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Advances in GPR Imaging with Multi-Channel Radar Systems from Pipes

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Abstract*— Advances in ground penetrating radar imaging with multi-channel systems have greatly improved the speed and areal coverage of the ground. Along with improved imaging software, datasets recorded with multi-channel systems can be processed at similar speeds to coarsely spaced single channel data that would normally require additional time for interpolation processes to fill in the gaps between lines. With the cross-line spacing approaching a 1/4 wavelength of the transmitted microwaves into the ground, multi-channel systems have the advantage of complete coverage of a site with no need for interpolation in most cases except to fill in the gaps between adjacent tracks if so desired. Multi-channel systems do require additional (radagram signal processes) in order to balance the channels and to condition the data prior to imaging. Spectral whitening and several other MERA methods are shown with their application to imaging of sites from Pipes of subsurface . Data processed from multi-channel GPR systems are shown. I have been using this technique for the detection of buildings pipes under the Mala Street in Sweden. Create the volume turned 2D in order to demonstrate the continuity of the best reflections across linear structures that have a slightly different depths and thickness of the overburden

I. INTRODUCTION

The advantages of multi-channel systems are that the full-resolution of GPR recording on the ground can be adequately handled by systems in which the antenna channel separation approaches distances less than the transmitted wavelength of central antenna frequency (Grasmueck et al., 2004; Novo et al., 2008). These design characteristics have been accomplished by many of the current GPR manufacturers of multi-channel systems. Even though the first introductions of multi-channel GPR systems dates back more than 15 years (Warhus et al., 1993), the complete acceptance of multi-channel recording was limited by the quality of the data and complex data processing (Francese et al., 2009). Wildly different frequency responses of the multi-channel antenna prevented useful amalgamation of the individual profiles into useful images. However, in the last few years, most of the multi-channel manufacturers have provided GPR systems where the antenna responses of the individual elements are much closer (Linford et al., 2010; Trinks et al., 2010; Simi et al., 2010)

Ground Penetrating Radar is a device that transmits short pulses of electromagnetic energy with pulse duration (1-20) ns with high frequency range (10-2500) MHz to the ground by a transmitting antenna [Sushil Sheena, 2004]. The energy propagation speed through the ground depends upon dielectric constant of the medium [Sushil Sheena, 2004; Sabbar Abdullah, 2008]. When the radar waves encounter an interface between two different materials (layers) with different refraction indices, some of the transmitted wave energy is reflected back to the surface. A receiver picks up these reflections as analogue signals. The input analogue signals are digitized and quantified using an analogue-to-digital converter in order to be ready for processing in the computer to create an image called the radargram. (Fig.1, 2, 3) [Sushil Sheena, 2004; Sabbar Abdullah, 2008; Hannu Luodes, 2008].

