TRANSFORMATION OF WENNER TO SCHLUMBERGER APPARENT RESISTIVITY OVER LAYERED EARTH BY THE APPLICATION OF A DIGITAL LINEAR FILTER+

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ABSTRACT

On the basis of the work done by Ghosh (1971) a digital linear filter was developed to transform Wenner sounding measurements to Schlumberger ones for the purpose of providing the interpretational aids in the Schlumberger domain. A sampling interval of six in a log-decade was used in arriving at the 19 point filter. The filter has an accuracy of about one percent.

INTRODUCTION

Of the two main field techniques used in resistivity sounding, the Schlumberger method is superior to the Wenner in that the field applications are easier and there is lesser influence of lateral inhomogeneities in the measurements (Kunetz, 1966; Keller and Frischknecht, 1966; Bhattacharya and Patra, 1968). The Wenner method, however, may have some advantages under certain field conditions in that the Wenner potential measurements are more stable than the potential gradient measurement of the Schlumberger system with the same quality of measuring equipment (Kunetz 1966). Unlike the Schlumberger system the number of available tools for interpreting the Wenner data is meagre as the master curves for this system are very few (Orellana and Mooney, 1966) and the handy auxiliary point method (Zohdy 1965) could not be used in its present form. Thus the idea of transforming the measurements and interpreting it in the Schlumberger domain with better know-how and abundant interpretational techniques would be useful. In 1954 Deppermann studied the interrelationship between the two systems and developed a numerical scheme to transform Wenner curves to Schlumberger ones. Koefoed (1968) on the basis of Deppermann's work arrived at an explicit relationship between the two apparent resistivities:

$$\rho_{aW} = 2a \int_{a}^{2a} \frac{\rho_{aS}}{s^2}\, ds \qquad (1)$$

where,

ρ_{aW} = Wenner apparent resistivity
ρ_{aS} = Schlumberger apparent resistivity
a = electrode spacing in the Wenner configuration
s = half current electrode spacing in Schlumberger configuration.

When the average value of ρ_{aS}/s^2 is approximately linear in the interval s = a to s = 2a, following Keofoed one can write equation (1) as

$$\frac{\rho_{aS}}{s^2} = \frac{\rho_{aW}}{2a^2} \qquad (2)$$

From Equation (2) we note that ρ_{aW} is approximately equal to ρ_{aS} at "s" equal to $a\sqrt{2}$. This suggests that the Schlumberger collection of standard graphs may be used for curve matching the Wenner data if one puts the cross at s = 1.4 and ρ_a = 1. This popular but approximate method was used by

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geophysicists to interpret the Wenner data until Orellena and Mooney supplemented their original 1966 collection with a Wenner set.

In recent years the linear filter method has been used to interpret the Schlumberger and Wenner soundings independently (Ghosh 1970, 1971a, b). Filters were developed to convert the apparent resistivity to the kernel and vice-versa. In this publication we have applied the filtering technique of Ghosh to obtain the psuedo-Schlumberger values from the given Wenner data. The linearity between the two systems required for designing the filter is evident from equation 1.

THE FILTER

The filter to carry out the desired transformation has been derived on the same lines suggested by Ghosh (1971). Mathematical expressions for the input Wenner and output Schlumberger functions needed for filter derivation can be found in the above mentioned publication. Spectra of these input and output functions were determined with the help of the Fourier transform and the filter spectra were obtained as the ratio of the spectrum of the output to that of the input function. A point, however, worth mentioning is that we found it logical to use a smaller sampling interval namely ln 10/6 in the design of the filter. Experience with the linear filter method has shown the apparent ill-behavior of filters determined using a sampling interval of ln 10/3 in certain extreme field situations involving very steep curves corresponding to large resistivity contrasts and/or large thickness ratios. For such cases a smaller sampling interval is desirable. In view of the tremendous gain of computer time in using the convolution method of resistivity calculation over other conventional techniques it is certainly feasible to use a much finer sampling rate (Johansen 1975). Our choice of ln 10/6 results in a filter having the following properties.

1) can adequately handle data corresponding to most resistivity distributions,

2) the reasonable number of operators (19) makes the operation handy and fast; also no storage problems in mini-computers.

The amplitude and phase spectra are shown in Figure 1 and the filter function in Figure 2. The 19 point filter derived after sampling the response at ln 10/6 is given in Table 1. The accuracy of the filter set has been tested in the same way as Ghosh (1970, 1971a) and found to be about one percent. The speed of operation of the filter on an IBM 7044 computer was within a second.

