On the analysis of LOTEM time series from Israel and the preliminary 1D inversion of data

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Abbildung 1: Overview of measurement setups (A,B,C from left to right)

1. Data Processing of TEM time series from the first Israel survey

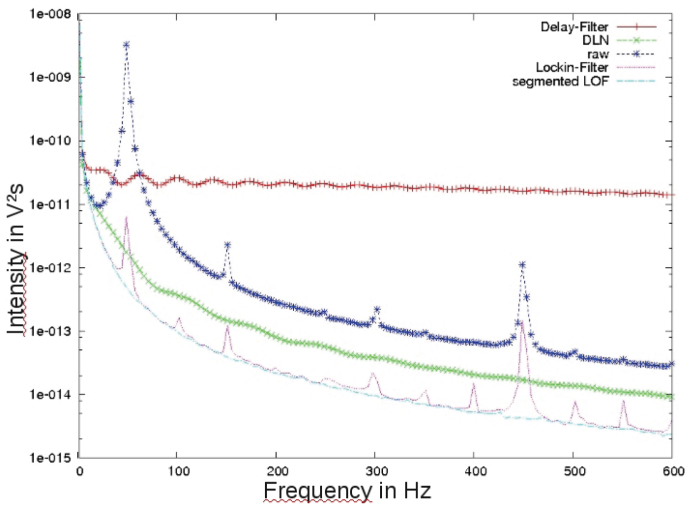

Abbildung 2: Power spectrum of Ex at station A/B before (blue asterisks) and after application of different filters

The measurement took place at the coast near Ashdod, Israel (fig.1), where the task is the detection of fresh groundwater bodies within the mediterranean submarine aquifers [3]. For that matter a 380 m long dipole emitting in a 50% duty cycle was used, located on the shoreline for stations A and C and at -300m offshore on the seabottom for station B. Receiver stations recorded four components of the EM field (Ex,Ey,$\dot{H}$y,$\dot{H}$z) with Summit receivers. Receivers at station C were set up 5 m beneath the water on the sea bottom.

- The measured transients consist of 4096 data points (DP) with a sample rate of 1/16 ms and 256 DP as onset. Switch time of Tx is $t_0 = 1500ms$.

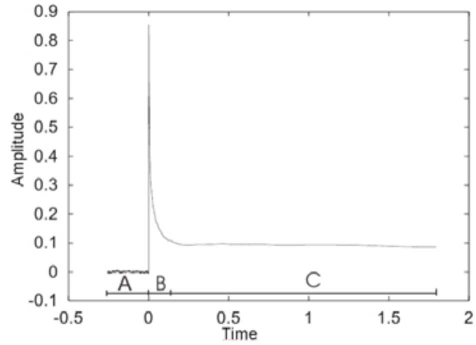

Abbildung 3: Parts of transient [5]

Noise measurements showed a dominant 50 Hz noise together with multiples (fig.2). The average noise power for each component is: $P_{N,Ex} = 0.2V^2, P_{N,Ey} = 0.02V^2, P_{N,\dot{H}y} = 4.8V^2, P_{N,\dot{H}z} = 0.2V^2$ (measured on land). Due to relative short offsets of 200-500 m between receiver and transmitter the signal is - except for Ey component - clearly visible in the raw transients.

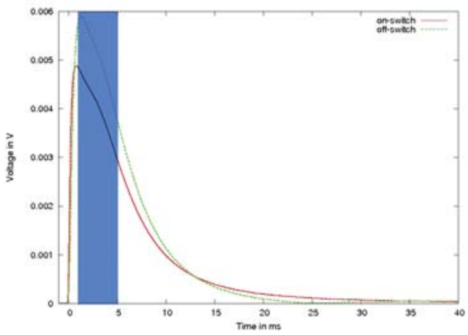

Abbildung 4: Stacked transients of only on-switches and only off-switches

2. Application of a segmented lockin filter

First step of the processing was to filter out the 50 Hz noise. This was done using a segmented lockin filter (LOF)

