GPR ANTENNA MEASUREMENTS IN TIME DOMAIN

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INTRODUCTION

Antennas are one of the most critical parts of a Ground Penetrating Radar (GPR). They should satisfy a number of demands, one of them is a wide frequency band. Antennas for an impulse GPR system should also have a linear phase characteristic in the operating frequency band as well as constant polarization. Due to the fact that GPR is essentially a near-range radar, its antenna system should possess low and short coupling between Tx and Rx antennas and both antennas should have short ringing. In addition GPR antennas should operate very close to the ground or even in contact with it. However changes in ground properties should not effect strongly the antenna performance. This stability of antenna performance with respect to different types of the ground and different elevations above it is the most essential specific feature of GPR antennas. Thus for full characterization of GPR antennas it is necessary to measure them not only in free space but also in realistic (or operating) working environment.

Since several years the International Research Centre for Telecommunications-transmission and Radar (IRCTR) is active in the area of developing new GPR systems. Development of a GPR antenna system is impossible without good antenna measurement facilities. Thus three different test sites have been created in IRCTR to perform GPR antenna measurements in time domain. They include an antenna far-field measurement site, a free space near-field scanner and a ground test range.

FAR-FIELD MEASUREMENT SITE

The far-field measurement site is a large empty room with antenna support structures made from polystyrene foam. The real part of the dielectric permittivity of the material is about 1.05 and the loss tangent is very small (of the order of 10^{-5}). To avoid the influence of reflections from the environment on the measurements time gating is used. The distance from an antenna under test (AUT) to the closest scatterer (in our case the floor and the ceiling of the room) is 160cm, which provides a reflection free time-window of more than 6.5ns for distances between Tx and Rx antennas up to 150cm and more than 4.5ns for distance between Tx and Rx antennas up to 300cm. The far-field measurement site is used for measurements of a waveform of the electromagnetic field radiated from AUT, for determination of the AUT gain, for matching AUT to a specific impulse generator and finally to measure antenna coupling in free space.

The far-field facilities are equipped with a set of impulse generators with different waveforms (among them a monopulse with duration 190ps (Fig. 1) and a monocycle with duration 0.8ns (Fig. 2)) and a 4 channels sampling scope K2-63 provided by SATIS-TL (Russia). The sampling scope allows to perform time domain reflectometry.

As an example of the measurements in the far field a transmission of a 190ps monopulse through two identical TEM horns placed at different distances and with different polarizations are presented in Fig. 3. In Fig. 3 the waveforms are shifted in time to compensate the time delay due to propagation and to achieve overlapping of the main pulses. The reflection-free time window in these measurements equals 4.5ns (from 5ns till 9.5ns in Fig. 3) and after that the measured waveforms show different behavior due to reflections from surrounding objects.

NEAR-FIELD MEASUREMENT SITE

The free space near-field facilities are placed in an anechoic chamber. The 2D scanner allows to scan an area of 2×2 m. AUT is positioned on the movable support structure made from PVC. This structure allows to vary the distance from AUT to the scanning plane and also to rotate AUT around the vertical axis. Two ultra wideband home-made sensors allow to do simultaneous measurements on two linear polarizations. The sensors are calibrated, so their frequency characteristics are known and can be deconvolved from the measured data. As a result an electric field distribution in the near field can be obtained. Far-field antenna patterns can also be reconstructed from these measurements. The free space near-field test site is used to perform time domain reflectometry of AUT and to measure spatial distribution of the near-field around AUT and the footprint of elevated (above the ground) AUT on the ground surface. The hardware equipment used in the near-filed measurement test site is the same as in the far-field test site.

As an example of measured data we present a transient radiation from the TEM horn [1] in main axis (Fig. 4) and a near-field footprint of the same antenna (Fig. 5). The antenna has been excited with the 190ps monopulse generator. Measurements have been done at the distance 34cm from the aperture.

