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# Rotate your Dipoles by 90 Degree - the Vertical CSEM Approach

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## SUMMARY

The acronym CSEM has widely become synonymous for frequency domain Controlled Source ElectroMagnetics with seabed nodes and horizontal towed dipole transmitters. While this incarnation of marine CSEM is certainly the best known CSEM variant, it is not necessarily always the best option for acquisition over a certain prospect.
Based on numerical modelling the differences between horizontal FD CSEM and vertical TD CSEM for given models were explored. The results show that time domain CSEM with vertical transmitter and vertical receiver dipoles is a viable alternative that provides high sensitivity, high depth of penetration as well as low disturbance by air wave and 3D structures. It's much smaller transmitter receiver distance creates an advantage in lateral resolution as well as in the detection of narrower or smaller structures.
Case studies with comparisons between inverted vertical-vertical CSEM data and well log results show the real world usefulness of the method as well as the necessity for close integration of the results with other geophysical data.
We argue that the marine CSEM landscape will become more divers and that acquisition layout and methodology for a given target needs to be evaluated on a case by case basis to achieve optimum results.

## Introduction

Frequency domain (FD) Controlled Source ElectroMagnetics (CSEM) with seabed nodes and horizontal towed dipole transmitters (see for example Constable, 2012 for a detailed discussion) has become a well-known tool to exploration. So well-known in fact that the term marine CSEM to some degree has become synonymous to this particular implementation of CSEM.
However, it may not always be the best option for CSEM acquisition over a certain prospect. Nowadays alternatives are available in the form of fast towed steamer acquisition or more detailed acquisition based on vertical dipole transmitters. Here we discuss the latter approach (Holten et al, 2009). The method is referred to as vertical-vertical CSEM as it uses a vertical transmitter orientation and the vertical electric field component $E_Z$ as main component for interpretation.

## Method and/or Theory

In vertical-vertical CSEM the source comprises out of two large electrodes in contact with the sea water connected to a powerful transmitter by heavy cables. While the lower electrode is placed on the sea floor the upper electrode is placed in the water column between 30 and 50 m below the sea surface. Its position is continuously controlled be the dynamic positioning system of the vessel to ensure verticality of the source.
Contrary to horizontal FD CSEM, the transmitter signal of vertical-vertical CSEM is discontinuous. First up to 6000 A are fed through the transmitter dipole, then the signal is switched off and the resulting E-fields are recorded.
Depending on the subsurface conductivity the transient decay is more or less fast. The example on the right of figure 1 shows the contrast between a fast decaying signal over resistive ground a.k.a. a reservoir (dashed) and a slower decaying signal (solid) over more conductive ground.

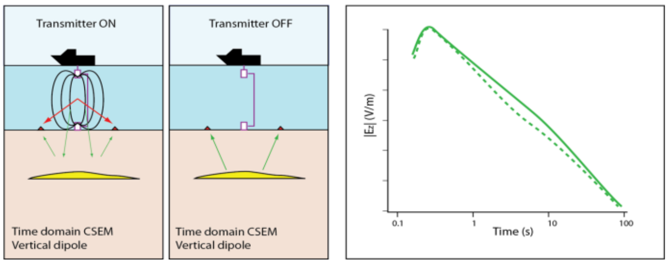


***Figure 1** Source configuration of vertical-vertical CSEM. Transient signals (right) are recorded while the transmitter is switched off.*

The transient approach allows gathering of information from deep targets with much smaller source receiver distance (typically around 1 km) than used in horizontal FD CSEM. This results in smaller volume averaging and a much more localized sensitivity distribution.

Also the depth of penetration is larger as in horizontal FD CSEM. Frenkel and Davydycheva (2012) calculated FD CSEM responses for a 100 Ωm, 100 m thick, 2 km wide 2D target as well as for a 2 km x 2 km 3D target in a 1 Ωm background at different depth below sea floor. They concluded that for a 2D target at 2 km below sea floor the relative responses are very weak at short offsets while the absolute response is weak at long offsets. They further state: "When the reservoir depth is equal to or greater than its diameter, its anomalous response at all frequencies/offsets is typically on the borderline of detectability."
For exactly the same models the anomalous response of vertical-vertical CSEM in 2D is greater than 30 % and in 3D is still greater 16 % (figure 2). In both cases the absolute field values are well above the noise level.

