EM3DANI File Format Instruction

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1 Input File Formats

There are two files required to run EM3DANI, the model file and the data file. A right handed Cartesian coordinate system with the z axis pointing down is used in all the input/output files.

1.1 Model file format

The model file describes the mesh geometry and model conductivity, and its format is independent of the type of EM problems (MT and CSEM have the same model file format).

1.1.1 Isotropic case

Following is an example model file for an isotropic model:

```
# Format:           EM3DModelFile_1.0
# Description:      The COMMEMI-3D2 model.
# ...
NX:     36
40000 ... 40000
NY:     58
40000 ... 40000
NAIR:    7
100 ... 100000
NZ:     36
50 ... 40000
Resistivity Type:  Conductivity
Model Type:        Linear
sigma:
  1.0000e-01 ... 1.0000e+01
Origin (m):    120000.00    120000.00         0.00
```

At the beginning of file, the lines preceded with '#' and empty lines will be ignored by the code, so that one can put any comment about this file at the beginning. The remainder of the model file will be read in by the code, following is a brief description.

- **NX**, **NY**: number of cells in x- (North-South) and y- (East-West) directions, respectively, followed by the cell sizes (in meters) in corresponding directions. the order of the cell sizes is from south to north for x-direction and from west to east for y-direction.
- **NZ**: number of earth cells in z- (Bottom-Top) direction (not including the air cells), followed by the cell sizes (from top to bottom) in z-direction.
- **NAIR**: number of air cells in z-direction, followed by the cell sizes (from bottom to top) in z-direction. Note the order of the air cell sizes is different from that of the earth cell sizes.
- **Resistivity Type**: indicates the model parameters given in this file is '`Conductivity`' or '`Resistivity`'.
- **Model Type**: indicates the form of the parameters is '`Linear`' or '`Log`' (log base 10).
- **sigma**: conductivities/resistivities of cells, not including the air cells.
- **Origin**: the offsets of the global origin from southern, western, and upper boundaries of the model (not including air), respectively. The global origin means it is also the origin in the data file.

Note that the order of the cell conductivities is that they vary fastest in x-direction and slowest in z-direction.

1.1.2 Triaxial anisotropy case

Following is an example model file for a triaxial anisotropic model:

```
# Format:            EM3DModelFile_1.0
# Description:       The marine canonical 1D anisotropic model: overburden TIV 1/1/10.
# ...
NX:     52
6400 ... 6400
NY:    114
6000 ... 6000
NAIR:    7
100 ... 6400
NZ:     60
100 ... 6400
```

```
Resistivity Type:  Conductivity
Model Type:        Linear
Anisotropy Type:   Anisotropy
sigmax:
  3.3000e+00 ... 1.0000e+00
sigmay:
  3.3000e+00 ... 1.0000e+00
sigmaz:
  3.3000e+00 ... 1.0000e+00
Origin (m):     14600.00     16000.00        0.00
```

Different from the isotropic case, for anisotropic case the type of the conductivity/resistivity must be explicitly told by adding one line (`Anisotropy Type:   Anisotropy`) in the model file. For triaxial anisotropy, each cell has three principal conductivities $\sigma_{x'}$, $\sigma_{y'}$, and $\sigma_{z'}$. Thus, the model file has three corresponding keywords: `sigmax`, `sigmay` and `sigmaz`.

1.1.3 Generally anisotropic case

Following is an example model file for generally anisotropic model:

```
# Format:          EM3DModelFile_1.0
# Description:     The 1D anisotropic model used by Josef Pek (2002)
# ...
NX:     22
40000 ... 40000
NY:     40
40000 ... 40000
NAIR:    7
100 ... 100000
NZ:     95
500 ... 60000
Resistivity Type: Conductivity
Model Type:       Linear
Anisotropy Type:  Anisotropy
sigmax:
1.00000e-04 ... 1.00000e-02
sigmay:
1.00000e-04 ... 1.00000e-02
sigmaz:
1.00000e-04 ... 1.00000e-02
strike:
```

```
0.00 ... 0.00
dip:
0.00 ... 0.00
slant:
0.00 ... 0.00
Origin (m):    120000.00    120000.00        0.00
```

For generally anisotropic case, the cell conductivity is described by three principal conductivities $\sigma_{x'}$, $\sigma_{y'}$, and $\sigma_{z'}$, and three Euler angles: anisotropic strike α, dip β and slant γ angles. Thus, the model file has three corresponding keywords for Euler angles: `strike`, `dip` and `slant`.

1.2 Data file format

The data file contains information about sources (CSEM only), site locations, frequencies/periods and data types, which is required by forward modeling. Besides, since the data file was formatted to be compatible with a future inversion code, it contains data values and data errors. Data values and errors won't be used by forward modeling, so their values can be set arbitrarily. Because, CSEM and MT have different sources and data types, their data file formats are designed to be different.

