Oral Presentations
16.2 Ground Penetrating Radar System for Locating Buried Utilities
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In this paper the design and operation of a ground penetrating FMW radar is described. Simulation and example measurements over a test site containing three targets at separations typical of those for real buried utilities are presented. It is seen that the position of the targets is accurately found and that quite closely spaced targets can be distinguished. The increased use of buried utilities in urban areas has produced a need for mapping tools to accurately locate buried pipes, electricity cables and more recently optical fibre ducting. Damage to these facilities during trenching operations can not only lead to health and safety hazards, but also to prove to be embarrassingly expensive. Ground penetrating radar is one of the few technologies capable of meeting this demand.

The use of pulsed radar is well established using the sub-nanosecond pulses that are required for this short range probing. These systems unfortunately tend to be expensive, whereas FMCW or set-frequency systems can take advantage of the mass availability of microwave/RF devices used in the mobile telephone and communications industries. For accurate location of buried targets multiple measurement points are needed, often requiring several transmit and receiver antennas. This presents a signal interpretation problem in being able to distinguish between the desired target response and the direct coupling between antennas. Affects both the design of the antenna array and the signal processing used in the system.

The paper discusses the choice of the operational frequency range. Although high frequencies are preferred to provide higher resolution of the location of an object, lower frequencies are preferred for their lower signal attenuation in the ground medium.

The electronic system is described in the paper including the techniques used to compensate for the non-ideal characteristics of the relatively inexpensive components used. The response from the targets can be further enhanced by suitable matched filtering to suppress random noise, or by clutter filtering to remove particular targets, such as the direct path signal between the transmitter and receiver antenna.

17.1 Image Reconstruction of the Subsurface Object Cross-Section from the Angle Spectrum of Scattered Field
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It is known that the scattered electromagnetic field may be expanded in terms of plane waves. A nonvanishing part of the plane waves spectrum may be obtained by measuring of the scattered field amplitude and phase at an arbitrary distance from the boundary “air-medium”. Evanescent part of plane waves spectrum corresponds to nonhomogeneous plane waves with amplitudes exponentially damping with increase of distance from the interface. Use of these various parts of the scattered field spectrum allows obtaining different images of the object investigated.

In the present work the results of the modeling and experiments in area of the buried objects imaging are given and studied by using the measurement data about the angle spectrum of scattered field and microwave tomography method.

Our experiments were carried out at frequencies from 1.25 to 5GHz. The following steps were taken to obtain the images:
- irradiation of the ground with embedded objects by an electromagnetic wave at normal incidence;
- rotation (scanning along circuit) of the receiving antenna in respect to a boundary “air-medium” normal;
- measurement of phase and amplitude of the total super high frequency scattered signal in dependence on the inclination angle of receiving antenna at all frequency points;
- calculation of the Fourier transform of the scattered field into direct line above the boundary of two media.

In the inverse problem, a complex function of space coordinates representing the normalized polarization currents, have been reconstructed. A modulus of the complex function is the image of the object under investigation. The reconstruction algorithm is based on Fourier inverse formulas. In the experiment, data on back-scattered field at 15 angles in the angle range of 0 – 180° with a constant angle step were used. As receiving and transmitting antennas, the horn measuring antennas were used. The investigation was carried out using different media (sand, pebble) that are placed in a box with dimensions of 1.5 x 1.0m2. Metallic and dielectric objects with dimensions of d = 1 x 5cm and heights of h = 0.5 to 2.5 cm (λ = 0.075m) were studied during the experiment.

It is shown that results obtained may be applied in practical tomography setups for detection and observation of different subsurface objects.

17.2 Imaging of Underground Objects by Using the Short-Term Videoups
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In the given work we present the experimental results of the system designed for obtaining microwave images of the buried objects. It may be done in time domain using scattered fields data. Our experimental system for investigation of scattering in time domain contains a source of pulses (radiation pulse generator with duration of pulses of 30 Ps and amplitude of 25 V), transmitting and receiving antenna and receiving oscilloscope interfaced with the personal computer controlling operational system and signal processing. The operating frequency range of the antenna system is 1.0 to 18 GHz.

The measurement method for reconstruction algorithm of radiomages in time domain includes the following steps:
- Irradiation of the ground with underground object by electromagnetic wave at normal incidence;
- Measurement of phase and amplitude of the scattered pulse signal at all frequency points;
- Storage of experimental data in PC data files;
- Calculation of the envelope modulation of a carrier frequency of scattered field.

The GPR images consist of multiple synthesized profiles that were collected as antennas were moved in a plane along the ground. The simple methods of the signal processing are utilized in the image reconstruction. They are the differentiation, the integration, the linear detection and quasi-optimal filtering.

The cross-section images of embedded underground dielectric objects were obtained in the experiments. The experiment was carried out with metallic dielectric objects that are placed in a box filled with sand. The objects had sizes of d ≈ 1 x 5 cm and heights of h ≈ 0.5 to 2.5 cm (λ = 0.075m).

Used GPR method has been compared with developed pulse time-domain Diffraction tomography method. For this purpose the Diffraction tomography method the image function is the modulus of the normalized polarization current distribution calculated for the subsurface region.

It is shown that results obtained may be applied in practical setups for detection and observation of different subsurface objects.

17.3 Comparison of Modelled Data with Ultra-wideband Impulse Radar Observations of Canonical Targets Buried in Dry Sand
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In support of a vehicle mounted forward looking UWB radar sensor for detecting surface laid landmines, measurements are being conducted to investigate the feasibility of detecting shallow buried landmines.

This ultra-wideband impulse radar system is utilises a bistatic TX/RX antenna arrangement transmitting a 120ps risetime impulse by a TEM horn. The bandwidth of which extends approximately from 500MHz to 2.5GHz. Radar backscatter measurements have been performed at incident angles of 20° to 40° to the ground.

Results of initial backscatter experiments conducted in a dry sand medium are compared with the backscatter signals predicted by FDTD modelled data. FDTD modelled data for target backscatter in moist soil conditions are also presented.