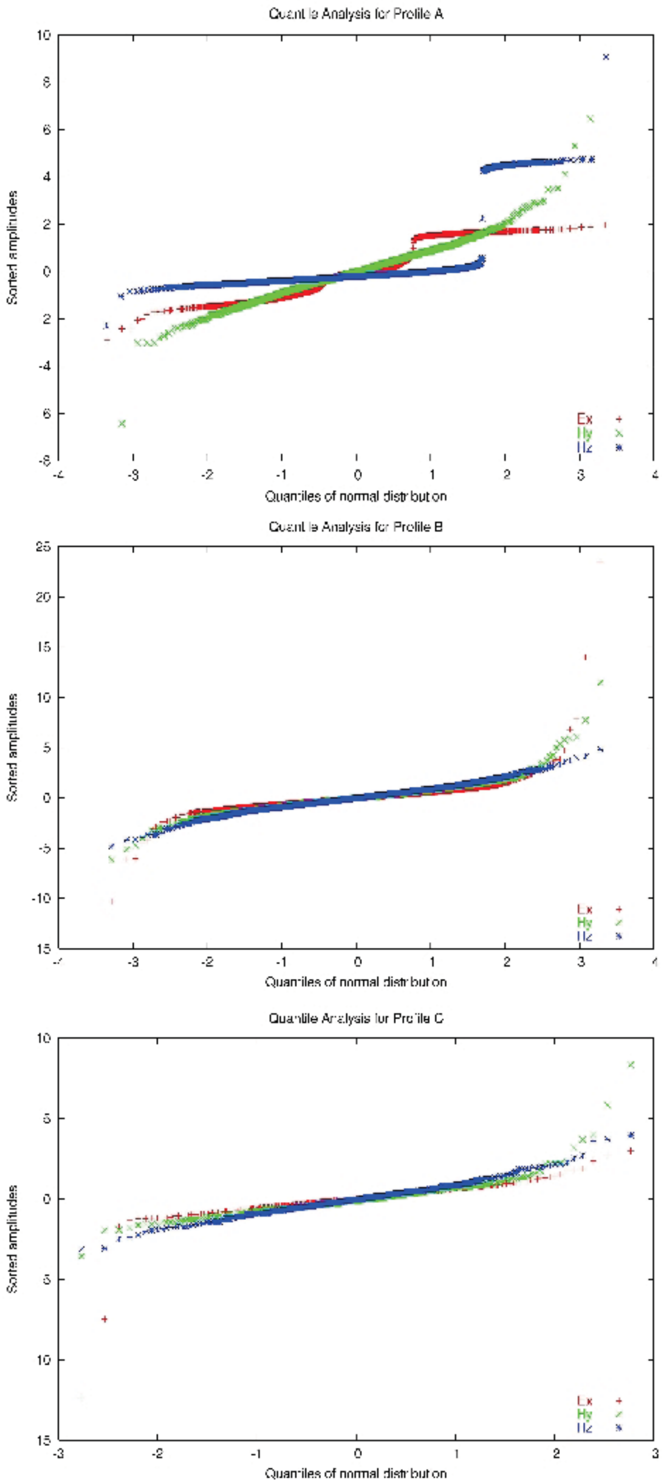

Abbildung 5: Quantiles of normal distribution for stations A,B,C from top to bottom

[1]. It fits harmonics in segments of 60 ms to the data and subtracts them. Amplitude and phase are computed with Fourier series expansion. Regarding the high dynamic of the transient at the time of the switch (e.g. switch on in part B of fig.3) the fitting is being done in parts A and C only [5]. In addition a 3rd degree polynomial is fitted in part C to simulate the descent of the transient. Other filters like Delay Lower Nyquist frequency (DLN), Delay filter or (not segmented) Lockin-Filter [1, 5] remove the noise less efficient for this dataset (fig.2).

