Detection of Fibre Optic cables using GPR

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Index terms **- Fibre optic cable detection, GPR, Antenna array.**

Abstract **- The detection of buried Fibre Optic (FO) cables in an urban environment is a problem when using GPR. The fibres themselves are not detectable as they are essentially sand. What can be detected is the cable strengthening, the jacket, the trenching, the ducts they are in and if included, any tracer wires or tape.**

Simulations were done with different frequency antennas and a 1GHz antenna was selected for practical trials. The equipment used in the tests was an 8 channel fast scan GPR, Groundvue 3-8, with modular interchangeable antennas. The data was processed in 2D and 3D using ReflexW (Sandmeier, K.J) .

The result shows that the cables can be detected in some ground conditions.

I. INTRODUCTION

Ground Probing Radar (GPR) is commonly used for detection of pipes and services such as electricity, water, gas and drains. These are either metallic or large non metallic structures.

The detection of buried fibre optic cables in an urban environment is more of a problem when using GPR. The fibres themselves are not detectable as they are essentially sand. What can be detected is the cable strengthening, the jacket, the trenching, the ducts they are in and if included, any tracer wires or tape.

The GPR for this application has to have a frequency high enough to give the required resolution. Due to this high resolution any stones, voids and other clutter objects will give return signals.

These false signals can be reduced by doing an area scan over a larger area giving a 3D timeslice over the survey area. Viewing this in a plan view optimises the rejection of discrete objects and allows the human pattern recognition to detect the linear path of the fibre. Further enhancements could use a combination of cross- and co-polarisation antennas to enhance linear features.

FO cables without metallic armour or cores are difficult to detect as they are non metallic and small diameter. If the FO cables are laid in ducts, detecting the ducts is easier as they are larger.

The GPR detects a target by the change in the electrical characteristic of the materias on either side of the material interface, either the conductivity or differences in the dielectric constants.

If the wavelenght of the GPR is longer than the diameter of the cable, the effective dielectric constant is the average of the different materials in the cable. (At 1GHz, the wavelength is approximately 10cm, much longer than the cable diameter). The FO fibre itself is glass, Er=5, but most of the cable is the strenthening and jacket which are plastic based. These have an Er in the region of 3 to 4. We can therefore assume an average dielectric constant of about 4 for any simulations. If the cables are laid in sand with an Er of 5 to 7, the difference in the dielectric constant is small. In practice there are other objects in the ground, stones, voids, moisture variations, rubble with concrete etc. giving similar or much larger signal amplitudes than the cable. Simulations and the practical results of practical GPR survey are used to illustrate the detection of FO cables.

II. SIMULATIONS

The simulations of the FO cables was done using GprMax 2D (Giannopoulos 2005).
The model used has a 16mm diameter cable (Er=4) buried 300mm down in sand (Er=6) with and without concrete (Er=9) rubble clutter. (Daniels, 2004) See figure 9 for the geometry.
Different frequencies, 400MHz, 1GHz and 3GHz were used in the simulations in order to define an optimal frequency.

Figures 1 to 3 shows the simulation results with the cable in the sand but no clutter.

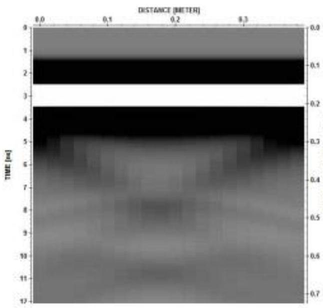

Figure 1. 400MHz, cable only

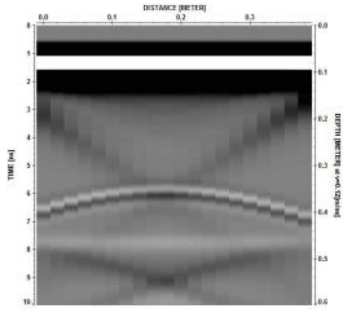

Figure 2. 1GHz, cable only

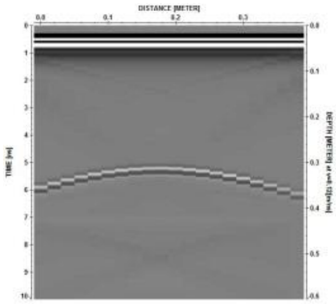

Figure 3. 3GHz, cable only

With 4 clutter objects added as in figure 9, the resulting simulations are shown in figures 4 to 6.

