Detectability of Conductors with B and dB/dt Measurements in TEM

A Simple Framework

Assume that a conductor has an exponential decay constant. This is a good approximation for eddy currents flowing at late time in a confined conductor in a TEM survey. Assume that the B-field decay can be given, as a function of time, by:

$$B(t) = A \cdot e^{-t / \tau} \qquad \text{(pT)}$$

where A is the arbitrary amplitude of the exponential decay and tau is the decay constant of the decay. The time t and tau are in units of seconds. Arbitrary units of pT have been used in the above.

By taking the time-derivative of the above, we can see that the corresponding dB/dt response from this conductor, as a function of time, is:

$$dB/dt(t) = (-A / \tau) \cdot e^{-t / \tau} \qquad \text{(pT/s)}$$

or, to use the more common units of nT/s

$$dB/dt(t) = (-0.001 \cdot A / \tau) \cdot e^{-t / \tau} \qquad \text{(nT/s)}$$

Sticking with the units of pT for B signals and nT/s for dB/dt signals, let's consider representative system noise for B and dB/dt systems. If the late-time noise for a B system (for example a fluxgate magnetometer) is 3 pT and the late-time noise level for a dB/dt system (for example, a coil) is 0.3 nT/s then we can calculate the Signal-to-Noise Ratio (SNR) of both systems at the same late delay time, T:

$$SNR(B) = (A / 3) \cdot e^{-T / \tau}$$

$$SNR(dB/dt) = (0.001 \cdot A / (0.3 \cdot \tau)) \cdot e^{-T / \tau}$$

If we compare the Signal-to-Noise Ratios for B and dB/dt in this case, we find:

$$SNR(B) / SNR(dB/dt) = 100 \cdot \tau \qquad (\tau \text{ is in units of seconds})$$

For tau higher than 0.01 seconds (10 msec) the above comparison is > 1, ie SNR (B) is higher than SNR (dB/dt). For tau of 100 msec (0.1 seconds, perhaps a tau value you could expect for a VMS deposit), the above ratio is 10, ie. the SNR for B is 10 times higher than the SNR for dB/dt at the same delay time. In this case, there is an extra factor of 10 SNR available for the B system to detect conductors in the important late-time windows of a TEM survey. In this situation, a signal well above noise in a B measurement can be buried in noise in a dB/dt measurement at the same delay time. For targets with tau higher, as you might expect for a nickel sulphide for example, the B measurement is favoured *even further* in SNR comparisons.

This gives a simple framework for comparing the potential Signal-to-Noise Ratios of B and dB/dt measurements at late time in TEM surveys.