avionics Series 15, IET, 2004..

[2] M. Nishimoto and V. Jandier, "Ground clutter reduction from GPR data for identification of shallowly buried landmines", *IEICE Trans. Electron*., vol. E93-C, no. 1, pp.85-88, 2010.

[3] M. Nishimoto, K. Tomura, and K. Ogata, "Waveform calibration of ground penetrating radars for identification of buried objects", *IEICE Trans. Electron*., vol. E95-C, no. 1, pp.105-109, 2012.

[4] M. Nishimoto, D. Yoshida, K. Ogata, M. Tanabe, "Extraction of a Target Response from GPR data for Identification of Buried Objects", *IEICE Trans. Electron.*, vol. E96-C, no.1, pp. 64-67, Jan. 2013.

[5] M. Nishimoto and D. Yoshida, "Signal processing for extraction of target response from distorted GPR data", *Proc. 2013 URSI International Symposium on Electromagnetic Theory*, 2013, Hiroshima, Japan, pp. 1109–1112.

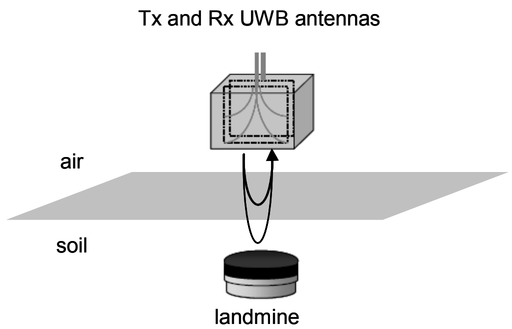

Fig. 1. Discrimination of buried landmine using a GPR measurement system.

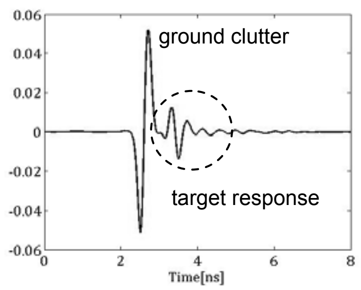

Fig. 2. Calibrated GPR response by the data preprocessing.

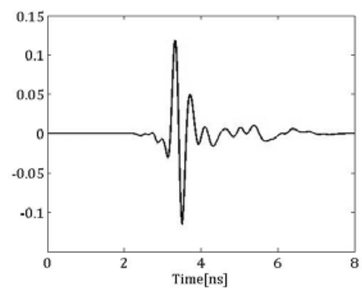

Fig. 3. Template: a reference waveform of the landmine used for landmine discrimination.

Table 1. Correlation coefficient R_{max}.

Target	R_{max}
Landmine model	0.98
PVC cylinder	0.53
EPS cylinder	0.88
Stone 1	0.40
Stone 2	0.46
Stone 3	0.39
Metal rod (0 deg)	0.54
Metal rod (90 deg)	0.86