Producing gas fields lie to the north and south of the area where this anomaly is located. So this anomaly may be indicative of the presence of a gas reservoir. However, the anomalous zone is small compared to the 3 km depth to producing gas in the area, and it might be expected that any anomaly due to such a deep source would be more widely dispersed. Perhaps the localized nature of the anomaly was caused by the localization of the conduit, which conducted hydrocarbons to surface, or by a localization of the supply of surface derived components needed to fix the minerals, causing this high resistivity and high polarizeability. Until core samples can be obtained these questions cannot be answered.

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LABORATORY MODELLING OF THE RESPONSE OF FIXED LOOP EM SYSTEMS OVER MULTIPLE TARGETS IN CONDUCTIVE ENVIRONMENTS USING THE PARALLEL LINE MODE OF OPERATION

K. Duckworth and C. Cummins

The large magnetic moments of fixed loop transmitters and the low geometric attenuation of their transmitted signal provide for potential depths of exploration in excess of 500 metres. This has led in the past decade to the development of several new devices of this type. However, this performance can only be achieved if the target conductor lies midway along the available traverse length which seldom exceeds 2000 metres. Any deviation from this geometry means that the anomaly due to a deep target is truncated by the ends of the available traverse. The requirement that the target be located at mid traverse can never be met in an exploration survey unless the location of the target is known ahead of the placing of the transmitter.

A remedy for this problem lies in the use of the parallel-line mode of operation which involves laying the transmitter loop across the strike trend of the conductor and running the traverse lines parallel to the transmitter as shown in Fig. 1. This procedure allows traverse lines to be of any desired length (limited only by the length of the transmitter) thereby eliminating the problem of the truncation of the anomalies and removing any need to know the location of the target prior to the laying of the transmitter loop.

A scale model study of this mode of operation is in progress in the Department of Geology and Geophysics of the

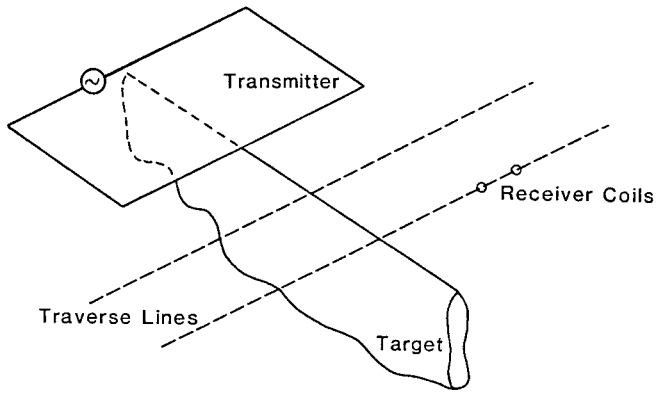

FIGURE 1
Parallel-line Turam survey configuration.

University of Calgary. A modelling tank is being employed with operation frequencies up to 400 kHz in order to permit simulations of conductive environments. The initial phase of the study is concentrating on free space modelling. Later work will use a conductive environment.

The conclusions of this study to date can be summarized as follows.

1. Current vortices induced into separate closely spaced parallel conductors show mutual interactions which result not only in the expected mutual changes in amplitude and phase as compared with the case when only one conductor is present but also mutual displacement of the locations of the current vortices within the conductors. Currents of opposite phase were found to repel each other with corresponding attraction between currents of identical phase. These effects must operate in all cases of electromagnetic induction but are only easily seen when induced vortices are of equal magnitude which is common in the parallel-line mode of operation.

