# A Standard for Exchangeable Magnetotelluric Data and Metadata

Working Group for Data Handling and Software - PASSCAL Magnetotelluric Program[1]

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**Version 0.0.1b – May 2020***

## Contents



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# 1 Introduction

Researchers using magnetotelluric (MT) methods lack a standardized format for storing time series data and metadata. Commercially available MT instruments produce data in formats that range from proprietary binary to ASCII, and recent datasets from the U.S. MT community have utilized institutional formats or heavily adapted formats like miniSEED. In many cases, the available metadata for these time series are incomplete and only loosely standardized, and overall these datasets are not "user friendly". This lack of resources impedes the exchange and broader use of these data beyond a small community of specialists.

The IRIS PASSCAL MT facility maintains a pool of MT instruments that are freely available to U.S. Principal Investigators (PIs). Datasets collected with these instruments are subject to data sharing requirements, and an IRIS working group advises the development of sustainable data formats and workflows for this facility. Following in the spirit of the standard created for MT transfer function datasets, this document outlines a new metadata standard for MT time series. This standard is a key pillar of MTH5, a new data format which we propose for the international community of MT practitioners. Further information regarding MTH5 will be available later in 2020.

The Python 3 module written for these standards are found at `https://github.com/kujaku11/MTarchive/tree/tables`.

# 2 General Structure

The metadata for a full MT dataset are structured to cover details from single channel time series to the full survey. For simplicity each of the different scales of an MT survey and measurements have been categorized starting from largest to smallest (Figure 1. These categories are: `Survey`, `Station`, `Run`, `DataLogger`, `Electric Channel`, `Magnetic Channel`, and `Auxiliary Channels`. Each of these are described in subsequent sections.

## 2.1 Metadata Keyword Format

The metadata key names should be self explanatory and they are structured as follows: `{category}.{name}`, where:

- `category` refers to a metadata category that has common parameters, such as `location` which will have a latitude, longitude, and elevation $\longrightarrow$ `location.latitude`, `location.longitude`, and `location.elevation`. These can be nested, for example `positive.location.latitude`
- `name` is the description name, where words should be separated by an underscore, e.g. `data_quality`.

Alternatively, the metadata names can be nested under category headings as commonly done in XML or JSON formats. See examples below for various flavors of ways to represent the metadata.

Table 1: Permissible values for data types

| **Data Type** |
| --- |
| String |
| Double (float) |
| Integer |
| Boolean |

## 2.2 Formatting Standards

Specific and required formatting standards for location, time and date, and angles are defined below.

### 2.2.1 Time and Date Format

All time and dates are given as an ISO formatted date-time string in the UTC time zone. The ISO date time format is `YYYY-MM-DDThh:mm:ss.ms+00:00`. Milliseconds can be accurate to 6 decimal places. Dates are formatted `YYYY-MM-DD`.