- Application of the filter reduced the noise power, computed at the end of the time series, to $P_{N,Ex} = 0.2nV^2, P_{N,\dot{H}y} = 0.2V^2$ and $P_{N,\dot{H}z} = 1.4nV^2$.
- The DC bias is removed by levelling the data in the onset after filtering.

Due to the short onset and the resulting error in determining the DC bias the inverted conductivities will exhibit a slight shift [4]. Higher accuracy can be achieved by averaging over a complete transmitter period.

3. Analysis of data distribution

The data measured with 50% duty cycle consists of two different sets of transients. One set is created when switching the current off and another when switching on. Because the given transmitter system shows a much shorter ramp time for off-switches, these transients are generally less broad and have a higher peak than those created by switch-on (fig.4). Cluster analysis [2] in the blue area of fig.4 resulted in two equally populated groups identified as on and off switches by cross checking the Ex component.

The distribution of the data in terms of probability can be visualized with quantiles of gauss distribution (fig.5). The mean values of all transients in a certain time segment are sorted by ascending value and are then plotted against an axis, which is scaled in such a way that normal distributed data will show as a line of slope 1. This has been done for each component over a 62 ms window at the end of each switch-off time series, which have been filtered and levelled beforehand.

The top graph shows that the distribution of Hz (and - to a smaller extent - Ex) at station A is dominated by a step. However, cluster analysis could not sort out these time series. The other stations show a much better result with normal distributed data for all components.

4. Stacking and 1D Occam inversion

After the data is analysed and if it needs no further editing (like correction of the right switch moment) it is ready to be stacked and smoothed.

- The data was stacked selectively omitting the highest and lowest 5% of the values per DP.