An example of this effect is shown in Figs 2 and 3 which show the parallel-line free space profiles over a folded conductor. In Fig. 3 the conductor was electrically continuous across the fold while in Fig. 2 two separate electrically isolated sheets were placed in the identical fold geometry. The amplitude profile (A) shows a pronounced arch effect because of the limited dimensions of the transmitter, the edges of which coincided with the ends of the profile as shown. The FSR profile (C) was not reduced to remove the primary field gradient (this being the mild slope across the FSR profile). This illustrates that this reduction is not necessary in the parallel-line procedure. The secondary field profile (B) was obtained by vector subtraction of the primary field from the measured amplitude and phase of the resultant field. The separate current vortices in the two separate sheets are indicated by the anomaly in Fig. 2. The positions of the adjacent edges of the vortices were found to be displaced away from the edge of each sheet when compared with the positions shown by a single sheet alone. From the point of view of interpretation the folded continuous conductor behaves very much as though it were a horizontal sheet located at the depth of the bottom edges of the folded sheet. The discontinuous fold presents a picture of two conductors

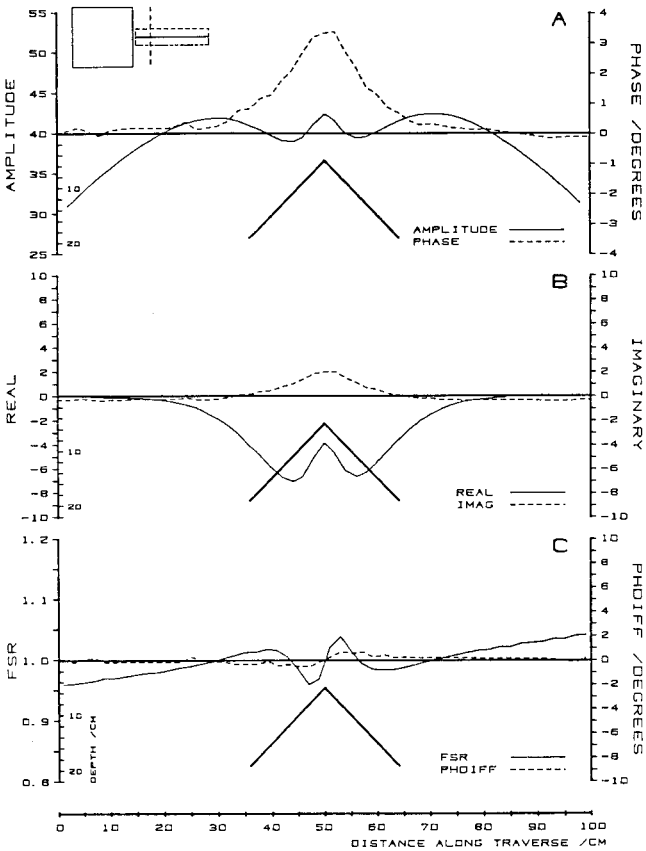

FIGURE 2
Parallel-line traverse, 30 cm from the transmitter loop over two oppositely dipping targets of type A at a separation of 0 cm, strike 90°, depth 5 cm, 400kHz.

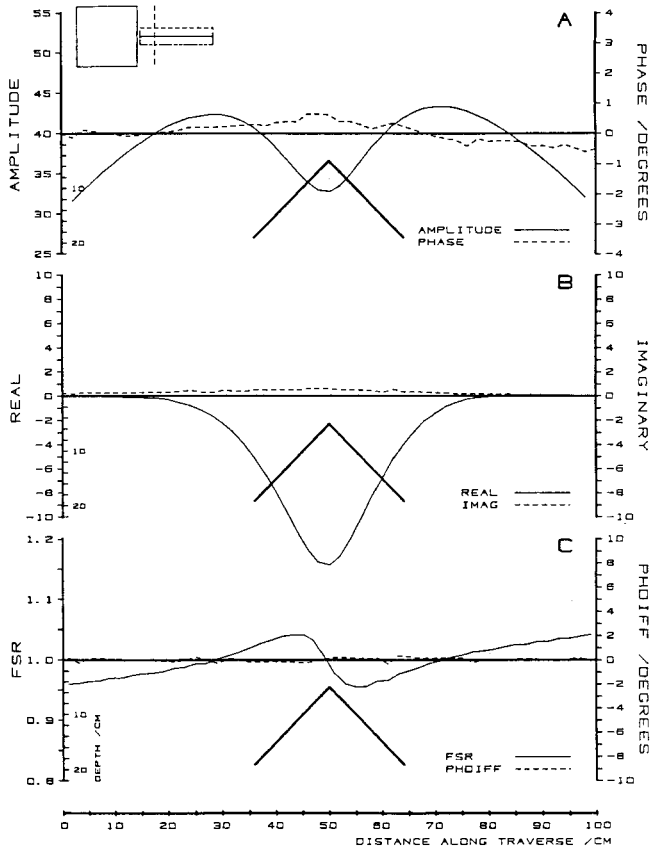

FIGURE 3
Parallel-line traverse, 30 cm from the transmitter loop, oppositely dipping targets of type A that are in perfect electrical contact, strike 90°, depth 5 cm, 400kHz.

which are resolved although they are not separated which might be described as infinite resolution.

