Azimuth Decomposition of SBL Data

F. A. Maaø[1], S. E. Johnstad[2], P. T. Gabrielsen[1], M. Panzner[1]

[1]*EMGS AS, Stiklestadveien 1, 7041 Trondheim,* [2]*HYDRO O&E, Sandsliv.90, 5254 Sandsli*

Summary
Seabed logging data are traditionally acquired along a line and can often be compared and interpreted directly. When data is acquired with different geometry and the source is no longer pointing towards the receiver this interpretation can be difficult. We consider an azimuth decomposition which takes into account the 3D acquisition geometry and that recovers the inline response under a plane layer assumption. We show that this approach can be used when this assumption is violated. However, the azimuth angle must be restricted under such conditions.

Introduction
In 2002 Eidesmo et al. and Ellingsrud et al. introduced a particular application of controlled marine source electromagnetic sounding called seabed logging (SBL). The SBL technique was introduced as a tool for hydrocarbon exploration, also in shallow waters (Johnstad et al., 2005). In particular it is very sensitive to thin resistive layers buried in the subsurface. This sensitivity relies on two important properties. First, the distance between the source and the receiver must be sufficiently large to obtain a response from the resistive layer. Second, a vertical component of the electric field must be present in the subsurface. When the vertical electric field enters a horizontal high resistive layer the amplitude will rise significantly due to the conservation of the electric current normal to the interface. This makes it possible to excite a partly guided event along a thin horizontal high resistive layer. A horizontal electric dipole is used as a source and is towed along the seafloor. The radiation pattern from this source is such that only the transverse electric field is excited in the direction perpendicular to the source (TE mode), and hence gives no or little sensitivity to thin horizontal high resistive layers. On the other hand, only a transverse magnetic field is excited in the direction along the source (TM mode). In a horizontally layered structure the response from the TM mode and the response from the TE mode will not mix at any source and receiver position due to rotational and translational symmetry. A source with arbitrary orientation (azimuth) with respect to the source-receiver (inline) direction can therefore be decomposed into its TE mode and its TM mode. Such decomposition can be very useful as data acquired with different azimuth can be directly compared. In the following we show examples of this and compare data with different azimuth under conditions which breaks the symmetry assumptions. We will focus the comparison to consider data due to the TM mode. For synthetic data we compare the resulting measured electric fields with a source pointing in the true inline direction.

Methodology
The horizontal components of the electric source are decomposed into one TM mode component and one TE mode component. The horizontal electric field measured along the inline direction is assumed to be caused by the TM component of the source, while the horizontal electric field measured normal to the inline direction and the vertical electric field is assumed to be caused by the TE component of the source. The TE mode data and TM mode data are normalized with the source TE and TM component, respectively.
We use synthetic data to study the accuracy of this decomposition in the presence of bathymetric variations as well as subsurface variations which breaks the symmetry assumptions. We compare decomposed TM data with true inline data where the source is always pointing towards the receiver.

Numerical Example

Data is generated for a model containing both bathymetric and subsurface variations violating the symmetry assumptions behind the azimuth decomposition. The model contains a 50 meters thick reservoir measuring 10 by 6.7 km in the x- and y-direction respectively. The reservoir depth is at 3000 meters with a resistivity of 100 Ohm m. The water depth is chosen relatively deep. The effect of the air layer can be quite strong in shallow waters and is not symmetry-breaking which is what we want to study. The response of several receivers is calculated. Figure 1 displays the results for one of the receivers with the most pronounced effect of symmetry breaking.

