FINAL

HDF5 EMI Attributes Definition

Version 1.0

JANUARY 7, 2022

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Version	**Effective Date**	**Remarks**
Version 1 Draft 1	12 AUG 2020	Initial release of draft for internal review
Version 1 Draft 2	21 AUG 2020	Changed “Project” to “ProjectID” Added “ReceiverSequence”
Version 1 Draft 3	28 AUG 2020	Updated typographical issues throughout
Version 1 Draft 4	01 SEP 2020	Added SwathWidth attribute
Version 1 Draft 5	31 MAR 2021	Incorporated Draft 4 review comments and two place holders
Version 1 Final	7 JAN 2022	Incorporated Draft 5 review comments, updated signature blocks, added IMU reference, clarified easting/northing

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1. Introduction

The DoD Environmental Data Quality Workgroup (EDQW), Advanced Geophysical Classification Subgroup (AGCS) has developed a standardized HDF5 file format definition for use with Advanced Geophysical Classification (AGC) electro-magnetic induction (EMI) sensor systems for use in munitions response efforts being conducted under the DoD Advanced Geophysical Classification Accreditation Program (DAGCAP)[1]. The DAGCAP HDF5 standard describes the raw file created from merging three data sources – AGC sensor data, platform positioning data, and platform attitude data. Platform positioning data are typically provided by global navigation satellite (GNS) systems (*e.g.*, GPS) and platform attitude data are typically provided by inertial measurement units (IMU) or attitude and heading reference systems (AHRS). The output specifications for these three sources are manufacturer dependent and does not currently fall under DAGCAP standardization requirements.

The HDF5 file format and libraries are designed and supported by the HDF Group[2]. The HDF file format supports n-dimensional datasets and each element in the dataset may itself be a complex object. The HDF5 libraries and file format (HDF5) are designed to manage, process, and store heterogeneous data. HDF5 is built for fast I/O processing and storage.

HDF5 is a self-describing hierarchical data format. An HDF5 file can contain one or more groups, datasets, and combinations thereof. Each level in the file can have associated attributes, or metadata. These attributes can be user-defined and attached to the file as a whole, or groups within.

This document is designed to codify this standard, "HDF5 EMI Attributes Definition." This document addresses the approved DAGCAP file naming convention, direction of travel and coil layout considerations, and the defined measurement types (and associated short codes) used in the HDF5 (.H5) files. Then each defined attribute will be discussed in detail in a dictionary format including definitions, units, and necessary clarifications. Finally, the structure and associated attributes for two example HDF5 measurement types (dynamic and static) will be discussed in detail.

2. File Naming Convention

EDQW has defined a standardized file naming convention for HDF5 AGC EMI data files. All AGC EMI data collected under DAGCAP accreditation shall be recorded using this naming convention. While the file naming convention is functionally the same for both dynamic and static data collection, there is one difference in usage:

Dynamic data collection:

```
<ProjectID>_<GeoID>_<MeasurementTypeCode>_<LineID>_<JulianDate>_<Version>.h5
```

Example:

```
REDWOOD_YARD_DAM_000001_2020095_000.h5

       or

J09CA013605_DU01_DAM_000001_2020095_000.h5
```

[1] https://www.denix.osd.mil/mmrp/advanced-geophysical-classification-accreditation-and-other-tools/
[2] https://www.hdfgroup.org/solutions/hdf5/

Static data collection:

```
<ProjectID>_<GeoID>_<MeasurementTypeCode>_<LocationID>_<JulianDate>_<Version>.h5
```

Example:

```
REDWOOD_YARD_SAM_001492_2020095_001.h5

        Or

J09CA013605_DU01_SAM_001492_2020095_001.h5
```

ProjectID – Alphanumeric identifier for the project or site. Example: "APG"
GeoID – Alphanumeric identifier for the project or site. Example: "Site1776"
MeasurementTypeCode – See Section 5. Example: "DAM"
LineID or LocationID – Numeric identifier for a dynamic survey line or a static cued measurement, zero-padded to six digits. Example "000001"
JulianDate – Date encoded as YYYYDDD, where YYYY is the 4-digit year (*e.g.*, 2020) and DDD is the day of the year (*e.g.*, January 31 is 031). Example: "2020095"
Version – A value, when used in combination with the other values insures a unique filename. It is intended to allow for repeating a measurement within a given day, without filename collision issues, zero-padded to three digits, starting with "000". Example: "000"

The delimiter between fields in the filenames is an underscore, "_", therefore underscores shall not be used within any alphanumeric fields. HDF5 files can be opened in a read-only mode with a variety of software packages including HDFView[3] from the HDF Group.

3. Direction of Travel and the Right-Hand Rule

For the purposes of this standard, a Cartesian coordinate system (*x*,*y*,*z*) is assumed. The layout of an example EMI array with the direction of travel and coordinate system, as shown in Figure 1, the direction of travel for an AGC system is defined as the positive *y axis*. The positive *x* axis therefore points to starboard (the right-hand side, looking from behind the array). Following the right-hand rule[4], the positive *z* axis is therefore pointed up from the ground surface. When labeling multi-component transmitters and receivers identifies individual components includes axis information, the labeling shall conform to this convention.