2. Direct comparison of the parallel-line and conventional modes of operation over the same conductive models shows that closely spaced parallel conductors of appreciable width are more easily resolved by the use of the parallel line procedure than by the conventional procedure. This can be seen by comparing Figs 4 and 5 which show profiles obtained over identical graphite slabs which were located at a depth equal to their width and a separation equal to 60% of their width. The superior resolution provided by the parallel-line procedure is most evident in the FSR profiles.

It appears that the current repulsion effect causes the currents on the inner edges of the two conductors to move apart, thereby allowing better resolution than might be expected. This effect must also operate when the conventional procedure is used but in that case the currents in the conductor nearest to the transmitter are very much stronger than those in the more distant conductor as can be appreciated from the profiles of real component of the secondary field in Fig. 5. In addition, the currents at the edge of the conductor facing the transmitter are dominant. Displacement of the current is not obvious in circumstances where adjacent currents have very unequal magnitudes.

3. Although thin vertical conductors are poorly coupled with the parallel-line transmitter any deviations of dip or strike from the vertical and perpendicular respectively, result in very strong coupling which provides secondary field and FSR anomaly magnitudes comparable to those provided by the conventional procedure. In nature it appears improbable that complete decoupling could ever be experienced. In the parallel-line procedure the transmitter can be placed directly over the target and not increasingly offset from the deeper targets, as in the conventional procedure. Consequently the measured anomalies can be significantly stronger in the parallel-line mode of operation.

4. The differential type of receiver used by the Turam device not only rejects coherent noise and emphasizes subtle effects in the anomaly but it can be focused on a particular depth of exploration interest by choice of separation. This can be as large as desired because of the weak primary field gradients along parallel-line traverses.

5. Field tests at the Night Hawk test range in the Province of Ontario, Canada have shown the parallel-line procedure to be equally applicable with either frequency or time domain EM systems. It provides immediate information on the width and dip of a conductor from a single transmitter as opposed to the need to move the transmitter to opposite sides of a wide

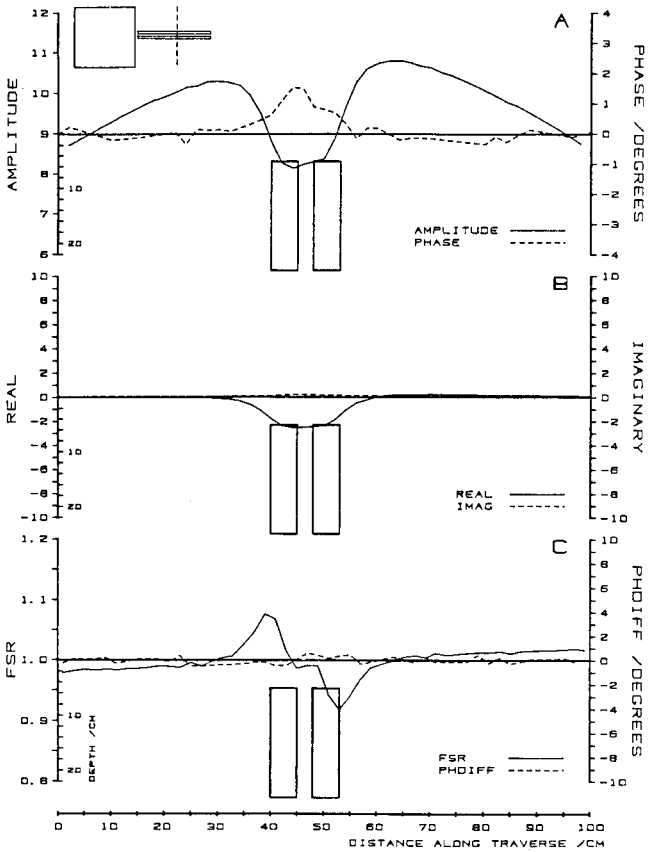

FIGURE 4
Parallel-line traverse, 70 cm from the transmitter, over two vertical targets of type C at a separation of 3 cm, strike 90°, depth 5 cm, 400kHz.

