TARGET VISUALISATION APPROACH BASED ON PHASED-ARRAY EFFECT IN ANTENNAS WITH TRANSIENT EXCITATION

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1. Introduction

Target visualisation is main goal of the practical radargram recovering procedure. There are a lot of visualisation algorithms (2D-filtering, migration, FFT etc.) that is mainly based on final images processing. Existent methods are not frequently allowed to get adequate results due to considerably complex properties of the surrounding target environment.

In this work an approach to target visualisation based on phased-array effect in antennas with transient excitation is proposed and discussed. This reconstruction method uses initial information about properties of the used for radargram getting antennas. Preliminary results of this approach, its applicability and sensitivity are presented.

2. An Approach of Target Visualisation

In contrast to antennas behaviour with sinusoidal or narrow frequency band excitation such one with transient excitation has some differences [1]. As a matter of fact transient radiation of an antenna depends on its geometry. If pulse generator impedance and input antenna impedance is matched in the antenna is observed so-called double-passing excitation mode [2]. In this case temporary structure of the antenna radiation field consists of three impulses sequence. Note that time delays between neighbouring impulses are associated to antenna length and the second impulse polarity is inverse one to the first and third pulses.

Let's consider monopole linear antenna with impulse excitation in Cartesian coordinates as it is shown in Fig. 1. Assume that the antenna length is L and a target coordinates is (X_0, Y_0). Distances from target to excitation point and antenna edges are R1 and R2, accordingly.

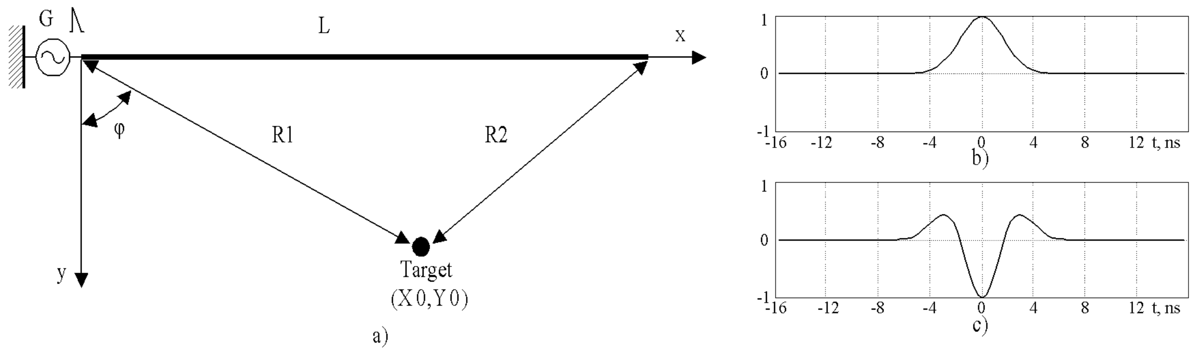

Fig.1. Schematic representation of the monopole antenna in the Cartesian coordinates (a), excited by symmetrical Gauss pulse (b) and normalised signal, scattered by the target (c).

Time delay between radiation and reception moments for the series of the impulses are:

$$\tau_1 = \xi \frac{2R1}{c},\ \tau_2 = \xi \frac{R1+R2}{c} + \frac{L}{c},\ \tau_3 = \xi \frac{2R1}{c} + \frac{2L}{c} \qquad (1)$$

where c - light velocity in a free space,

$\xi=(\varepsilon/\mu)^{1/2}$ - ambient space admittance,

ε and μ - electric and magnetic permeability, accordingly.

Temporal differences between neighbouring signals are equal:

$$\Delta\tau_1 = \tau_2 - \tau_1 = \frac{L}{c} + \xi\,\frac{R2 - R1}{c}$$
$$\Delta\tau_2 = \tau_3 - \tau_2 = \frac{L}{c} + \xi\,\frac{R1 - R2}{c} \qquad (2)$$

There is a special solution (R1 = R2), when temporal differences depends on antenna length only:

$$\Delta\tau_1 = \Delta\tau_2 = \frac{L}{c} \quad (R1 = R2) \qquad (3)$$

It means that we can narrow directional pattern of the antenna and increase distinguishing ability of the buried targets. Purity of the target visualisation depends on time resolution between neighbouring pulses. As an ideal cases using Dirac-pulse as a sounding signal the shape and space position of any target can be perfectly restored. Absolute time delays for every pulses and mutual intervals between neighbouring ones are shown in Fig. 2.