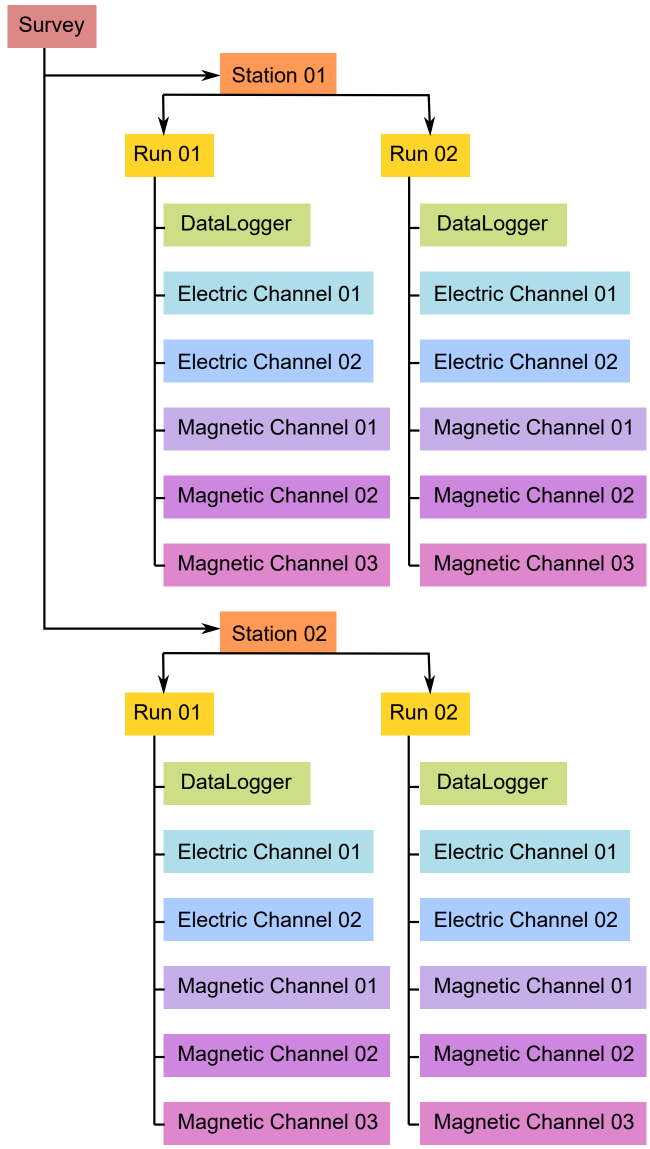


Figure 1: Schematic of a MT time series file structure with appropriate metadata.

### 2.2.2 Location

All latitude and longitude locations are given in decimal degrees in the well known datum **The entire survey should use only one datum that is specified at the Survey level.**

- All latitude values must be $< |90|$ and all longitude values must be $< |180|$.
- Elevation and other distance values are given in meters.
- Datum should be one of the well known datums, WGS84 is preferred, but others are acceptable.

### 2.2.3 Angles

All angles of orientation are given in degrees. Orientation of dipoles and magnetometers should be given in geographic coordinates where angles are assumed to be clockwise positive from Geographic North = 0. If a station was collected not in geographic coordinates this needs to be specified in `station.orientation.option`.

## 2.3 Units

Units should all be from the metric system. Abbreviations and full names are acceptable, for example `mV` and `millivolts`. Below are a summary of common acceptable units:

Table 2: Acceptable units

| **Measurement Type** | **Unit Long Name** | **Unit Short Name** |
|---|---|---|
| Angles | degrees | deg |
| Distance | meters | m |
| Latitude/Longitude | decimal degrees | deg |
| Resistance | Ohms | Ohms |
| Resistivity | Ohm-meters | Ohm-m, Ohmm |
| Temperature | Celsius | C |
| Time | seconds | s |
| Voltage | Volts | V |

### 2.4 String Formats

Any list should be comma separated.

Table 3: Acceptable String Formats

| **Style** | **Description** | **Example** |
|---|---|---|
| free form | an unregulated string that can contain {a-z, A-Z, 0-9} and special characters | This is free form! |
| alpha numeric | a string that contains no spaces and only characters {a-z, A-Z, 0-9, -, /, _} | WGS84 or GEOMAG-USGS |
| controlled vocabulary | Only certain names or words are allowed | station.orientation.option = geographic |
| url | a full URL that a user could put into a web browser | https://www.passcal.nmt.edu/ |
| date | ISO formatted date YYYY-MM-DD in UTC | 2020-02-02 |
| date time | ISO formatted date time YYYY-MM-DDThh:mm:ss.ms+00:00 in UTC | 2020-02-02T12:20:45.123456+00:00 |
| Temperature | Celsius | C |
| Time | seconds | s |
| Voltage | Volts | V |

# 3 Survey

A survey describes an entire dataset that covers a specific time span and region. This may include multiple PIs in multiple data collection episodes but should be confined to a specific experiment. The `Survey` metadata category describes the general parameters of the survey.