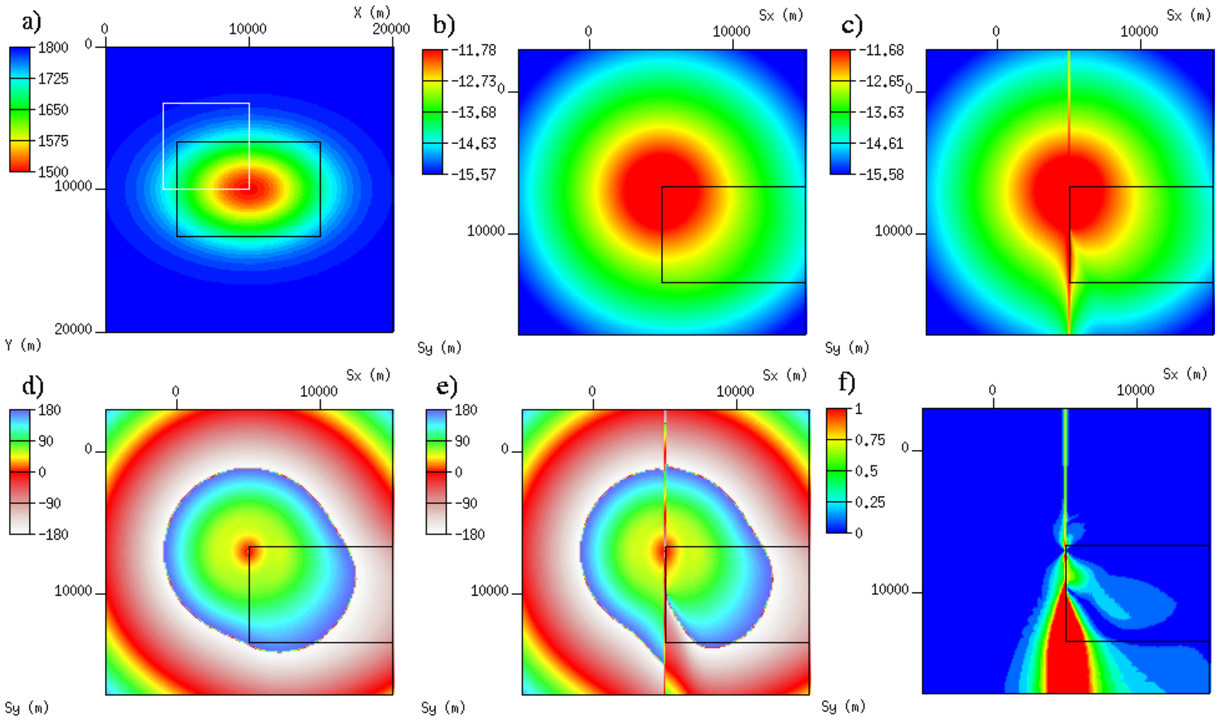

Figure 1. Synthetic example of azimuth decomposition. The bathymetry is shown together with an outline (black rectangle) of the reservoir (a). Data was calculated for 49 receivers covering the white sqaure. The reservoir depth is 3000 m. The true horizontal inline amplitude response is shown in (b), while the decomposed amplitude response for sources pointing in the x-direction is shown in (c) (logarithmic scale). The true inline phase response is shown in (d), while the decomposed phase response is shown in (e). The absolute value of the relative difference between the true inline response and the azimuth decomposition is shown in (f). The values in (f) are given in steps of 0.1.

The comparison with true inline data shows that the largest deviations occur when the azimuth angle and lateral variations are large. This is where the TM component of the source is small and where even a small mixing between TE and TM will give a significant contribution to the inline component.

Real Data Example

The following real data example is from the North Sea. It consists of both true inline data and azimuth data with a base source frequency of 1.0 Hz. Figure 2a shows the survey layout together with the bathymetry map. True inline data are recorded along receiver line 1 and 2 when the towlines Tx01 and Tx02 are active, while azimuth data is acquired along receiver line 2 with the towline Tx03 active. One exception is receiver Rx13 which records inline data also for towline Tx03.
In Figure 2b and c, Magnitude vs. Offset (MVO) for electric data is shown. True inline data for receiver Rx13 is displayed together with the decomposed azimuth data for receiver Rx10 and Rx16. These receivers are placed approximate 2 km from towline Tx03. As these two receiver responses are covering an area close to each other one could expect that the measurements will be similar. For comparison, the azimuth data is also shown prior to decomposition. Instead the receiver is oriented to

be parallel with the active towline Tx03. It is evident that the decomposition of the azimuth data into a TM mode enables us to make use of these types of data together with true inline data.

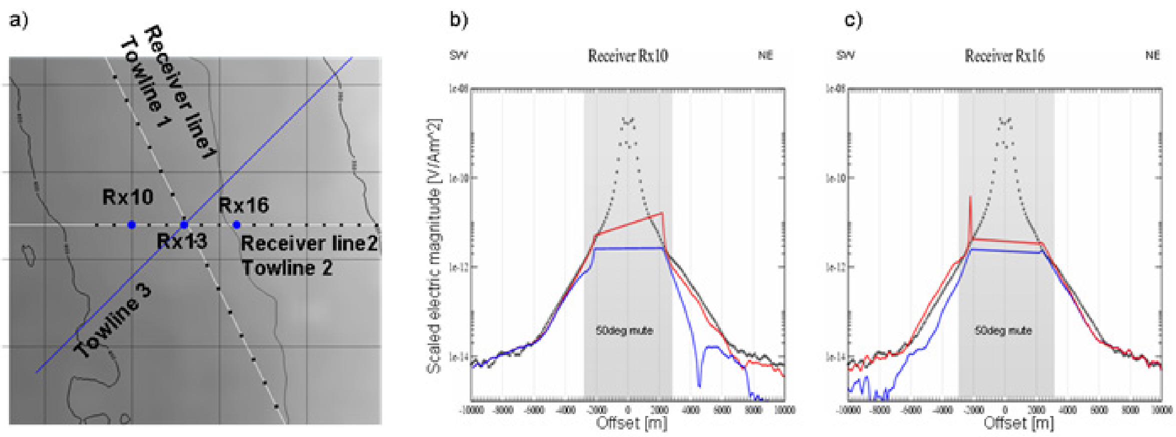

Figure 2. Bathymetry map with the survey layout. Black squares are receiver positions, solid lines are towlines. Receivers and corresponding towline discussed below are marked with blue (a). Figure b and c show Magnitude vs. Offset (MVO) for electric data at 1.0 Hz. Black circle is true inline data for receiver Rx13, red solid line is decomposed azimuth data and blue solid line is data prior to decomposition. Grey area indicates azimuth mute applied.