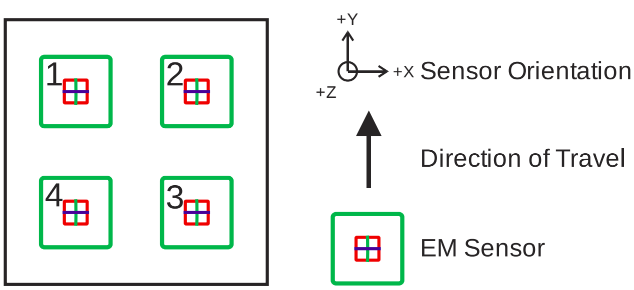


Figure 1 – The array layout with the direction of travel and coordinate system

[3] https://www.hdfgroup.org/downloads/hdfview/
[4] For example, https://en.wikipedia.org/wiki/Right-hand_rule

Similarly, the example outputs in sensor frame for the IMU is shown in Figure 2.

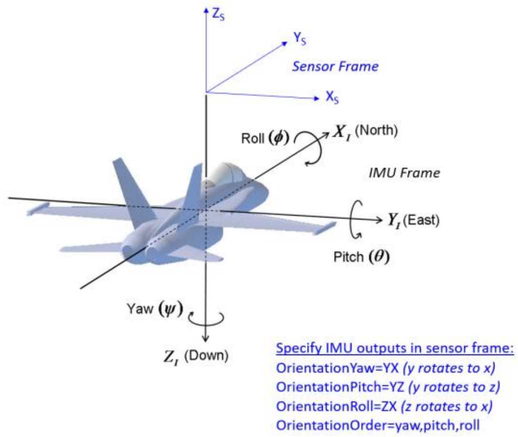


Figure 2 – An example IMU with the outputs in sensor frame

4. Coil / Loop Description Convention

This standard currently supports the specification of coils/loop extents of two shapes, rectangular and circular (round). The number of vertices used to specify the coil extents informs the parsing software of the coil's shape.

The extents of rectangular coils are defined by 4 vertices, while the extents of circular coils are defined by 33 vertices. Examples are shown below.

Rectangular Coil:

```
A:(x=-0.3750,y=0.3750,z=0.000),(x=-0.0250,y=0.3750,z=0.000),(x=-0.0250,y=0.0250,z=0.000),(x=-
0.3750,y=0.0250,z=0.000)
```

Circular/Round Coil:

```
E:(x=0.2500,y=0.0000,z=0.0000),(x=0.2452,y=0.0488,z=0.0000),(x=0.2310,y=0.0957,z=0.0000),(x=0.207
9,y=0.1389,z=0.0000),(x=0.1768,y=0.1768,z=0.0000),(x=0.1389,y=0.2079,z=0.0000),(x=0.0957,y=0.2310
,z=0.0000),(x=0.0488,y=0.2452,z=0.0000),(x=0.0000,y=0.2500,z=0.0000),(x=-
0.0488,y=0.2452,z=0.0000),(x=-0.0957,y=0.2310,z=0.0000),(x=-0.1389,y=0.2079,z=0.0000),(x=-
0.1768,y=0.1768,z=0.0000),(x=-0.2079,y=0.1389,z=0.0000),(x=-0.2310,y=0.0957,z=0.0000),(x=-
0.2452,y=0.0488,z=0.0000),(x=-0.2500,y=0.0000,z=0.0000),(x=-0.2452,y=-0.0488,z=0.0000),(x=-
0.2310,y=-0.0957,z=0.0000),(x=-0.2079,y=-0.1389,z=0.0000),(x=-0.1768,y=-0.1768,z=0.0000),(x=-
0.1389,y=-0.2079,z=0.0000),(x=-0.0957,y=-0.2310,z=0.0000),(x=-0.0488,y=-0.2452,z=0.0000),(x=-
0.0000,y=-0.2500,z=0.0000),(x= 0.0488,y=-0.2452,z=0.0000),(x= 0.0957,y=-0.2310,z=0.0000),(x=
0.1389,y=-0.2079,z=0.0000),(x= 0.1768,y=-0.1768,z=0.0000),(x= 0.2079,y=-0.1389,z=0.0000),(x=
0.2310,y=-0.0957,z=0.0000),(x= 0.2452,y=-0.0488,z=0.0000),(x= 0.2500,y= 0.0000,z=0.0000)
```

5. Measurement Type Codes

The defined types of measurements have been split into two categories, dynamic (Table 1, beginning with "D") and static (Table 2, beginning with "S") and assigned three-letter measurement codes.

Table 1 – Dynamic Measurement Types

	Dynamic Measurement Types	
Type Code	Type Name	Description
DBG	Dynamic Background Measurement	Dynamic background survey over a known source-free area
DAM	Dynamic Anomaly Measurement	Dynamic survey for detection and classification of metallic anomalies.
DQC	Dynamic Quality Control	Dynamic survey of one or more emplaced targets for QC purposes (IVS)
DFT	Dynamic Function Test	Dynamic functional test of the individual sensor component responses to a standard object (*e.g.*, sISO[5]), placed at a precisely known location relative to the sensor
DSP	Dynamic Spin Test	Dynamic QC measurement for man-portable systems (*e.g.*, the MPV)
DTP	Dynamic Test Pit	Dynamic survey over an established test pit. Typically for generating response curve data for a new TOI to be modeled or added to the site-specific library
DXM	Dynamic Miscellaneous (X) Measurement	Dynamic survey which does not fit within any of the above types

[5] sISO – small Industry Standard Object. See "EM61-MK2 Response of Three Munitions Surrogates," NRL Memorandum Report NRL/MR/6110--090-9183, Naval Research Laboratory, Washington, DC, March 12, 2009.