Table 4: Attributes for Survey category

| **Metadata Key** | **Description** | **Type** | **Required** | **Style** |
|---|---|---|---|---|
| acquired_by.author | principal investigator(s) responsible for survey | string | true | free form |
| acquired_by.comments | comments about who acquired the data, could include the various groups or contractors | string | true | free form |
| archive_id | alphanumeric name for the project e.g USGS-GEOMAG | string | true | alpha numeric |
| archive_network | network code given by PASSCAL/IRIS/FDSN | string | true | alpha numeric |
| citation_data_set.doi | citation dataset doi number | string | true | url |
| citation_journal.doi | citation journal doi | string | false | url |
| comments | comments about survey that are not in the summary | string | false | free form |
| country | country/countries survey located in, if multiple they should be comma separated | string | false | free form |
| datum | datum of latitude and longitude coordinates, should be a well-known datum [ WGS84 ] and will be the reference datum for all location | string | true | alpha numeric |
| geographic_name | geographic location(s) of survey in general terms | string | true | free form |
| name | descriptive name of the survey | string | true | free form |
| northwest_corner.latitude | location of northwest corner of survey [ degrees ] | float | true | number |
| northwest_corner.longitude | location of northwest corner of survey [ degrees] | float | true | number |
| project | alphanumeric name for the project e.g USGS-GEOMAG | string | true | alpha numeric |
| project_lead.email | email address of the project lead | string | true | email |
| project_lead.name | name of the project lead | string | true | free form |
| project_lead.organization | name of the organization for the project lead | string | true | free form |
| release_status | defined status of how the data can be used. Options are [ Unrestricted Release \| Paper Citation Required \| Academic Use Only \| Conditions Apply ] | string | true | controlled vocabulary |
| southeast_corner.latitude | location of southeast corner of survey [degrees] | float | true | number |
| southeast_corner.longitude | location of southeast corner of survey [degrees] | float | true | number |
| summary | summary paragraph of survey including the purpose, difficulties, data quality, summary of outcomes if the data have been processed and modeled | string | true | free form |
| time_period.end_date | end date of survey in UTC | string | true | date |
| time_period.start_date | start date of survey in UTC | string | true | date |

### 3.1 Example Survey XML String


```
<?xml version="1.0" ?>
<survey>
    <acquired_by>
        <author>None</author>
        <comments>None</comments>
    </acquired_by>
    <archive_id>None</archive_id>
    <archive_network>None</archive_network>
    <citation_dataset>
        <doi>None</doi>
    </citation_dataset>
    <citation_journal>
        <doi>None</doi>
    </citation_journal>
    <comments>None</comments>
    <country>None</country>
    <datum>None</datum>
    <geographic_name>None</geographic_name>
    <name>None</name>
    <northwest_corner>
        <latitude type="float" units="decimal degrees">None</latitude>
        <longitude type="float" units="decimal degrees">None</longitude>
    </northwest_corner>
    <project>None</project>
    <project_lead>
        <email>None</email>
        <organization>None</organization>
        <author>None</author>
    </project_lead>
    <release_status>None</release_status>
    <southeast_corner>
        <latitude type="float" units="decimal degrees">None</latitude>
        <longitude type="float" units="decimal degrees">None</longitude>
    </southeast_corner>
    <summary>None</summary>
    <time_period>
        <end_date>1980-01-01</end_date>
        <start_date>1980-01-01</start_date>
    </time_period>
</survey>
```

# 4 Station

A station encompasses a single site where data are collected. If the location changes during a run, then a new station should be created. If the sensors, cables, data logger, battery are replaced during a run but the station remains stations, then this can be recorded in the `Run` metadata but does not require a new station entry.

