ITU-T

I n t e r n a t i o n a l   T e l e c o m m u n i c a t i o n   U n i o n

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

L.84
(07/2010)

SERIES L: CONSTRUCTION, INSTALLATION AND PROTECTION OF CABLES AND OTHER ELEMENTS OF OUTSIDE PLANT

Fast mapping of underground networks

Recommendation ITU-T L.84

Recommendation ITU-T L.84

Fast mapping of underground networks

Summary

Recommendation ITU-T L.84 describes a fast solution for mapping underground networks, necessary to plan the execution of work using trenchless or digging techniques and to optimize the path, thus avoiding the risk of damage to both the existing infrastructures and the drilling equipment. This Recommendation gives advice on general requirements about this solution and the output of utility maps.

History

Edition	Recommendation	Approval	Study Group
1.0	ITU-T L.84	2010-07-29	15

Keywords

CAD, fast solution, GIS, GPR, ground penetrating radar, 3D.

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications, information and communication technologies (ICTs). The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

Compliance with this Recommendation is voluntary. However, the Recommendation may contain certain mandatory provisions (to ensure, e.g., interoperability or applicability) and compliance with the Recommendation is achieved when all of these mandatory provisions are met. The words "shall" or some other obligatory language such as "must" and the negative equivalents are used to express requirements. The use of such words does not suggest that compliance with the Recommendation is required of any party.

INTELLECTUAL PROPERTY RIGHTS

ITU draws attention to the possibility that the practice or implementation of this Recommendation may involve the use of a claimed Intellectual Property Right. ITU takes no position concerning the evidence, validity or applicability of claimed Intellectual Property Rights, whether asserted by ITU members or others outside of the Recommendation development process.

As of the date of approval of this Recommendation, ITU had not received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database at http://www.itu.int/ITU-T/ipr/.

CONTENTS

Introduction

Nowadays, Georadar (GPR – ground penetrating radar) is used for the investigation of the soil before using trenchless techniques, in order to detect some utilities below the ground, like gas or water ducts, that intersect the area where the trench should be dug. But the existing technologies require the post-processing of data, which is time-consuming and requires highly-skilled staff. It is recommended to use the fast solution GPR3D (ground penetrating radar 3 dimensions), in order to reduce time and to be usable by unskilled people.

Recommendation ITU-T L.84

Fast mapping of underground networks

1 Scope

This Recommendation:

- gives some application criteria;
- gives advice on the features of GPR3D system for performing the fast investigation of the soil;
- gives advice on how to produce the final map of the investigated area.

2 References

None.

3 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

CAD Computer-Aided Drafting

GIS Geographical Information Systems

GPS Global Positioning System

GPR Ground Penetrating Radar

GPR3D Ground Penetrating Radar 3 Dimensions

NGN Next Generation Networks

Rx Receiver

Tx Transmitter

4 Ground penetrating radar

A radar can detect discontinuities below ground, in addition to its normal use for locating objects in the air. The equipment used in a GPR system is schematically represented in Figure 1.