Table 2 – Static Measurement Types

	Static Measurement Types	
Type Code	Type Name	Description
SBR	Static Background Reconnaissance Measurement	Raw measurements for the purpose of validating a potential location for future SBG measurements
SBV	Static Background Validation Results	Results of a background validation test, SBRs are used as the inputs for these tests
SBG	Static Background Measurement	Static measurement over a known source-free location
SAM	Static Anomaly Measurement	Static measurement over an identified location with an anomaly source
SMD	Static Model	Forward-modelled static data
SQC	Static Quality Control	Static measurement of an emplaced target for QC purposes (IVS)
SRB	Static Reference Background	SBG measurement associated with a specific SFR measurement
SFR	Static Function Reference	"Gold-standard" reference file for SFT comparison
SFT	Static Function Test	Static functional test of the individual sensor component responses to a standard object (*e.g.*, sISO), placed at a precisely known location relative to the sensor
STP	Static Test Pit	Static measurement over an established test pit. Typically for generating response curve data for a new TOI to be modeled or added to the site-specific library
SXM	Static Miscellaneous (X) Measurement	Static measurement which does not fit within any of the above types
SLB	Static Library	Static measurement to collect data for adding a new TOI to a library

6. File Structure/Group Definitions

A generic HDF5 file can contain one or more groups, datasets, and combinations thereof in a hierarchical structure. The hierarchical structure of the HDF5 EMI file format outlined in this document has four parts.

The Root Group contains one or more Transient Groups. The metadata associated with this group is described in Section 7.1.

There will be at least one Transient Group named: Transients. There may be additional Transient Groups depending on the datatype, such as BackgroundTransients in the case of an SFT HDF5 file. The metadata associated with this group is described in Section 7.2.

Within each Transient Group, there are one or more Transmitter Groups, one for each of the sensor's transmitters. These groups contain the dataset table for each transient dataset or measurement. There are no attributes currently associated with Transmitter Groups.

Each Transmitter Group will contain one or more dataset tables for each EMI measurement. Static data files will only contain one, while dynamic data files will contain a series. The metadata associated with this group is described in Section 7.3.

The internal organization of an SFT HDF5 file, as presented in HDFView 3.0, is shown in Figure 3.

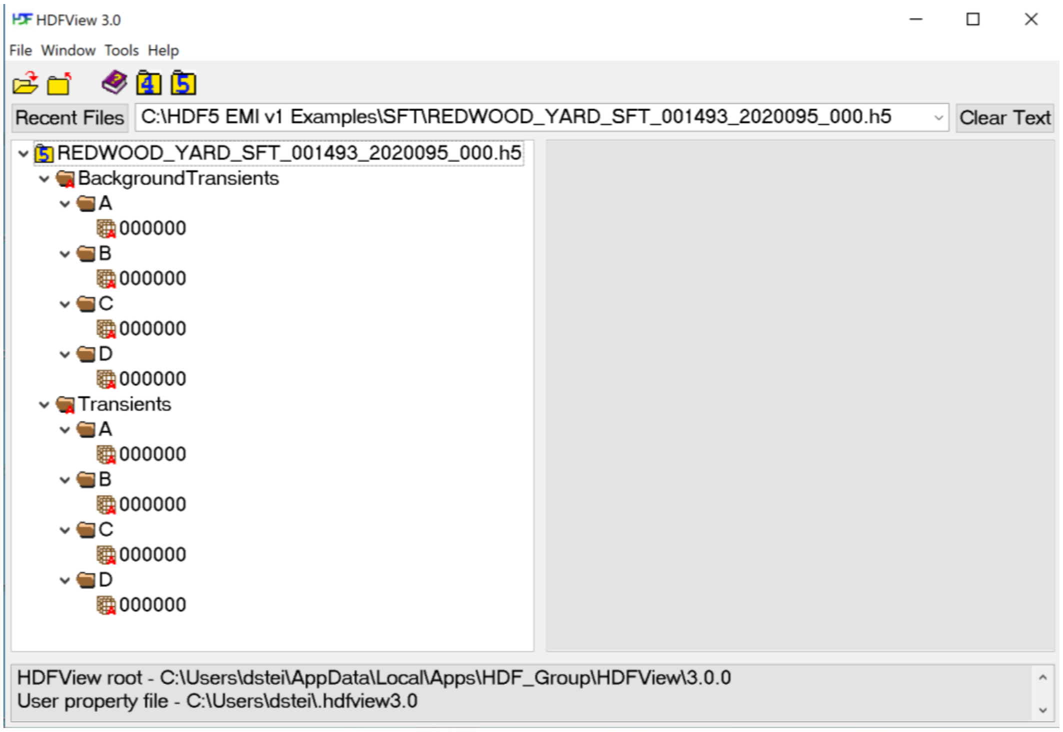


Figure 3 – Example SFT HDF5 file, presented in HDFView 3.0

7. Attribute Definitions / Lexicon

A generic HDF5 file can contain one or more groups, datasets, and combinations thereof in a hierarchical structure. Each level in the file can have associated attributes, or metadata. These attributes can be user-defined and attached to the file as a whole, or groups within.