1.2.1 CSEM data file format

Following is an example CSEM data file:

```
# Format:           CSEMData_1.0
# Description:      inline and broadside, two frequencies.
Dipole Length:        1.0      (optional, default value < 10)
Phase Convention:     lead     (optional, default value is "lead")
Source Location (m):         2
#           X            Y            Z      Azimuth          Dip
         0.00         0.00       950.00        90.00         0.00
         0.00         0.00       950.00         0.00         0.00
Receiver Location (m):      101
#           X            Y            Z
         0.00     -2000.00      1000.00
    ...
         0.00      8000.00      1000.00
Frequencies (Hz):       2
    2.50000e-01
    1.00000e+00
DataType:     6
```

```
Ex
Ey
Ez
Bx
By
Bz
Data Block:    2424
# FreqNo.  TxNo.   RxNo.   DTypeNo.  RealValue       ImagValue       Error
     1        1       1        1    1.000000e+00    1.000000e+00    2.000000e-02
     1        1       1        2    1.000000e+00    1.000000e+00    2.000000e-02
     1        1       1        3    1.000000e+00    1.000000e+00    2.000000e-02
     1        1       1        4    1.000000e+00    1.000000e+00    2.000000e-02
     1        1       1        5    1.000000e+00    1.000000e+00    2.000000e-02
     1        1       1        6    1.000000e+00    1.000000e+00    2.000000e-02
     1        1       2        1    1.000000e+00    1.000000e+00    2.000000e-02
     1        1       2        2    1.000000e+00    1.000000e+00    2.000000e-02
     1        1       2        3    1.000000e+00    1.000000e+00    2.000000e-02
     1        1       2        4    1.000000e+00    1.000000e+00    2.000000e-02
     1        1       2        5    1.000000e+00    1.000000e+00    2.000000e-02
     1        1       2        6    1.000000e+00    1.000000e+00    2.000000e-02
     ...
     2        2     101        6    1.000000e+00    1.000000e+00    2.000000e-02
```

The following is an brief explanation of the keywords of the data file.

- **Dipole Length**: followed by a real value, representing the length (in meters) of the electric dipole source. If the length is bigger than 10, then the transmitter will be treated as a finite length line source rather than a point dipole. This is optional, and the default value is less than 10, which means by default the source is regarded as a point dipole.

- **Phase Convention**: followed by a string. Phase "`lead`" corresponds to the e^{iwt} time dependence, while phase "`lag`" corresponds to the e^{-iwt} time dependence. This is optional, and the default value is "`lead`".

- **Source Location**: followed by an integer, which is the number of transmitters. The x, y, z locations (in meters), the rotation angle (degrees clockwise from x) and the dip angle (degrees positive down) of transmitters are listed below it.

- **Receiver Location**: followed by an integer, which is the number of observation sites. The x, y, z locations (in meters) of sites are listed below it.

- **Frequencies**: followed by the number of frequencies, and the frequency values (in Hz) are listed below it.

- **DataType**: specify the data types that will be computed by forward modeling (or used by inversion). For CSEM the allowed **DataType**s are the complex electromagnetic fields (don't have to be all six components but any combination of them).

- **Data Block**: followed by the number of data points, the maximum value of which is $N_{freq} * N_{source} * N_{site} * N_{type}$. A table of data parameters is given below it. The first column of the data table is the frequency index for each datum, the second column is the source/transmitter index, the third column is the site index and the fourth column gives the data type index. The fifth and sixth columns corresponds to the real and imaginary parts of the data. The last column is the standard error. Note that the last three columns won't be used by forward modeling.

1.2.2 MT data file format

Following is an example MT data file:

```
# Format:          MT3DData_1.0
# Description:     generated at 21-Nov-2019 14:20:21
Phase Convention:    lead     (optional, default value is "lead")
Receiver Location (m):      55
#          X            Y            Z
    -8000.00    -10000.00         0.00
    ...
     8000.00     10000.00         0.00
Frequencies (Hz):      31
    1.00000e+02
    ...
    1.00000e-04
DataType:  Rho_Phs
DataComp:     4
RhoXY
PhsXY
RhoYX
PhsYX
Data Block:    6820
# FreqNo.  RxNo.   DCompNo.    Value          Error
     1        1       1    1.000000e+00    2.000000e-02
     1        1       2    1.000000e+00    2.000000e-02
     1        1       3    1.000000e+00    2.000000e-02
     1        1       4    1.000000e+00    2.000000e-02
     1        2       1    1.000000e+00    2.000000e-02
```

```
 1        2       2    1.000000e+00    2.000000e-02
 1        2       3    1.000000e+00    2.000000e-02
 1        2       4    1.000000e+00    2.000000e-02
 ...
31       55       4    1.000000e+00    2.000000e-02
```

Compared with the CSEM data file, the MT data file does not contain information about sources. Besides, MT has different data types (Impedance, apparent resistivity and phase, and tipper) from CSEM, and each its data type contains multiple components (**DataComp**). The allowed values of **DataType** and **DataComp** are listed in the following table:

DataType	DataComp	Real or complex
Impedance	ZXX, ZXY, ZYX, ZYY	Complex
Impedance_Tipper	ZXX, ZXY, ZYX, ZYY, TZX, TZY	Complex
Rho_Phs	RhoXX, PhsXX, RhoXY, PhsXY, RhoYX, PhsYX, RhoYY, PhsYY	Real
Rho_Phs_Tipper	RhoXX, PhsXX, RhoXY, PhsXY, RhoYX, PhsYX, RhoYY, PhsYY, RealTZX, ImagTZX, RealTZY, ImagTZY	Real

2 Output File Formats

The output files may include a forward data file(*.dat), or a forward response file(*.resp), and/or a forward field file(*.field). All these files contains forward modeling results, but in different types/forms.

