Effect of Pulse Fidelity on Detection of Landmines

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ABSTRACT

Detection of landmines based on complex resonance frequencies has been studied in the past and no distinctive results have been reported. Especially for low metal content landmines buried at depths greater than 9 cm, resonant frequencies become fairly distributed in the background and no specific frequency of interest can be used. However, in a typical impulse radar, spectral energy density of the transmitted pulse can be very broad and its peak can be located anywhere. Usually, a compromise is made between penetration depth and feature resolution for spectral energy peak allocation. Pulse amplitude, duration, symmetry, its spectral energy distribution, ringing level all affect depth and resolution metrics in a complicated way. Considering receiver dynamic range, we study two distinct pulses having different spectral energy density peaks and their detection ability for landmines with little or no metallic content. We carry out experiments to show that pulse shape/fidelity is critical to obtain desired contrast in post-processing of data.

Keywords: GPR, landmine detection, pulse fidelity

1. INTRODUCTION

Ground penetrating radar (GPR) is an electromagnetic technique for subsurface imaging. Detection of landmines and unexploded ordnances are some applications of GPR [1]. In these systems, short duration, typically sub-nano second pulses with large amplitudes are desired [2-5]. The fidelity of the generated pulse is particularly important because the return echo includes surface clutter which makes the detection of the target object very difficult. Pulse fidelity can be measured in terms of pulse full width half maximum (FWHM), full width one tenth maximum (FWTM), ringing level and pulse amplitudes [6-9]. Considering these metrics, we studied two different monocycle pulses with 370 ps and 880 ps durations.

2. PULSE FIDELITY

The two Gaussian monocycle pulses studied are shown in Figs. 1 and 2 along with their spectral energy distribution over frequency. Short pulse has duration of 370 ps with 112.5 ps FWHM on positive side. Long pulse has duration of 880 ps with 280 ps FWHM on positive side. Besides these, additional metrics on these two pulses are summarized in Table 1.

It is well known that the resonant frequencies of most land mines fall within 1 to 5 GHz, and any transmitted pulse should cover this frequency band, in order to, at least, excite one of the resonances of the landmine. However, identification based purely on complex resonance frequencies is very difficult as they are closely spaced and vary in frequency response depending on soil conditions. Thus, pulses with one targeted at the lower end of the resonance spectrum and the other around the center of the spectrum are designed to study the effects of pulse durations on target detection.
Fig. 1 Short monocycle pulse with duration 370 ps, a) pulse in time, b) energy spectrum.

Fig. 2 Long monocycle pulse with duration 880 ps, a) pulse in time, b) energy spectrum.

Comparison of pulse metrics for both pulses is shown in Table 1.

<table>
<thead>
<tr>
<th>Metric</th>
<th>370ps</th>
<th>880ps</th>
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<tbody>
<tr>
<td>Vpp (V)</td>
<td>1.9823</td>
<td>1.6763</td>
</tr>
<tr>
<td>Vpeak+/Vpeak</td>
<td>1.0181</td>
<td>0.6763</td>
</tr>
<tr>
<td>FWHM+ (ns)</td>
<td>0.1125</td>
<td>0.2800</td>
</tr>
<tr>
<td>FWHM- (ns)</td>
<td>0.1120</td>
<td>0.1950</td>
</tr>
<tr>
<td>FWHM+/FWHM-</td>
<td>1.0045</td>
<td>1.4359</td>
</tr>
</tbody>
</table>
3. SIMULATION

3D electromagnetic model of the bistatic radar is shown in Fig. 3. Metal disk is chosen as a representative target. Signal sent by the transmit antenna and its return echo are shown in Fig. 4.

<table>
<thead>
<tr>
<th></th>
<th>FWTM+ (ns)</th>
<th>FWTM- (ns)</th>
<th>FWTM+/FWTM-</th>
<th>20 log(Vring/Vmax) (dB)</th>
<th>Max. Ringing Level Magnitude</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.1730</td>
<td>0.4350</td>
<td>0.9532</td>
<td>-18.5350</td>
<td>0.1184</td>
</tr>
<tr>
<td></td>
<td>0.1815</td>
<td>0.3100</td>
<td>1.4032</td>
<td>17.6437</td>
<td>0.0887</td>
</tr>
</tbody>
</table>

Fig. 3 3D electromagnetic simulation model for A-scan analysis.
Fig. 4 Transmitted and received signal from the antenna.

4. LANDMINE DETECTION

Two different pulses with 370 ps and 880 ps durations were used to detect glass bottle, M14 AP landmine, TS 50 AP landmine and plastic bottle. The B-scan images for two different pulses are shown in Figs. 5 through 8. Depending on the penetration depth and the feature size, it is not possible to state short or long duration pulse provides better detection results. It is expected that short pulses, have higher resolution ability and can distinguish nearby clutter more easily but more rapidly attenuates as it penetrates into the soil. The spectral energy density for short duration pulse also peaks around 2.3 GHz whereas long duration pulse peaks around 1.2 GHz. It is interesting to observe that 880 ps pulse duration provides better B-scan images for M14 and TS50 AP landmines and 370 ps pulse provides better resolution for glass, plastic bottles and other clutter.

Fig. 5 Glass bottle buried 3 cm beneath soil surface, a) 370 ps, b) 880 ps.
Fig. 6 M14 buried 3 cm beneath soil surface, a) 370 ps, b) 880 ps

Fig. 7 TS50 buried 6 cm beneath soil surface, a) 370 ps, b) 880 ps.
Fig. 8 Plastic bottle buried 6 cm beneath soil surface, a) 370 ps, b) 880 ps.

REFERENCES