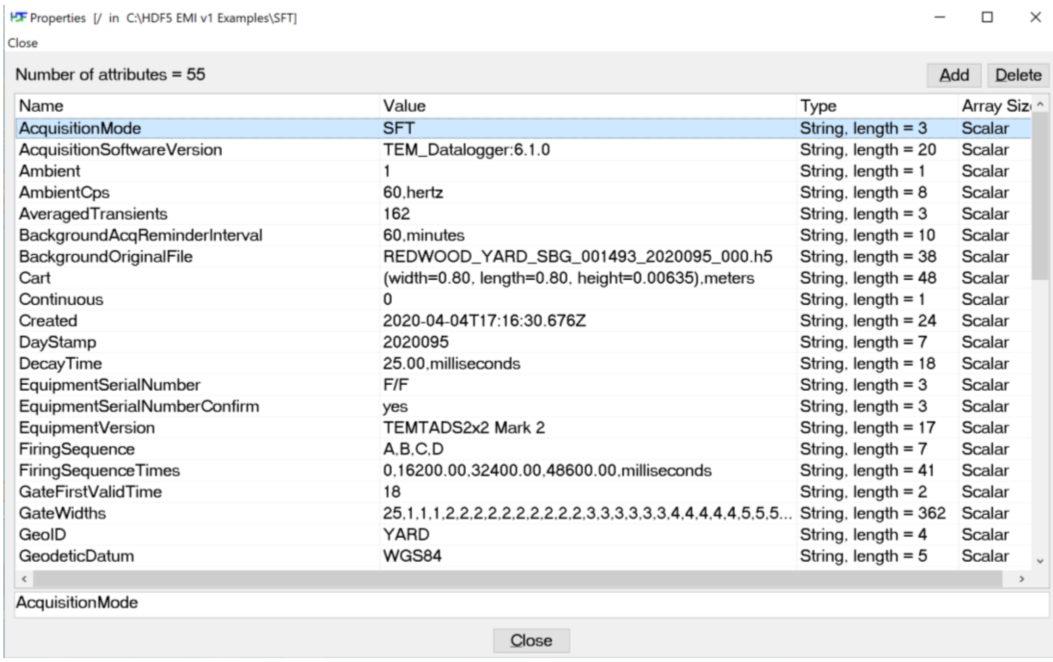
The DAGCAP HDF5 EMI Attributes Definition is a consensus standard developed to codify the organization and required metadata that is deemed necessary for AGC data stored in an HDF5 file. In this section, each defined attribute is presented along with details necessary for proper implementation. Attributes marked “Required” must be present in the file; however a dummy value of “*” may be used to indicate that the value is not recorded. “Optional” indicates that the attribute can be used but are not required. Table 3 - Table 5 enumerate the attributes and then each attribute is discussed in more detail.

All attribute values are stored as a single string each, including the values and units. The length of each string is variable. All units should be spelled out fully using lowercase letters, *e.g.*,“volts” rather than “V”.

NOTE: Since several different time scales, spanning many decades are appropriate in discussing AGC data collection, the appropriate time unit for each attribute value is used rather than a consensus time unit.

7.1. Root (File) Level Attributes

The internal organization of an SFT HDF5 file, as presented in HDFView 3.0, is shown in Figure 3. A portion of the file-level attributes of the same file, in SFT HDF5 file are shown in Figure 4. The file-level attributes defined in this standard are listed in Table 3.


Properties [/ in C:\HDF5 EMI v1 Examples\SFT]
Close
Number of attributes = 55
Add Delete

Name	Value	Type	Array Siz
AcquisitionMode	SFT	String, length = 3	Scalar
AcquisitionSoftwareVersion	TEM_Datalogger:6.1.0	String, length = 20	Scalar
Ambient	1	String, length = 1	Scalar
AmbientCps	60,hertz	String, length = 8	Scalar
AveragedTransients	162	String, length = 3	Scalar
BackgroundAcqReminderInterval	60,minutes	String, length = 10	Scalar
BackgroundOriginalFile	REDWOOD_YARD_SBG_001493_2020095_000.h5	String, length = 38	Scalar
Cart	(width=0.80, length=0.80, height=0.00635),meters	String, length = 48	Scalar
Continuous	0	String, length = 1	Scalar
Created	2020-04-04T17:16:30.676Z	String, length = 24	Scalar
DayStamp	2020095	String, length = 7	Scalar
DecayTime	25.00,milliseconds	String, length = 18	Scalar
EquipmentSerialNumber	F/F	String, length = 3	Scalar
EquipmentSerialNumberConfirm	yes	String, length = 3	Scalar
EquipmentVersion	TEMTADS2x2 Mark 2	String, length = 17	Scalar
FiringSequence	A,B,C,D	String, length = 7	Scalar
FiringSequenceTimes	0,16200.00,32400.00,48600.00,milliseconds	String, length = 41	Scalar
GateFirstValidTime	18	String, length = 2	Scalar
GateWidths	25,1,1,1,2,2,2,2,2,2,2,2,2,2,2,3,3,3,3,3,3,4,4,4,4,4,5,5,5...	String, length = 362	Scalar
GeoID	YARD	String, length = 4	Scalar
GeodeticDatum	WGS84	String, length = 5	Scalar