- **forward data file** has exactly the same format as the input data file, contains forward responses at selected data points (i.e. frequencies/sources/receivers/data types) matching the input data. This type of file is usually output in an inversion process, used to evaluate the misfit between the predicted (output) data and the observed (input) data.

- **forward response file** is obtained by running the code with the 'forward only' (FO) mode, contains full forward responses (i.e. for all frequencies/sources/receivers/data types listed in the input data file). It is much easier to read forward responses from a forward response file than a forward data file. Thus, it is highly recommended to run the code with FO mode.

- **forward field file** contains the solved electric fields defined at cell edges of both modes of all frequencies and sources, which are the solutions of linear systems and independent of receiver locations and data types. Usually this type of file is not needed (and they can have big size), but it is useful when you want to plot the fields (such as Figure 9 and 11 in the paper).

2.1 Forward response file format

Because CSEM and MT have different data types, they also have different formats of response file. Following is an example CSEM response file

```
# Format:          CSEMResp_1.0
# Description:     Response file generated at Sun 03 Nov 2019 08:40:23 PM CST
Source Type:         HED
Phase Convention:    lead
Source Location (m):        2
#          X            Y            Z      Azimuth          Dip
        0.00         0.00       950.00        90.00         0.00
        0.00         0.00       950.00         0.00         0.00
Receiver Location (m):     101
#          X            Y            Z
        0.00     -2000.00      1000.00
        ...
        0.00      8000.00      1000.00
Frequencies (Hz):       2
    2.50000e-01
    1.00000e+00
DataType:     6
Ex
Ey
Ez
Bx
By
Bz
Data Block:     404
# FreqNo.  TxNo.   RxNo.            Ex(Re,Im)                        Ey(Re,Im)              ...
     1        1       1      2.042471e-25 -4.682482e-25    4.818843e-12  1.046415e-12       ...
     1        1       2     -8.499339e-26  1.430610e-25    5.364407e-12  8.946792e-13       ...
     1        1       3      1.841974e-25 -1.972745e-25    6.074221e-12  6.052666e-13       ...
     ...
     2        2     101     -4.415483e-16 -2.883927e-15   -5.104415e-29 -2.290809e-29       ...
```

and following is an example MT response file

```
# Format:          MT3DResp_1.0
# Description:     Response file generated at Mon 18 Nov 2019 04:24:07 PM CST
Phase Convention:    lead
```

```
Receiver Location (m):      55
#          X           Y            Z
    -8000.00    -10000.00         0.00
    ...
     8000.00     10000.00         0.00
Frequencies (Hz):      31
    1.00000e+02
    ...
    1.00000e-04
DataType:  Rho_Phs
DataComp:     4
RhoXY
PhsXY
RhoYX
PhsYX
Data Block:     1705
# FreqNo.  RxNo.        RhoXX          PhsXX         RhoXY          PhsXY        ...
     1        1          0.77         178.41      10373.86          43.93        ...
     1        2          0.77         178.42      10373.86          43.93        ...
     1        3          0.77         178.42      10373.86          43.93        ...
     ...
    31       55          0.00         114.80        155.08          54.61        ...
```

In the response file, the information about sources, site locations, frequencies/periods and data types is simply copied from the input data file. Except that, the rest content is a table of the response, which is quite easy to understand. Unlike the data table in the data file, one row of the response table corresponds to all data types of a single frequency of a single site.

2.2 Forward field file format

CSEM and MT have the same format of forward field file. Following is an example:

```
# Frequencies:     7
# Transmitters:    2
Grid dimension:    72    54    43

Frequency #:    1
Transmitter #:  1
x-component: real
   1.000000e+00   1.000000e+00 ...
x-component: imag
```

```
   0.000000e+00   0.000000e+00 ...
y-component: real
   0.000000e+00   0.000000e+00 ...
y-component: imag
   0.000000e+00   0.000000e+00 ...
z-component: real
   0.000000e+00   0.000000e+00 ...
z-component: imag
   0.000000e+00   0.000000e+00 ...
Transmitter #:    2
...
Frequency #:    2
Transmitter #:  1
...
```

The format is very easy to understand. At the beginning the number of frequency, the number of polarization mode (transmitter), and the grid dimension are given. Next, the real and imaginary parts of E_x, E_y and E_z of each frequency and each polarization mode are listed in turn.