Table 5: Attributes for Station category

| **Metadata Key** | **Description** | **Type** | **Required** |
|---|---|---|---|
| archive_id | 5 char name A-Z; 1-9 for station | string | true |
| id | general name for station | string | true |
| geographic_name | closest geographic reference name to station | string | true |
| location.latitude | longitude location [ degrees (hh.mmss) ] | float | true |
| location.longitude | latitude location [ degrees (hh.mmss) ] | float | true |
| location.elevation | elevation [ m ] | float | true |
| location.datum | datum for lat, lon location should be a well known datum and same as the survey datum | string | true |
| location.declination.value | declination value | float | true |
| location.declination.epoch | declination epoch | string | true |
| location.declination.model | declination model | string | true |
| comments | any comments about station | string | false |
| time_period.start | start time and date of data logging [ISO UTC ] | string | true |
| time_period.end | stop time and date of data logging [ ISO UTC ] | string | true |
| num_channels | number of channels recording needs to be the same number as entries in channels_recorded | int | true |
| channels_recorded | list of channels recorded [EX, EY, HX, HY, HZ \| ...], needs to be same length as num_channels | string | true |
| data_type | type of data collected [ BB \| LP \| AMT \| Combo \| ...] | string | true |
| orientation.option | orientation coordinate system [ geographic \| channel-measurement specific \| ...] | string | true |
| orientation.method | [ compass \| differential GPS \| gyroscope \|...] | string | false |
| provenance.creation_time | creation time of time series data for storing | string | true |
| provenance.software.name | name of software used to store time series | string | true |
| provenance.software.version | version of software used to store time series | string | true |
| provenance.submitter.author | name of person or group submitting archive data | string | true |
| provenance.submitter.organization | name of organization or institution submitting archive data | string | true |
| provenance.submitter.url | url of group submitting archive data | string | true |
| provenance.submitter.email | email of person or group submitting archive data | string | true |
| provenance.comments | any comments on the history of the data | string | false |
| provenance.log | log of any changes made to time series data | string | false |

### 4.1 Example Station JSON String


```
{
    "station": {
        "archive_id": "test sta_code",
        "channels_recorded": "[ex, ey, hx, hy, hz]",
        "comments": "comments test",
        "data_type": "MT",
        "geographic_name": "Paris, TX",
        "id": "test name",
        "location.datum": "WGS84",
        "location.declination.epoch": "MTM01",
        "location.declination.model": "MTM01",
        "location.declination.value": -12.3,
        "location.elevation": 1230.0,
        "location.latitude": 40.019,
        "location.longitude": -117.89,
        "num_channels": 5,
        "orientation.method": "compass",
        "orientation.option": "geographic north",
        "provenance.comments": "goats",
        "provenance.creation_time": "2010-04-01T10:10:10+00:00",
        "provenance.log": "EY flipped",
        "provenance.software.author": "Peacock",
        "provenance.software.name": "mth5",
        "provenance.software.version": "1.0.1",
        "provenance.submitter.author": "submitter name",
        "provenance.submitter.email": "mt@em.edi",
        "provenance.submitter.organization": "mt inc",
        "provenance.submitter.url": "mt.edi",
        "time_period.end": "2010-01-04T07:40:30+00:00",
        "time_period.start": "2010-01-01T12:30:20+00:00"
    }
}
```

# 5 Run

A run represents data collected at a single station with a single sampling rate. If the dipole length or other such station parameters are changed between runs, this would require adding a new run. If the station is relocated then a new station should be created. If a run has channels that drop out the start and end period will be the minimum time and maximum time for all channels recorded.