AcquisitionMode
Close

Figure 4 – A portion of the file-level attributes for an example SFT HDF5 file

Table 3 – File Attributes

Name	Required (All)	Required (Static)	Required (Dynamic)	Optional
AcquisitionMode	X			
AcquisitionSoftwareVersion	X			
Ambient	X			
AmbientCps	X			
AveragedTransients	X			
BackgroundAcqReminderInterval				X
BackgroundOriginalFile				X
Cart	X			
Continuous	X			
CountsPerMillivolt				X
Created	X			
DayStamp	X			
DecayTime	X			
EquipmentSerialNumber	X			
EquipmentSerialNumberConfirm	X			
EquipmentVersion	X			
FinalDecayLevel				X
FiringSequence	X			
FiringSequenceTimes	X			
GateFirstValidTime	X			
GateWidths	X			
GeoID	X			
GeodeticDatum	X			
HDF5EMITagDefinitionVersion	X			
HeightOfTransmitterAssemblyAboveGround	X			
HeightOfZCoilCenterAboveTransmitterAssembly	X			

Name	Required (All)	Required (Static)	Required (Dynamic)	Optional
Holdoff	X			
LocationID		X		
LineID			X	
LogarithmicallyDecimated	X			
MagneticDeclination	X			
MaximumBackgroundVariation				X
MeasurementNumber	X			
NominalDecimationFraction	X			
Operator	X			
OrientationRegistrationSystem	X			
OrientationRegistrationSystemOffset	X			
OriginalBasePath				X
ProjectID	X			
QcWindowEndTime	X			
QcWindowStartTime	X			
RawValues				X
ReceiverGains	X			
ReceiverLayout	X			
ReceiverNormalVectors	X			
ReceiverSaturationThreshold	X			
ReceiverSequence	X			
ReceiverThickness	X			
ReceiverTurns	X			
SampleWidth	X			
SensorFunctionReferenceOriginalFile				X
SpatialRegistrationSystem	X			
SpatialRegistrationSystemOffset	X			
SwathWidth			X	
Tractor				X
TransmissionCurrentThreshold	X			
TransmitterDutyCycle	X			
TransmitterLayout	X			
TransmitterNormalVectors	X			
TransmitterThickness	X			
TransmitterTurns	X			
UnsortedChannels				X
WaveformOversampleCount				X

Definitions and data requirements for the attributes listed in Table 3 are described in detail below:

AcquisitionMode

- Definition: See definitions in Section 5
- Required Status: Yes
- Units: N/A
- Example: SAM
- Notes: None

AcquisitionSoftwareVersion

- Definition: Identifies data acquisition software and version
- Required Status: Yes
- Units: N/A
- Example: TEM_Datalogger:6.1.0
- Notes: None

Ambient

- Definition: Boolean which indicates if time gates selected to reject local power line frequencies were used
- Required Status: Yes
- Units: N/A
- Example: 1 (true)
- Notes: The power line frequency (50/60 Hz) to be used is defined in the attribute "AmbientCps".

AmbientCps

- Definition: Local power line frequency to be rejected
- Required Status: Yes
- Units: hertz
- Example: 60,hertz
- Notes: None

AveragedTransients

- Definition: Number of transients averaged together representing the stored data
- Required Status: Yes
- Units: N/A
- Example: 162
- Notes: Most AGC systems have a bi-polar transmitter waveform (see Figure 5). The value of this attribute represents the total number of completed bipolar waveforms averaged together to form a single transient.

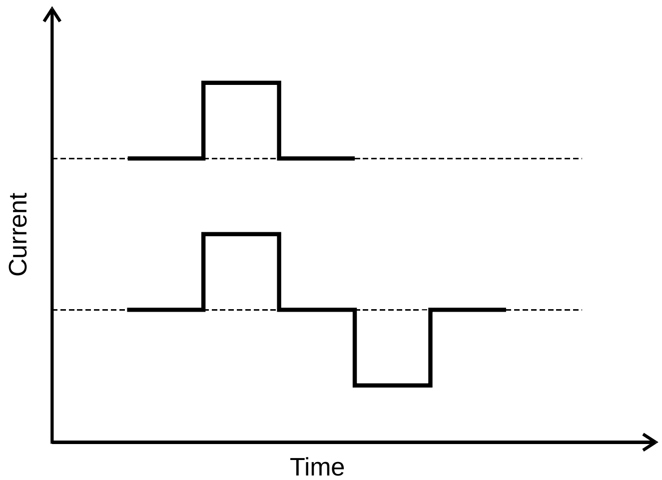


Figure 5 – Transmitter waveforms (upper) unipolar, (lower) bipolar

BackgroundAcqReminderInterval

- Definition: Time interval for reminder to operator to take a new background (*e.g.*, SBGs)
- Required Status: Optional
- Units: minutes
- Example: 120,minutes
- Notes: The DAGCAP QSR or a project specific QAPP will specify the duration of this period.

BackgroundOriginalFile

- Definition: Filename of previously collected background HDF5 file which is recommended to be used to background subtract the included data
- Required Status: Optional, unless the file contains a “BackgroundTransients” group
- Units: N/A
- Example: REDWOOD_YARD_SBG_001492_2020095_000.h5
- Notes: None

Cart

- Definition: Physical dimensions of the EMI sensor array itself
- Required Status: Yes
- Units: meters
- Example: (width=0.75, length=0.75, height=0.08),meters
- Note: Edge to edge dimensions, including any inter-coil spacing. See Figure 6 and Figure 7 for clarification.
- Notes: As defined in Figure 6, length is in the along-track direction and width is in the cross-track direction.

