KHFFILT

Karous-Hjelt and Fraser filtering of VLF measurements

Version 1.1a (c) 2004, Markku Pirttijärvi

Introduction:

The KHFFILT program can be used to perform Karous-Hjelt and Fraser filtering on geophysical VLF (very-low-frequency) data. In VLF method two orthogonal components of the magnetic field are measured, and normally the tilt angle, α, and ellipticity, e, of the vertical magnetic polarization ellipse are derived. Real (in-phase) and imaginary (quadrature) components, however, are traditionally used in Scandinavia and also in KHFFILT program. These components are based on the tilt angle and ellipticity as: $Re = \tan(\alpha) \cdot 100$ % and $Im = e \cdot 100$ %.

The KHFFILT program requires a PC with 32-bit Windows 9x/NT4/2000/XP operating system and a graphics display of at least 1024×800 resolution. Memory requirements and processor speed and are not critical, since the program uses dynamic memory allocation and the filtering (and contouring) is fast to perform even on slow computers. The KHFFILT program has a simple graphical user interface (GUI) that can be used to change some parameters, to handle file input and output, and to visualize the original and filtered VLF responses. The user interface and the data visualization are based on the DISLIN graphics library.

Installing the program:

The program requires following files:

KHFFILT.EXE	the executable file
DISLIN.DLL	dynamic link library for the DISLIN graphics

The distribution file (KHFILT.ZIP) contains also a short description file (_README.TXT), this user's manual (KHFFILT_MANU.PDF) and an example data file (EXAMPLE.DAT). To install the program, create a new directory and copy or unzip (Pkzip/Winzip) the distribution files there. To be able to start the program from a shortcut that locates in a different directory move or copy the DISLIN.DLL file into the WINDOWS\SYSTEM folder or somewhere where a path always exists.

Starting the program:

On startup the KHFFILT program reads the DISLIN graphics parameters from the KHFFILT.DIS file. If the file cannot be found when the program starts, a new file with default parameter values is created automatically. The program then displays the standard Windows "Open file" dialog to

select the VLF input data file. The program then builds up the graphical user interface shown in the Appendix and creates the VLF response graph (not shown in the Appendix).

The main window of the KHFFILT application has two menus. The "File" menu has nine options:

Read VLF data	open and read in existing VLF data.
Save VLF data	save the (interpolated) VLF data into a file.
Save Fraser data	save the Fraser filetered VLF data into a file.
Save Karous data	save the Karous-Hjelt filtered data into a file.
Read disp.	read in new graph parameters from a *.DIS file.
Save Graph as PS	save the graph in Adobe's Postscript format.
Save Graph as EPS	save the graph in Adobe's Encapsulated Postscript format.
Save Graph as PDF	save the graph in Adobe's Acrobat PDF format.
Save Graph as WMF	save the graph in Windows metafile format.

Selecting these menu options brings up a typical Windows file selection dialog that can be used to provide the name of the file for open/save operation. Data files are stored in text format. The graphs are saved as they appear on the screen in landscape A4 size.

The "Exit" menu has only one item, which is used to confirm the exit operation. On exit the FRASER.OUT and KAROUS.OUT files contain the Fraser and Karous-Hjelt filtered data, respectively. Errors that are encountered before the GUI starts up are reported in the KHFFILT.ERR file. Inside GUI mode run-time errors are displayed on the screen.

Program controls:

The three push buttons are used to change the data displayed in the graph area. The "Show data" button selects the original VLF data, "Show Fraser" button displays the Fraser filtered data and "Show K-H contours" displays the Karous-Hjelt filtered pseudosections. Note that since both filtering methods are based on the real component of the VLF data, the program reads only one data component from the input file (see the chapter "File formats" for more information).

The "Spacing" text field defines the step between profile points. Both Fraser and Karous-Hjelt filtering require that the data have equal distances between the measurement points. To achieve this, the data are always interpolated. The default value is based on the original data (profile length divided by number of points minus one). However, increasing this value will smooth the filtered data and improve the quality of the Karous-Hjelt filtered pseudo-sections in particular. Note also that the "Save VLF data" menu-item, saves the interpolated data and not the original data.

The "Max depth" and "Skin-depth" text fields are related to Karous-Hjelt filtering. The first one defines the depth extent of the filtering, i.e., the maximum length of the filter. Note that if the data contains several closely spaced conductors, a long filter (large Max depth-value) may not be advantageous because it can combine the two separate targets at large depths. Note also that in VLF method the depth of investigation is typically less than 100 m, so there is no need to use large maximum depth values. The "Skin-depth" value defines an additional enhancement by normalizing the currents with the skin depth, i.e., it tries to take the effect of the attenuation of the EM field into

account. The value should be based on the skin depth of the host medium (typically between 50-1000 m). The default value is zero, which means that the skin depth normalization is not used at all.

The "Update"-button must be used to validate the changes made in the abovementioned text fields.

The "Max z-level" and "Min z-level" scroll bars are used to change the scaling of the maximum and minimum contour values in the Karous-Hjelt filtered pseudosection. The contour plot has a fixed number (21) of contour levels.

The "Reverse sign" push button reverses the sign of the VLF-data component. Consequently, the sign of the Fraser and Karous-Hjelt filtered data also changes. Note that the sign conventions are not implicit in VLF measurements. For practical reasons, however, it is advantageous to denote conductive targets with positive Fraser and Karaous-Hjelt filtered anomalies. The European practice is to use red color for conductive (hot) targets.

The "Gray/Color" push button can be used to change between grayscale or color scale (rainbow) in the Karous-Hjelt filtered pseudosections.