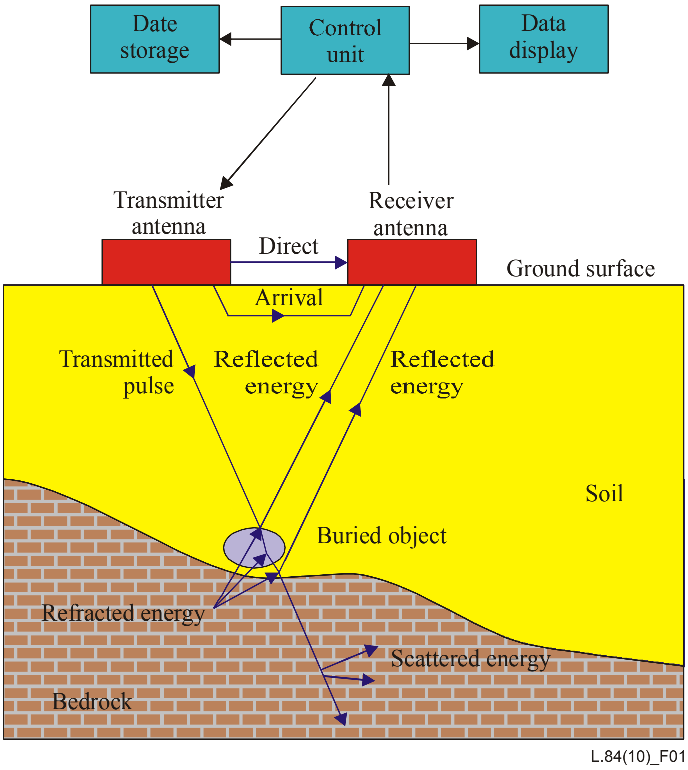

Figure 1 – GPR logical scheme

An antenna transmits an electromagnetic wave into the ground and the back-scattered radiation is received and then processed, to extract the information relevant to buried objects. Usually any discontinuity of the electromagnetic properties of the soil (dielectric constant and conductivity) is detected. Objects can be classified according to their geometry: planar surfaces, long and thin objects (cables and pipes), local objects. Wideband time-domain impulse radar systems are available commercially and are usually offered with a range of antennae to suit the desired probing range. The extent of ground penetration is limited by the attenuation of the signal: the penetration increases at longer wavelengths, but resolution is higher at shorter wavelengths, so the choice of frequency is usually a compromise between the two. In Table 1, some frequency values are shown with an approximate estimate of the expected penetration in favorable propagation conditions.

Table 1 – Frequency vs penetration

Penetration (m)	**Frequency (MHz)**
0.5 – 1.0	1000
1.0 – 2.0	500
2.0 – 1.0	200
5 – 15	100
10 – 30	50
30 – 50	25
50 – 100	10

The investigation depth is also strictly related to the nature of the ground: GPR works best in dry granular soils and may not be able to see far through waterlogged or dense clay.

Most antennae have relatively small footprints which means that rapid and wide-area surveying can only be achieved with array radar systems. These systems use more than one antenna, mounted on a fixed scheme, which allows the acquisition of a large amount of data in a relatively short time, and so makes easier the final interpretation of the probing results.

Particularly in urban areas, it is recommended to use an array radar system, to improve the probability of detection of underground utilities and reduce the overall investigation time.

5 GPR3D fast investigation

From the point of view of the operators, nowadays GPR systems present the following limits:

- 2D real-time results displayed on the monitor are difficult to understand for people (Figure 2); therefore, it is necessary to make some parallel scansion to eliminate false alarms;
- in order to have 3D results and the information about buried objects, post-processing of the field data is mandatory.

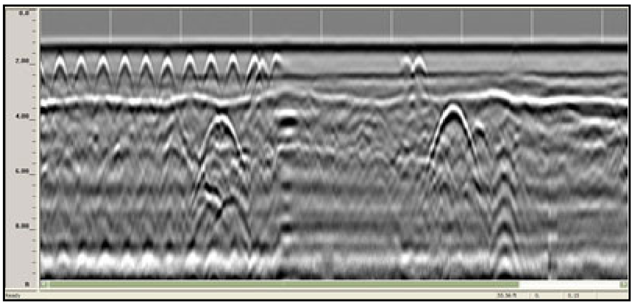

Figure 2 – Traditional GPR results

The fast GPR3D should be realized by an antenna array and should have the following features:

- it should display in real time the 3D results about buried utilities;
- it should be user friendly so that unskilled people can understand the problems without difficulty;
- it should detect univocally underground services using 3D GPR acquisition;
- it should georeference traces and they should be imported in a GIS system or in a CAD file.

The main advantage of such a GPR3D fast system shall be the time reduction for the introspection and the improvement of the reliability.

5.1 Hardware

The GPR3D machine should have particular features in order to support most of the functionalities required in the soil introspection activity.

First, the trolley of the georadar shall be mainly composed of dielectric material to avoid interference with radio signals used by the machine.

The georadar shall be equipped with devices, such as a GPS receiver and an odometer, which allow to fix the geographical coordinates.

The georadar includes a ruggedized laptop connected with antennae and other devices. The laptop running a particular software is the console that allows the operator to control the entire machine.

It is recommended that the hardware of the georadar support an operative temperature range compliant with the application, and the power supplies support all the activities for at least one whole working day.

The GPR3D acquisition speed should be as fast as a walking pace.

The entire introspection activity using the georadar should be performed by a single person, i.e., he or she should guide the machine, check the results on the display and mark with spray on the road the presence of the buried object.

5.1.1 Antenna system

It is recommended that the georadar device use an antenna system (rx and tx dipoles) able to detect both transversal and longitudinal buried utilities.

In order to support fast acquisition, the antenna system shall perform the introspection in one-pass scanning of the area to be investigated.

The depth of the investigation should be 100 cm at least. For this reason, it is recommended to use a frequency that allows to reach the desired depth and to have a good resolution.

5.1.2 GPS receiver

It is recommended that GPR be equipped with a GPS receiver, so that it can georeference all buried objects, i.e., real spatial coordinates (latitude and longitude) are associated to the buried objects, in order to track the path of the investigation.