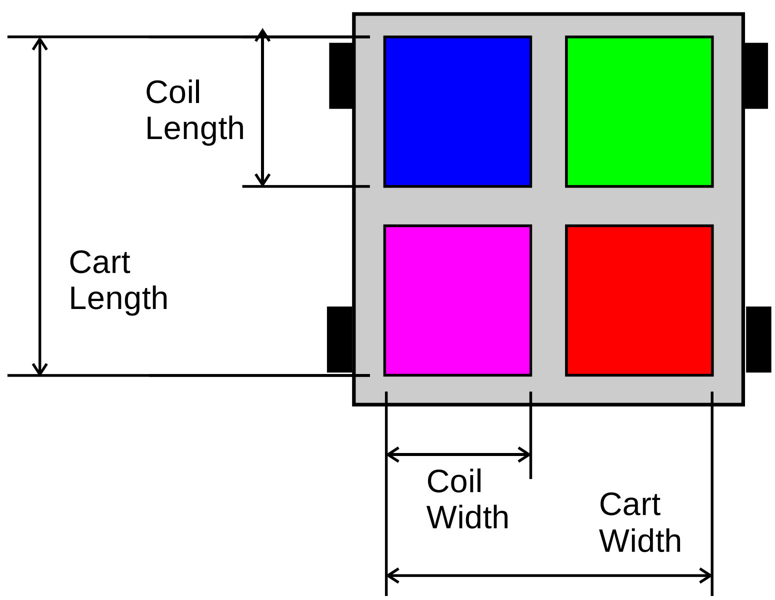


Figure 6 – Schematic of horizontal dimensions relevant to the “Cart” attribute

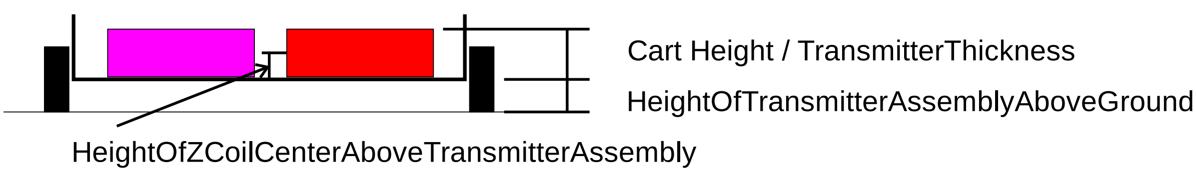


Figure 7 – Schematic of vertical dimensions relevant to the “Cart” attribute and others, as indicated

Continuous

- Definition: Indicates if the file was collected in a dynamic (1) or a static mode (0) mode

- Required Status: Yes
- Units: N/A
- Example: 0
- Notes: None

CountsPerMillivolt

- Definition: Vendor-specified measurement scaling factor to convert raw measurement to voltage
- Required Status: Optional
- Units: 1/millivolts
- Example: 6.43400,1/millivolts
- Notes: This value is reported in units of mV rather than volts, as per the attribute name.

Created

- Definition: Creation time of file, in ISO 8601 format time
- Required Status: Yes
- Units: See https://en.wikipedia.org/wiki/ISO_8601
- Example: 2020-04-04T17:12:11.851Z
- Notes: See https://en.wikipedia.org/wiki/ISO_8601

DayStamp

- Definition: Year and data of file creation in Julian date format
- Required Status: Yes
- Units: N/A
- Example: 2020095
- Notes: Format is YYYYDDD where the “YYYY” is the year (*e.g.*, 2020) and “DDD” is the day of the year (*e.g.*, 095). As an example, January 31 is “031”.

DecayTime

- Definition: Fundamental decay time of the EMI measurement
- Required Status: Yes
- Units: milliseconds
- Example: 25.00,milliseconds
- Notes: Currently, 2.78, 8.32, and 25.00 milliseconds are typical values for current AGC systems.

EquipmentSerialNumber

- Definition: An ASCII string identifying the sensor system used
- Required Status: Yes
- Units: N/A
- Example: F/F or CA1007
- Notes: None

EquipmentSerialNumberConfirm

- Definition: Confirmation that a mechanism has been implemented to verify that the correct system is identified by serial number.
- Required Status: Yes
- Units: N/A

- Example: yes
- Notes: Possible values are “yes” and “no”.

EquipmentVersion

- Definition: ASCII string to denote the hardware version of the system used to generate the file
- Required Status: Yes
- Units: N/A
- Example: TEMTADS2x2 Mark 2
- Notes: None

FinalDecayLevel

- Definition: Software defined QC value
- Required Status: Optional
- Units: percent
- Example: 10,percent
- Notes: None

FiringSequence

- Definition: Denotes the firing order of transmitters for systems.
- Required Status: Yes
- Units: N/A
- Example: A,B,C,D
- Notes: Comma-delimited, these labels should be used consistently throughout other attributes.

FiringSequenceTimes

- Definition: Time intervals between the firing of each transmitter (denoted in FiringSequence). Accounts for total time on each transmitter, including bipolar waveforms and multiple transients for averaging. The firing of the first transmitter in the sequence is “0.”
- Required Status: Yes
- Units: milliseconds
- Example: 0,16200.00,32400.00,48600.00,milliseconds
- Notes: Must be populated even for single-transmitter systems, *e.g.*, the MPV, with a value of “0”.

