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SHORT NOTE

The location of TEM transmitter loops underground and in rugged terrain

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ABSTRACT

The size, shape and location of transmitter loops is of fundamental importance in the design of both surface and drillhole TEM surveys. The shape and location of the loop, with respect to a target conductor, strongly affects the level of electro-magnetic coupling between the loop and the conductor. The effect of sloping terrain on the coupling field of a surface loop is shown for several terrains. In the case of transmitter loops located underground, both maximum and minimum coupling can be obtained at several positions and attitudes of conductors located around the loop. Transmitter loops located on sloping terrain or in inclined mine workings can often provide greater control over the level of energisation of the target conductor than loops located on a flat terrain. In these circumstances it is possible to determine conductor location and attitude with greater accuracy. Computing the electro-magnetic coupling fields of transmitter loops, for various attitudes of the target conductor, is mandatory when designing TEM surveys and interpreting survey data.

Keywords: drillhole, em coupling, loops, mine workings, rugged terrain, TEM, underground

INTRODUCTION

Drillhole TEM surveys which use a single axial-component receiver probe, obtain directional and attitude information about the target conductor by using several transmitter loops located so that they are either maximally or minimally coupled to the conductor. The data are acquired by surveying the drillhole several times, each time with the transmitter loop in a different position. Modern drillhole TEM surveys using a three-component receiver probe can obtain directional and attitude information about the target conductor from a single survey of the drillhole. These surveys often use a single transmitter loop which is positioned to maximise electro-magnetic coupling to the target conductor. However several loop positions are sometimes used to ensure that the conductor is energised regardless of its orientation.

The size and shape of the transmitter loop determines the shape and intensity of the primary magnetic field whereas loop current affects only the field intensity. Macnae (1980) illustrated the shape, direction and intensity of the field for a variety of rectangular loops. The primary magnetic field flux coupling to a dipping conductor depends on the amplitude of the component of the field normal to the conductor axis. Dickson and Staples (1987) demonstrated that contours of the flux intensity of a loop located on a horizontal plane, computed for a variety of conductor dips, are an effective and essential tool in designing TEM surveys. Richards (1987) described their use in designing drillhole TEM surveys at Broken Hill, NSW, to minimise the number of loops needed, and thus reduce survey costs, and to predict the anomaly with computer modelling.

When the transmitter loop is located on a sloping plane, such as the side of a hill, or inclined mine workings, it is necessary to consider the apparent dip between the sloping plane of the loop and the axis of the conductor. The primary magnetic field diagrams described by Dickson and Staples (1987) for example, can be rotated in the plane of the diagram to position the rectangular loop on the sloping plane. This shows the flux-coupling for a dipping conductor buried below the sloping terrain. Similar diagrams showing the flux linking the whole range of dipping and plunging conductors could be computed to determine the optimum coupling position for a transmitter loop located on an undulating plane.

RUGGED TERRAIN

The shape of the terrain can effect the shape and size of the transmitter loop so all these parameters need to be considered when positioning surface loops. Some surprising and useful arrangements of loop positions can evolve for various conductor orientations when positioning loops in rugged terrains and in inclined mine workings. Dickson and Staples (1987) concluded that maximum coupling with a steeply dipping conductor occurs beneath the leading edge of a rectangular loop when the loop is located on the hanging wall of the conductor. Maximum coupling with a horizontal conductor also occurs on the axis of the loop. Figure 1 shows a variety of possible loop positions for obtaining maximum coupling to conductors dipping 0, 30, 60 and 90 degrees from the horizontal. The slope of the terrain is 30 degrees. The diagrams are scaled from those presented by Dickson and Staples (1987) for a rectangular loop and serve to show the various possibilities that the geophysicist could consider when optimising loop positions to maximally couple to a dipping conductor.