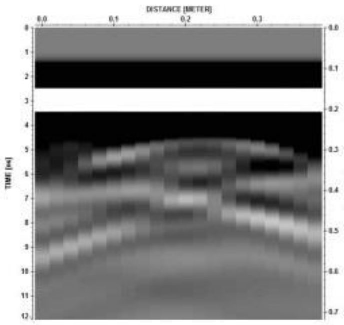

Figure 4. 400MHz, cable+clutter

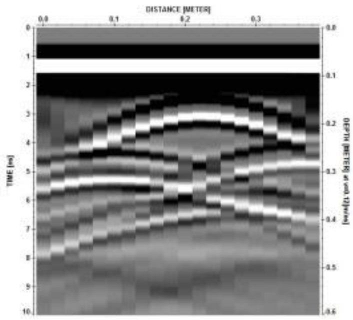

Figure 5. 1GHz, cable+clutter

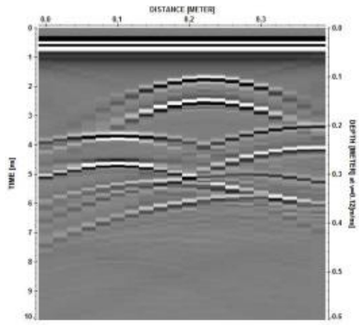

Figure 6. 3GHz, cable+clutter

Judging from the simulations, there is little possibility of seeing the FO cable with a 400MHz antenna, the 1GHz is possible and the 3GHz best. However, due to the typical depth of the FO cables, 300 to 400mm, and a potential uneven surface, the 3GHz GPR is not suitable. The attenuation would be very high and the groundclutter would give strong fast changing returns with possible ringing.

Applying migration to the raw 1GHz data above reduces the hyperbolas to "point" objects as shown in figres 7 and 8 with cable only and cable plus clutter.

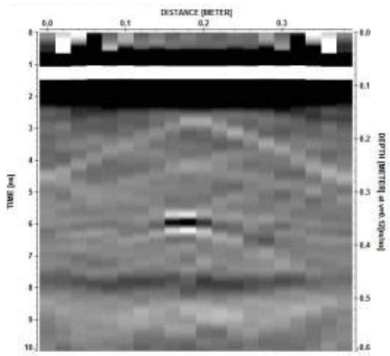

Figure 7. 1GHz cable, migrated

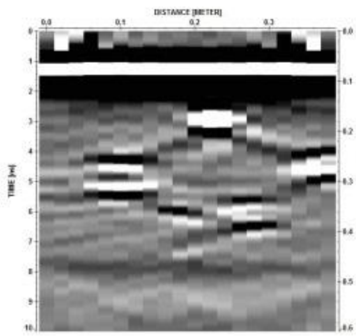

Figure 8. 1GHz cable+clutter, migrated

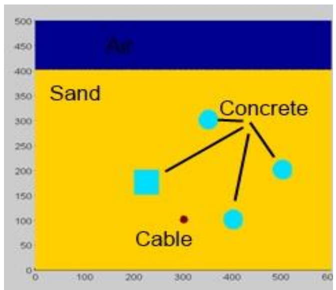

Figure 9. Simulation model

The presence of the clutter items not only makes it difficult to see the cable amongst the clutter but also changes the shape of the cable return due to the raypath distortion as it goes through the concrete blocks. The only way to detect the presence of a cable as opposed to a stone / clutter is to do a number of parallel runs and using timeslicing to see the linear path of the cable.

III GPR SURVEY

It was therefore decided to use an 8 channel array of 1GHz to test the detectability on a testsite with different ground conditions. The system used was an Utsi Electronics Groundvue 3-8 system with 1GHz antennas spaced 120mm apart, see figure 10.

The ground was coarse gravel with some larger stones. These caused the encoder wheel to jump, giving distance errors on adjecent transects. However, the fixed antenna array spacing meant that the dataset from each transect was accurately positioned. The test area is divided into three sections, L-R in figure 11.

A high loss section
A high clutter section
A low loss, low clutter section.

Each section is about 10m long and there are FO cables runs in each of them. (There are also other copper cables and services below the FO cables.)

A typical 2D GPR trace from one of the antenna is shown in figure 11. The top trace is the data with basic processing (background removal, dewow, and gain), the bottom part with migration added.