GateFirstValidTime

- Definition: Denotes the first time gate (for logarithmically windowed data) identified by the equipment vendor as the first time gate which is not influenced by phenomena such as transmitter ringdown.
- Required Status: Yes
- Units: N/A
- Example: 18
- Notes: None

GateWidths

- Definition: Width of time gates, or windows, for logarithmically decimated data
- Required Status: Yes
- Units: microseconds

- Example: 25,1,1,1,2,2,2,2,2,2,2,2,2,2,3,3,3,3,3,3,4,4,4,4,4,5,5,5,5,6,6,6,7,7,7,8,8,8,9,9,10,10,11,12,12,13,13,14,15,16,17,17,18,19,20,21,22,24,25,26,27,29,30,32,34,35,37,39,41,43,46,48,51,53,56,59,62,65,69,72,76,80,85,89,94,99,104,109,115,121,127,134,141,149,156,165,173,182,192,202,213,224,236,248,261,275,290,305,321,338,356,374,394,415,436,459,484,509,536,564,594,625
- Notes: This attribute does not explicitly include the unit.

GeoID

- Definition: Alphanumeric string to describe the specific survey area in which the data was collected
- Required Status: Yes
- Units: N/A
- Example: Grid1001
- Notes: Underscores, "_", are used as delimiters in filenames and therefore are not valid characters for use as part of a GeoID.

GeodeticDatum

- Definition: Geodetic datum for the position data
- Required Status: Yes
- Units: N/A
- Example: WGS84
- Notes: None

HDF5EMITagDefinitionVersion

- Definition: Indicates what version of this specification applies to the file
- Required Status: Yes
- Units: N/A
- Example: 1.0
- Notes: None

HeightOfTransmitterAssemblyAboveGround

- Definition: This value is the height of the EMI array above the ground, as can be easily measured in the field
- Required Status: Yes
- Units: meters
- Example: 0.20,meters
- Notes: This value will vary with deployment mode.

HeightOfZCoilCenterAboveTransmitterAssembly

- Definition: Distance from a defined measurement point (ideally the same point as in attribute "HeightOfTransmitterAssemblyAboveGround" to the vertical center of the EMI array)
- Required Status: Yes
- Units: meters
- Example: 0.04635,meters
- Notes: As this distance is typically not easily measured in the field, this value is expected to be a vendor-provided value in most cases.

HoldOff

- Definition: The delay after the transmitter shutoff time before decay data acquisition starts
- Required Status: Yes
- Units: microseconds
- Example: 50,microseconds
- Notes: None

LocationID

- Definition: Zero-padded, numeric value corresponding to a measurement location (*e.g.*, flag number)
- Required Status: Yes for static measurements. No for dynamic measurements.
- Units: N/A
- Example: 001492
- Notes: Values must be zero-padded to 6 digits.

LineID

- Definition: Zero-padded, numeric value corresponding to a survey line number
- Required Status: Yes for dynamic measurements. No for static measurements.
- Units: N/A
- Example: 000001
- Notes: Values must be zero-padded to 6 digits.

LogarithmicallyDecimated

- Definition: Boolean value indicating if the EMI data stored in the file has been logarithmically windowed (1) or is a set of raw, unwindowed data (0)
- Required Status: Yes
- Units: N/A
- Example: 1
- Notes: None

MagneticDeclination

- Definition: The declination of the Earth’s magnetic field local to the survey area
- Required Status: Yes
- Units: degrees
- Example: -10.70,degrees
- Notes: None

MaximumBackgroundVariation

- Definition: Maximum acceptable variation in SBG measurements from reference
- Required Status: Optional
- Units: percent
- Example: 10,percent
- Notes: None

MeasurementNumber

- Definition: The version number of a measurement for the day, provided to allow for additional measurement of an anomaly or line to provide for unique filenames and data sets
- Required Status: Yes
- Units: N/A
- Example: 000
- Notes: The first measurement is measurement "000," the next is "001," etc.
- Notes: This value resets to "000" each day.

NominalDecimationFraction

- Definition: Fractional width used to generate logarithmically windowed data
- Required Status: Yes
- Units: percent
- Example: 5.00,percent
- Notes: In the example, the width of each time window (or time gate) is nominally 5% of center time of the time window.

Operator

- Definition: Alphanumeric string identifying the operator of the sensor system
- Required Status: Yes
- Units: N/A
- Example: Doug Oldenburg
- Notes: None

OrientationRegistrationSystem

- Definition: Alphanumeric string identifying the orientation registration system used in the sensor system (*i.e.*, IMU or AHRS)
- Required Status: Yes
- Units: N/A
- Example: 3DMGX3-25
- Notes: None

OrientationRegistrationSystemOffset

- Definition: Three-dimensional offset of the orientation system location from the bottom, center of the EMI array
- Required Status: Yes
- Units: meters
- Example: (x=0.0000,y=0.0000,z=0.634),meters
- Notes: Currently the reference location is the bottom, center of the array. In future versions of this specification, values such as this one will be referenced with respect to a vendor-defined location on the sensor system.

OriginalBasePath

- Definition: Fully qualified path to the original location of the data file
- Required Status: Optional
- Units: N/A
- Example: `C:\Users\Operator\Documents\TEM Data\REDWOOD\YARD\2020095\SAM`
- Notes: Format varies by operating system on the data acquisition system.

