

Energising Conductive Targets with Low Frequency TEM Surveys

In TEM surveys, it can be important to use low transmitter frequencies to energise and detect the highly-conductive parts of a target in preference to less-conductive parts or other unwanted conductors. If transmitter frequencies are not low enough then there is a risk that conductive targets may be overlooked.

As an example, consider the simple case where a TEM step response (response to an isolated single step in the primary field at time zero) is *the sum of* a power-law decay (such as that from a half-space):

$$P(t) = A \cdot t^{-3/2} \quad (\text{pT})$$

and an exponential decay (such as that from a confined conductor):

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

where A is the amplitude of the power-law decay, B is the amplitude of the exponential decay and tau is the decay constant of the exponential decay. A power of -1.5 is used, simulating the step response of a conductive half-space. The time t and tau are in units of seconds. The exponential decay will be used to simulate the response of a conductive target buried in a conductive half-space. Arbitrary units of pT have been used in the above.

A step response is an idealised response. In practice, TEM responses are measured using a system with a transmitter frequency that allows stacking of signals to reduce measurement noise. The response that will be measured with a system operating at a given frequency can be predicted by convolution of the actual transmitter waveform with the step response. A range of theoretical TEM decays are calculated here in order to illustrate the ability of TEM systems, operated at a range of frequencies, to detect the response of good conductors. Responses are calculated simulating the same step change in transmitter current as above, but repeated periodically.

In Figure 1, responses are calculated to simulate a simple target with exponential decay constant 100 msec. A=0.004, B=5 pT and tau=0.1 seconds. Off-time decays are calculated for a conventional 50% duty cycle castle transmitter waveform at frequencies of 0.125, 0.25, 0.5, 1, 2, 4, 8 and 16 Hz. The plot shows the predicted decay on a log-log scale. In Figure 2, responses are calculated to simulate a deeper, more conductive target – it has an exponential decay of smaller amplitude but longer decay constant of 500 msec. A=0.004, B=2 pT and tau=0.5 seconds. Off-time decays are calculated for the same transmitter waveform and the same range of transmitter frequencies as used in Figure 1.

In the example with tau of 100 msec, it can be seen that, for transmitter frequencies higher than 1 Hz, there is a reduction in measured signal amplitude from the slower-decaying parts of the signal. In the case of the tau of 500 msec, data from transmitter frequencies higher than 0.25 Hz is reduced in amplitude by the repetition of the transmitter. Aside from the suppression of slowly-decaying responses, a further issue with operating surveys with high base frequencies is that measurements are not made late enough in time to characterise responses.