Table 6: Attributes for Run category

| **Metadata Key** | **Description** | **Type** | **Required** |
|---|---|---|---|
| id | run ID | string | true |
| comments | comments on run, commonly station name with 0-90-9 or a-z, mt01a or mt01_01 | string | false |
| time_period.start | start date and time of data logging [ ISO UTC ], should be the minimum time between all channels recorded | string | true |
| time_period.end | stop date and time of data logging [ ISO UTC ], should be the maximum time between all channels recorded | string | true |
| sampling_rate | sampling rate of run (samples per second) | float | true |
| channels_recorded | list of channels recorded as components [ [EX, EY, HX, HY] \| ...] | string | true |
| data_type | type of data collected [ BB \| LP \| AMT \| Combo \| ...] | string | true |
| acquired_by.author | person(s) responsible for run this can be different from the PI's listed at he survey level | string | true |
| acquired_by.email | email of lead run operator | string | false |
| provenance.comments | any comments on the history of the data for the run | string | false |
| provenance.log | log of any changes made to time series data | string | false |
| data_logger.manufacturer | data logger manufacturer name | string | true |
| data_logger.model | data logger model name | string | true |
| data_logger.serial | data logger serial number | string | true |
| data_logger.comments | comments about data logger | string | true |
| data_logger.timing_system.type | type of timing system [GPS \| internal \| ... ] | string | true |
| data_logger.timing_system.drift | any drift in internal clock [ seconds ] | float | true |
| data_logger.timing_system.uncertainty | uncertainty associated with internal clock [seconds] | float | true |
| data_logger.timing_system.comments | comments on timing system | string | false |
| data_logger.firmware.version | firmware version | string | true |
| data_logger.firmware.date | date on firmware | string | true |
| data_logger.firmware.author | author of firmware | string | false |
| data_logger.power_source.type | power source type [ Pb-acid battery \| solar panel \| Li battery \| ...] | string | true |
| data_logger.power_source.id | power source id | string | false |
| data_logger.power_source.voltage.start | starting voltage of power source | float | true |
| data_logger.power_source.volage.end | ending voltage of power source | float | true |
| data_logger.power_source.comments | comments on power source | string | false |

### 5.1 Example Run XML String

```
<run>
    <acquired_by>
        <author>T. Lurric</author>
        <email>mt@mt.org</email>
    </acquired_by>
    <channels_recorded>[EX, EY, HX, HY, HZ, temperature]</channels_recorded>
    <comments>None</comments>
    <data_logger>
        <power_source>
            <voltage>
                <start type="float" units="volts">14</start>
                <end type="float" units="volts">12</end>
            </voltage>
            <type>pb-acid</type>
            <id>10</id>
            <comments>solar panel</comments>
        </power_source>
        <id>mt01</id>
        <manufacturer>MT r' Us</manufacturer>
        <type>broadband</type>
        <timing_system>
            <type>GPS</type>
            <drift type="float" units="seconds">0.00001</drift>
            <uncertainty type="float" units="seconds">0.00001</uncertainty>
            <notes>None</notes>
        </timing_system>
        <firmware>
            <author>MT r' Us</author>
            <version>12.15.a</version>
            <name>FGDMT</name>
        </firmware>
    </data_logger>
    <data_type>MT</data_type>
    <id>mt01a</id>
    <provenance>
        <comments>None</comments>
        <log>None</log>
    </provenance>
    <sampling_rate type="float" units="samples per second">256.0</sampling_rate>
    <time_period>
        <start>1980-01-01T00:00:00+00:00</start>
        <end>1980-01-01T00:00:00+00:00</end>
    </time_period>
</run>
```

# 6 Electric Channel

Electric channel refers to a dipole measurement of the electric field for a single station for a single run.