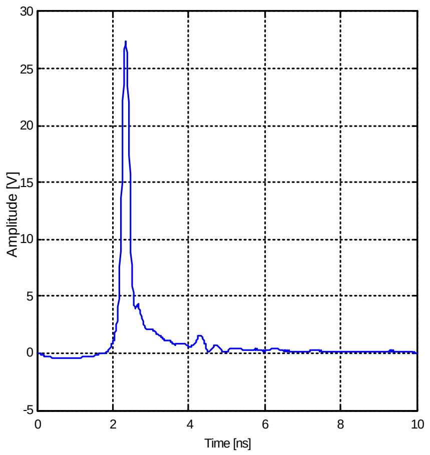

Fig. 1

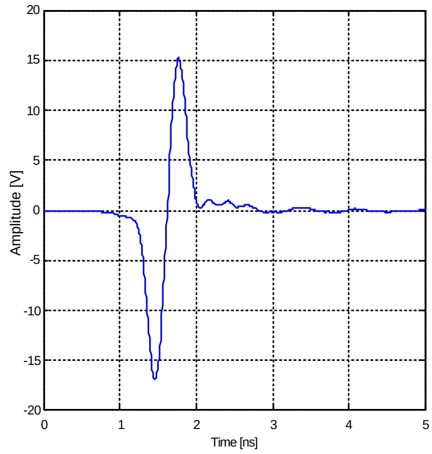

Fig. 2

Fig. 1. Output of the 190ps monopulse generator
Fig. 2. Output of the 0.8ns monocycle generator

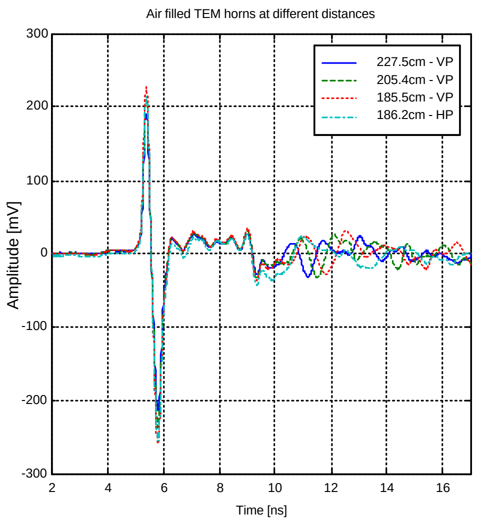

Fig. 3

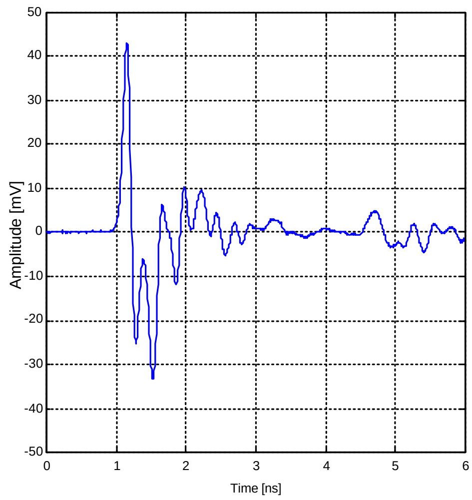

Fig. 4

Fig. 3. Far-field measurements of the TEM horn
Fig. 4. Transient radiation from the TEM horn in the near field