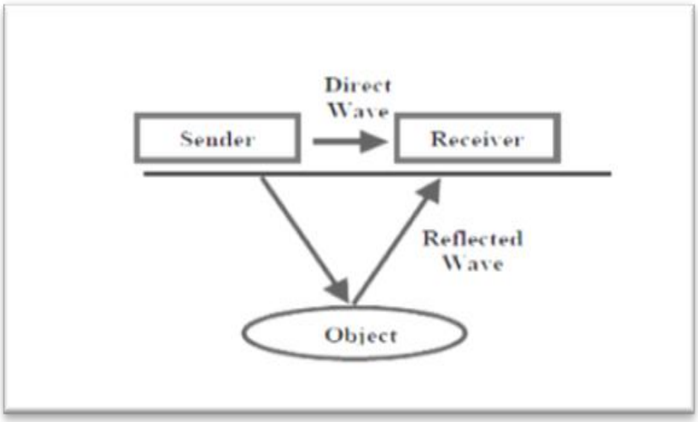

Fig 1: Illustration of different paths of reflection of radar waves

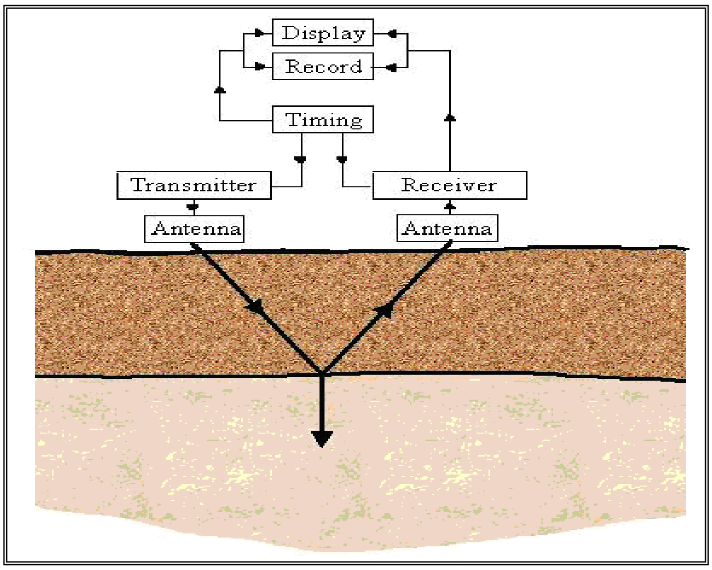

Fig 2: Illustration of the behavior of the radar waves from the beginning of transmission until it is received by receiver antenna. [Basson, 2000].

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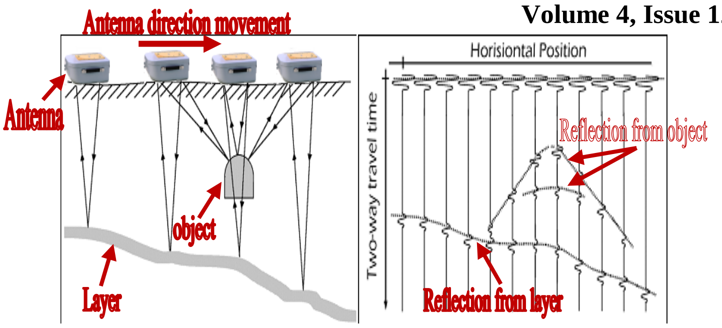

Fig 3 illustrates the principle of ground penetrating radar detection. It shows clearly that the radar wave is reflected by the buried object (on the left). The results recording are show on the right. [Hannu Luodes, 2008].

The difference in media of the underground changes the phase angle and the amplitude of the radar waves which appears as sharp edges on the radar gram [Sushil Sheena, 2004]. Upon receiving the reflected signals from the ground, an analog-to-digital converter is used to digitize these signals with time and store them as radar images or radar gram [Bernth Johansson, 2005]. Knowing the type of the media in which the electromagnetic wave is moving is necessary to predict the depth of penetration because it is related to the dielectric constant of the media using the following relation:

$$v_m = \frac{c}{\sqrt{\varepsilon_r}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where c is the speed of the light in a space ε_r is a dielectric constant of the medium, v_m is a radar wave speed. We can determine the depth of the body using the following relation:

$$d_r = \frac{v_m t_r}{2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

Where d_r is the depth of the body, v_m is a radar wave speed; t_r is the travelling time of the radar wave [Sushil Sheena, 2004; Bernth Johansson, 2005]. The depth of penetration of the radar wave is also dependent upon both the frequency of the wave and the electrical properties of the media. The higher frequencies used, the lower depth is achieved. However, using high frequencies is usually accompanies with high resolution of the radar gram and vice versa [Annan. A. P, 2004]. The best penetration is achieved in high resistivity media. Low resistivity media on the other hand attenuate the signals which results in low or shallow penetration [Bernth Johansson, 2005; Jorge Luis Porsani, 2007].

For the available frequencies (10 – 2500) MHz the penetration of the GPR signals is about (less than 1meter up to tens of meters). The most effective parameter on the depth of the GPR signals is the resistivity of the media. Even with low frequencies the signals may reach less than one meter if the medium was a low resistivity one [Sushil Sheena, 2004; Sami Eyuboglu, 2004], because only the electric component of the electromagnetic wave reacts with the medium of penetration. Hence, the electrical properties of the medium are the most important in determining the attenuation effect of the medium on the EM wave. (fig.4) [Sushil Sheena, 2004; Bernth Johansson, 2005; Kun Fa Leeabc, 2009].

