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Effects of a conductive rail on parallel apparent resistivity measurements

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Effects of a conductive rail on parallel apparent resistivity measurements

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Front cover

Apparent resistivity data being collected at the GCR test site. Photo credit: Dr. J.E. Chambers.

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Foreword

This report examines the effects of a conductive metal rail on apparent resistivity measurements made along a line running parallel to it.

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Contents

FIGURES

Summary

Apparent resistivity measurements made in proximity to a rail track are likely to be affected by preferential current channelling through the conductive rails. This report quantifies these effects using a simplified semi-analytic model to represent the rail. The results show that the commonly used measurement configurations are all affected in a similar manner, with greater distortion of the data at larger depths of investigation. The degree of distortion also depends on the contact resistance between the rail and the ground. The effect is least, however, for the Dipole-Dipole configuration, which is therefore recommended for resistivity surveys undertaken parallel to conductive rails. It is also recommended that the rail-ground contact resistance be measured during repeat resistivity surveys to allow the effects of the rail to be evaluated.

1 Introduction & Method

A conductive metal rail will affect apparent resistivity measurements made on the ground surface adjacent to it. Intuitively, one would expect the apparent resistivity to be reduced, since some current will be preferentially channelled through the rail. The purpose of this report is to quantify these effects on measurements made along a line running parallel to the rail. The examples shown relate specifically to electrical resistivity tomography (ERT) surveys to be undertaken at the Great Central Railway (GCR) test site as part of the Railway Geotechnics project (E2117S83).

The effect of the rail line is modelled using an infinitely long hemi-cylinder of radius $r_c = 0.05$ m embedded in an otherwise homogeneous half-space of resistivity $\rho = 1000$ Ωm. The cylinder is assumed to be a perfect conductor. However, it has a finite interface conductance per unit area of g Sm^{-2} to account for the effect of contact resistance between the rail and the ground. The ERT electrodes are placed at spacings of 2 m along a line parallel to the rail and 2.6 m away from it (Figure 1).

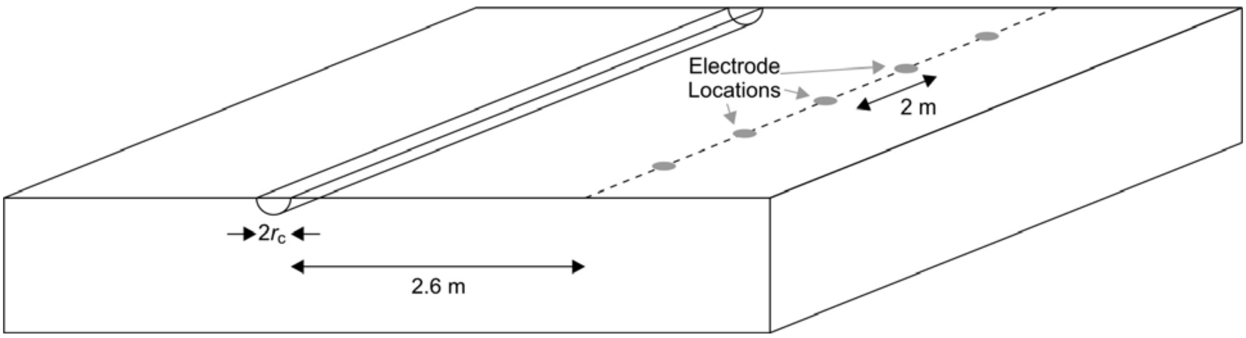

Figure 1: Schematic diagram indicating the hemi-cylinder used to simulate the rail and the locations of the electrodes.

In general, multi-electrode ERT array configurations can be constructed from sums of basic two-electrode ("pole-pole") configurations. The effects of the hemi-cylindrical rail on these pole-pole configurations are calculated using the expressions derived in Wait (1983), in particular the approximation given by his Eq. 16. The results are given in terms of ρ_a/ρ, where ρ_a is the apparent resistivity measured by the configuration in the presence of the rail and ρ is the resistivity of the half-space. The resistivity ratio is plotted as a function of the median depth-of-investigation for each array configuration (Edwards, 1977). The median depth-of-investigation $\tilde{z}$ depends on the array type and increases with the overall length of the configuration. For this study, the maximum configuration length was chosen to be 80 m.

