Propagation parameters for medium frequency signals in a transmission line at different positions within a mine entry

Jingcheng Li*, Nicholas W. Damiano, Miguel A. Reyes

The National Institute for Occupational Safety and Health

626 Cochrans Mill Road

Pittsburgh, PA 15236, USA

JLi16@cdc.gov, NDamiano@cdc.gov, MAReyes@cdc.gov

***Abstract*—A medium frequency (MF) communication system used in underground coal mines generally couples its electromagnetic signals to existing conductors in a mine entry (tunnel), and exchanges signals with transceivers near the conductors. The conductors act as a transmission line (TL). The propagation characteristics of the TL, which play a major role in determining the performance of an MF communication system, can be affected by a mine environment. This paper compares the measured propagation parameters of a TL in three different positions within a mine entry. This comparison shows that the differences between the electrical properties of local coal and rock close to the TL can influence the propagation characteristics of the TL when in a different position.**

Keywords—propagation characteristics; transmission line

I. INTRODUCTION

In the 1970s, researchers found that a conductor within a coal mine entry (tunnel) permitted a medium frequency (300 kHz – 3 MHz) (MF) signal to parasitically propagate for distances in the kilometer range [1]. Since then, research has focused on characterizing this phenomenon through measurements and simulations, and developing an MF communication system that can use an existing metal infrastructure in mines.

Several types of conductors, such as AC power cables, metal lifeline cables, or trolley wires can be configured as RF transmission line (TL) to carry signals down an entry. In this TL configuration, the conductor serves as the forward signal path and the surrounding coal and rock serve as the return path. MF propagation parameters have been found to be position-dependent for a TL conductor within an entry [2]. However, the influence of the TL return path on the TL propagation characteristics is still not entirely known because of the complexity in accurately measuring the electrical properties of coal and rock over a long entry. Historically, MF studies and simulations have made assumptions regarding the frequency independence and uniform distribution of the electrical properties of coal and rock [2]. In an attempt to understand the electrical properties of in-situ coal and rock, researchers at the National Institute for Occupational Safety and Health (NIOSH) have conducted a series of experiments and collected hundreds of impedance measurements to characterize the electrical properties of in-situ coal and rock at different locations within coal mine entries. The measurements showed that the impedances of coal and rock vary not only with frequency but also mine entry location. NIOSH researchers observed impedance differences reaching a factor of 6 between different points of the same entry [2]. Because the impedance measurements directly reflect the electrical properties of the in-situ coal and rock, the findings suggest that their electrical properties are dependent on both frequency and location. An experiment was designed to collect the propagation parameters of a TL laid in three positions on the mine entry floor to further characterize the effects of the coal and rock electrical properties on the propagation parameters of a TL in a different position. The purpose was to determine if the differences between these parameters could be attributed to the differences between the electrical properties of local coal and rock near the conductor.

II. TL TEST CONDITIONS

This TL experiment was conducted in an entry within an active coal mine. The diagram in Fig. 1 shows the dimensions of the mine entry as well as the separation distances and three positions of the TL represented by the three longitudinal lines (left, center, and right). The conductor was laid on the floor in one position at a time. The insulated conductor measured 457.2 meters, and consisted of a twin lead with its terminals shorted together at each end to form a single conductor for MF signals. No other conductors were present in the entry. The entry had areas of mud along the right side, was relatively dry in the center, and had some areas where water had accumulated on the left side. The mine entry floor served as part of the TL return path. As shown in [4], this TL configuration created a controlled environment in which the return current is mostly concentrated over the part of the ground directly beneath the conductor. This suggests that the local ground closer to the conductor has a greater influence on the signal propagation of the TL. To evaluate the influence of the local ground return path of the TL, researchers measured the impedances of the ground in the three positions.

III. Measurments

A. Coal and Rock Impedance Measurements

The experiment included recording tens of impedance measurement samples between two points of coal and rock within the entry. The measurements showed that the lower impedance measurements were generally observed in areas with a higher water content. The impedances of the return paths of the TL in the right and left positions were lower than that of the center return path because of a higher water content. Because attaining a precise impedance measurement over a 457-m ground return path of the TL is complex, a relative estimation of the impedance of the return path at each of the positions was calculated based on the water accumulations observed.

