Comparison of Radio Imaging Method (RIM) Electromagnetic Wave Tomography with In-Mine Geological Mapping in the Liddell, Bulli and Wongawilli Coal Seams

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Summary

The radio imaging method (RIM) of coal seam mapping relies on the natural waveguide effect exhibited by coal seams to electromagnetic wave propagation. Whenever coal seams are disrupted by a natural geological discontinuity, the waveguide disruption causes a measurable change in the wave attenuation. Attenuation measurements can be analysed directly or, if sufficient data are available by tomography, to indicate the location of the anomaly and its likely severity. Such information is of vital importance in modern underground coal mining.

In February, 1987 a series of trial surveys were conducted in three Australian mines by a survey team from Stolar Inc. of the USA. The results showed that the natural wave attenuation is 46dB/100 m in the Liddell Seam, 36 dB/100 m in the Wongawilli Seam and 13 dB/100 m in the Bulli Seam. In the Bulli Seam propagation over distances in excess of 600 m is possible.

The surveys were conducted over test sites where dykes and other geological features exist. Wave propagation was clearly disrupted by the dykes and it was possible to image their location by tomographic means. An application for RIM in Australian mines has been clearly indicated.

Electromagnetic wave propagation

Experimental work and numerous field surveys in the United States (Hill, 1984; Shope, 1987) show that it is possible to transmit electromagnetic waves at a frequency of about 500 kHz for several hundred metres through coal seams before they are absorbed by the earth. Beyond a hundred metres or so, the propagation at a single frequency can be described by the equation

$$H(r) = \frac{C}{\sqrt{r}} e^{-\alpha r} \qquad (1)$$

where H is the magnetic field intensity,
C is a constant dependent on the transmitter, receiver and the properties of the coal and surrounding strata,
α is the natural wave attenuation measured in nepers per metre,
and r is distance measured in metres.

It becomes a relatively straightforward operation to rearrange this expression in terms of the voltage induced across the terminals of the receiving antenna. A value of the constant term in the expression is obtained by a calibration survey down a mine roadway where no geological disturbances exist, and a value of the natural wave attenuation can be obtained.

Factors which affect the propagation include the seam height and the conductivities and dielectric constants of the coal and surrounding strata. Water and mineral content, are of course, the main factors affecting conductivity. Calibration surveys are needed in all surveys to establish local attenuation rates.

Survey methods

Much modern underground coal mining is conducted by what is known as the retreat longwall method. Parallel mine roadways some 1 km long and 250 m apart are first pre-driven. A longwall mining machine then ranges backwards and forwards between the roadways cutting coal. Movable hydraulic supports hold the roof in the vicinity of the machine but once they move forward the roof is allowed to collapse behind.

The longwall method is very efficient. However, equipment costs are high (in the order of $20 million) and the method is not able to negotiate geological structures and dykes without severe disruption to production.

Given the economics of longwalling and the requirement for pre-driven roadways, RIM surveys between longwall roadways can do much to protect mine operators against unexpected disruptions to production.

Two survey methods are used. A direct ray scan is a survey directly across the panel with transmitter and receiver moving in parallel down the two roadways. A profile of attenuation rates indicates which section of the unmined panel might contain geological anomalies.

A diagonal ray scan involves making numerous measurements at differing points down the receiving roadway from each of the transmitting points. The attenuation data thus obtained can be analysed by tomography to allow the position and shape of the anomalous body to be determined. The diagonal ray scan is used for detailed coal seam mapping.

