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Landmine Detection Using Impulse Ground Penetrating Radar

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1. Introduction

Landmine detection and discrimination has becoming a challenging issue for the radar researcher because it is a very difficult and dangerous job. According to United Nations data, there are an estimated 110 million antipersonnel land mine buried over 60 countries, which cost twenty-six thousand innocent lives throughout the world every year [2]. Despite the great efforts of UN Mine Action Program and other humanitarian demining organizations, only 100, 000 mines are found and destroyed per year from the earth. At this rate, clearing all the 110 million mines from the earth will require 1100 years, assuming no new mines are laid. There are thousand of types of landmines such as metallic type, plastic or low metal landmines, and so on. Metal detectors or EMIS (electromagnetic induction spectroscope) are the most popular and mature tools to detect the landmines. However, the probability of false alarm is very high, about 0.997 (that is for every item detected, there is a 99.7 percent that it is a scrap and 0.3 percent chances that it is a mine). Moreover, these can not detect non metallic (plastic) mines. In this paper, we propose the GPR (Ground Penetrating Radar), for the detection and discrimination of antipersonnel landmines, as a technique that has capability to detect metallic and non-metallic buried landmines.

2. Radar System

In this research work, we used impulse GPR having 150 Pico second pulse-width, which operates in time domain. GPR is a device, which transmits an electromagnetic wave into the earth and receives the echo (reflected signal) from the earth to investigate the signature of the buried target or subsurface layer [5]. It has been a well-established and reliable technology for the underground pipes and cables detection, archaeological survey, and other civil engineering work [1]. It can discriminate the object when the dielectric constant is changed, so it can discriminate the landmine as its dielectric constant is different from soil, no matter whether it is metal or nonmetal landmine.

The impulse radar generates the pulse with a wide frequency spectrum and performed sampling at successive pulse to obtain the signal wave form. The block diagram of the impulse radar is shown in Fig. 1. The impulse signal $s_1(t)$ is generated by the pulse generator, and transmitted via TX. Antenna. The pulse width is represented in ns (nano-second) as shown in Fig. 2. The echo signal from the target $s_2(t)$ is received via RX. Antenna. The delay time of echo signal τ_2 is also represented in ns, which is too small to reconstruct the image. Therefore, the sampler is used to convert the delay time of echo signal in ms (milli-second) and represented by $\tau_2^{'}$. The relation between τ_2 and $\tau_2^{'}$ is given by the following equation.

$$\tau_2[ns] = \frac{1}{1000}\tau_2^{'}[ms] \qquad (1)$$

2. Signal Processing Method

Signal processing is a vital step for landmine detection with GPR as GPR signals contain not only the response from a potential mine target, but also contains unwanted coupling signals from ground surface, clutter signal from the buried scraps such as nails, cans, and so on. In addition, they are very sensitive to the dielectric constant of the soil. For the signal processing of impulse radar data, we proposed SAR processing method, which

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is based on migration technique. It is a promising method to suppress the clutter and to extract feature by reproducing the three-dimensional imaging.

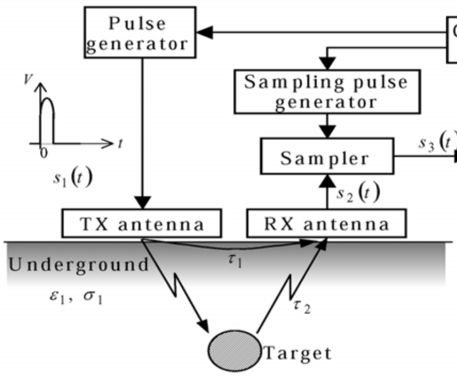

Fig.1 The simple block diagram of the impulse radar•

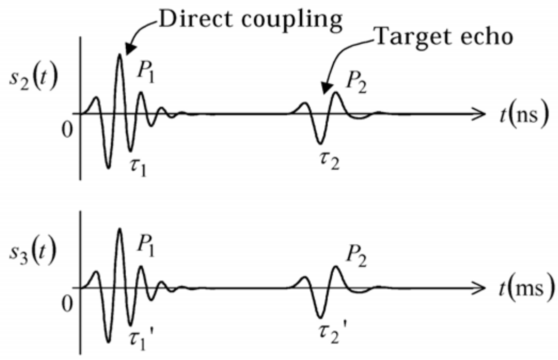

Fig. 2 Comparison between the receiving signal $s_2(t)$ and output signal from Sampler $s_3(t)$ of typical impulse radar

• In SAR processing, a set of transmitting and receiving antennas are seperated equally over a synthetic aperature length. This is also known as migration technique [4]. The time domain radar signal is received, which can be represented in the A-scope and the B-scope. The echoes from the point target are represented in the A-scope as shown in Fig. 3.

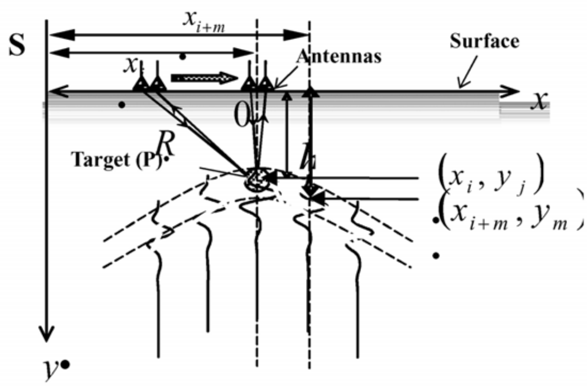

Fig. 3 Synthetic aperture radar (SAR) processing method (Migration technique)•

When the co-ordinates of the point target are $P(x_i, y_j)$, the echoes or receiving signal are distributed along a trajectory, which is expressed as following

$$y^2 = (x - x_i)^2 + y_j^2 \quad (2)$$

The echo received at the antenna, which is just above the point target is higher than the echo received at the antenna, which is away from the point target. All the distributed echoes along the trajectory are combined to get high signal level at (x_i, y_j), which is expressed as

$$Q(x_i, y_j) = \sum_{m=-M}^{M} D_m . P(x_{i+m}, y_m) \quad (3)$$

Where $y_m = \sqrt{(x_{i+m} - x_i)^2 + y_j^2}$ and D_m is a weighting function. $2M + 1$ is the total number of echoes along the trajectory. If an ideal impulse is transmitted and received, the horizontal (azimuth) resolution received by the Eq. (5) would be equal to $2M + 1$ antenna being spaced over a synthetic aperture length [4].

3. Experiment

3.1) Experimental Setup

The main objective of the research work is to detect landmines in Afghanistan, where the ground is very dry sand. Therefore, the resulting experimental setup used for the work described in the paper is summarized in Fig. 1. The experimental set up consists of experiment field made in wooden container with dry sand, antenna moving bar on the top of container to scan the target, various types of landmine, pulse radar system, data storing computers, and so on. A wooden container has a dimension of 140 cm in length, 100 cm in breadth and 120 cm in height and absorption material is attached on the four sides and the bottom.

Fig. 3 The experimental setup•

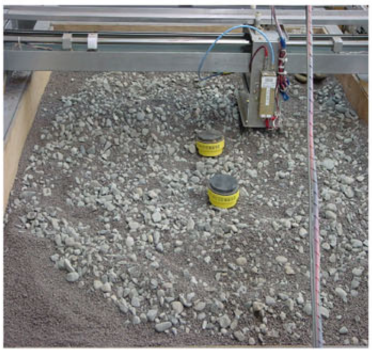

Fig. 4 TYPE 72 landmines on inhomogeneous field•

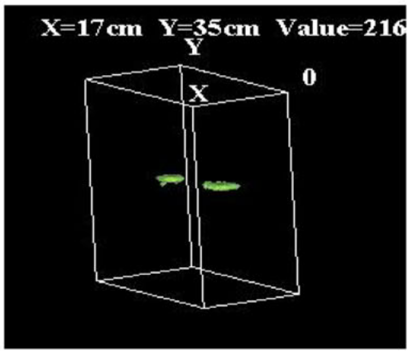

Fig. 5 Three dimension image of TYPE 72 landmines•

The antenna is a vital component of GPR. In this experiment we used the spiral antenna having diameter 8 cm in length 8 cm in height. The performance of the antenna is good from 1 GHz to 10 GHz, which was conformed by measuring the S parameters. It is noted that the landmines are generally buried between a few and 20 centimeters under the surface.