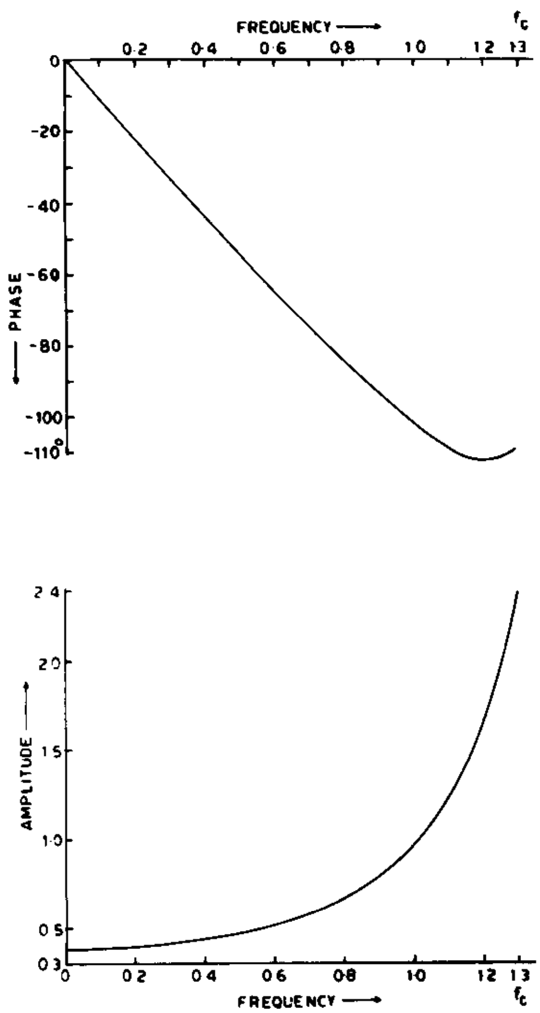

Fig. 1. The amplitude and phase spectra of the filter.

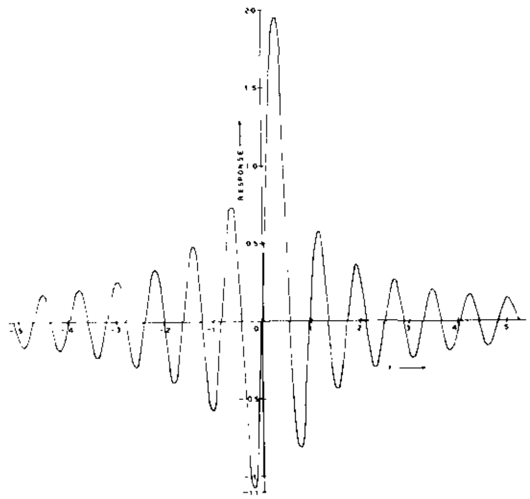

Fig. 2. The filter function

TABLE 1. The digital filter coefficients and their abscissa values.

j	abscissa X_j	filter coefficients C_j
1	− 4.3749	0.0156
2	− 3.9912	− 0.0386
3	− 3.6074	0.0477
4	− 3.2236	− 0.0594
5	− 2.8399	0.0752
6	− 2.4561	− 0.0974
7	− 2.0723	0.1295
8	− 1.6886	− 0.1744
9	− 1.3048	0.2515
10	− 0.9210	− 0.3724
11	− 0.5373	0.5834
12	− 0.1535	− 0.9896
13	+ 0.2303	1.9171
14	0.6140	− 0.4094
15	0.9978	0.1915
16	1.3815	− 0.1135
17	1.7653	0.0786
18	2.1491	− 0.0539
19	2.5328	0.0185

Application

Convolution of the filter operators given in Table 1 with the Wenner measurements results in psuedo-Schlumberger values:

$$\rho_{as}(x) = \sum_{j=1}^{n} c_j \rho_{aW}(y_j) = \sum_{j=1}^{n} c_j \rho_{aW}\left[\ln\frac{1}{\lambda} - x_1 - (j-1)\frac{\ln 10}{6}\right]$$

where x_1 is the abscissa of the filter coefficient with index 1 and n is the index of the last filter coefficient.