If the rail were not present then ρ_a/ρ would be unity, but for a conductive rail in electrical contact with the ground then it should be expected that $\rho_a/\rho < 1$. The quality of the contact is controlled by the interface conductance. It may be possible, using Eq. 10 of Wait (1983) and the general expression for contact resistance $R = V / \int_S \mathbf{J}.d\mathbf{S}$, to calculate a realistic value for g from a contact resistance measurement made between the rail and a point on the ground. However, this calculation will be quite involved numerically and the details have not yet been worked out. It is easy though to simulate the worst-case scenario of zero contact resistance ($g = \infty$), in which the effect of the rail will be greatest. It will be shown that the general conclusions of this study are not changed by the choice of g.

The types of configurations under consideration are shown in Fig. 2. Apart from the basic pole-pole configurations, they were chosen from the many possible arrangements on the recommendations presented in Dahlin & Zhou (2004). For configurations with remote electrodes, these were placed 1000 m from the rail in the direction perpendicular to its axis.

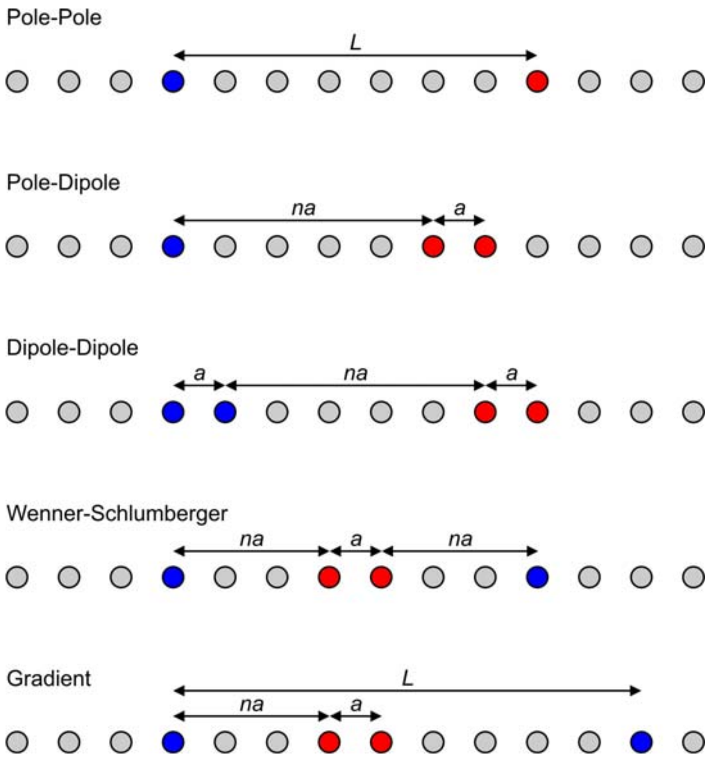

Figure 2 Simulated ERT measurement configurations showing current (blue) and potential (red) electrodes.

2 Results

The effects of increasing $\tilde{z}$ on the simulated apparent resistivity data are shown in Figs. 3-7 for Pole-Pole, Pole-Dipole, Dipole-Dipole, Wenner-Schlumberger and Gradient configurations respectively. The effect of increasing depth-of-investigation on the measured apparent resistivity is remarkably similar for all the arrays that were tested. In every case, the greater the depth-of-investigation, the greater the reduction in the measured apparent resistivity caused by the conductive rail. This seems intuitively reasonable since greater depths are probed by longer configurations, which one would expect to be influenced more strongly by the rail. For shorter configurations, however, some array types are affected more than others, although not to a great degree. This is illustrated by Fig. 8, which shows the Pole-Pole, Pole-Dipole and Dipole-Dipole results on the same graph and in more detail. Note that Wenner-Schlumberger and Gradient arrays are not shown in Fig. 8. This is because the effect of the rail on these configurations is very similar to that on the Pole-Dipole array (the reason for this can be appreciated on a qualitative level; the Wenner-Schlumberger and Gradient arrays are essentially Pole-Dipole arrays with the distance to the "remote" electrode reduced).