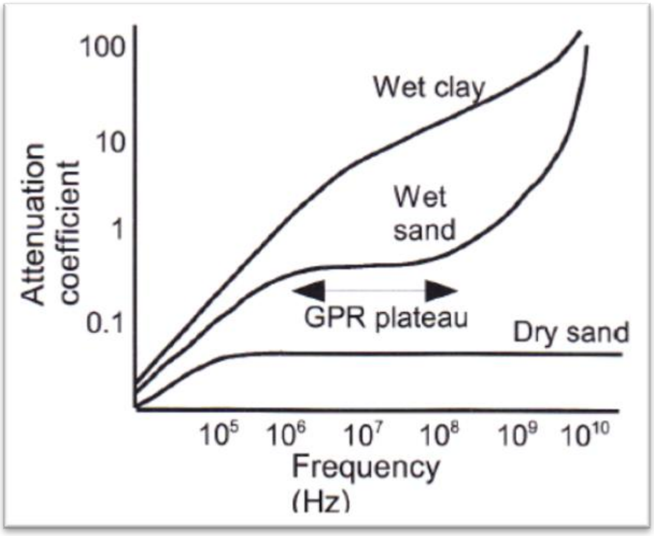

Fig.4: Illustrates the attenuation coefficient of the radar wave as a function to the frequency into the wet and dry media [Bernth Johansson, 2005; Kun Fa Leeabc, 2009].

The depth of penetration of the radar wave can be determined in different media by using the relation:

$$D = \frac{35}{\sigma} \text{ (meter).} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

D is a penetration depth (meter); σ is an electric conductivity of the mediums [Bernth Johansson, 2005]. See table 1.

Material	Typical Relative Permittivity	Electrical Conductivity, mS/m	Velocity, m/ns	Attenuation, dB/m
Air	1	0	0,30	0
Distilled Water	80	0,01	0,033	0,002
Fresh Water	80	0,5	0,033	0,1
Sea Water	80	3000	0,01	1000
Dry Sand	3 - 5	0,01	0,15	0,001
Saturated Sand	20 - 30	0,1 - 1,0	0,06	0,03 - 0,3
Limestone	4 - 8	0,5 - 2	0,112	0,4 - 1
Shales	5 - 15	1 - 100	0,09	1 - 100
Silts	5 - 30	1 - 100	0,07	1 - 100
Clays	5 - 40	2 - 1000	0,06	1 - 300
Granite	4 - 6	0,01 - 1	0,13	0,01 - 1
Dry Salt	5 - 6	0,01 - 1	0,13	0,01 - 1
Ice	3 - 4	0,01	0,16	0,01

Table 1: Illustrates electromagnetic wave speed, electrical conductivity, attenuation coefficient of the signal and the typical relative permittivity to the different media [Bernth Johansson, 2005; Kun Fa Leeabc,2009].

II. FIELD WORK

(Mira mala), a well-developed system consists of several antennas have the same frequency (400 MHz) connecting with each other in a complex manner for the purpose of conducting two-dimensional and three-dimensional measurements directly and not a single dimension, as is the case in ways currently used and available to us. In addition to the use of (GPS) with the system (Total station) to determine the work sites are very accurate. As using this system (the Mira mala) often in the detection of effects as well as cables and pipes. Where he conducted many of the measurements for the detection of buried pipes at the site, has been analyzing and processing the data using a specialized program in a data processing system. As the results were very clarity and precision that are lacking in current methods, in addition to the brevity of the work which could be up to more than 60% of the time.

