GROUND PENETRATING IMAGING RADAR – RESULTS TO DATE

Ralph Bernstein
r.bernstein@wittentech.com
Witten Technologies, Inc.
Boston, MA USA

Mike Oristaglio
m.oristaglio@wittentech.com
Witten Technologies, Inc.
Boston, MA USA

Doug Miller
d.miller@wittentech.com
Witten Technologies, Inc.
Boston, MA USA

Robert Green
r.green@wittentech.com
Witten Technologies, Inc.
Boston, MA USA

Key words: radar, underground mapping, ground penetrating radar, gas, electric, imaging, utilities

ABSTRACT

A three dimensional underground mapping system has been developed to support electric, gas, water, and communications utility locating and mapping. The objective of the work was to reduce underground accidents, installation and maintenance costs, and lost revenue from outages. A prototype Ground Penetrating imaging Radar (GPiR) system was developed and tested at eight utilities. Technical success let to the development of a parallel radar system providing high-speed and low cost underground mapping.

I. INTRODUCTION

In support of the US Electric Power Research Institute (EPRI) and the Gas Technology Institute (GTI) and their utility customers, an underground radar imaging system was defined, contracts let, and a prototype system developed and utility tested. The objective was to detect, locate, and map conductive and nonconductive underground features and structures, and to produce easily interpretable three-dimensional (3D) images. The depth goal for ground penetration was four meters. The purpose of the Ground Penetrating imaging Radar (GPIR) system was to:

- reduce accidental line and cable cuts
- reduce lost revenue from excavation accidents
- reduce construction and maintenance costs
- support underground infrastructure surveying
- upgrade existing underground maps

Underground objects to be detected and mapped include:

- electric distribution and transmission power lines
- gas transmission and distribution lines
- water lines
- sewage lines
- communications lines
- system ducts
- building foundations
- underground construction barriers and debris
- underground gas, water, oil, etc.

An example of a GPiR "virtual test pit" mapping done in New York for Consolidated Edison is shown in Fig. 1, two underground transmission lines at a depth of approximately one meter were located and mapped and superimposed on a photo of that area.

Fig. 1 Underground Transmission lines detected by GPiR

Fig. 2 is a map produced from the image data showing the underground transmission lines. Accurate horizontal and vertical position is displayed and has been verified by on-site inspection. These results will allow faster and safer excavation during repairs and new utility installations.

Previous underground radar imaging used conventional ground penetrating radar (GPR), which provided only a reflected radar signal from an underground object. This signal did not allow an operator to easily distinguish between a singular object, such as a rock, or a linear object such as a pipe, nor did it allow the discerning of small objects.