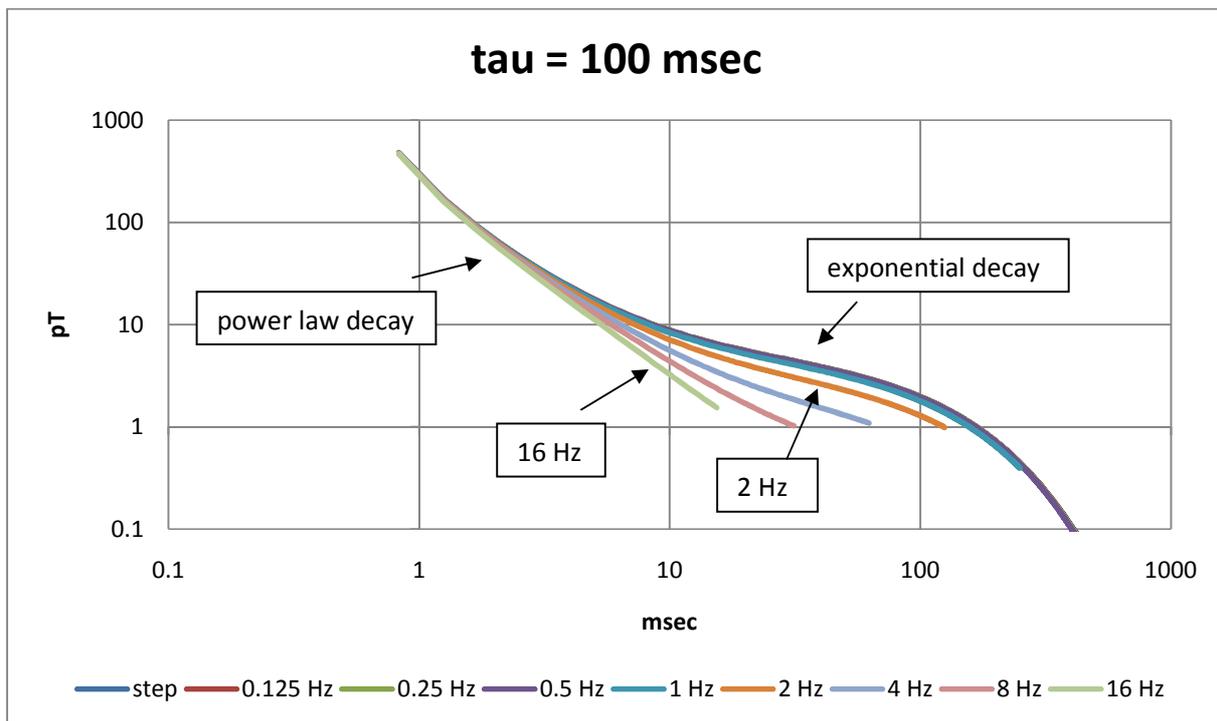


Figure 1: Simulated B Field TEM decays for a target with exponential decay constant 100 msec combined with a half-space response.

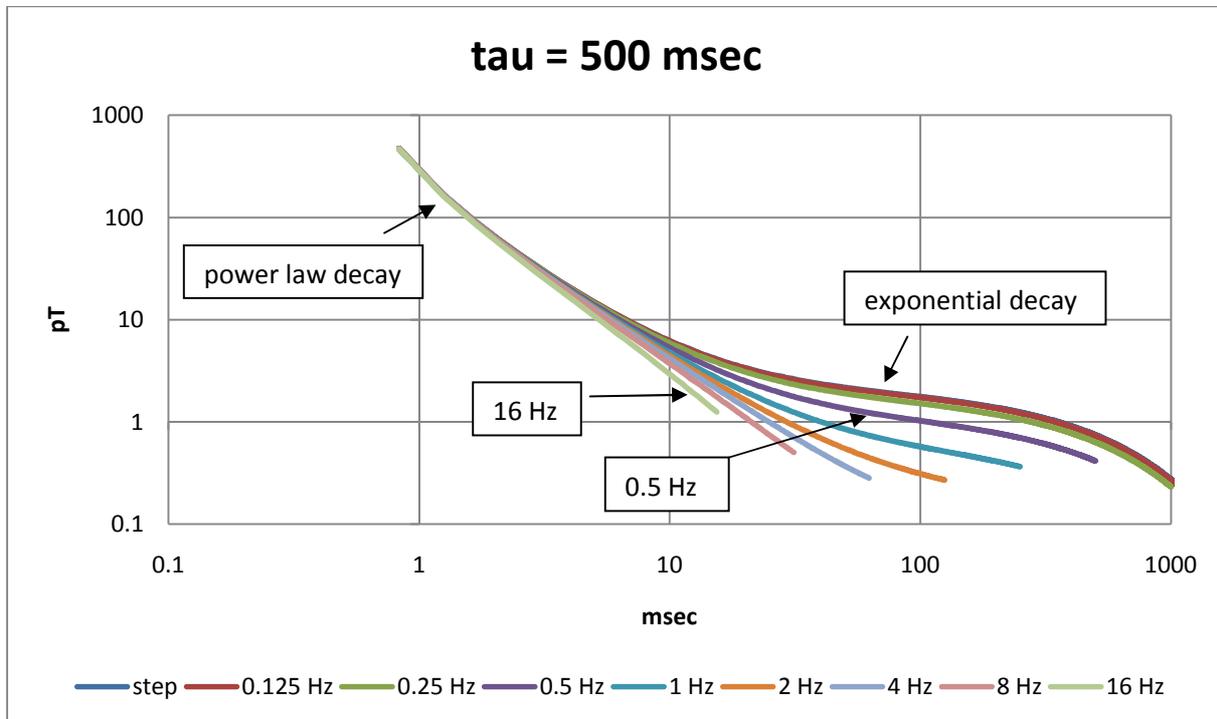


Figure 2: Simulated B Field TEM decays for a target with exponential decay constant 500 msec combined with a half-space response.

Figure 3 shows the effects on off-time exponential decays of varying base frequencies. As an example, at a TEM base frequency of 2 Hz, a response with a decay constant of 200 msec will be attenuated to less than 40% of the response that would be observed at a low frequency. At 2 Hz, a response with 400 msec decay constant would be attenuated to less than 20% of the low frequency response. It is desirable to operate at a point in the red area of the plot where responses from targets are not significantly attenuated.