File formats:

Before starting up the program make sure that your input data files (*.DAT) are formatted properly. The following example illustrates the format of the input VLF data file.

```
Synthetic VLF data

30 2

  20.000   2.349  -14.636  2222.633  37.753
  40.000   3.731  -16.339  2159.510  38.755
  60.000   5.763  -18.146  2079.178  39.902
  80.000   8.158  -20.152  1981.082  41.240
  ...
 580.000   1.003   10.426  2370.703  35.563
 600.000   1.490    9.340  2394.223  34.925
```

Lines 2 and 4 are used for comments and can be left empty. The first line defines a header text (max. 40 characters). The 3.rd line defines the number data points on the profile (NOP) and the column index (ICO) for the component of the VLF data that is to be processed (real or imaginary). The next NOP lines define the profile coordinate (X, meter) and the measured data values.

There is no (practical) limit for the number of data points, since dynamic memory allocation is used. The header text is used as a second line in the response graph title. If the header text line is empty the default title in the KHFFILT.DIS file is used instead. The profile coordinates must be in continuously ascending or descending order. If they are in descending order, the whole profile is reversed automatically. If the step between the first two profile points X2-X1 < 0.5, the profile coordinates are converted from kilometers to meters (multiplied by 1000). Note also that the data file can contain several data columns, of which one is read for processing. This means that the same data file can contain, for example, VLF-R apparent resistivity and phase (as in the example above).

Manual editing of the column indices is (currently) required to choose the correct data column for the KHFFILT program.

The results are saved to text files in column format. The Fraser filtering results are stored in two columns that refer to the profile coordinate and the filtered values. The Karous-Hjelt filtering results are stored in three columns that refer to the profile and depth coordinate and the filtered value. Note that the Fraser filtered data does not have the same profile length as the original data, and that the filtered data are placed between the original (or interpolated) data points. Likewise, the profile positions of Karous-Hjelt filtered data are horizontally shifted from depth to depth. For historical reasons the #-character is used in results file to comment out lines for the Gnuplot plotting program.

Graph options:

Several graph parameters (see Appendix) can be changed by editing the KHFFILT.DIS file. Thus, the resulting graphs can be localized into any language. Thus, the resulting graphs can be localized into any language. Note that the format of the KHFFILT.DIS file must be preserved. If the format of the file should become invalid, one should delete the file and a new one with default parameter values will be generated automatically the next time the program is started. The file format and default parameter values are shown below.

```
  40   40   40
 400  300   0.80 0.67
   0  -50.  50.

VLF measurement
Test data
Fraser filtering
Karous-Hjelt filtering
Response
Distance (m)
Real component
Imag component
Depth (m)
unnormalized
```

- The 1.st line defines three character heights. The first one is used for the main title and the graph axis titles, the second is used for the axis labels, the third is used for the plot legend text.
- The 2.nd line defines first the x- (horizontal) and y- (vertical) position of the origin of the main graph (in pixels). The third and the fourth parameter define the length of the x- and y-axis relative to the size of the total width and height of the plot area (eg. 0.5= 50 % of the width or height), which is equal to 2970×2100 pixels (landscape A4).
- The 1.st parameter on the 3.rd line defines whether grayscale (0) or colors (1) should be used for the Karous-Hjelt pseudosections. The other two parameters define the initial minimum and maximum values of the pseudosection scale bar (%). These values are stored after program exit.
- The fourth line should be left empty.
- The following lines define various text items of the graph (max. 40 characters).
  - Main titles of the VLF graph.
  - The second title line of all graphs.

- Main title of the Fraser graph.
- Main title of the Karous-Hjelt graph.
- Two axis names of the VLF and Fraser graphs.
- Two legend names of the VLF and Fraser graphs.
- The name of the vertical axis of the Karous-Hjelt graph.
- The last line defines the additional text used in the color scale of the Karous-Hjelt filtered data graph to represent unnormalized data (Skin depth= 0.0).

Additional information

Originally, I wrote the KHFFILT program in January 2002 as a hobby. I revised the program in September 2002 when I had received a grant from Tönning Foundation. The program is based on an older KHF processing program that has been developed over the last few years by several persons at the University of Oulu (e.g., Juha Mursu, Kari Komminaho, and me). If I recall it right, the idea of adding attenuation with depth (based on skin depth) came from Prof. Pertti Kaikkonen. Information about theory of the filtering methods and VLF method in general can be found from:

Fraser, D.C., 1969: Contouring of VLF-EM data. Geophysics, 34, 958-967.
Karous, M. and Hjelt, S.-E., 1983: Linear filtering of VLF dip-angle measurements, Geoph. Prospecting, 31, 782-794.
McNeill, J.D. and Labson, V.F. 1992: Geological mapping using VLF-radio fields. In M.N. Nabighian (Ed.): Electromagnetic methods in applied geophysics, Volume 2, Application. SEG.

The KHFFILT program is written in Fortran-90 style using Compaq Visual Fortran 6.6. The graphical user interface is based on the DISLIN graphics library (version 7.6) by Helmut Michels. The program distribution includes the DISLIN.DLL file that is required for the GUI. The official WWW homepage of DISLIN is at "http://www.dislin.de". Since the DISLIN graphics library is independent form the operating system the KHFFILT program could be compiled on other operating systems (Solaris, Linux) without any modifications.

I'm going to make the source code available for free, but I do not intend to provide any support for the program. If you find the computed results erroneous or if you have suggestions for improvements, please, inform me.

Terms of use and disclaimer:

You can use the KHFFILT program free of charge. If you find the program useful, please, send me a postcard. The program is provided as is. The author (MP) and the University of Oulu disclaim all warranties, expressed or implied, with regard to this software. In no event shall the author or the University of Oulu be liable for any indirect or consequential damages or any damages whatsoever resulting from loss of use, data or profits, arising out of or in connection with the use or performance of this software.

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Appendix: