New Method of Ground Penetrating Radar for Delineation and Mapping of Shallow Coal Seam

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Abstract: This article presents the practical empirical analysis and applied evaluation of the impulse radar method and shows that significant performance benefits can be achieved in ground penetrating radar applications. These benefits are successfully demonstrated in field trials of a newly-designed acquisition and processing GPR system. An original contribution has been made in establishing a method of the measurements of GPR for coal seam. This enables the maximum penetration depth of a GPR system to be characterized of shallow coal seam as basic analogue recording radar system with multi-configuration antenna. Similarly, the resolution is expressed as basic analogue recording radar system with antenna orientation variation which is also selective with frequency antenna. These expressions prove to be useful to design acquisition and processing in characterizing GPR performance and could improve data quality, and then could allow information other than reflector depth for a defined application. A design acquisition of impulse radar technique is undertaken, which demonstrates the empirics of an impulse radar technique using multi configuration antenna with fixed offset. It is concluded that a physically realizable newly acquisition method of GPR has far reaching benefits in the form of higher resolution images from raw data.

1 INTRODUCTION

Under coal outcrop in general there are clay layers. Coal layering that is not exposed at surface is usually embosomed by clay layer, above and under coal seam. In coal exploitation phase, information about coal thickness, its position, fracture plane and its water content is highly required. Such information is required for initial determinations of topping-off overburden, digging direction and coal rank. Information of coal seam as well as its overburden thicknesses can increase efficiency in digging process because the volume of overburden layer which must be dug can be estimated. Currently, intensive boring must be carried out to know the information and many boring points must be set up to estimate lateral position of coal and thickness of its overburden.

This boring step which must be carried out results in a high production cost. Information about fracture planes in coal outcrop can serve the purpose of initial determination of digging direction. At present in the exploitation stage of coal production, the blade at bulldozer or bucket at bucket wheel excavator appears to be dull quickly due to digging orientation which is perpendicular to fracture planes in coal seam. Besides the impact of way of the digging, inefficiency in equipment performance is generated since the need of fuel increases and results in higher production cost (Ibrahim *et al.*, 2004 and Ibrahim, E, 2005).

To obtain the information mentioned above, it is necessary to apply a method that must fullfill certain criteria due to physical properties of coal that is easy to fall into pieces and does not have pores (Van Krevelen, 1993). Such criteria are for example: not destructive since the nature of coal is fragile, high resolution which is required to obtain information of water content and fracture plane in coal, continuous and quick in operation which is needed for overall information in coal seam. Ground-penetrating radar (GPR) represents one of altenative and promising methods to overcome such problems. Moreover, the application of GPRfor coal exploration is so far not

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in standard form, especially in the acquisition mode and its data processing (Annan, 2001).

This article describes an attempt to optimally image layered coal seams by setting up a standard design of acquisition modes of GPR and its data processing.

2 METHODS

In order to get a reliable result to set a new procedure in designing acquisition and its data processing for shallow layered coal, 3 stages of investigation were established: measurement on coal samples at laboratory scale, 2D and 3D forward modeling and field measurement.

2.1 Measurement at Laboratory Scale

Measurements in laboratory were carried out on coal samples taken from coal outcrop at Tanjung Enim, South Sumatra, Indonesia to determine their dielectric constants at 1GHz frequency. This was done using reflection principle with 1GHz antenna frequency. The resulted data were then processed to determine dielectric constant values. To obtain reliable results, some processing steps were carried out: spiking deconvolution, dewow, declip, set-time zero, fk-filtering, frequency filtering and time to depth conversion. From the processed data, dielectric constant values were then determined. These values of dielectric constants would be used as input parameter for modelling of high frequency electromagnetic waves in 2D and 3D.

2.2 2D and 3D Forward Modelling

Using dielectric constants resulting from laboratory samples and geometry of 2D as well as 3D body, a forward modelling was carried out. It was implemented with free-availably GPRMax2D and GPRMAx3D (Giannopoulos, 2003 and Ibrahim, 2005). It is based on FDTD scheme after Yee (Yee,1966).

The result of 2 D modelling of coal body surrounded by clay is as follows (see fig. 1).

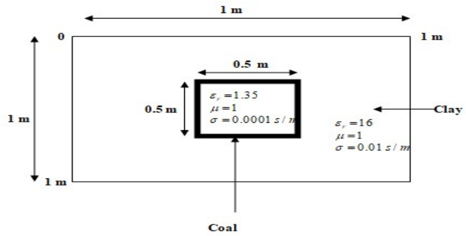

Figure 1: Two Dimension (2D) Modeling of coal and Clay (Ibrahim, 2005)

The position of coal could be determined, which is based on its signature (fig. 2).

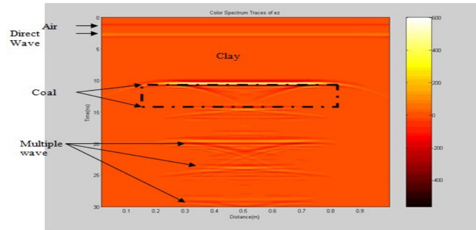

Figure 2: Radargram from the result of execution 2 D modelling of coal and clay (figure 1) (Ibrahim, 2005)

Figs. 4 and 5 show the results of 3D modelling as shown in fig. 3.

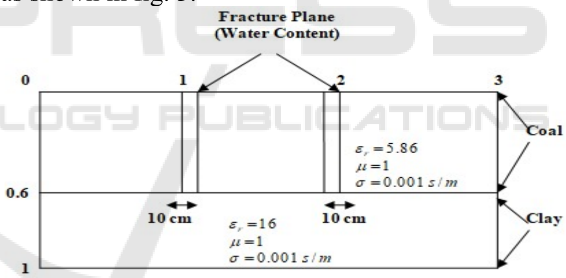

Figure 3: Coal modelling with fracture planes and clay layer under coal (Ibrahim, 2005)

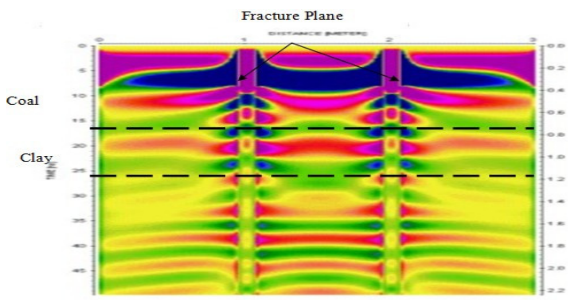

Figure 4. Radargram for x direction polarization (xx mode) from the result of execution coal modelling with fracture planes and clay layer under coal (figure 3) (Ibrahim, 2005)

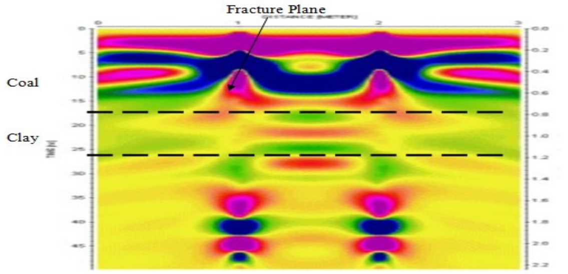

Figure 5: Radargram for y direction polarization (yy mode) from the result of execution coal modelling with fracture planes and clay layer under coal (figure 3) (Ibrahim, 2005)

It can be seen that fracture planes could be determined, in which xx configuration gave more clearer radargram compared with that of yy configuration.

2.3 Measurement of Limited Field Scale

Measurement on coal outcrop (fig. 6) was conducted at Bukit Asam mine shaft, Tanjung Enim, South Sumatra with various antenna orientation (fig. 7).

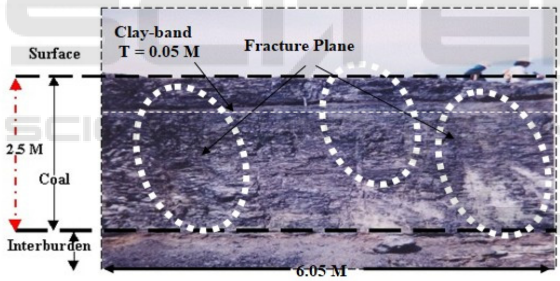

Figure 6: Measured coal outcrop (Ibrahim, 2005)

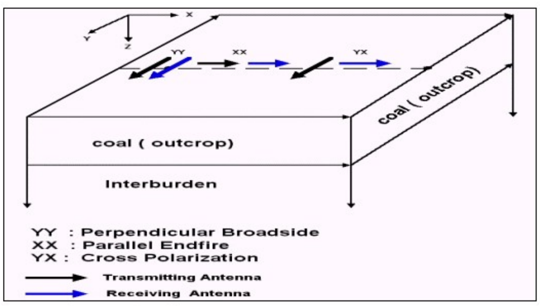

Figure 7: Acquisition mode of reflection profiling using bistatic antenna with centre frequency of 100 MHz direct on coal outcrop (Ibrahim, 2005)

GPR campaign with 100 MHz was assigned. Three different antenna orientations (yy, xx and yx configurations) were used. The height of the antenna for 3 different configurations were the same, in that the antenna stood direct on outcrop. (Ibrahim et.al, 2004)

The acquired data were then processed with processing steps similar to the steps applied on radargram from measurement in laboratory. In addition, influences of water content and fracture planes detected by each variation of antenna orientation (yy, xx and zx configurations) are also shown in the results.

For verification of the results of acquisition and processing steps that we propose here, we also applied them for the data taken from coal outcrop with same coal rank but different physical properties laterally.

3 RESULTS

A forward modelling of 2D or 3D body with dielectric constant for coal with various ranks as input data results radargram is shown in figs.2, 4 and 5. In general, 2D modelling provided information of clear coal position, which was based on signature in the form of waveform. To define the existence of fracture planes, 3D modelling should be applied. In some cases numerically, multiple effects always existed in data since the value contrast of dielectric constant between coal and clay was very large. Practically such an effect was also recognizable in raw data. Determination of dielectric constant of coal samples was carried out by using GPR antenna with 1 GHz frequency. Similar processing steps to data acquired from field measurement were applied to data from laboratory measurement.

Measurement with yy configuration could produce information of thickness of coal seam and various water content in coal seam. (fig. 8).

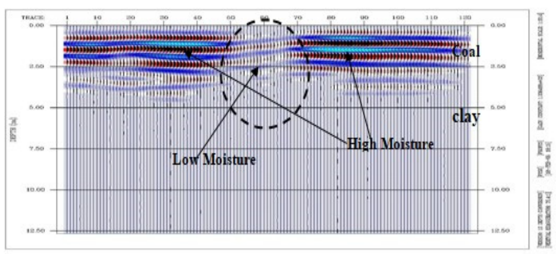

Figure 8: Profile of acquired GPR records after processing at coal outcrop in yy mode (Ibrahim, 2005)

Measurement with xx configuration provided information of the existence of fracture planes and water content variation in coal seam as well as its thickness.(fig. 9)

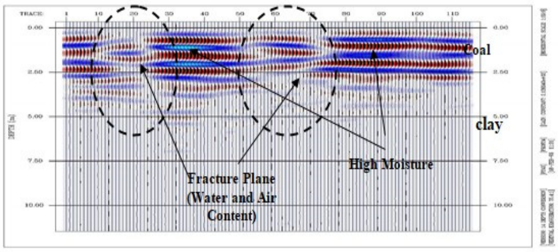

Figure 9: Profile of acquired GPR records after processing at coal outcrop in xx mode Ibrahim, 2005)

Information of fracture planes and water content could be extracted from the measurement with yx antenna configuration, but that of the coal seam thickness could not be clearly determined (fig. 10).

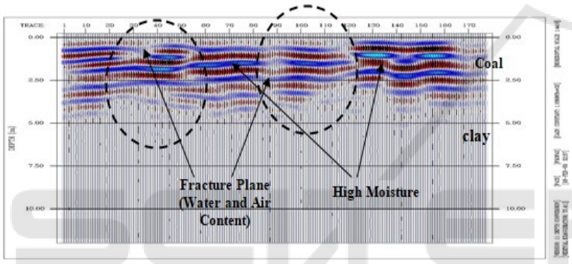

Figure 10: Profile of acquired GPR records after processing at coal outcrop in yx mode (Ibrahim, 2005)

For implementation to real condition of field, yy configuration showed the results of accurate measurement of various coal positions and geometry on various field conditions and locations with reasonable results. Information of the thickness and water content extracted from the measurement using multi-configuration as applied in this investigation could be validated with the result from direct measurement (Ibrahim *et al*., 2004). In addition, some techniques in the interpretation phase are a valuable tool to aid in the interpretation. Windowing attribute could be applied to determine variation in water content laterally using various antenna configurations (yy, xx and yx configurations) as well as to distinguish water content from coal with 2 different ranks laterally on the basis of amplitude values. High value of amplitude intensity is associated with high water content and vise versa (Ibrahim, 2005).

The thing there proved with measurement at different positions and coal dimension at location was different from accountable result. Information of thickness and water content from coal outcrop by using measurement of this way its (the result could be validated with the result of direct measurement analysis) (result of measurement of outcrop geometry and result of laboratory analysis from the sample taken at the outcrop) (Ibrahim, 2005).

Window attribute (interval of Amplitude) was applicable to determine lateral variation of coal water content good to antenna; configuraton variation (way of yy, way of xx or way of yx) also to differentiate water content of two coal ranks which are different laterally based on values of amplitude. High amplitude intensity value is associated with high water content while low amplitude intensity value is associated with low water content (Ibrahim, 2005).

4 CONCLUSIONS

It is concluded that the results from 2D and 3D forward modelling are generally in concordance with the results of field measurement. Such a modelling can therefore be made as an aid tool to design field measurement in order to achieve an optimal result. This optimalisation is realized in the form of determination of position and orientation of direction of the antenna and steps of which need to be performed regarding data processing. It includes determination of signature coal in radargram, elimination of direct wave and multiple reflection and determination of the use of antenna with appropriate selected frequency and procedure to analyse the result of data processing. From coal physical aspect, it needs to be recognized whether the direction of fracture plane is approximately parallel or perpendicular to strike. The information can be extracted with the use of antenna

The results of field measurement data indicate that the information of fractureplane can be extracted using yx-configuration. Such information can not be obtained using 2D and 3D forward modelling that excludes changes of EM wave polarisation after being reflected by conductive medium in its algorithm. Then if the fracture plane orientation is unknown, measurement of GPR at coal outcrop must use three configurations, i.e. yy-, xx and yx-configurations. In general, based on the results from measurement with various antenna orientations as well as their data processing and analysis, it is concluded that GPR is a reliable tool in the stage of coal exploitation.

Specifically this research gives a scientific contribution from the use of *GPR* in coal exploitation phase, which introduces a new procedure in data acquisition and processing to obtain structural information, i.e. layering and fractureplane and information of lithology (water content and coal rank). A GPR survey for coal exploitation should be designed using three different antenna orientations: xx, yy and yx in the case that fracture plane orientation is unknown. In the case that fracture plane orientation is recognized, survey line using xx antenna orientation is sufficient to be carried out. The orientation of survey line is arranged to be perpendicular to the fracture plane orientation.

This investigation is very important in coal exploitation since the application of GPR in coal mining has been very limited so far. This is due to the low dielectric contrast between the coal seam and surrounding host rocks.

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