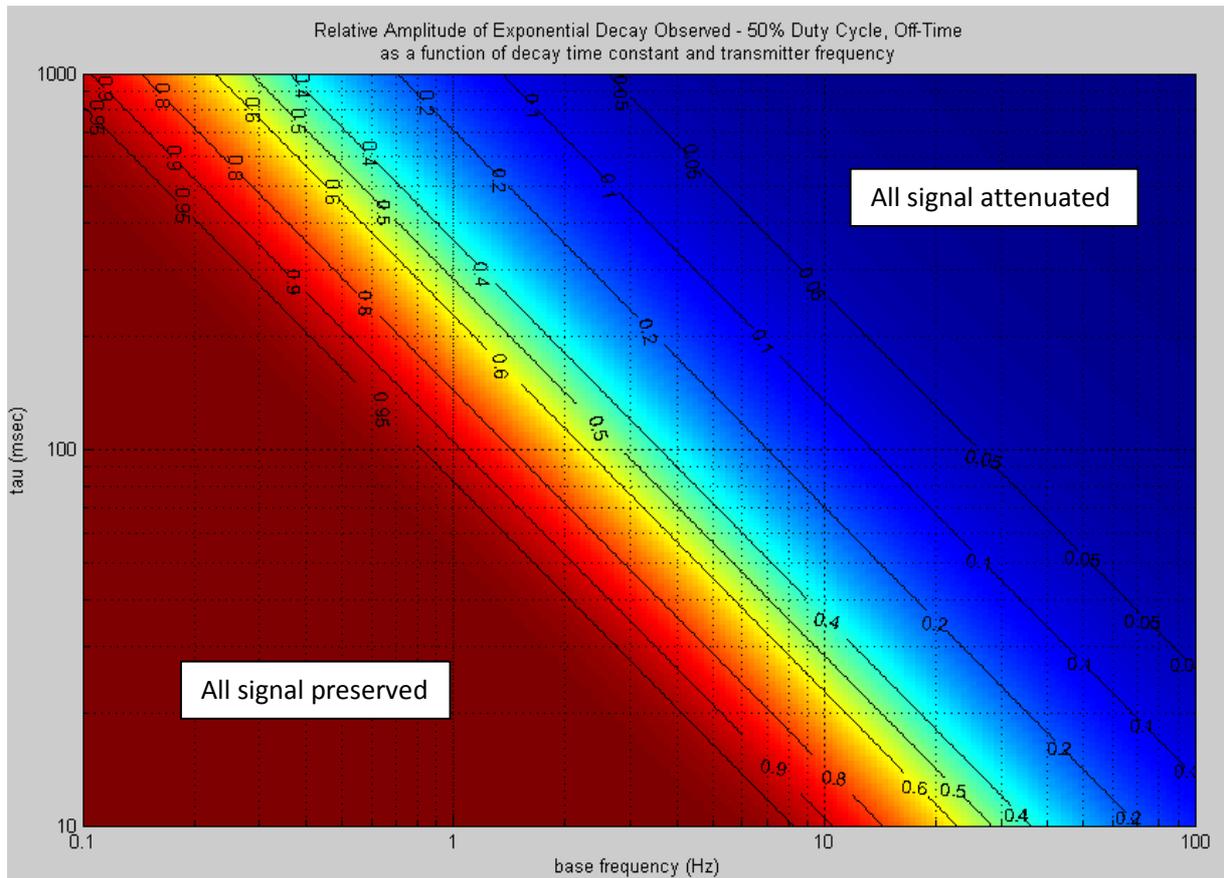


Figure 3: The relative amplitude of an exponential decay measured as a function of decay constant (y-axis, msec) and the transmitter base frequency (x-axis). A 50% duty cycle off-time measurement is used.

TEM surveys operated at frequencies which are *inappropriately high* for the target have the potential to give misleading and/or ineffective results because the response of the target can be suppressed. Operating TEM surveys at low frequencies has the potential to define the most conductive parts of the target and discriminate them from less-conductive parts.

The true late-time decay constant of targets is regularly under-estimated, even with no conductive host response present. This is a significant problem for airborne EM systems due to the high base frequencies thereof (25 Hz or higher). Decay constants of any conductive targets are attenuated, leaving a false impression of the conductivity and hampering discrimination. This need not be the case for ground or borehole EM measurements. For EM applications targeting highly-conductive bodies, low frequencies are required. This means that transmitters should be operated at appropriately low frequencies and sensors that have a high signal-to-noise ratio at low frequencies should be used.