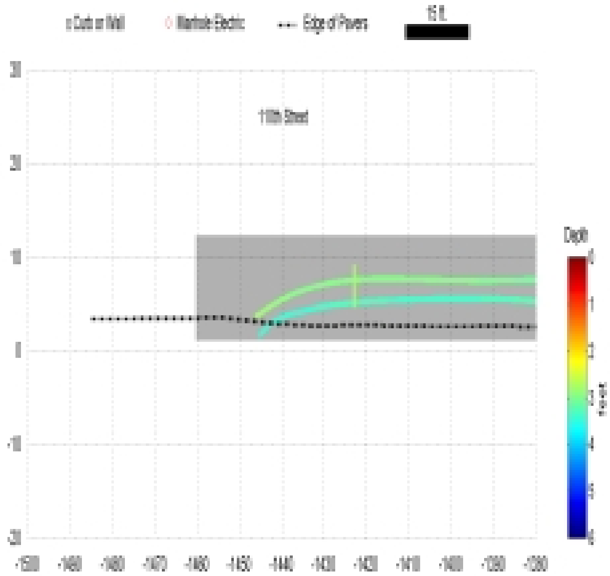

Figure 2 Map of transmission line from GPiR data

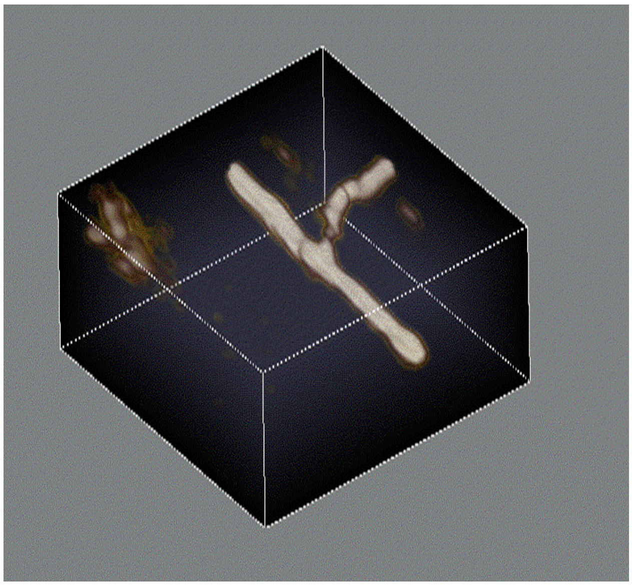

Fig. 4. A 3D image formed from multiple radar returns

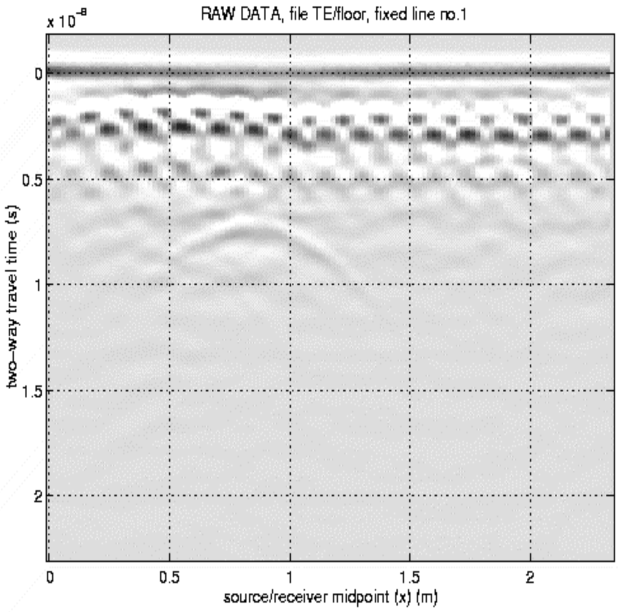

Fig 3 Example of conventional GPR return

By combining multiple two-dimensional radar echo returns of the type shown in Fig. 3 and the use of radar signal focusing and image 3D formation algorithms, an image of the type shown in Fig. 4 can be formed. This image can be easily be interpreted, and shows the relationship between objects in a very clear and natural way.

II. HISTORY

EPRI and GTI utility members needed to reduce accidents and maintenance costs. EPRI believed that producing 3D images of underground radar data would better discern and accurately map features in the underground infrastructure. It was anticipated that tomographic image processing, which included radar focusing, image enhancement, image formation and 3D image representation would improve the interpretability of the complex radar data. EPRI and GTI also wanted to assure that the technology would be available to the user community. Toward this end, a three-phase GPIR development program was defined in 1998, which included a GPiR commercialisation phase:

Phase I - GPR Assessment and Experiments
Phase II - Advanced GPiR Prototype Development
Phase III - Commercialisation of GPiR

II. GPR ASSESSMENT AND EXPERIMENTS

Schlumberger-Doll Research performed the initial phase of the research. The GPiR assessment system in Phase I evaluated a number of competing GPR's. The radars included GSSI, SSI, Mala, and GeoRadar. These radars all provided similar data results. Precise radar positioning control was also needed to scan selected test areas. A computer-controlled large x-y mapping grid was built to position the radar over the area to be mapped. The radar data were processed by advanced signal and image-processing algorithms to create accurate 3-D images of the underground infrastructure. Testing and evaluation was done at over 18 different sites chosen by eight EPRI utility members. The sites tested included typical construction sites, downtown streets and intersections, proposed street electric vault locations, and underground cables under streets and at substations. Images were acquired to a depth of 1.5 to 3 meters. Recent tests in sandy soil showed a depth of 6 meters. Very conductive soils such as clay allow only a shallow depth of less than 1 meter.