Table 7: Attributes for Electric category

| **Metadata Key** | **Description** | **Type** | **Required** |
|---|---|---|---|
| dipole_length | length of dipole [ m ] | float | true |
| channel_number | channel number [ 1 \| 2 \| 3 \| 4 \| 5 \| 6 \|...] | int | true |
| component | [ Ex \| Ey \| Ez ] | string | true |
| azimuth | azimuth of dipole N = 0, E = 90 [ degrees ] | float | true |
| time_period.start | start date and time of data logging [ ISO UTC ] | string | true |
| time_period.end | stop date and time of data logging [ ISO UTC ] | string | true |
| positive.id | sensor id number | string | true |
| positive.latitude | positive sensor location latitude [ degrees (hh.mmss) ] | float | false |
| positive.longitude | positive sensor location longitude [ degrees (hh.mmss) ] | float | false |
| positive.elevation | positive sensor location elevation [ m ] | float | false |
| positive.datum | positive datum for location [ WGS84 ] | string | false |
| positive.type | type of electric sensor [ Ag-AgCl \| Pb-PbCl \| ...] | string | true |
| positive.manufacturer | electric sensor manufacturer | string | true |
| positive.comments | comments on electric sensor | string | false |
| negative.id | sensor id number | string | true |
| negative.longitude | negative sensor location latitude [ degrees (hh.mmss) ] | float | false |
| negative.latitude | negative sensor location longitude [ degrees (hh.mmss) ] | float | false |
| negative.elevation | negative sensor location elevation [ m ] | float | false |
| negative.datum | negative datum for location [ WGS84 ] | string | false |
| negative.type | type of electric sensor [ Ag-AgCl \| Pb-PbCl \| ...] | string | true |
| negative.manufacturer | electric sensor manufacturer | string | true |
| negative.comments | comments on electric sensor | string | false |
| contact_resistance_1.start | contact resistance at beginning of measurement, positive polarity [ Ohm ]" | float | false |
| contact_resistance_2.start | contact resistance at beginning of measurement, negative polarity [ Ohm ] | float | false |
| contact_resistance_1.end | contact resistance at end of measurement, positive polarity [ Ohm ] | float | false |
| contact_resistance_2.end | contact resistance at end of measurement, negative polarity [ Ohm ] | float | false |
| ac.start | AC at start of measurement [ V ] | float | false |
| ac.end | AC at end of measurement [ V ] | float | false |
| dc.start | DC at start of measurement [ V ] | float | false |
| dc.end | DC at end of measurement [ V ] | float | false |

Table 8: Attributes for Electric category continued

| **Metadata Key** | **Description** | **Type** | **Required** |
|---|---|---|---|
| units | units of electric field data [ counts \| mV/km \| ... ] | string | true |
| sample_rate | sample rate of electric channel (samples.second) | float | true |
| comments | comments about electric field measurement | string | false |
| data_quality.rating | data quality rating based on some sort of statistic | integer | false |
| data_quality.warning_comments | any warnings about data quality | string | false |
| data_quality.warning_flags | a value flagging bad data | float | integer |
| data_quality.author | person who did QA/QC on data | string | false |
| filter.name | filter name in filter table, can be a list. Needs to be ordered in which filters were applied | string | false |
| filter.comments | any comments on the filtering | string | false |
| filter.applied_b | have filters been applied [ True \| False ] | string | true |

## 6.1 Example Electric Channel JSON String


```
{
 "dipole_length": 59.7,
 "channel_number": "1",
 "component": "EX",
 "azimuth": 0,
 "time_period.start": 2020-01-02T12:30:15+00:00,
 "time_period.end": 2020-01-05T16:20:15+00:00,
 "positive.id": "101",
 "positive.latitude": 35.5578,
 "positive.longitude": -117.38754,
 "positive.elevation": 103.4,
 "positive.datum": "WGS84",
 "positive.type": "Ag-AgCl",
 "positive.manufacturer": "Zaps",
 "positive.comments": "Sitting on the shelf since last year",
 "negative.id": "102",
 "negative.latitude": 35.5588,
 "negative.longitude": -117.38754,
 "negative.elevation": 105.8,
 "negative.datum": "WGS84",
 "negative.type": "Ag-AgCl"
 "negative.manufacturer": "Zaps",
 "negative.comments": "Sitting on the shelf since last year",
 "contact_resistance_1.start": 1200.0,
 "contact_resistance_2.start": 1210.0,
 "contact_resistance_1.end": 1205.0,
 "contact_resistance_2.end": 1205.0,
 "ac.start": 0.03,
 "ac.end": 0.04,
 "dc.start": 0.001,
 "dc.end": 0.002,
 "units": "counts",
 "sample_rate": 256,
 "comments": "cables chewed on 2020-01-07",
 "data_quality.rating": 3,
 "data_quality.warning_comments": "cables chewed 2020-01-07",
 "data_quality.warning_flags": "Nan",
 "data_quality.author": "Q. Sea",
 "filter.name": "[counts2mv, datalogger024]",
 "filter.comments": "comments on filters applied",
 "filter.applied_b": "true"
}
```

# 7 Magnetic Channel

A magnetic channel is a recording of one component of the magnetic field at a single station for a single run.