Australian trials

The Australian trial RIM surveys were conducted over a two week period at Liddell Colliery (Coal and Allied Operations

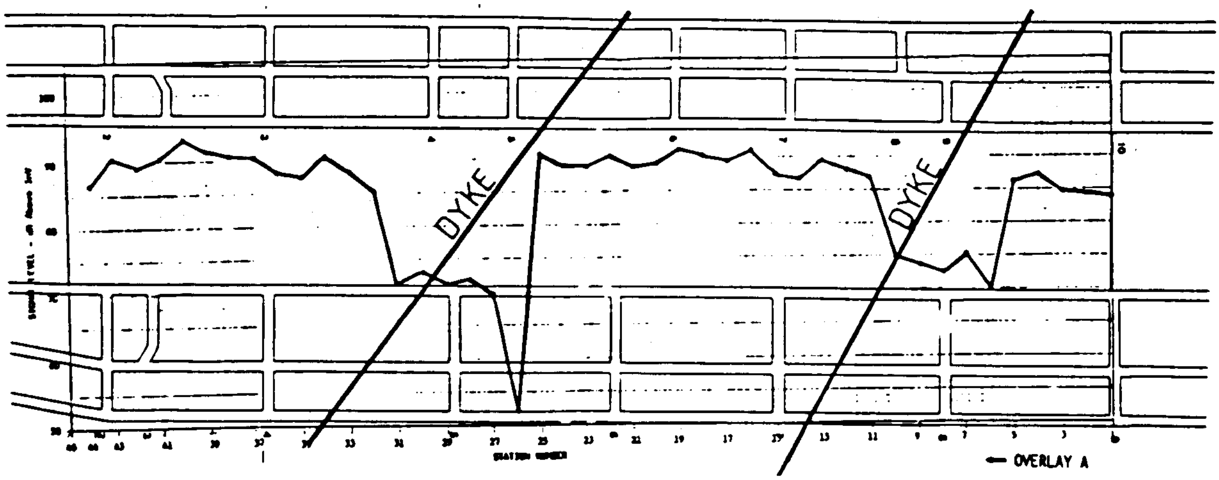

FIGURE 1
Kemira Colliery, direct ray scan.

Pty Ltd), West Cliff Colliery (Kembla Coal and Coke Pty Ltd) and Kemira Colliery (Broken Hill Proprietary Ltd). At all mines, calibration surveys and direct and diagonal ray scans were conducted. Natural attenuation rates ranged from 46 dB/100 m at Liddell, to 36 dB/100 m at Kemira and 13 dB/100 m at West Cliff — the maximum range that signals could have been detected using this equipment was 615 m, at West Cliff.

Examples of results are shown in Figs 1 and 2. These are from the Kemira Colliery survey where the targets were dykes crossing a blocked out longwall panel. The profile of results from the direct ray scan, Fig. 1, shows a marked increase in signal attenuation as soon as the dykes are intersected. Their influence on the wave propagation cannot be doubted.

The tomographic results from the diagonal ray scan, Fig. 2, show how it is possible to reconstruct the approximate shape of the dykes. As in all tomography, resolution is a function of the angular coverage, but it is clear that the linear nature of the dykes, especially the one at a steeper angle to the roadways can be determined.

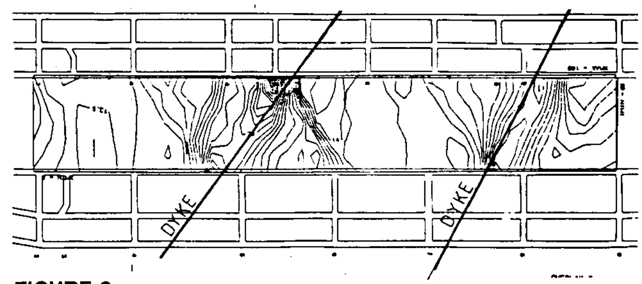

FIGURE 2
Kemira Colliery, diagonal ray scan.

An application to Australian mines

While the results from Kemira Colliery are most promising, not all anomalous regions indicated by the surveys, particularly those from Liddell Colliery, were found to contain geological anomalies of mining significance. It is clear then that the wave propagation is sensitive to a number of factors. The presence of water is one obvious consideration and not all water bearing beds and structures need represent a mining hazard.

RIM surveys, however, still have a place in underground mine exploration. It is seen as a complementary tool to surface geophysical surveying, in-seam seismic surveying, horizontal in-seam drilling and geological mapping. The key to its successful application lies in the careful assessment of all the geological and geophysical information available to the mine planning engineer.

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