There are hundreds of types of landmines such as metal, plastic or very low metal nines, non-metal, and so on. It is cheap, effective, and stealthy when it is buried. In this experiment, we used TYPE-72 non-metal landmine (diameter 8 cm and height 4 cm).

Table 1.Specification of Impulse Radar

Pulse width	150 ps
Power	$P_t = \mathbf{27}$ dB, $V_t = \mathbf{5}V_{0-p}$
Pulse repetition frequency (prf)	$f_c = \mathbf{20}$ MHz, $T_c = \mathbf{50}$ ns,
Range	0-7.7ns
Receiver	Correlation type
Radar unit size	(25x38x100)mm
Antenna type	Bow-tie dipole

3.2) Data Acquisition and Signal Processing Results

A TYPE-72 (nonmetal landmine) was buried in the experimental field at 5 cm. In this measurement, we used impulse radar having a 150 pico second pulse width, in the time domain. The specification of impulse radar is shown in Table 1. In this experiment, we scan the two dimensional data in x axis and y axis to reconstruct the B-scan and three dimension image of the target. We moved the GPR antenna 40 cm in y axis 20 cm in x axis at the increment of 2 cm in each axis. The data collected from this measurement was processed by SAR method. The three dimensional (3-D) image of TYPE-72 landmine is shown in the Fig. 5. We get the clear circle of image of the landmine. Thus, we could identify and discriminate the target and clutter.

In this experiment, the data acquisition time is pretty long as we used only a set of transmitting and receiving antenna. In order to scan one square meter area, we have to take numbers of traces and it takes hours to complete data acquisition. Therefore, we arranged 12 sets of spiral antennas in an array as shown Fig.6. The data acquisition time had been reduced 12 times than in former one. We performed the experiment with these arrangement of antennas using nonmetallic landmines and stones. The PMN-2, TYPE-72 landmine and two stones are buried about 5 cm below an inhomogeneous test site as in previous experiment. The signal processing was performed by migration technique as in previous experiment. The 3-D imaging of experiment result is shown in Fig. 8, which clearly demonstrates the circular image of the nonmetallic landmine. However, the image of the stone is irregular. The 3-D image could be rotated to see the target image from different angle and prospection. Thus, this high resolution 3-D image would be significant to overcome the problems such as clutter suppression and feature extraction.

Fig. 6 An array of antennas in an inhomogeneous test site•

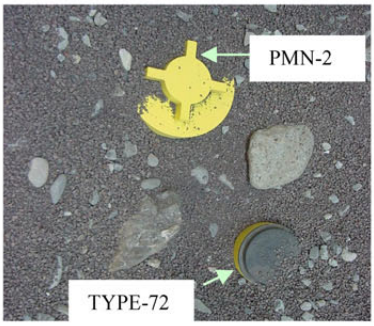

Fig. 7 Nonmetallic landmines and stones on an inhomogeneous test field•

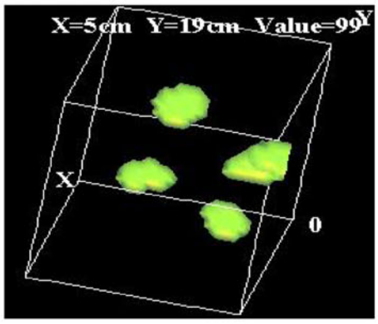

Fig. 8 Three dimension image of landmines and stones•

4. Conclusions

From the research, we found that GPR, the most advanced technology, could successfully detect the metallic and the non-metallic landmine safely and accurately. In addition, we found the attractive features and limitations of impulse radar. The data acquisition time and signal processing time of the impulse GPR is faster and simpler than the frequency domain GPR [3]. It can be done in real time speed if an array of antennas is used. Moreover, the hardware configuration is light and compact. However, the dynamic range of pulse radar is lower than the frequency domain radar; in consequence, the computational facility is limited and could not enjoy the super resolution image [6]. The 3-D imaging clearly demonstrates high resolution image of nonmetallic land-mine. The 3-D image could be rotated to see the target image from different angle and prospection. Thus, this high resolution 3-D image would be significant to overcome the problems such as clutter suppression and feature extraction.

5. Acknowledgement

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6. References

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