Test of different metal electrodes for IP measurement in time domain

F. Postic(1),(2) and C. Doussan(1)

(1) *UMR EMMAH INRA/UAPV, Avignon, France*
(2) *ARVALIS Institut du Végétal, France*

Standard IP survey requires the use of non-polarisable electrodes, which generally consist in a porous cup/wood filled with a liquid electrolyte, such as $CuSO_4$. If these electrodes give the best results in terms of measurement quality, their set up in the field is time consuming and requires a good soil-electrode contact with the inner electrolyte trough the porous cup. Moreover, this kind of electrodes in long term survey (over 6 months to a year) for hydrological or agricultural applications for examining subsoil variations with time lapse acquisition, necessitate frequent refilling, are susceptible to leak out and to modify the soil environment next to the electrode. In that case, solid electrodes, such as metal electrodes, would be easier to handle and install, particularly for long term survey. However, it is known that metal electrodes may exhibit electrochemical reactions with the surrounding and soil and heterogeneous polarization among electrodes along the survey line. The magnitude of these parasitic effects may depend on the metal alloy used and a metal electrode exhibiting the closest behaviour to non-polarisable electrode would be a good balance between practicability and measurement quality.

In this study, we have tested 4 types of metal alloys for electrodes in IP measurements: bronze ($CuSn_4Zn_4Pb_4$), brass ($CuZn_{39}Pb_3$), cupronickel ($CuNi_{10}Fe_1Mn$) and stainless-steel, in conjunction with classical $Cu/CuSO_4$ non-polarisable electrode as a reference. These measurements were made in various conditions: grassland, crop field and fallow land. IP Measurements were conducted with Wenner protocol, electrode spacing from 0.5 m to 1.0 m, using an Iris Instruments Syscal pro. We used 20 time-windows up to 1000 ms. After a 20 ms delay, the first time-window length is 10 ms, then followed by 5 time-windows of 20 ms, 3 of 30 ms, 3 of 40 ms, 3 of 50 ms, 2 of 60 ms, 70 ms, 80 ms, 90 ms. Metal electrodes diameter was 12 mm except cupronickel 15 mm. Non-polarisable electrodes were made with porous ceramic cups from gardening equipment, filled with saturated $CuSO_4$ liquid solution and a copper rod immerged into the solution. Quadripoles of each electrode's types were left in the field for a long term monitoring.

From the data set acquired with these measurement settings, we extracted 4 variables describing the behaviour of each type of metal alloy electrode with respect to the non-polarisable electrode. At first, we compared the relative difference of chargeability: $\delta M = (M_i - M_n) / M_n$ between each metal alloy electrodes and the non-polarisable electrode, where M_i is the chargeability measured with metal alloy electrode, and M_n is the chargeability measured non-polarisable electrodes. This difference reports about the global quality of the measurement with each metal alloy. In order to express the sensitivity of the signal probed by each type of electrode to external electrical noise, we counted the relative number of negative voltage (RNN) values measured in each 20 time-windows over the all voltages measured. The difference between decay curves of metal/non-polarisable electrodes was estimated by the mean squared error (MSE) of each time windows. Finally, we fitted each IP decay curves that exhibited at least 2 decay times in our conditions with 2 power regressions. The first regression is applied to the first 3 time-windows, and the second to the rest of the decay curve. From these data fitted, we calculated the relative difference of the time exponents ($\delta\tau$) between each metal alloys and non-polarisable electrode, in the same manner as we did for the relative difference of chargeability value M.

The results for IP measurements done at a short time scales (i.e. a few minute-hour after electrode installation) show that the relative difference of the chargeability, δM (Fig. 1), was the smallest for bronze, reaching 16.6 % with non-polarisable electrode. Stainless-steel and brass are relatively close, with 26.2 and 30.2 % of relative difference respectively, while δM for cupronickel was as high as 88 %. Bronze had also the smallest relative number of negative voltage RNN ~ 0.16 % (Fig. 1), whereas brass and stainless-steel had RNN ~ 7 to 15 times higher. Non-polarisable electrode never showed negative voltages. Stainless-steel, and brass to a lesser extent, exhibited a large variability in the number of erratic negative voltage, underlining sensitivity to noise. The smallest MSE was obtained by bronze, closely followed by stainless-steel and brass, while cupronickel gets at least a double score. Relatively good fits were obtained with a power regression for the voltage decay curves, mean r^2 ranged from 0.99 for the first decay to 0.82 for the second, with more variability in the signal measured. This fitting of time exponent of decay curves resulted also in the smallest relative difference of $\delta\tau$ for the bronze electrodes (8 to 9 % for the first and second time constants). For the others metal alloys, $\delta\tau$ ranged from 17 % to 73 %.