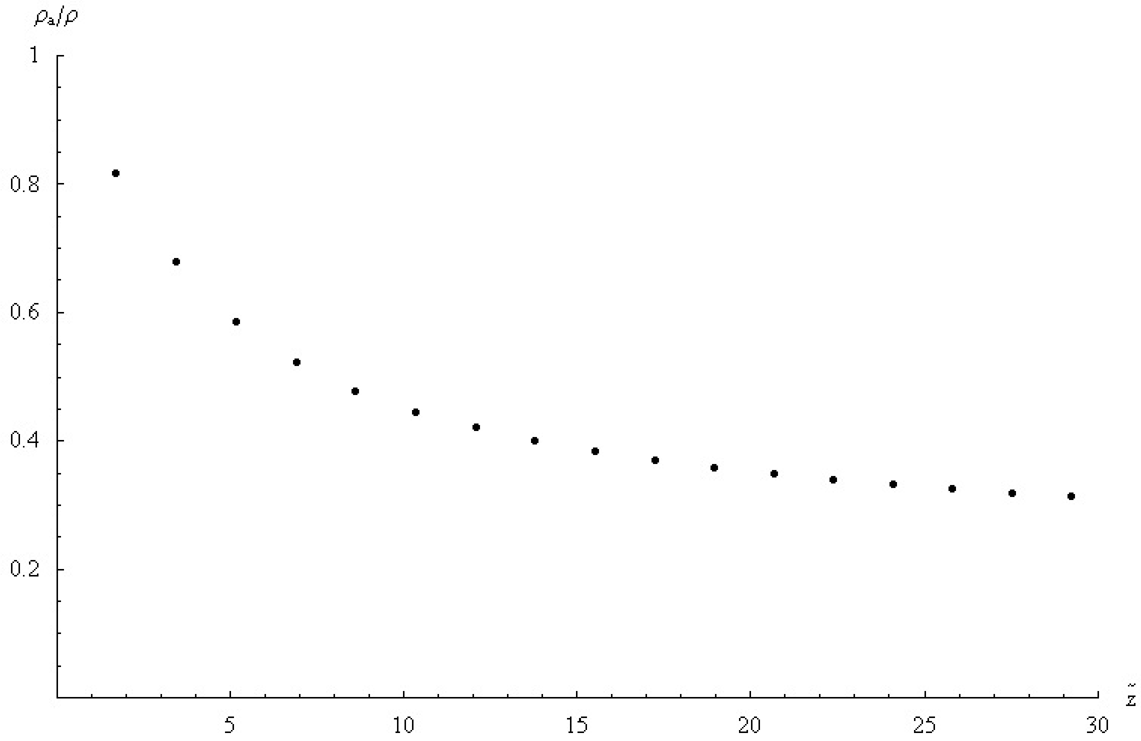

Figure 3: Dependence of apparent resistivity on depth-of-investigation for Pole-Pole arrays.