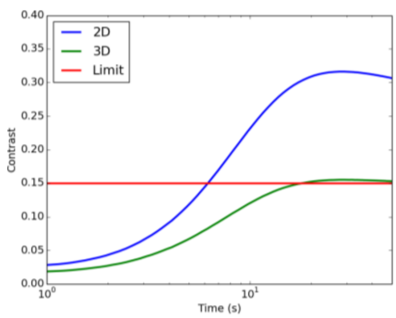


***Figure 2** Contrast towards background for a 2000 m deep 2000 m wide 2D/3D structure.*

The sensitivity of vertical-vertical CSEM can be significantly higher than that of horizontal FD CSEM. Figure 3 shows an example where we results from Conell and Key (2012) have been recalculated for vertical-vertical CSEM. While horizontal FD CSEM reaches maximum sensitivity at large offsets and low frequencies, vertical-vertical CSEM has a sensitivity maximum with about three times as high sensitivity (note the difference in colour scale) at short offsets and intermediate times.

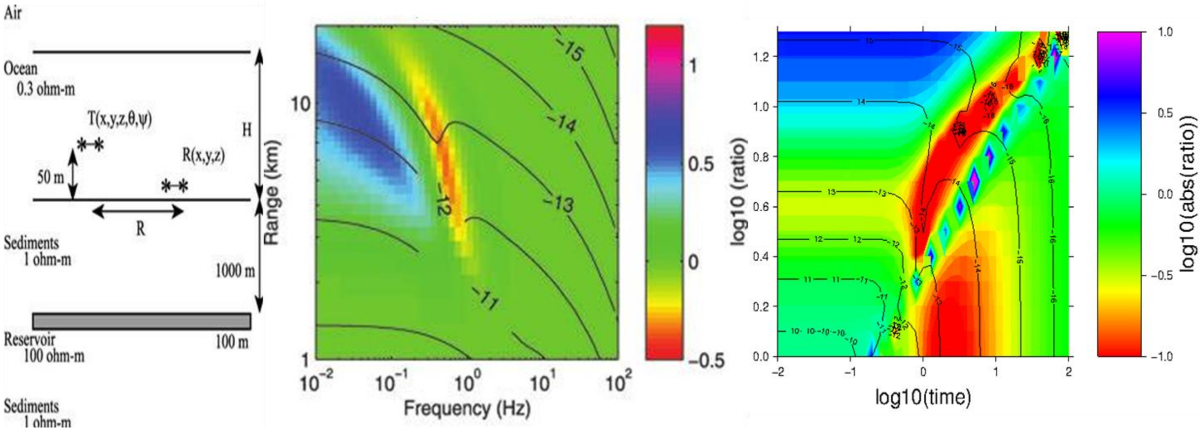


***Figure 3** Sensitivity comparison for horizontal FD CSEM (middle) and vertical-vertical CSEM (right) based on the model on the left. Model and FD calculations from Conell and Key, 2012. Note the difference in color scale.*

On the basis of smooth 1D Occam inversion studies Key (2009) concluded a smaller resolution for the vertical-vertical E-field in FD. While that is can be true for a single position in FD, inversion tests show that combining several transmitter receiver offsets in time domain overcomes this problem.

An example for a successful campaign is shown on figure 4. The inversion result of the Kakelborg prospect (Kaffas et al. 2013) is presented overlaid with the deep induction log result. Both show a distinctive change in resistivity around 1100 m depth. A prominent seismic amplitude anomaly was found to be non resistive. The 2012 well log confirms the resistivity distribution. No hydrocarbons were found.

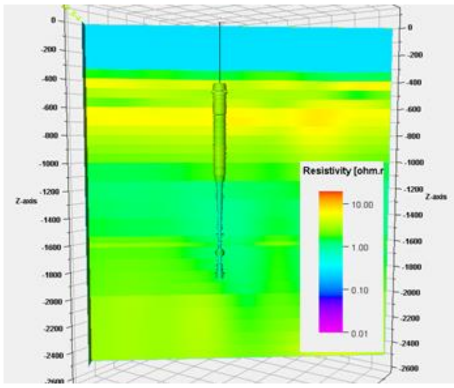


***Figure 4** Inversion result from the Kakelborg survey (Kaffas et al., 2013) overlaid with induction log result.*

**Conclusion:**

Proven alternatives to conventional marine CSEM do exist. As demonstrated the vertical-vertical TD CSEM method often results in higher and more localized sensitivities with less 3D effects than horizontal FD CSEM. For each particular situation benefits and drawbacks of different CSEM acquisition options should be analysed for a case by case decision.

**References**

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