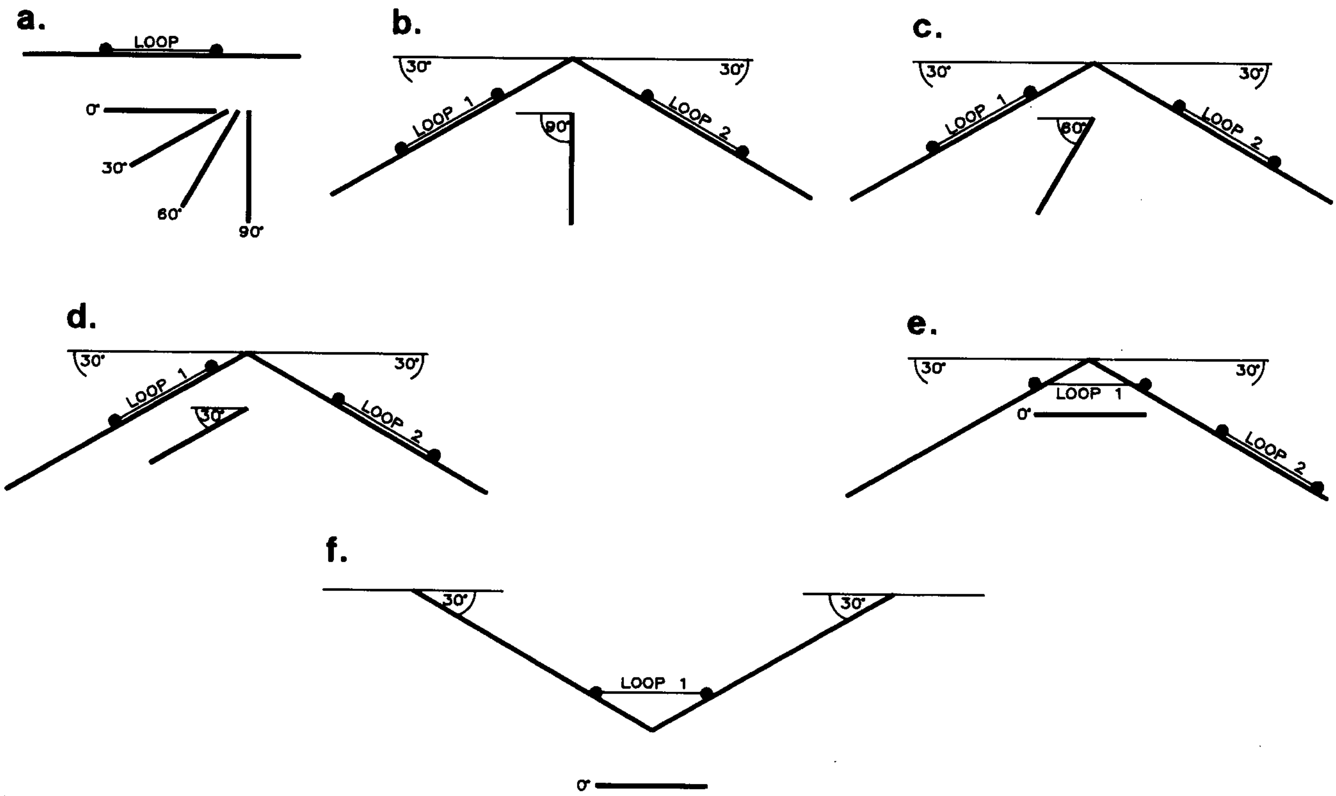

Fig. 1. Fig. 1a. shows the maximally coupled positions for conductors dipping 0, 30, 60 and 90 degrees for a horizontal, rectangular, surface transmitter loop. Figs 1b. to 1e. are obtained by rotating Fig 1a. onto the sloping terrain. Loop 1 moves up-slope and loop 2 moves down-slope with decreasing conductor dip. The loop that couples to a horizontal conductor buried below a valley is shown in Fig. 1f. In cases b to f the terrain slopes at 30 degrees. The figures are scaled from the flux diagrams illustrated by Dickson and Staples (1987) for a 300 m x 600 m loop.

Figure 1a shows the various approximate positions for conductors that are well-coupled to a rectangular loop located on a horizontal terrain. Figures 1b to 1f show the results of rotating Figure 1a onto sloping terrain and the well-coupled loop positions for four dipping conductors located below the terrain. The possibility of two loops located on opposite sides of the hill coupling to a dipping conductor is obvious. Note that loop 1 moves up-slope and loop 2 moves down-slope with decreasing conductor dip. The magnetic flux coupling from loop 2 is of lower intensity and opposite polarity to that from loop 1 because loop 2 is located on the footwall side of the conductor. For the case of a horizontal conductor located below the apex of a hill or a valley, the maximally coupled loop would straddle the hill and the valley as illustrated by loop 1 in Figures 1e and 1f, respectively. Another possible loop position for energising a horizontal conductor is shown by loop 2 in Figure 1e.