Multi-channel imaging at the MALÅ Geosciences site in Sweden was recently made using the MALÅ MIRA16 channel GPR system. The separation of the antennas for this equipment are 8 cm. Shown in Figure 5,6 is a 2D time-slice image showing pipes buildings beneath an MALÅ street in Sweden . The 2D volume generated was transformed in order to better show the continuity of reflections across linear structures that have slightly different depths and overburden thickness. (Pulse imaging on the same site was completed and shows pipes less clearly since the phase of the pulse changes dramatically across the subsurface pipes and other linear structures). The data was collected by MALÅ Geoscience of Sweden. The system is an FMCW multi-channel system. The data are band passed to present typical pulse radar grams which have an optimum center frequency near 400 MHz. The system is an FMCW multi-channel system. The data are band passed to present typical pulse radar grams which have an optimum center frequency near 400 MHz . I have been using this technique for the detection of buildings pipes under the Mala Street in Sweden. Create the volume turned 2D in order to demonstrate the continuity of the best reflections across linear structures that have a slightly different depths and thickness of overburden.

Fig 5 : survey by MIRA MALÅ Geoscience in Sweden with GPS and Total station system

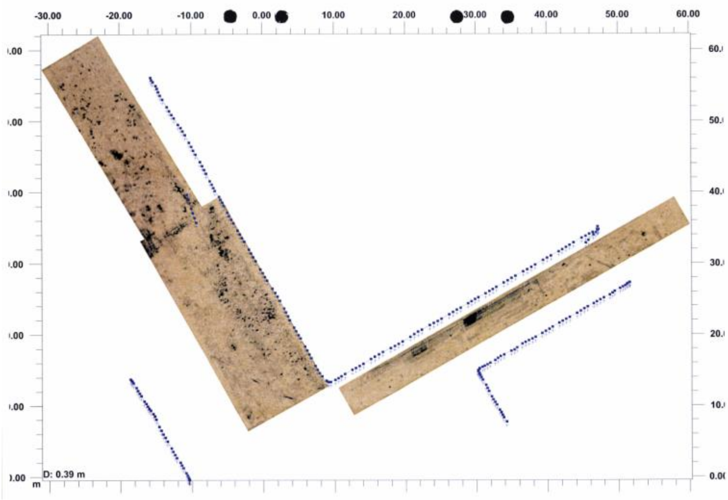

Fig 6 : survey MIRA MALÅ in depth 0.39 m

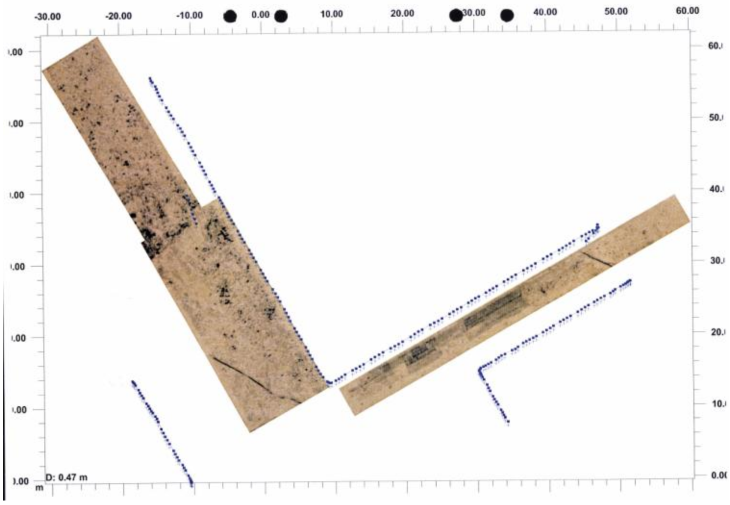