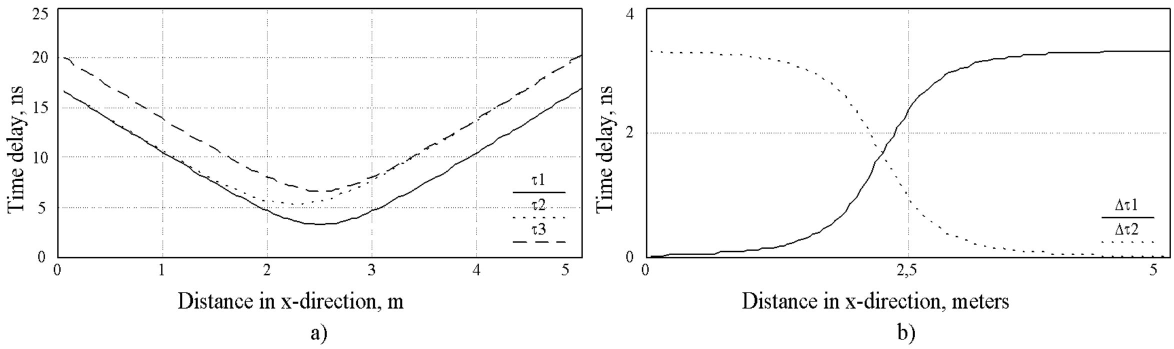

Fig.2. Time delay of the pulses (a) and between neighbouring pulses (b) scattered by the target as a function of antenna position. The monopole length is 0,5 meter; target position (X0,Y0) is (5, 1) meters.

3. Radar Imaging

Let's use time-domain physical-optic (TD-PO) method for radar imaging simulation [3]. This computing algorithm has enough precision and adequate reflects real situation. Besides it extremely decreases the calculation time and allows using for radar imaging ordinary mathematics software like Mathlab or Mathcad.

The TD-PO method takes into account diffracted by the target ray trajectories only. Therefore receiving signal Rx(t) is a result of linear sum of delayed and weighted N copies of the radiated signal Tx(t)

$$Rx(t) = \sum_{i=1}^{N} Tx(t) \qquad (4)$$

Assume that position of transmitter and receiver is coincided. Calculation results getting for two cases of numerical simulation of the radar imaging – with and without phased-array effect consideration are shown in Fig.3. The first image does not take into account physical length of the antenna and has got only for excitation point radiation. The second one includes radiation components connected with current reflection from the antenna's edge and reflected current termination in the excitation point. The calculation has been executed for the unfavourable case when excitation pulse duration exceeds the antenna length up to 2 times.

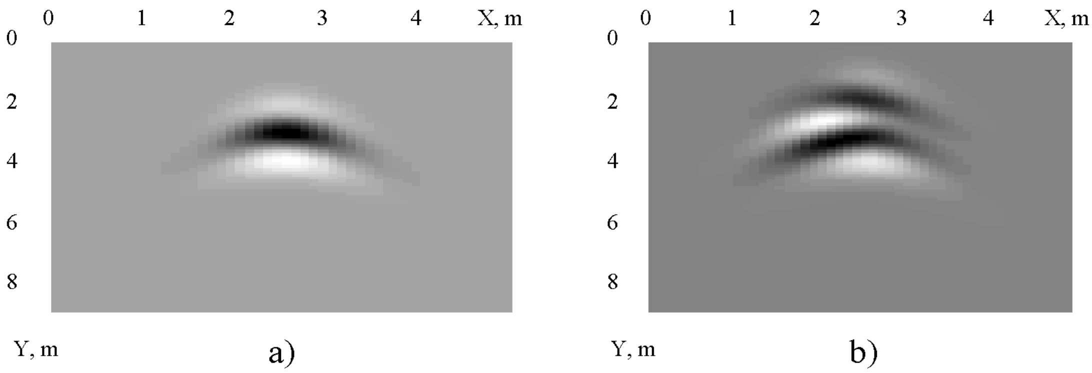

Fig. 3. Numerical TD-PO simulation of the radar imaging for subsurface target: (a) radiation only from excitation point of the antenna; (b) radiation taking into account phased-array properties of the antenna. Antenna length is 0,5 meter; excitation pulse duration is 5 ns.

4. Target Visualisation

There are wide possibilities of the proposed method realisation. Try to use the fact that receiving signals are independence from target position and apply the simplest target visualisation algorithm from the radar imaging. It can be written by the following:

$$Tx_r(t-\tau) = \begin{cases} Tx(t-\tau),\ \ if\ Tx(t) \geq \delta\ \ and\ \ Tx(t-2\tau) \geq \delta \\ 0,\ otherwise \end{cases} \tag{5}$$

where Tx - receiving signal waveform
Tx_r - recovering signal waveform
δ - threshold quantity

It is usual filtering of initial radargram by the described criteria. Recovering radargram consists of those samples only that are situated in the middle of two exceeded given threshold level samples. Precision of the image reconstruction is depended on the threshold quantity. Evolution of the recovering radargram versus threshold level changing is shown in Fig. 4. If it is equal zero, recovering radargram coincides with initial one. The threshold quantity is bigger the radargram is clearer. Note that threshold polarity may be both positive and negative. Choosing polarity it can be possible to separate metal target from non-metal ones.