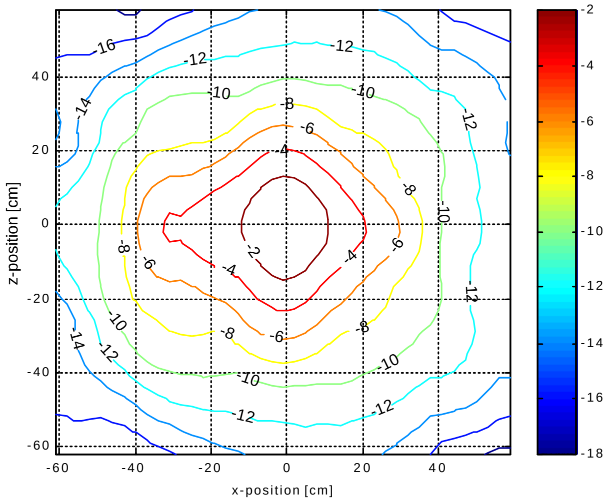

Fig. 5. Normalized footprint (in dB) of the TEM horn in free space

GPR ANTENNA TEST SITE

While for conventional antenna measurements in free space are sufficient for the full antenna characterization, for GPR antennas it is not the case. The ground situated in the near-field of these antennas influences drastically on their performance. Thus facilities, which allows to measure near-field of these antennas directly in the ground, are necessary for full characterization of GPR antennas. Such facilities have been created in IRCTR [2]. It was decided to use dry sand as a “standard ground”. A wooden box with dimensions 2×2×1.5m is filled with ‘homogeneous’ sand. Dielectric permittivity of the sand is assumed to be equal to 4. The test-range is separated from the surroundings by wooden walls, covered with a water proof plastic coating. A home-made sensor is used in order to measure the field 17.4cm below the air-ground interface in the center of the box. In order to position an antenna under test in a proper place a 3D scanner has been mounted above the test range. A schematic drawing of the test site is presented in Fig. 6. For AUT positioned in the center of the test site the reflection free time window is larger than 6ns. Such duration of the reflection free time window and the depth of the sand box allow to measure the responses of AUT excited with pulses shorter than 2.5ns. The test site is used for waveform measurements of the field radiated into the ground, dependence of the radiated into the ground field from the AUT elevation (so-called elevation profile) and the footprint in the ground. The elevation profile is obtained by the measurement of the radiated field in the ground for different elevations of antenna and provides important information about antenna-to-ground coupling and the influence of the ground on the antenna performance. The antenna coupling in the presence of the ground is measured in the GPR test range. The time domain reflectometry of GPR antennas is also done in this test site.

In the GPR test site we use impulse generators with a monocycle waveform and with durations 0.8ns, 1.1ns and 2.5ns and the sampling scope ZX-10400 provided by GeoZondas Ltd (Lithuania) with a sampling rate 25kHz per channel, bandwidth up to 6GHz and a RMS noise level below 0.5mV without averaging.

The footprint of the air filled TEM horn in the ground is presented in Fig. 7. The antenna has been elevated 1cm above the ground and it was excited with a 0.8ns monocycle. Not full XY-plane has been scanned and thus only a part of the footprint is presented in the figure.

CONCLUSIONS

For the development of new GPR antennas and their full characterisation three different test sites have been created in IRCTR. They are the far-field measurement site, the near-field scanner in the anechoic chamber and the ground test site. These measurement facilities allow to measure transient near- and far-fields of AUT in free space and in the ground, spatial distribution of the near-field in free space and in the ground, reflections from AUT in time domain, elevation profile of AUT and coupling between antennas in GPR antenna system. Due to high quality hardware the antenna measurements can be done with high accuracy and repeatability. The test facilities have been used to characterize a number of well-known antennas (such as TEM horn, spiral antenna, etc.) and several newly developed in IRCTR antennas (dielectric embedded dipole, dielectric filled TEM horn [3]).

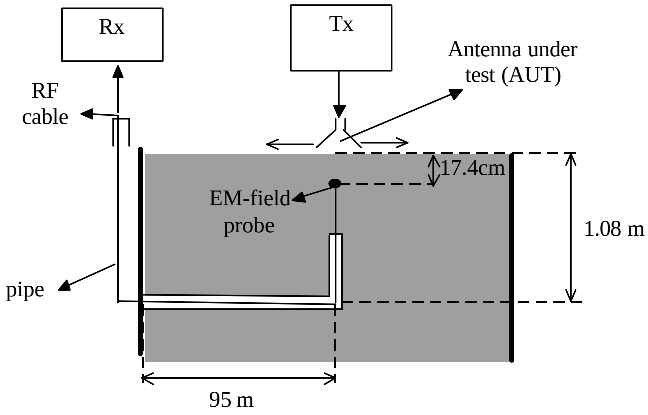

Fig. 6. GPR antenna measurement test site

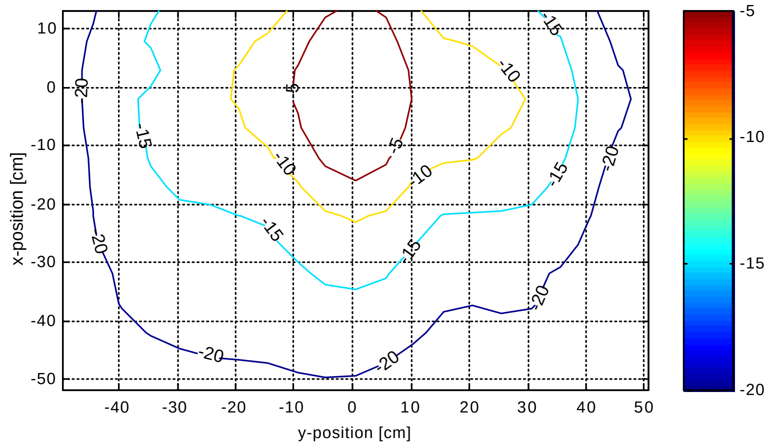

Fig. 7. Normalized footprint (in dB) of the TEM horn at the depth 17.5cm in the sand

ACKNOWLEDGEMENTS

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