5.1.3 Odometer

It is recommended that:

- an odometer be used, in order to correct GPS errors;
- the odometer introduces an error less than 1 cm for each metre.

5.2 Software

It is recommended that the software perform automatically data elaboration in real-time, avoiding the post-processing phase.

The man-machine interface should be user friendly, and should allow the operator to examine the results both of longitudinal and transversal buried utilities.

The operator records georeferenced buried utilities, and it is recommended that he or she adds attributes, such as a text description, environmental images, acquired by a webcam, or audio files, recorded during acquisition. These buried objects are recorded like WayPoints both in GIS output and in CAD.

The software should record tracks in a georeferenced way.

5.2.1 Migration

It is recommended that a migration algorithm be implemented in georadar software, so that data are easily understood by unskilled people (Figure 3), that is unskilled operators in geophysics data analysis. As for seismic data, migration is used to compensate for distortions caused by non-horizontal reflectors and for collapsing diffraction hyperbolas into their apex. Migration algorithms valid for post-stack migration of seismic data may be successfully used to migrate radar data. A good estimate of the material velocity is needed to produce a good result.

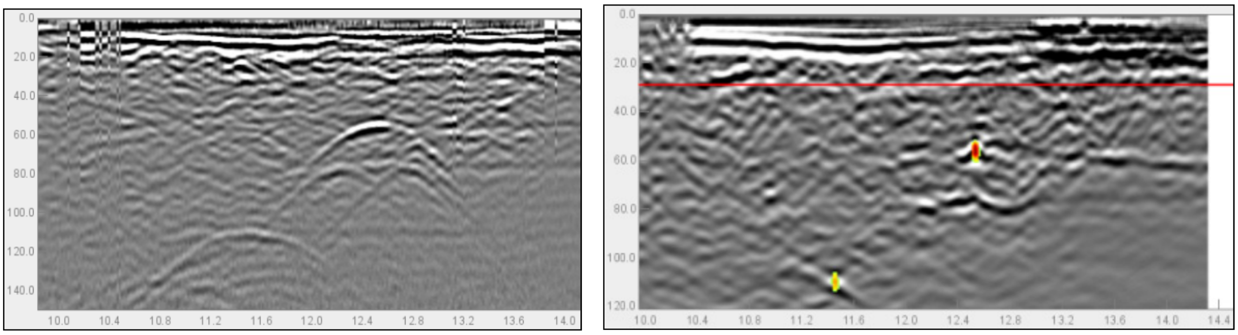

Figure 3 – Example of raw data and migration

On the left side of Figure 3, there are raw data while on the right side the real-time elaboration results are visible: the red line shows the trench depth and the two yellow bullets represent migrated data related to respectively two buried utilities.

5.3 GPR3D output system

One of the main aspects of the soil investigations for the detection of underground utilities is the production of maps that can be easily used by operators performing installation or maintenance work on site. The final report shall provide details of buried utilities.

The final map, showing the position of the detected utilities, shall be drawn with respect to the same coordinate system adopted in the field, so that it is easy to correlate the map with the local environment.

The software of GPR3D systems must provide a link with a CAD station and GIS to transfer directly on a digital map the information relevant to the position and depth of the detected underground utilities.

5.3.1 CAD

The software shall have the possibilities to create a file compliant with CAD format with all data of the investigation, like WayPoint, Track and attributes.

When an existing CAD cartography of the investigated area is available, the information relevant to the position of the detected utilities should be integrated with the existing cartography by directly updating it.

5.3.2 GIS

The software shall have the possibilities to create a file compliant with GIS system with all data of the investigation, like WayPoint, Track and attributes.

5.4 Additional features

The uninterrupted development of urban areas requires a detailed knowledge of the route of buried networks, their hindrance and the soil stratigraphy in order to simplify laying and maintenance works. Before planning a new infrastructure, a series of inspections should be carried out. This is usually done by digging some essays (Figure 4). This kind of invasive inspection causes many inconveniences to traffic, people and public activities.

Figure 4 – Digging essay for existing utilities localization

5.4.1 GPR3D "Digging Essay"

In order to avoid troubles for people's safety, the GPR3D system should be used, in order to locate the buried utilities, without dismantling the roadbed. The GPR3D procedure for the location of utilities in a small area should be carried out by acquiring a series of parallel profiles. A series of georadar profiles should be acquired in a row so that they are parallel to each other and at the same distance from each other.