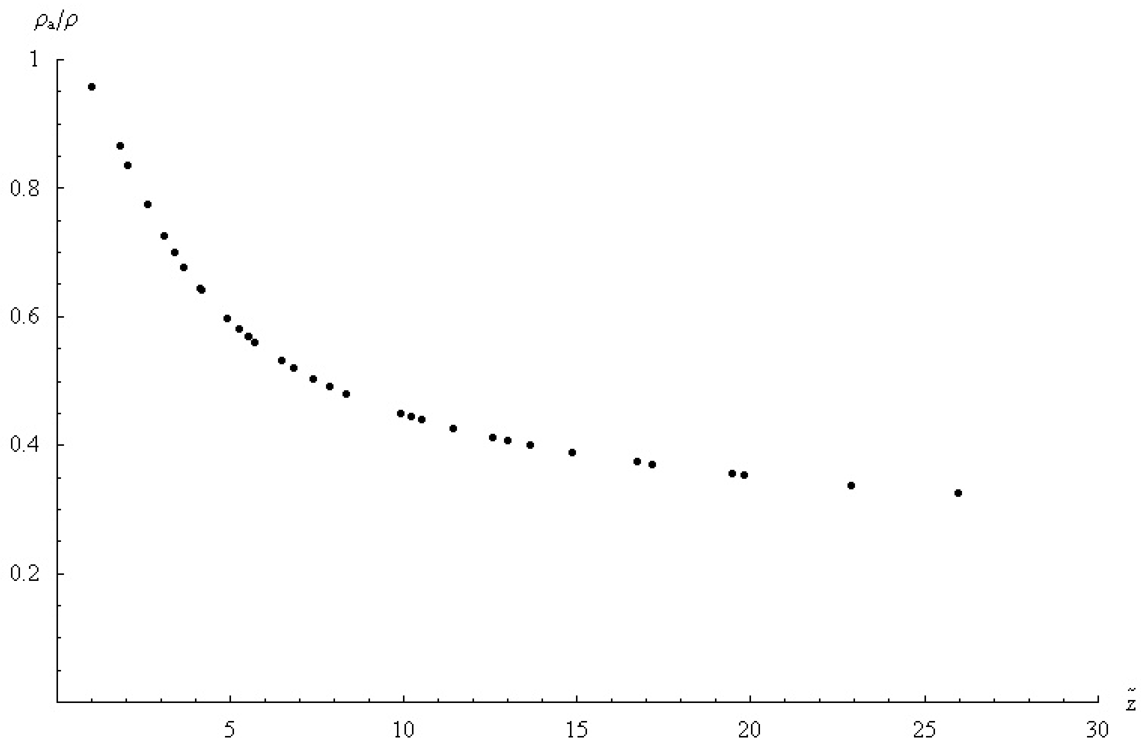

Figure 4: Dependence of apparent resistivity on depth-of-investigation for Pole-Dipole arrays.

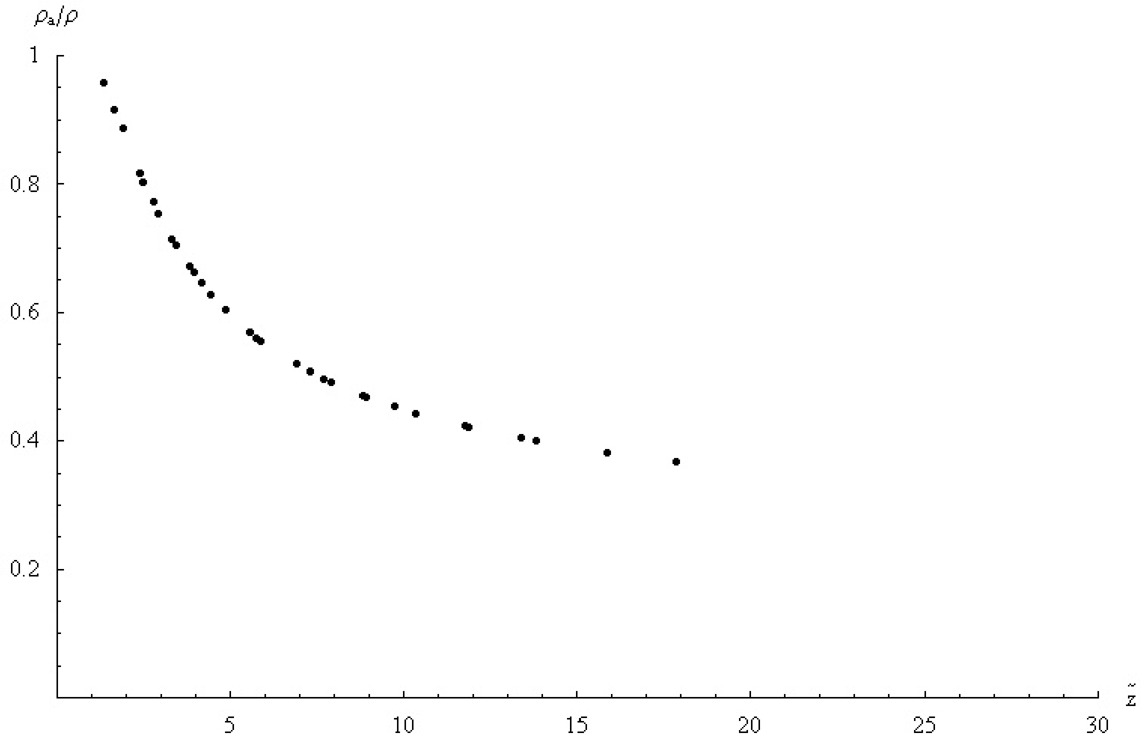

Figure 5: Dependence of apparent resistivity on depth-of-investigation for Dipole-Dipole arrays.

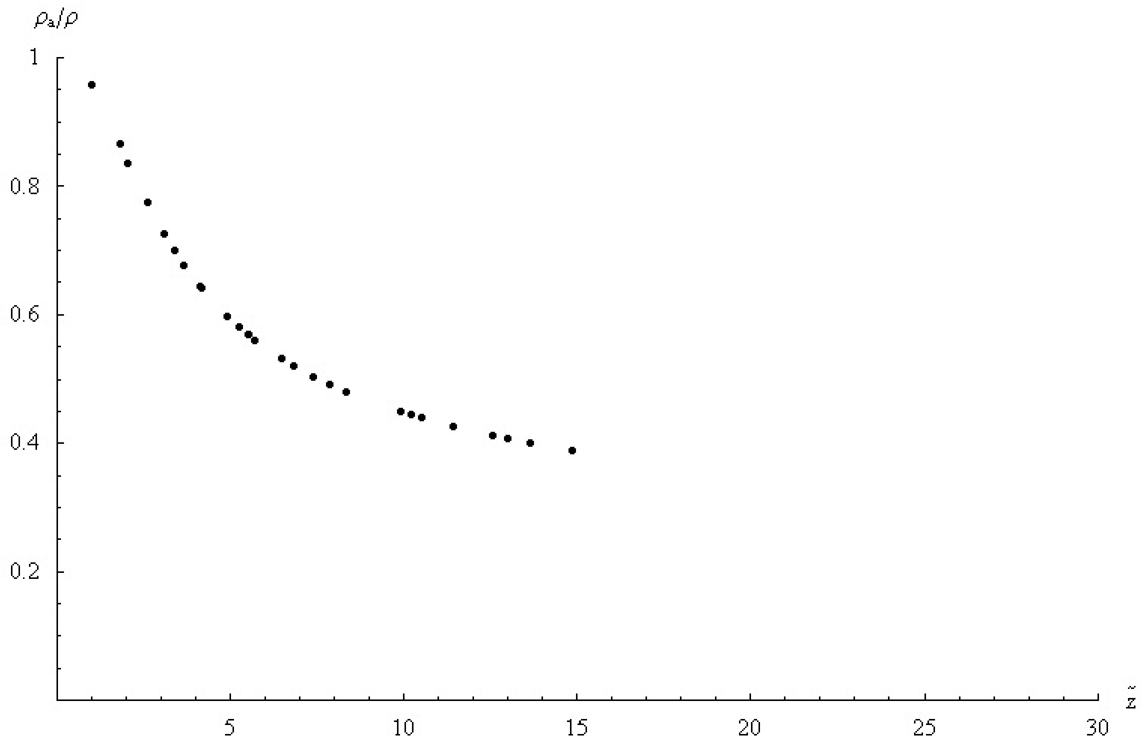

Figure 6: Dependence of apparent resistivity on depth-of-investigation for Wenner-Schlumberger arrays.

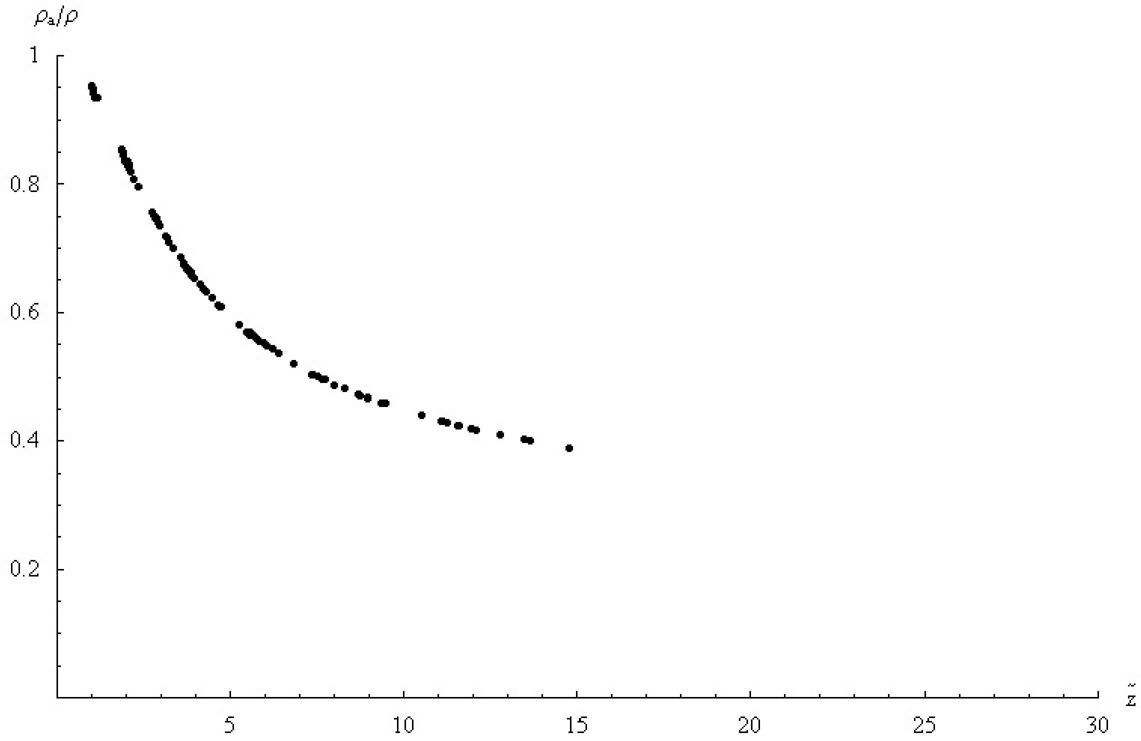

Figure 7: Dependence of apparent resistivity on depth-of-investigation for Gradient arrays.