Table 9: Attributes for Magnetic category

| Metadata Key | Description | Type | Required |
|---|---|---|---|
| sensor.type | type of magnetic sensor [ Induction Coil \| flux gate \| ...] | string | true |
| sensor.manufacturer | magnetic sensor manufacturer | string | true |
| sensor.comments | comments on sensor | string | true |
| sensor.id | sensor id number | string | true |
| channel_number | channel number [ 1 \| 2 \| 3 \| 4 \| 5 \| 6 \|...] | int | true |
| component | [ Hx \| Hy \| Hz ] | string | true |
| azimuth | azimuth in `station\_coordinates` [ degrees ] | float | true |
| time_period.start | start date and time of data logging [ ISO UTC ] | string | true |
| time_period.end | stop date and time of data logging [ ISO UTC ] | string | true |
| location.longitude | sensor longitude degrees | float | true |
| location.latitude | sensor latitude in degrees | float | true |
| location.elevation | sensor elevation in meters | float | true |
| location.datum | datum for location [ WGS84 \| ... ] | string | true |
| units | units of magnetic field data [ counts \| mV \| ... ] | string | true |
| sample_rate | sample rate of magnetic channel (samples.second) | float | true |
| h_field_min.start | minimum h-field value at beginning of measurement | float | false |
| h_field_max.start | maximum h-field value at beginning of measurement | float | false |
| h_field_min.end | minimum h-field value at end of measurement | float | false |
| h_field_max.end | maximum h-field value at end of measurement | float | false |
| h_field.units | units of h-field measurement [ nT \| ...] | string | false |
| comments | comments on magnetic field measurments | string | false |
| data_quality.rating | data quality rating based on some sort of statistic | integer | false |
| data_quality.warning_comments | any warnings about data quality | string | false |
| data_quality.warning_flags | a value flagging bad data | integer | false |
| data_quality.author | person who did QC.QA on data | string | false |
| filter.name | filter name in filter table, can be a list. Needs to be ordered in which filters were applied | string | false |
| filter.comments | any comments on the filtering | string | false |
| filter.applied_b | have filters been applied [ True \| False ] | string | true |

### 7.1 Example Magnetic Channel JSON String


```
{
 "sensor.type": "Induction Coil",
 "sensor.manufacturer": "MT ‘r Us",
 "sensor.comments": "new coil",
 "sensor.id": "2149",
 "channel_number": 5,
 "component": "HZ",
 "azimuth": 90,
 "time_period.start": 2020-01-02T12:30:15+00:00,
 "time_period.end": 2020-01-05T16:20:15+00:00,
 "location.longitude": -117.0,
 "location.latitude": 45.0,
 "location.elevation": 107.4,
 "location.datum": "WGS84",
 "units": "counts",
 "sample_rate": 256,
 "h_field_min.start": -10,
 "h_field_max.start": 10,
 "h_field_min.end": -9,
 "h_field_max.end": 9,
 "h_field.units": "nT",
 "comments": "not buried all the way ",
 "data_quality.rating": 4,
 "data_quality.warning_comments": "windy during the day",
 "data_quality.warning_flags": 0,
 "data_quality.author": "Q. Sea",
 "filter.name": "[counts2mv, datalogger024, coil2149]",
 "filter.comments": "Calibrated 2018-01-01",
 "filter.applied_b": "[true, false, false]"
}
```

# 8 Filters

Filters is a table that holds information on any filters that need to be applied to get physical units, and filters that were applied to the data to analyze the signal. This includes calibrations, notch filters, conversion of counts to units, etc. The actual filter will be an array of numbers contained within an array named `name` and formatted according to `type`. The preferred format for a filter is a look-up table which internally can be converted to other formats.