B. Propagation Parameters of TL

The TL measurement method introduced in [3] was used in this experiment, which covered the frequencies from 300 kHz to 1 MHz in step sizes of 1 kHz. The conductor was installed in the left, center and right positions, sequentially. Two of the propagation parameters of the TL attained in the experiment are presented in this paper: the characteristic impedance (Fig. 1) and the line power loss rate (Fig. 2). Fig. 1 plots the characteristic impedance measurements of the three TL positions as a function of frequency. The variation of the characteristic impedances with respect to frequency at each of the TL positions is attributed to the variation of the electrical properties of the coal and rock of the local return path. Fig. 2 plots the power loss rates in dB/km and the line fit functions to enable comparison.

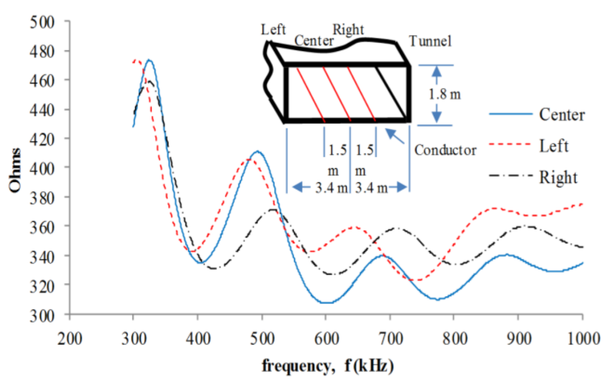

Fig. 1. Characteristic impedances of the TL in three positions.

IV. Discussion and conclusions

This paper compares two MF propagation parameters of a TL laid in three different positions on a coal mine floor. The experiment focused on exploring the effects of the electrical properties in the return path on the propagation characteristics of the TL, specifically, the effects of the electrical properties of in-situ coal and rock on the characteristic impedance and power loss rate measurements for the TL. The data measured yielded different results between the propagation parameters at the three positions. These variations can be attributed to the differences in the electrical properties of the local coal and rock near the conductor. The differences between the measured parameters were as much as 12.3% for the characteristic impedance and as much as 11.6% for the power loss rate. Although the difference between the signal losses at the three different positions is not significant to the overall propagation of the signal, the results further validate the findings in previous research that the TL propagation characteristics were position-dependent. This highlights an important consideration focused on installation practices, in that comparing results from a conductor positioned near the entry roof and one positioned near the entry floor, where the measured sample impedances on the roof were six times as great as those on the floor, resulted in a signal loss rate difference of 74% [2]. This loss difference can be attributed partly to the difference in the electrical properties between the roof and floor. Ultimately, these results can serve the mining industry by identifying a major consideration for installing MF systems in underground coal mines and highlighting the critical need to factor in local electrical properties when evaluating TL installations.

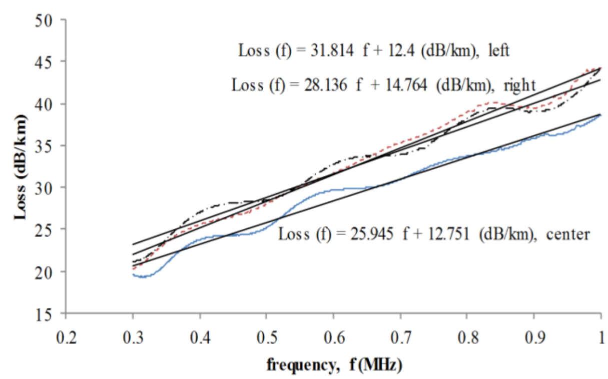

Fig. 2. Power loss rate of the TL in three positions.

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The findings and conclusions in this report are those of the author(s) and do not necessarily represent the views of the National Institute for Occupational Safety and Health.

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