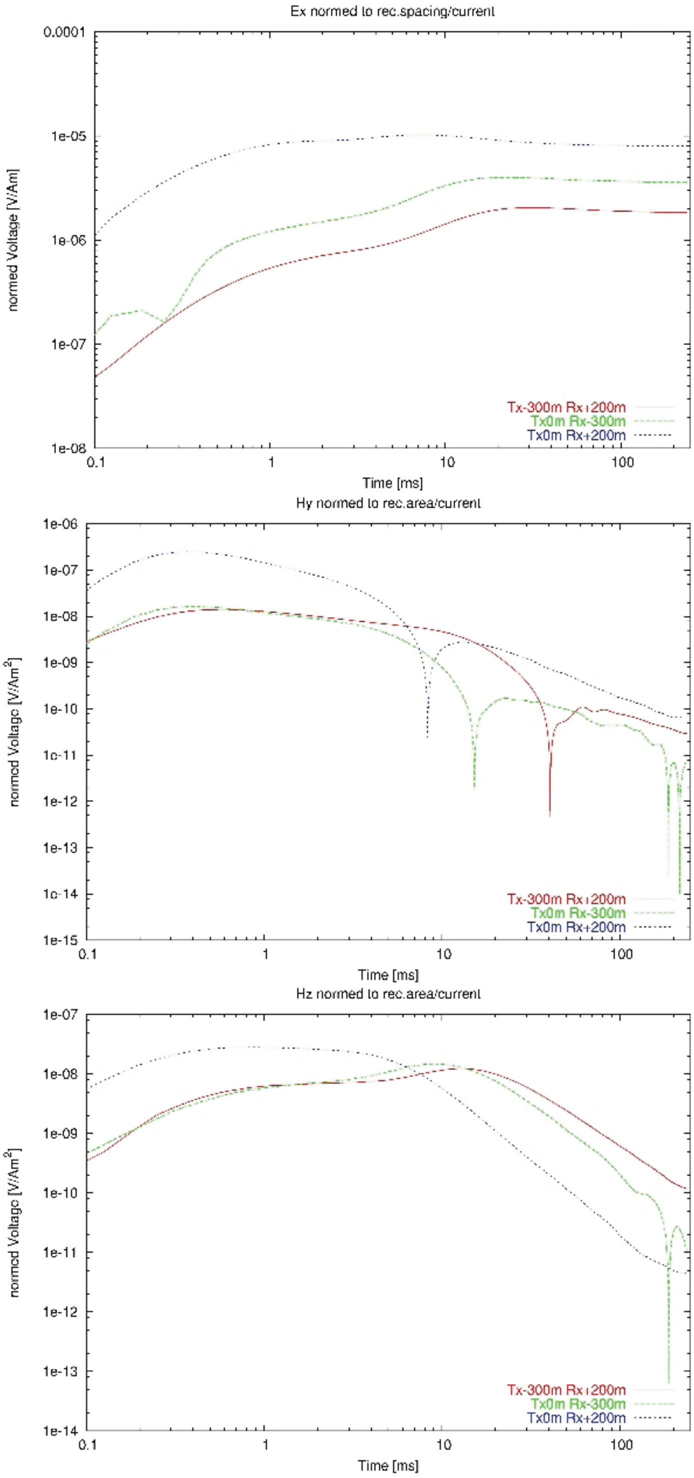

Abbildung 6: Normalized stacked transients sorted by component

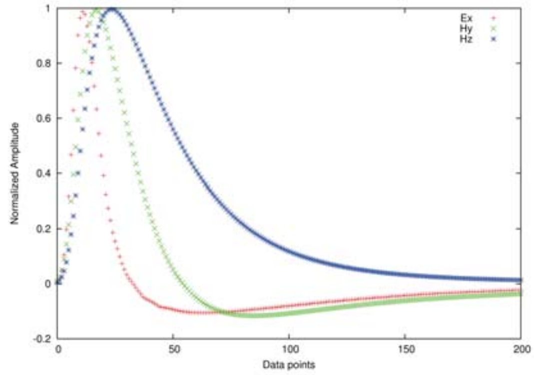

Abbildung 7: Normalized system responses measured broadside

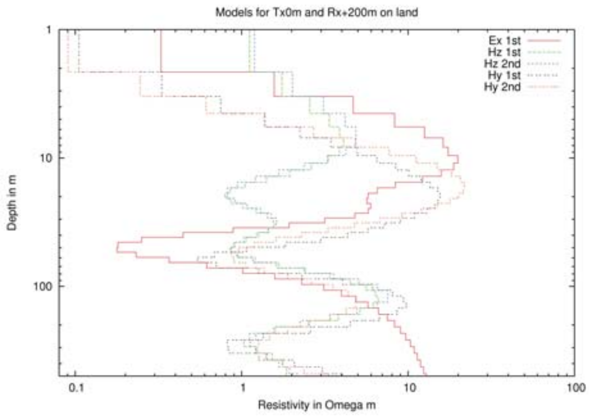

Abbildung 8: Result of Occam inversion of data at station A for 1st and 2nd order roughness

- Afterwards it was smoothed with a dynamic Hanning window function.

Fig.6 shows the normalized transients of the stations sorted by components. Field setup is according to fig. 1. Ex shows a noticeable "bump" in early times at receiver station C, which could be a 2D effect of the water-land interface. More on interpretation of this data can be found in *Lippert et al., 2010*.

System responses measured on land are shown in fig.7 and are used for convolution in forward calculation. Fig.8 shows the Occam inversion results for station A. All components show a good conductor at about 80 m depth between two more resistive layers at approximately 10 m and 150 m depth, which represent the sought fresh water bodies. $\dot{H}z$ could resolve a second good conductor, which is not visible in $\dot{H}y$ and only indicated in Ex. These results are in good agreement with the SHOTEM measurements of this area.

5. Future research

Some system responses measured broadside include negative values. This is supposed to be a geometric phenomenom related to the 'air wave'. Future measurements of the system response will therefore be conducted in the laboratory.

For the geometries of stations B and C there are at the moment no inversion codes available, therefore they will be interpreted using 2D forward modelling. Joint inversions using different LOTEM components will be realized.

6. References

Literatur

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[4] A. Osman. Interpretation der LOTEM-Daten in näherer Umgebung von den Bohrungen des KTB. *Diploma Thesis, Institute for Geophysics, University of Cologne*, 1995.

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