The actual positions for the loops on the sloping terrain depend on the slope of the terrain and on the dip, depth and position of the conductor. The optimum positions for loops minimally coupled to conductors buried below rugged terrain can also be determined from Figure 1, with consideration to the conclusions of Dickson and Staples (1987) regarding maximum coupling.

The use of several loop positions, either maximally or minimally coupled to the conductor, clearly provides the geophysicist with more information about the attitude and location of the anomalous conductor than is otherwise obtainable from transmitter loops located on a plane that allows limited coupling to the conductor. This could provide a more restricted target for exploratory drilling which can lead to real economic and strategic benefits for an exploration programme.

UNDERGROUND

Transmitter loops can be located underground along a series of mine workings. Additional conductor locations for maximum and minimum coupling are possible in the whole-space around the loop, compared to surface loops where the conductor is usually located below the loop.

A conductor which is oriented parallel to the plane of a rectangular loop has at least four locations where it is well-coupled to the loop. In Figure 2, conductors a and b are located on the axis of the loop, conductors c and d are in the plane of the loop. At least four positions of maximum coupling are also possible for a conductor oriented normal to the loop (conductors e, f, g and h in Figure 2). The electro-magnetic coupling between buried inclined transmitter loops and a dipping conductor can be obtained by rotating Figure 2 in the plane of the diagram. Optimum locations for conductors having other dips can be determined in a similar way, with consideration for symmetry of the field about the loop.

Doe et. al. (1990) described the use of an underground transmitter loop to survey underground drillholes in the CSA mine at Cobar, NSW. The horizontal loop was located 830 metres underground to provide improved coupling to the

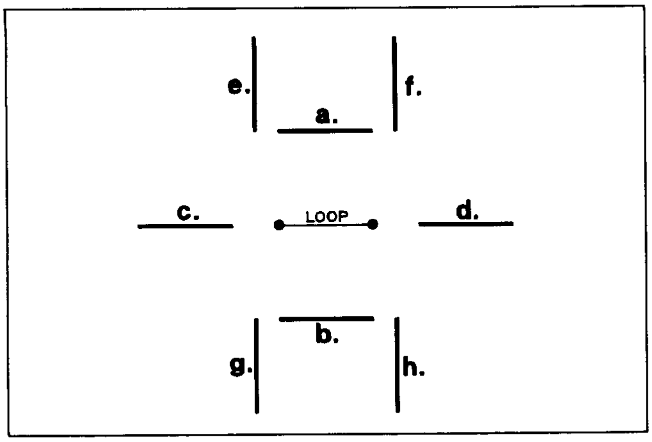

Fig. 2. Eight possible positions for conductors maximally coupled to a rectangular, underground transmitter loop are shown for conductors oriented parallel (a, b, c and d) and normal (e, f, g and h) to the plane of a loop. Diagrams like this can be used to determine coupling positions for dipping conductors located anywhere around an underground inclined loop.

deeply buried, steeply dipping, conductive, copper-zinc mineralisation that would otherwise be weakly coupled to a surface loop. The approximately triangular shape of the loop was a consequence of the limited access available in the mine shafts. The survey was effective in detecting anomalies from the deeply buried mineralisation but they concluded that the loop was not favourably oriented for energising some of the mineralised bodies. They mentioned the possibilities and advantages of using an underground vertical loop, located in vertical rises, horizontal shafts and interconnecting drillholes, to energise the steeply dipping conductors.

The restrictions imposed by mine access determines the location, shape and orientation of the transmitter loop. It is important then to calculate the coupling field for the resultant polygonal loop to assist with survey design and analysis of the survey data.

CONCLUSIONS

The electro-magnetic flux that couples surface transmitter loops with buried conductors can be computed for a range of conductor dips and used to predict the level of primary energisation of a buried conductor. The method described by Dickson and Staples (1987) for predicting conductor coupling from the computed field can be applied to polygonal shaped loops located on sloping terrain and loops located underground. Computing the electro-magnetic coupling fields of polygonal shaped transmitter loops for various attitudes of the target conductor is essential for optimally locating TEM loops and interpreting survey data. The judicious positioning of loops on a rugged terrain or along inclined mine workings can provide the geophysicist with more accurate information about the location and attitude of a buried conductor.

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