Fig 7 : survey MIRA MALÅ in depth 0.51 m

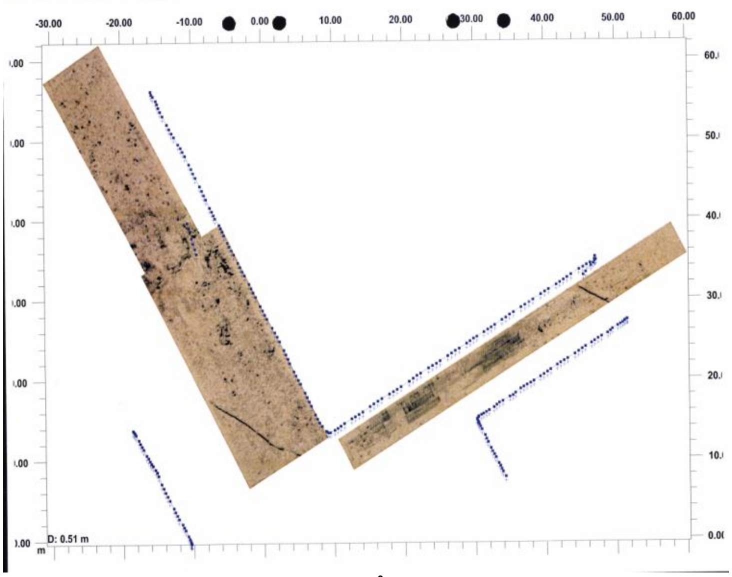

Fig 8: survey MIRA MALÅ in depth 0.51 m

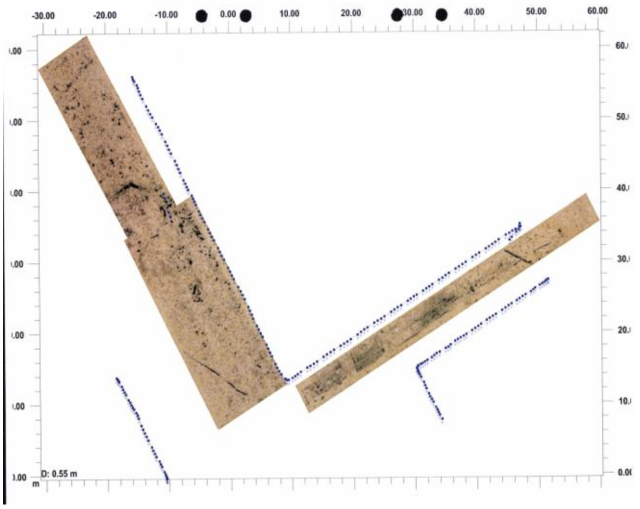

Fig 9: survey MIRA MALÅ in depth 0.55 m

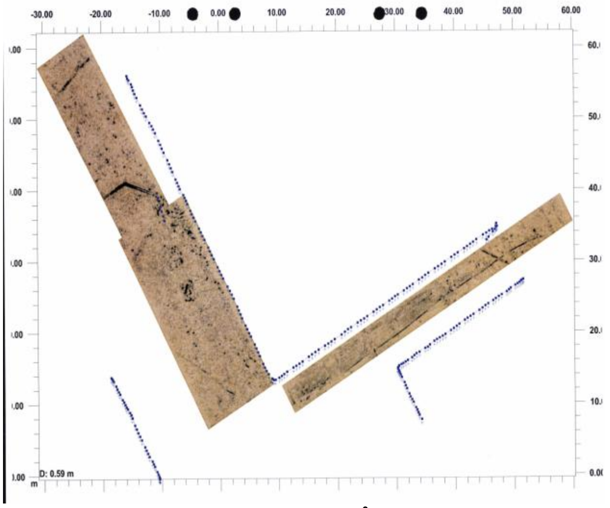

Fig 10 : survey MIRA MALÅ in depth 0.59 m

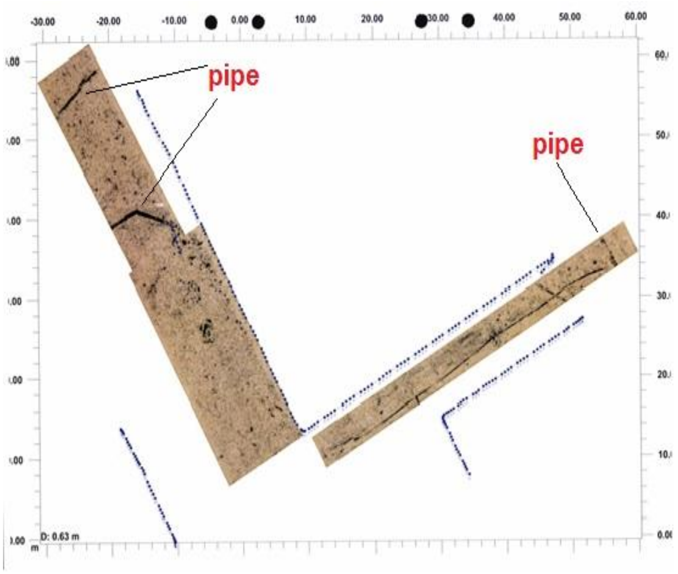

Fig 11: survey MIRA MALÅ in depth 0.63 m

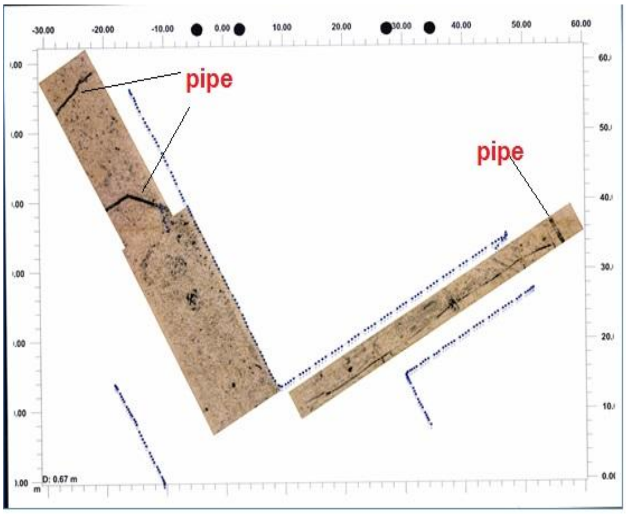

Fig 10 : survey MIRA MALÅ in depth 0.67 m

III. CONCLUSION

Subsurface imaging with multi-channel GPR provides the most efficient method for surveying sites that can accommodate large radar systems. The speed with which data can be collected, the density of sampling of the ground, along with the high quality and similarity of antenna channels bodes for increased usage of multi-channel systems in the future for all subsurface imaging disciplines.

REFERENCES

[1] Ground Penetrating Radar: Theory and Applications Editor Harry M. Jol

[2] Sushil Sheena Suvarna "Reconstruction of ground penetrating radar images using techniques based on optimization" a thesis submitted to the Graduate Faculty of North Carolina State University in partial fulfillment of the requirements for the Degree of Master of Science, 2004, p (1-4).

[3] Sabbar Abdullah Salih" Applications of Ground Penetrating Radar (GPR) in Detection of Groundwater Table" Department of Applied Geology, College of Science, University of Tikrit, Tikrit, Iraq, This research achieved in Division of Environmental and Resources Survey Center of Northeast Asian Studies, Tohoku University, Sendai, Japan, 2008, p (1-3).