The benefit of decomposing azimuth data is seen by looking at a Normalized Magnitude vs. Offset (NMVO) map including both true inline data and decomposed azimuth data. This map is created by normalizing all receiver responses with a reference response and posting the NMVO value for a given offset at the midpoint between the source and receiver position (Ellingsrud et al., 2002). Figure 3a show such a map for NMVO values at 4 kilometer source-receiver offset. True inline data are posted along the receiver lines 1 and 2, while the decomposed azimuth data will map outside the receiver line. The NMVO values are consistent between the two data types and gives additional data coverage and information to the survey. Some azimuth data points are not comparable with the true inline data. These are recordings with small receiver-source offset giving a high azimuth angle and a small TM source component. Since these data points are uncertain they should be muted. Only data with source-receiver angle less than 50 degrees is shown in Figure 3b. This mute is shown as a grey area in Figure 2a and b.

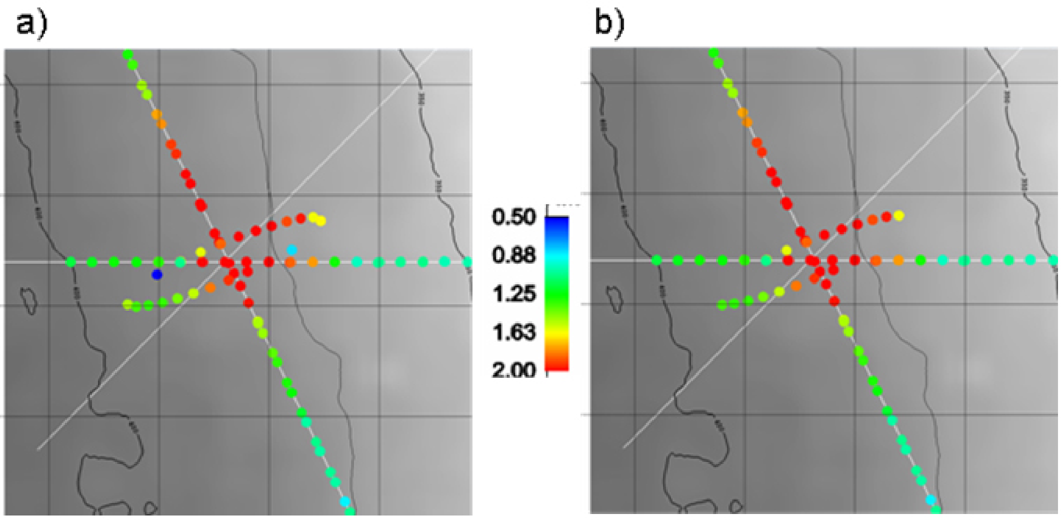

Figure 3. NMVO map at 4km source-receiver offset with true inline and decomposed data displayed together. No azimuth mute applied is shown in a, while data with azimuth angle larger than 50 degrees are muted in b. The two data types show consistent results and gives additional information to the survey.

Conclusions

A decomposition of SBL data into TE mode and TM mode can be very useful for direct comparison of data recorded with different azimuth angles. In particular it helps the interpretation of real data acquired with azimuth receivers. However, the method is based on a plane layered assumption, and must be used with caution in the presence of large azimuth angles.

Acknowledgment

We wish to thank Hydro O&E and emgs for the permission to publish the results.

References

Eidesmo, T., S. Ellingsrud, L. M. MacGregor, S. Constable, M. C. Sihna, S. Johansen, F. N. Kong, and H. Westerdahl,, 2002, Sea bed logging (sbl), a new method for remote and direct identification of hydro carbon filled layers in deep water areas: First Break, **20**, 144-152.

Ellingsrud, S., T. Eidesmo, S. Johansen, M. C. Sihna, L. M. MacGregor, and S. Constable, 2002, Remote sensing of hydrocarbon layers by seabed logging (sbl): The Leading Edge, **21**, 971-982.

Johnstad, S.E., B.A. Farrelly, and C. Ringstad, Seabed logging on the North Sea Troll Field, Offshore Technology Conference, 2-5 May 2005, Houston, Texas.