Even knowing that the FO cables are laid between 300 and 400mm, one cannot pinpoint where they are in all the clutter.

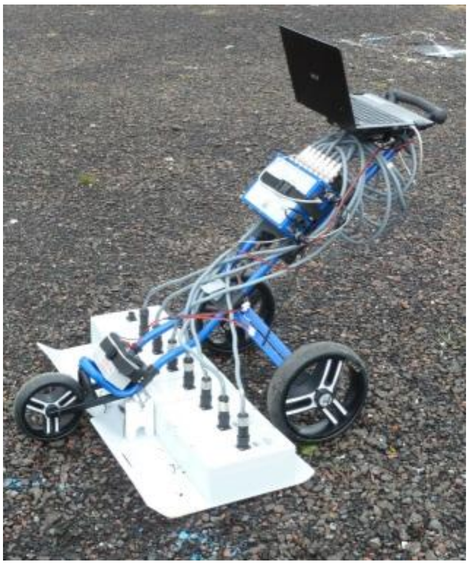

Figure 10. Groundvue 3-8

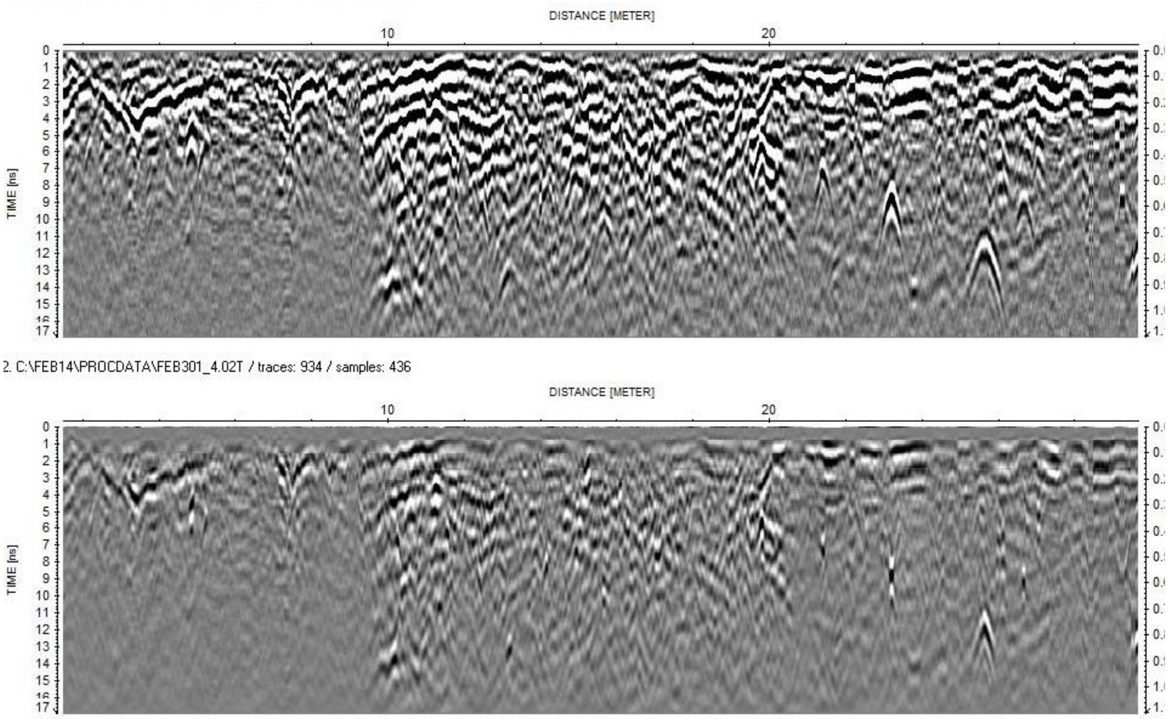

Figure 11 2D data from test area, migrated data on the bottom

IV 3D TIMESLICES

When the migrated data is collected into a 3D dataset and timesliced, the FO cables show up as linear features. Figure 12 shows the data with a normal greyscale (white to black for negative to positive amplitudes). The cable is highlighted in red.