It is important to note that filters will be identified by name and must be consistent throughout the file. Names should be descriptive and self evident. Examples:

- `coil_2284` ⟶ induction coil number 2284
- `counts2mv` ⟶ conversion from counts to mV
- `e_gain` ⟶ electric field gain
- `datalogger_024` ⟶ data logger number 24 response
- `notch_60hz` ⟶ notch filter for 60 Hz and harmonics
- `lowpass_10hz` ⟶ low pass filter below 10 Hz

In each channel there are keys to identify filters that can or have been applied to the data to get an appropriate signal. This can be a list of filter names or a single filter name. An `applied_b` key also exists for the user to input whether that filter has been applied. Can be a single Boolean `true` if all filters have been applied, `false` if none of the filters have been applied. Or can be a list the same length and the filter name list identifying if the filter has been applied. `name: "[counts2mv, notch60hz, e_gain]"` and `applied_b: "[true, false, true]"`.

Table 10: Attributes for Filters

| **Metadata Key** | **Description** | **Type** | **Required** |
|---|---|---|---|
| type | type of filter [look up \| poles-zeros \| converter \| FIR \| ...] | string | true |
| name | unique name for the filter such that it is easy to query | string | true |
| units_in | units of data going in [ counts \| mV/km \| ... ] | string | true |
| units_out | units of data coming out [ counts \| mV/km \| ... ] | string | true |
| calibration_date | date of calibration | string | true |
| comments | any comments on the filtering | string | false |

## 8.1 Example Filter JSON String

```
{
 "type": "look up",
 "name": "coil_8897",
 "units_in": "mV",
 "units_out": "mV",
 "calibrationate": "2015-07-01",
 "comments": "interpolated from poles and zeros"
}
```

# 9 Auxiliary Channels

Auxiliary channels include state of health channels, temperature, etc.

Table 11: Attributes for Auxiliary category

| Metadata Key | Description | Type | Required |
|---|---|---|---|
| type | type of data recorded [ temperature \| GPS \| ...] | string | true |
| units | units of magnetic field data [ counts \| mV \| ... ] | string | true |
| channel_num | channel number [ 1 \| 2 \| 3 \| 4 \| 5 \| 6 \|...] | int | true |
| component | channel number [ 'None' \| ... ] | string | true |
| sample_rate | sample rate (samples.second) | float | true |
| comments | any comments on the auxillary channel | string | false |
| data_quality.rating | data quality rating based on some sort of statistic | integer | false |
| data_quality.warning_comments | any warnings about data quality | string | false |
| data_quality.warning_flags | a value flagging bad data | integer | false |
| data_quality.author | person who did QC.QA on data | string | false |
| filter.name | filter name in filter table, can be a list. Needs to be ordered in which filters were applied | string | false |
| filter.comments | any comments on the filtering | string | false |
| filter.applied_b | have filters been applied [ True \| False ] | string | true |

## 9.1 Example Auxiliary JSON String


```
{
    "auxiliary": {
         "azimuth": 0.0,
         "channel_number": 1,
         "comments": null,
         "component": "temperature",
         "data_quality.author": "mt",
         "data_quality.rating": 5,
         "data_quality.warning_comments": null,
         "data_quality.warning_flags": "0",
         "filter.applied": [false],
         "filter.comments": null,
         "filter.name": ["counts2mv"],
         "location.datum": "WGS84",
         "location.elevation": 1200.3,
         "location.latitude": 40.12,
         "location.longitude": -115.767,
         "sample_rate": 256.0,
         "time_period.end": "2010-01-04T07:40:30+00:00",
         "time_period.start": "2010-01-01T12:30:20+00:00",
         "type": "auxiliary",
         "units": "celsius"
    }
}
```