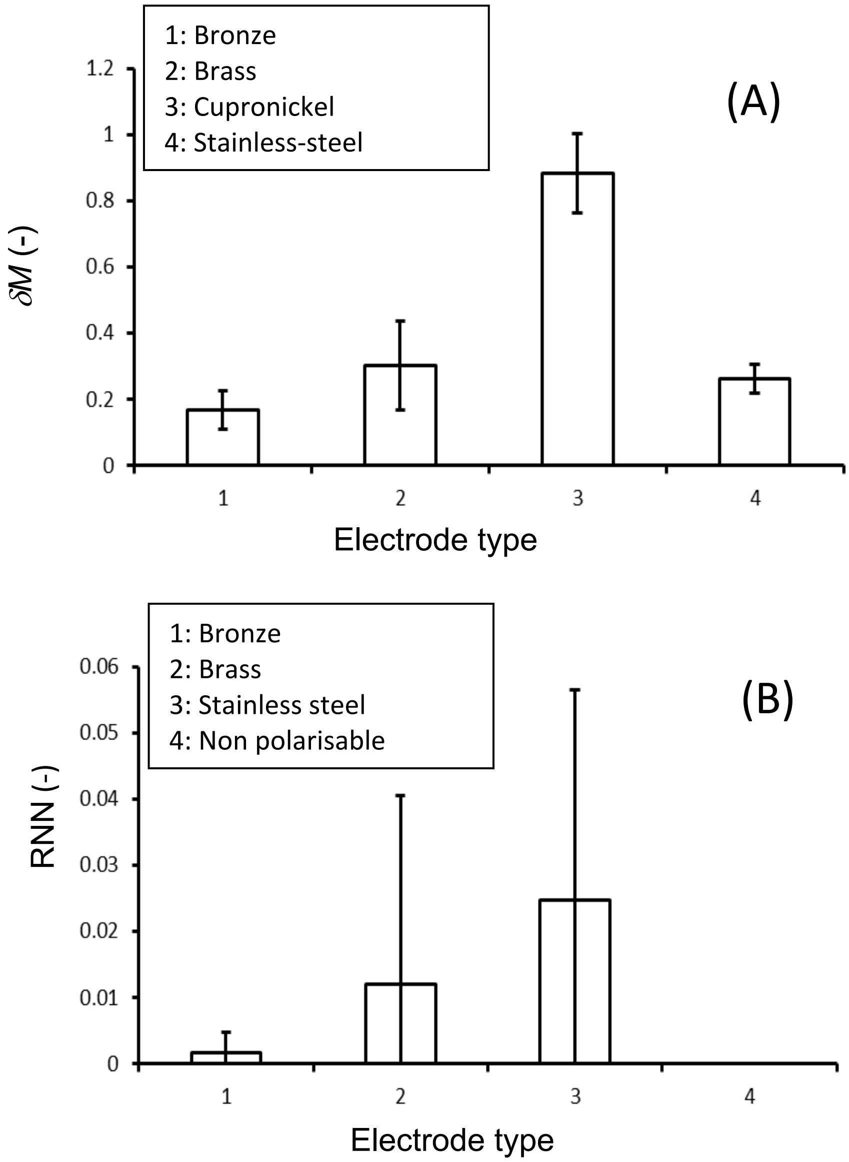

Fig. 1: (A) Relative difference of chargeability relative to non-polarisable electrode (δM) for bronze (1), brass (2), cupronickel (3) and stainless-steel (4) electrodes (mean ± s.d.). (B) Relative number of negative voltage (RNN) measured in 20 time-windows of a IP decay curve for bronze (1), brass (2), stainless-steel (3) and non-polarisable (4) electrodes (mean ± s.d.).

From this study, bronze exhibited best results for all the criteria studied relative to non-polarisable electrode (i.e. chargeability, mean error between decay curves, number of erratic, negative measurement, variability, and time decay constants) than other metal alloys for IP measurements on a short time scale (minutes to hours) and thus was closest to non-polarisable electrode behaviour. First measurements for a longer time-scale after installation for monitoring (i.e. ~3 months) tend to show that bronze electrodes are still effective for IP measurements.