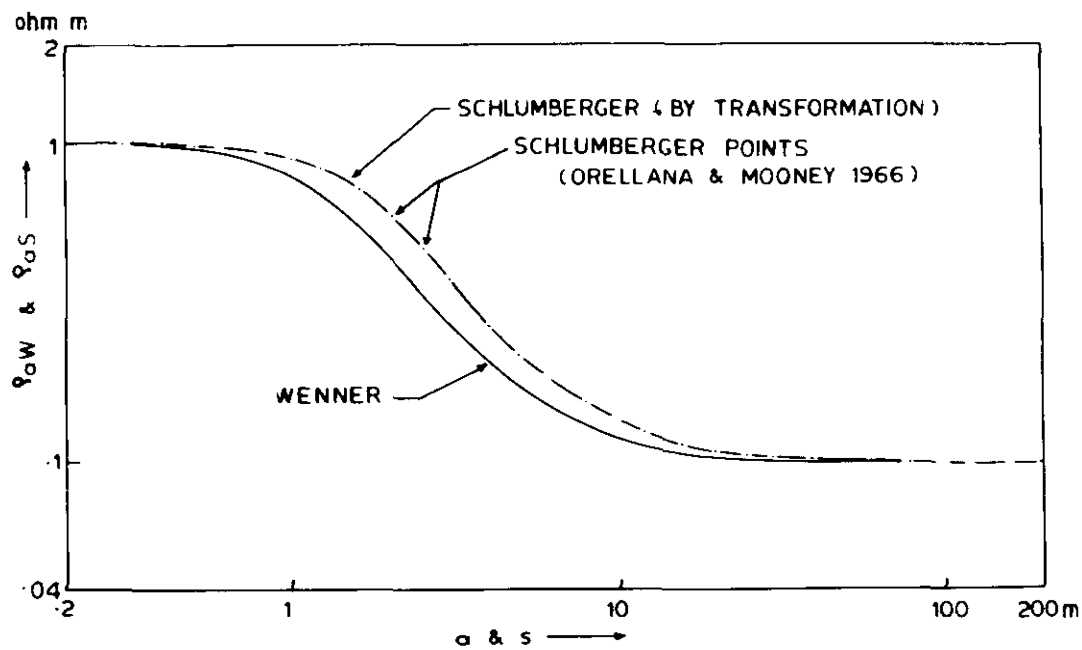

Fig. 3. Transformation of theoretical Wenner data to Schlumberger data by the application of the filter. The actual Schlumberger values for the same distribution are also shown.

The result of this application is shown in Figure 3. The case under discussion is a theoretical example taken from the table of resistivity values by Orellana and Mooney (1966) having the following layering parameters:

$\rho_1 = 1$ ohm m $\quad \rho_2 = 0.2$ ohm m $\quad \rho_3 = 0.1$ ohm m

$h_1 = 1$ m $\quad h_2 = 3$ m

The full drawn curve is the Wenner data. Discrete values of it are convolved with the filter set given in Table 1 resulting in the psuedo-Schlumberger curve given by the dashed curve. The actual Schlumberger values for the same distribution given in Orellana and Mooney's table are the dots which are in very good agreement with the psuedo-Schlumberger curve.

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REFERENCES

Bhattacharya, P. K., and Patra, H. P., 1968. Direct current geoelectric Sounding, Elsevier, Amsterdam.

Deppermann, K., 1954. Die abhangigkeit des sceinbaren Widerstandes vom Sondenabstand bei der Vierpunkt-Methode, Geophysical Prospecting 2, p. 262-273.

Ghosh, D. P., 1970. The application of linear filter theory to the direct interpretation of geoelectrical resistivity measurements. Ph.D. thesis. Published.

Ghosh, D. P., 1971a. The application of linear filter theory to the direct interpretation of geoelectrical resistivity sounding measurements, Geoph. Prosp. 19, p. 192-217.

Ghosh, D. P., 1971b. Inverse filter coefficients for the computation of apparent resistivity standard curves for a horizontally stratified earth, Geoph. Prosp. 19, p. 769-775.

Johansen, H. K., 1975. An interactive computer/graphic-display-terminal system for the interpretation of resistivity sounding, Geoph. Prosp. 23, p. 449-458.

Keller, G. V., and Frischkencht, F. C., 1966. Electrical methods in Geophysical Prospecting, Pergamon Press, New York.

Koefoed, O., 1968. The application of the kernel function in interpreting geoelectrical resistivity measurements, Gebruder Borntraeger, Stuttgart.

Kunetz, G., 1966. Principles of direct current resistivity prospecting, Geoexploration monograph series 1, nr.1, Gebruder Borntraeger, Stuttgart.

Orellana, E. and Mooney, H. M., 1966. Master tables and curves for vertical electrical sounding over layered structures, Intercientia, Madrid.

Zohdy, A. A. R., 1965. The auxiliary point method of electrical sounding interpretation and its relationship to the Dar Zarrouk parameters: Geophysics, v. 30, no. 4, p. 644-660.