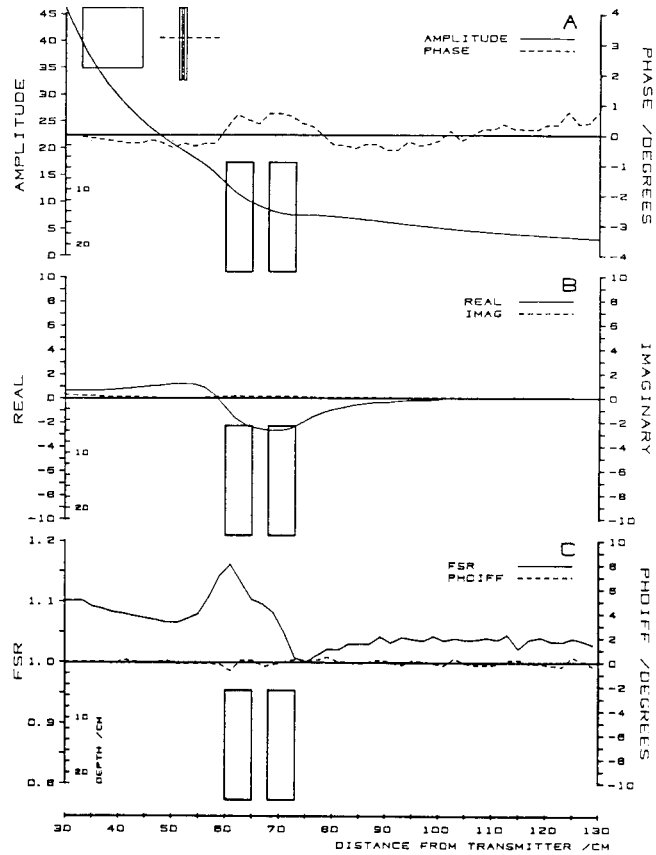

FIGURE 5
Conventional traverse over two vertical targets of type C at a separation of 3 cm, strike 0°, depth 5 cm, 400kHz.

conductor in the conventional procedure in order to get an indication of target width. Dip information is inevitably lost in the conventional use of fixed transmitters. The modelling showed the conventional response of thick vertical conductors to be almost indistinguishable from the response of thin dipping conductors. This lack of dip information in data obtained by means of conventional profiles is a problem for either time or frequency domain surveys. The unlimited line length is equally valuable to either type of survey.

6. In uniformly conductive overburden or host environments the parallel-line procedure will detect only lateral conductivity contrasts and therefore will emphasise the response of target conductors while responding poorly to gradational changes in host or overburden conductivity. For long transmitters which provide almost zero primary field gradient along parallel-line traverses, the response will also be free of extraneous gradients due to the conductive environment. This contrasts with conventional profiles which show strong gradients due to the conductive environment in addition to the normal free space gradient of the primary field.

INTERPRETATION OF DOWN-HOLE TRANSIENT EM DATA USING CURRENT FILAMENTS

A. C. Duncan

Introduction

Large loop down-hole TEM surveys have recently become popular in Australia. They provide a means of locating receivers closer to targets and beneath signal-attenuating overburdens. Estimates of conductor position and orientation can be made from analysis of the shape and polarity of the responses, but these estimates have no mathematical justification and are largely subjective.

Barnett (1984) introduced the idea of using a least squares inversion to fit the magnetic field of a current filament to the measured response of a plate. In this way an effective sub-surface current distribution can be found for each channel. Complex models have now been developed for TEM interpretation using filaments of variable geometries.