III. ADVANCED PROTOTYPE DEVELOPMENT

Following the successful assessment experiments, a production and parallel radar system was designed and built by Witten Technologies, Inc. (WTI). The commercial system, called the Computer Assisted Radar Tomography (CART) imaging system uses a patented parallel radar array built for WTI by the Swedish company Malå Geoscience. The Mala radar was chosen for a number of reasons, including multi-polarization advantages and technical capability. This new van-pulled or tractor-pushed mobile GPiR allows production underground mapping of large areas. Parallel data acquisition is implemented with an array of 16 radars (8 transmitters and 8 receivers) to cover a swath width of 2 meters at a speed of 1000 meters per hour. It collects enough data in a single pass to form a full 3D image beneath its track (see Fig. 5).

Fig. 5 Tractor driven CART GPiR system.

IV. COMMERCIALIZATION OF GPIR

This phase of GPiR mapping and locating is now being implemented by WTI, headquartered in Boston, MA. Accurate digital and hard copy three-dimensional images and maps of the world's underground infrastructure are provided as a mapping service. The WTI GPiR mapping services is under the trademark of the CART Imaging System.

Extensive mapping has now been done for electric, gas, water, and communications companies. This new system enables utilities, construction companies, and others involved with underground infrastructure to create precise 3-D maps of the complex array of electric, gas, water, and communications lines and also impediments to construction and excavation. Armed with this information, the utilities and construction companies can now better manage, maintain, and build underground networks that serve downtown business centers and residential areas at lower cost and with fewer accidents. The CART GPiR system (see Fig. 5) can efficiently conduct "virtual digs" ahead of excavation, enhancing both productivity and safety on utility construction and maintenance job

IV. RESULTS AND DISCUSSION

GPiR systems can efficiently conduct "virtual digs", and with suitable processing, can generate accurate 3D radar maps of the subsurface. To obtain sharp and accurate 3D images requires precise GPR positioning, multi-polarization surveys, and 3D GPiR image processing. The quality of GPiR images and the depth of mapping vary with soil conditions and near-surface complexity of the mapping area. Typical depths are two to three meters, with up to six meters under low conductive soil conditions. Low conductive soils, such as dry sand has the greatest depth capability and wet clay the least depth.

Commercial GPR systems differ, but the images obtained from various GPR's after processing in controlled and field tests are almost indistinguishable from each other.

The project development team led by Dr. Mike Oristaglio, was named by *Engineering News-Record* as one of its prestigious "Top 25 Newsmakers" in construction for 2000.

V. CONCLUSIONS

GPiR offers significant advantages over conventional GPRs. There is significant detail in 3D GPiR images. Cuts and patches in the roadbed are especially clear. In typical conditions, current GPR systems can image individual metal and plastic pipes (> 8 cm diameter) to depths of 1 - 2 m. Larger structures, such as conduits with multiple lines or buried foundations, have been imaged at depths of 3 m. In complex areas, pipes and other utility targets are not always recognizable in the images. The development of a highly parallel radar imaging system has reduced mapping times by an order of magnitude. The ground penetrating imaging radar (GPiR) system, sponsored by EPRI and GTI, has now been commercialised by WTI and mapping services using the technology are available.

REFERENCES

1. Ground Penetrating imaging Radar (GPiR) – Phase II, EPRI Technical Report TR-1006152, March 2001.
2. Imaging Radar Maps Underground Objects, IEEE Computer Applications in Power, July 2000, pp. 20-24.