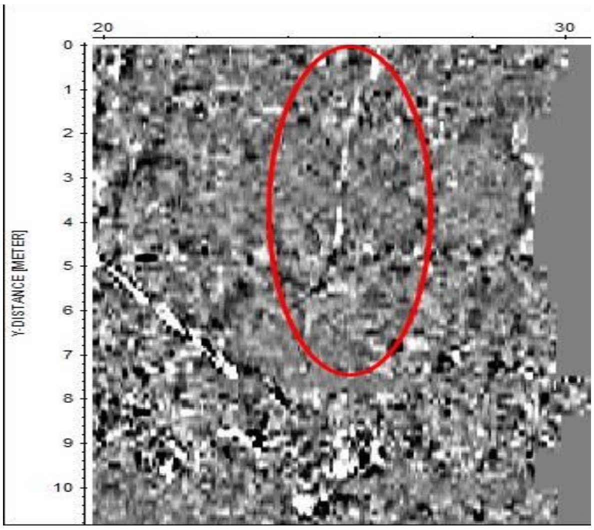

Figure 12 Timeslice at 32 cm.

Another timeslice is shown at a slightly deeper depth. This time the data is enveloped and viewed in white to black for 0 to positive. The cables are highlighted in figure 13.

Due to the very faint FO cable signals, they will only show up when the radar crosses the cables at right angles. This is the angle for which the migration is done. If the target is at any other angle it will be defocused in the migration process. For a full coverage of cables at any angle, it is required to do other GPR runs, orthogonal to the first ones.

On another area of the test site, FO cables go to a junction box. This area was surveyed by doing one run with the multi channel GPR. The timeslice of the area just next to the box is shown in figure 14. This ground is relatively free from clutter, giving a clear return from the cable

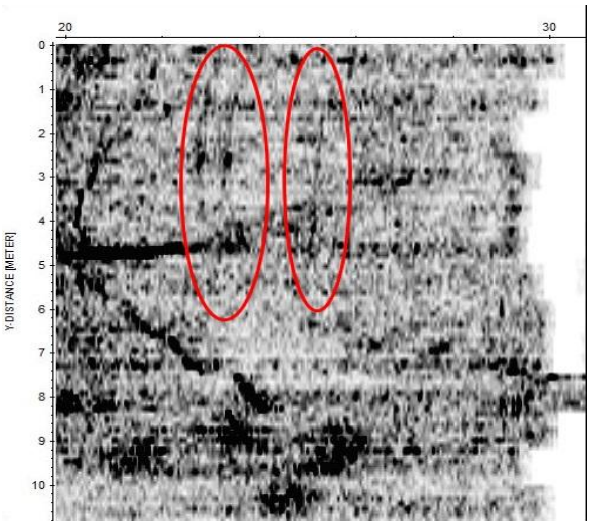

Figure 13 Timeslice at 37 cm.

V CONCLUSIONS

Using a GPR frequency between 1 and 2 GHz makes it possible to detect Fibre Optic cables in uncluttered, low loss ground. To reduce the false alarms from stones, voids and other objects, the data has to be viewed in timeslices for the operator to trace the linear cable pattern. Using the multi channel high speed GPR makes this task more accurate and faster.

ACKNOWLEDGMENT

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REFERENCES

[1] Daniels, D. (2004). "Ground Penetrating Radar", 2nd edition, IEE, Stevenage, UK, pp74 & 83.

[2] Giannopoulos, A. (2005) *GPRMAX: Finite-Difference Time-Domain Simulator for Ground Penetrating Radar* at http://www.gprmax.org.

[3] Sandmeier, K.J. ReflexW software available at http://www.sandmeier-geo.de/GPR.html.

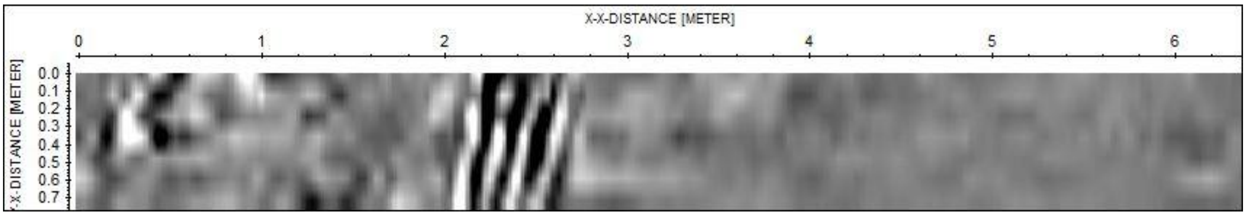

Figure 14 Three FO cables at 30cm depth in un-cluttered ground