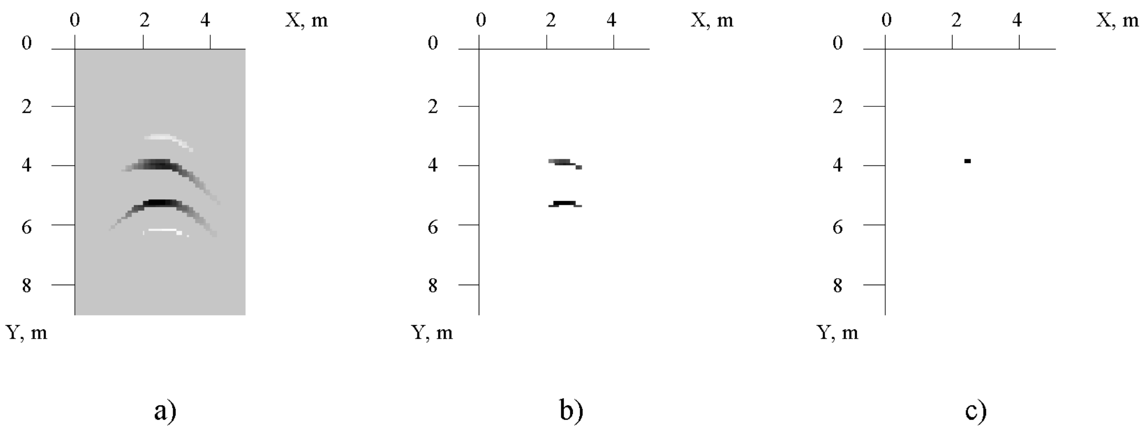

Fig. 4. Recovered radargram as a function of the threshold quantity. Threshold level is increased with its changing from (a) to (c).

Successive radargram simulation and target reconstruction is shown in Fig. 5. In this case has been used an optimal threshold quantity. It can be seen that reconstructed target position has a little displacement by comparison with initial geometry. Probably it is cased by used of monopole antenna instead of dipole one. Note that such recovering procedure does not depend from excitation signal and correlation between pulse duration and antenna length. Therefore it can be possible to reconstruct radar imaging independently from shape of sounding signal.

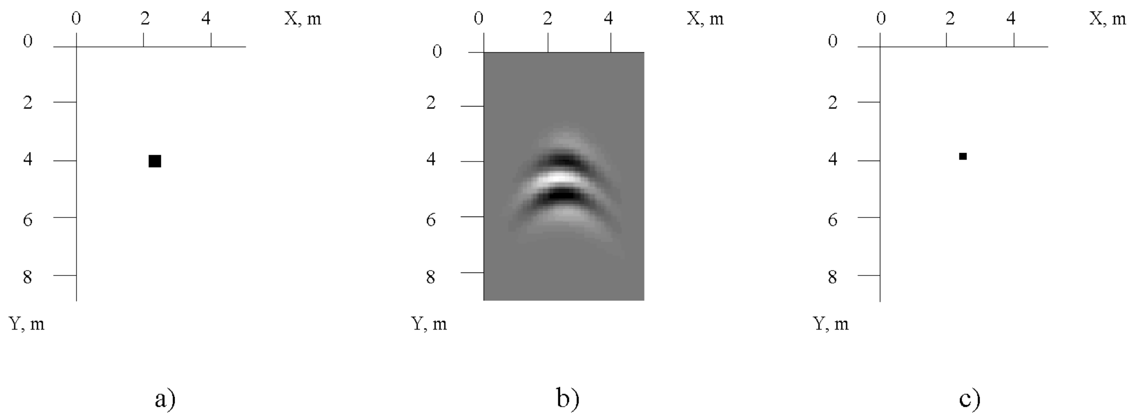

Fig. 5. Target visualisation procedure: initial conditions (a), computed radargram (b) and recovered image with optimal threshold parameter (c).

5. Conclusions

An approach of target visualisation has been proposed. This method is based on phased-array effect in a linear antenna with transient excitation. The widest abilities of various type of target visualisation including possibility of metal and non-metal target separation have been shown.

Results of the presented work are expected to implement for studies of noise and disturbance influence to reconstruction handling and apply this method for practical radargram analysis.

6. References

[1] A.Boryssenko, V.Prokhorenko, «Phased-Array Effect in Antennas with Transient Excitation», *2000 IEEE International Conference on Phased-Array Systems and Technology*, 20-26 May, 2000, Dana Point, California.

[2] A.Boryssenko, V.Tarasuk, «Ultra-Wide Band Impulse Antennas for Subsurface Radar application», *Proceedings of the 1999 Antenna Applications Symposium,* Amherst, USA, September 15-17, 1999, pp. 478-504.

[3] A.Boryssenko, V.Prokhorenko, V.Tarasuk «Time-Domain Physical-Optic Simulation Technique for Electromagnetic Imaging by Subsurface Radar», *16th Annual Review of Progress in Applied Computational Electromagnetics,* March 20-25, 2000, Monterey, California.