5.4.2 Stratigraphic soil investigation

In addition to its use for locating buried utilities, the GPR3D can also detect ground characteristics. Nowadays probing techniques are used, but the GPR3D system can be used in order to understand where it is more convenient to cut and dig, without creating problems to people. The electromagnetic soil backscatter is processed to extract the information relevant to the ground features: water content and granulometry. The ground features can be extracted by analysing the electromagnetic signature of the ground response.

Appendix I

Italian experience regarding fast solution GPR3D

(This appendix does not form an integral part of this Recommendation)

Nowadays, in Italy, the deployment of the NGN has been driven towards the infrastructure laying miniaturization and so towards the use of trenchless techniques. For this reason, mapping of underground network is needed, and so the GPR3D system solution is implemented and other additional features are in progress.

The first step is to create a system to locate underground facilities, in order to understand where it is possible to cut without problems. The Italian GPR3D system solution is shown in Figure I.1.

Figure I.1 – Real-time GPR3D Italian system

The Italian GPR3D system solution can display in real time the 3D results about buried utilities; it is used for plants of various operators and more than 20 km of investigation have been just made in few months.

It is possible to import georeferenced data in a GIS system or in a CAD file. Georeferenced traces with all buried objects recorded during the investigation, with information about the distance from the start point and the depth can be seen. For example, after the investigation, the operator can press a GIS button on the interface of the georadar, create the file compliant with the GIS system, and finally he can drag and drop this file into the GIS system maps, thus being able to see all the information recorded during the investigation (Figure I.2). The same operation can be done for the CAD output file (Figure I.3).

Figure I.2 – GPR data imported in GIS system

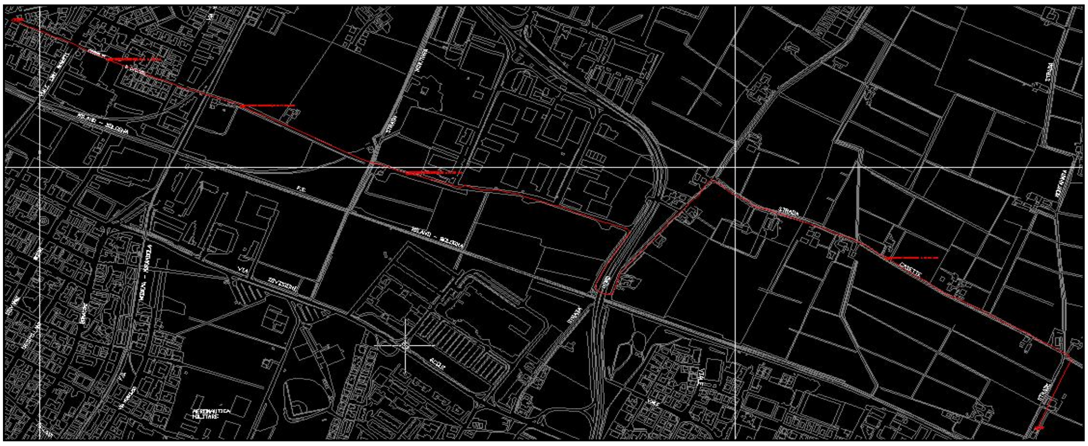

Figure I.3 – GPR data imported in CAD file

Bibliography

[b-ITU-T L.39] Recommendation ITU-T L.39 (2000), *Investigation of the soil before using trenchless techniques*.

[b-Cottino] Cottino, E., Di Buono, N. (2009), *A complete enabling solution for FTTx network infrastructure,* IWCS.

SERIES OF ITU-T RECOMMENDATIONS

Series A	Organization of the work of ITU-T
Series D	General tariff principles
Series E	Overall network operation, telephone service, service operation and human factors
Series F	Non-telephone telecommunication services
Series G	Transmission systems and media, digital systems and networks
Series H	Audiovisual and multimedia systems
Series I	Integrated services digital network
Series J	Cable networks and transmission of television, sound programme and other multimedia signals
Series K	Protection against interference
Series L	**Construction, installation and protection of cables and other elements of outside plant**
Series M	Telecommunication management, including TMN and network maintenance
Series N	Maintenance: international sound programme and television transmission circuits
Series O	Specifications of measuring equipment
Series P	Terminals and subjective and objective assessment methods
Series Q	Switching and signalling
Series R	Telegraph transmission
Series S	Telegraph services terminal equipment
Series T	Terminals for telematic services
Series U	Telegraph switching
Series V	Data communication over the telephone network
Series X	Data networks, open system communications and security
Series Y	Global information infrastructure, Internet protocol aspects and next-generation networks
Series Z	Languages and general software aspects for telecommunication systems

Printed in Switzerland
Geneva, 2010