[4] Hannu Luodes "Natural stone assessment with ground penetrating radar" Estonian Journal of Earth Sciences, 2008, 57, 3, 149-155.

[5] Bernth Johansson, Johan Friborg "Applied GPR technology, theory and practice" 2005.

[6] Annan. A. P. "Ground Penetrating Radar Principles, Procedures & Applications".

[7] Jorge Luis Porsani and William A. Sauck "Ground penetrating radar profiles over multiple steel tanks: Artifact removal through effective data processing" Geophysics, vol. 72, No. 6, November-December, 2007; p.77.

[8] Sami Eyuboglu, Hanan Mahdi, and Haydar Al-Shukri "Detection of water leaks using ground penetrating radar" Department of Applied Science University of Arkansas at Little Rock, USA, 2004.

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ISO 9001:2008 Certified
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[9] Kun FaLeeabc, Reason Hongb, Yu Min Kangc, Cheng Sung Wangd ,Kuo An Lina "Detecting the Weathering Structure of Shallow Geology via for Ground-Penetrating Radar"Int. J. Appl. Sci. Eng., 2009. 6, 3; 207.

[10] **Basson. 2000**, Ground Penetrating Radar (GPR), a Research Published in Internet.

[11] Barton, K., Stenvik, L., Birgisdottir, B., 2009, A Chieftain's Hall or a Grave; Ground Penetrating Radar.

[12] Francese, R.G., Finzi, E., Morelli, G., 2009. 3-D high-resolution multi-channel radar investigation of a Roman village in Northern Italy. Journal of Applied Geophysics, Volume 67, Issue 1, Pages 44-51.