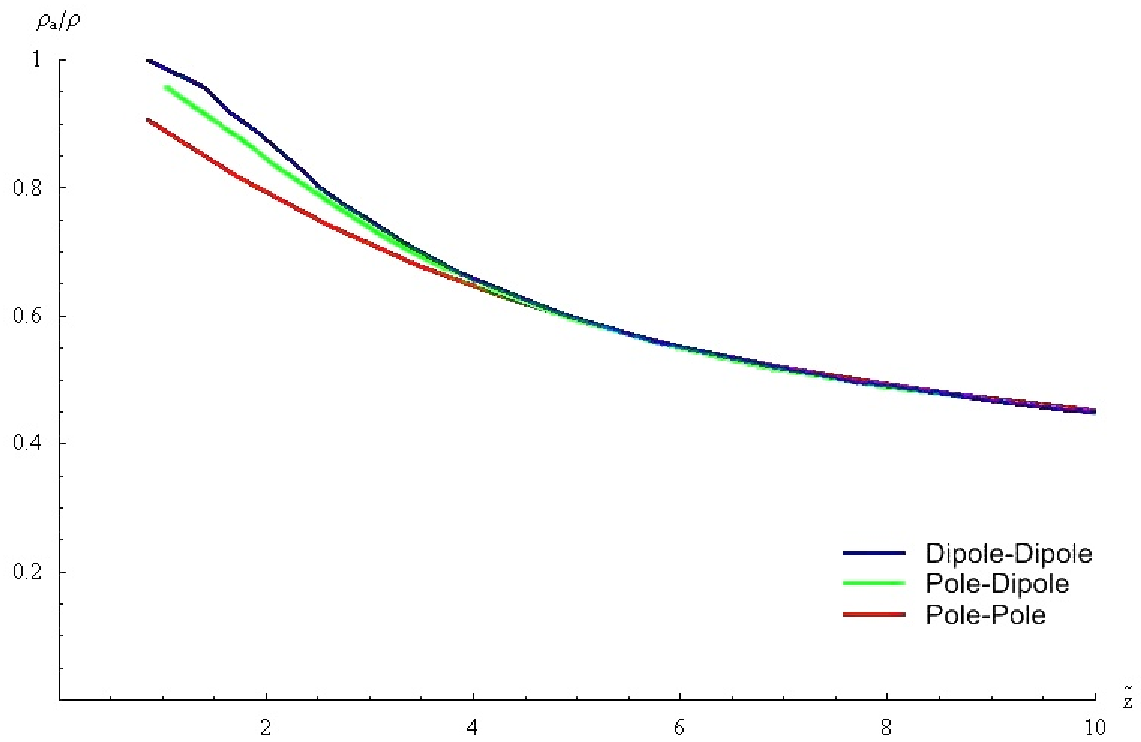

Figure 8: Dependence of apparent resistivity on depth-of-investigation for Pole-Pole (red), Pole-Dipole (green) and Dipole-Dipole (blue) arrays.

By examining Fig. 8, one can see that for $\tilde{z} < 4$-5 m there is an advantage to using Pole-Dipole over Pole-Pole, and a further advantage to using Dipole-Dipole over Pole-Dipole. This is likely to be due to differences in the sensitivity distributions of the different array types. The sensitivity distribution of a given configuration depends on where the current flows in the surrounding region. Since the electric field of a dipole decreases more rapidly with distance than that of a pole, the current will flow closer to the measurement line for configurations containing dipoles than for configurations containing poles. Therefore, we would expect short Dipole-Dipole configurations to be less sensitive to the presence of the rail than corresponding Pole-Pole or Pole-Dipole configurations.

It is likely that the effect on ERT measurements made at the GCR site will not be as severe as those simulated here. This is because there will be a non-zero contact resistance between the rail and the ground. Figure 9 shows the effect of varying the contact resistance, which is proportional to the dimensionless parameter $c = 1/(g\rho r_c)$, where r_c is the model cylinder radius.

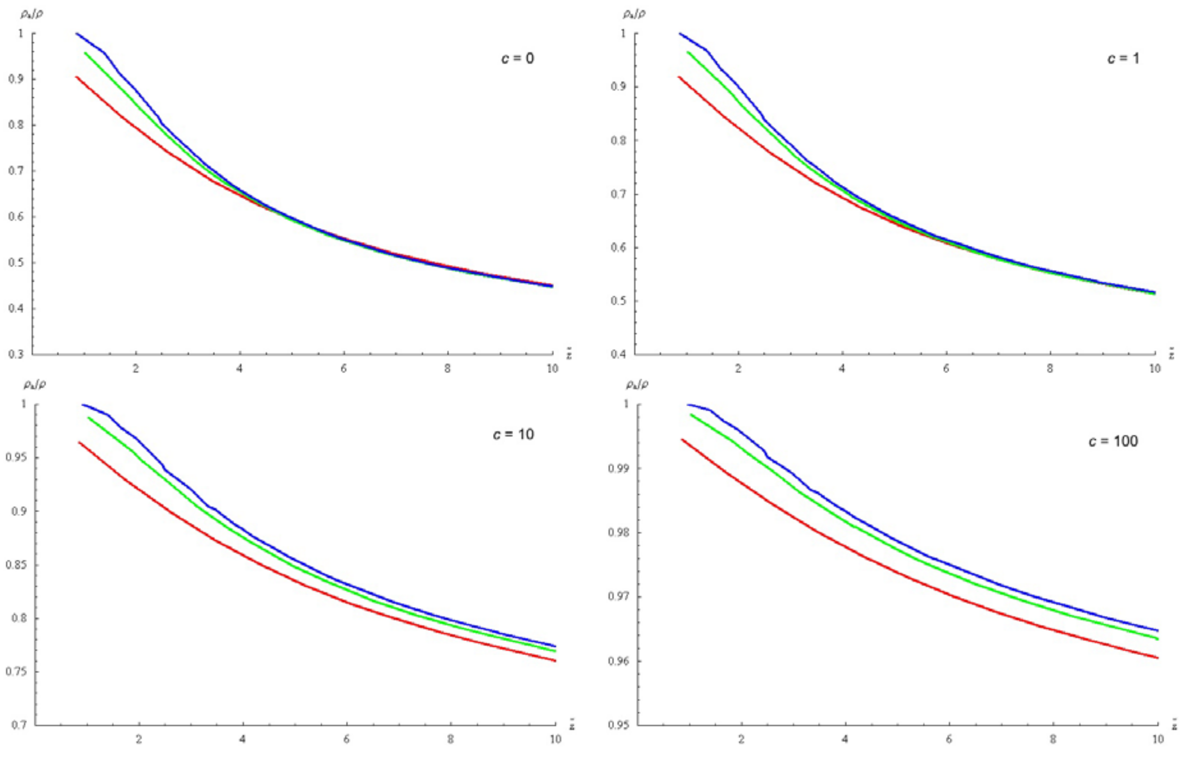

Figure 9: Dependence of apparent resistivity on depth-of-investigation for Pole-Pole (red), Pole-Dipole (green) and Dipole-Dipole (blue) arrays, and $c = 0$ to $c = 100$. Note that the vertical scale of each graph is different.

Figure 9 indicates that, whatever the contact resistance of the rail, the Dipole-Dipole array is affected the least, and is therefore the best choice. It also shows that, for larger contact resistances, the superiority of the Dipole-Dipole configuration is reduced in magnitude, but extends to greater depths-of-investigation.

3 Conclusion

The effects of a conductive rail track on apparent resistivity measurements made along the direction parallel to it have been investigated using a simple semi-analytical model. As expected, the apparent resistivity is reduced by the presence of the rail. It was found that all commonly used ERT array configurations are affected to a similar degree. However, there are small advantages to be gained by using configurations containing dipoles (close pairs of current and / or potential electrodes). Consequently the configuration that is influenced least by the rail is the Dipole-Dipole type, and therefore this is recommended for use when conducting ERT surveys parallel to rail lines. The reduction in apparent resistivity is more pronounced at greater depths of investigation, and this effect may manifest itself as a decrease in resistivity with depth in any resulting ERT image. In general, the severity of the effect on the apparent resistivity data depends on the contact resistance between the rail and the ground, and is this more pronounced if the contact resistance is low. Making a quantitative assessment of the degree of influence of the rail for a known measured contact resistance should be possible, but this would require further work. It is recommended that an additional procedure be included in field operations to measure the rail-ground contact resistance so that its effect on the ERT surveys can be evaluated. This is particularly relevant to resistivity monitoring programmes that include a series of repeat surveys to assess the effects of long-term seasonal changes.

4 References

The references listed below are held in the Library of the British Geological Survey at Keyworth, Nottingham. Copies of the non-confidential references may be purchased from the Library subject to the current copyright legislation. Confidential reports cannot be released without the written permission of the client.

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