ProjectID

- Definition: Alphabetical string identifying the project or site where the data was collected
- Required Status: Yes
- Units: N/A
- Example: APG
- Notes: Underscores, "_", are used as delimiters in filenames and therefore are not valid characters for use as part of a ProjectID.

QcWindowEndTime

- Definition: End time for SFT / DFT test data
- Required Status: Yes
- Units: microseconds
- Example: 1071.0,microseconds
- Notes: These values are typically the vendor-suggested values.

QcWindowStartTime

- Definition: Start time for SFT / DFT test data
- Required Status: Yes
- Units: microseconds
- Example: 136.0,microseconds
- Notes: These values are typically the vendor-suggested values.

RawValues

- Definition: Indicates if the instrument was operated in a diagnostic mode where scaling factors were not applied to the stored data
- Required Status: Optional
- Units: N/A
- Example: 0
- Notes: 0=false (normal instrument operation), 1=true (no scaling factors, used for instrument debugging).

ReceiverGains

- Definition: Gain factors which should be applied to the stored EMI for proper scaling
- Required Status: Yes
- Units: N/A
- Example: AX:1562.5,AY:1562.5,AZ:1562.5,BX:1562.5,BY:1562.5,BZ:1562.5,CX:1562.5,CY:1562.5,CZ:1562.5,DX:1562.5,DY:1562.5,DZ:1562.5

- Notes: The receiver coil labels used in this attribute shall match those given in the attribute "ReceiverSequence."

ReceiverLayout

- Definition: Vertex by vertex layout of each receiver loop's location within the EMI array
- Required Status: Yes
- Units: meters
- Example: AX:(x=-0.200,y=0.240,z=0.040),(x=-0.020,y=0.240,z=-0.040),(x=-0.200,y=0.160,z=-0.040),(x=-0.200,y=0.160,z=0.040),AY:(x=-0.240,y=0.200,z=0.040),(x=-0.160,y=0.200,z=0.040),(x=-0.160,y=0.200,z=-0.040),(x=-0.240,y=0.200,z=-0.040),AZ:(x=-0.240,y=0.240,z=0.000),(x=-0.160,y=0.240,z=0.000),(x=-0.160,y=0.160,z=0.000),(x=-0.240,y=0.160,z=0.000),BX:(x=0.200,y=0.240,z=0.040),(x=0.200,y=0.240,z=-0.040),(x=0.200,y=0.160,z=-0.040),(x=0.200,y=0.160,z=0.040),BY:(x=0.160,y=0.200,z=0.040),(x=0.240,y=0.200,z=0.040),(x=0.240,y=0.200,z=-0.040),(x=0.160,y=0.200,z=-0.040),BZ:(x=0.160,y=0.240,z=0.000),(x=0.240,y=0.240,z=0.000),(x=0.240,y=0.160,z=0.000),(x=0.160,y=0.160,z=0.000),CX:(x=0.200,y=-0.160,z=0.040),(x=0.200,y=-0.160,z=-0.040),(x=0.200,y=-0.240,z=-0.040),(x=0.200,y=-0.240,z=0.040),CY:(x=0.160,y=-0.200,z=0.040),(x=0.240,y=-0.200,z=0.040),(x=0.240,y=-0.200,z=-0.040),(x=0.160,y=-0.200,z=-0.040),CZ:(x=0.160,y=-0.160,z=0.000),(x=0.240,y=-0.160,z=0.000),(x=0.240,y=-0.240,z=0.000),(x=0.160,y=-0.240,z=0.000),DX:(x=-0.200,y=-0.160,z=0.040),(x=-0.200,y=-0.160,z=-0.040),(x=-0.200,y=-0.240,z=-0.040),(x=-0.200,y=-0.240,z=0.040),DY:(x=-0.240,y=-0.200,z=0.040),(x=-0.160,y=-0.200,z=0.040),(x=-0.160,y=-0.200,z=-0.040),(x=-0.240,y=-0.200,z=-0.040),DZ:(x=-0.240,y=-0.160,z=0.000),(x=-0.160,y=-0.160,z=0.000),(x=-0.160,y=-0.240,z=0.000),(x=-0.240,y=-0.240,z=0.000),meters
- Notes: The receiver coil labels used in this attribute shall match those given in the attribute "ReceiverSequence."

ReceiverNormalVectors

- Definition: Specifies the orientation of each receiver coil using unit vectors
- Required Status: Yes
- Units: unit vector (e.g., (x=1.0000,y=0.0000,z=0.000))
- Example: AX:(x=1.0000,y=0.0000,z=0.000),AY:(x=0.0000,y=1.0000,z=0.000),AZ:(x=0.0000,y=0.0000,z=1.000),BX:(x=1.0000,y=0.0000,z=0.000),BY:(x=0.0000,y=1.0000,z=0.000),BZ:(x=0.0000,y=0.0000,z=1.000),CX:(x=1.0000,y=0.0000,z=0.000),CY:(x=0.0000,y=1.0000,z=0.000),CZ:(x=0.0000,y=0.0000,z=1.000),DX:(x=1.0000,y=0.0000,z=0.000),DY:(x=0.0000,y=1.0000,z=0.000),DZ:(x=0.0000,y=0.0000,z=1.000)
- Notes: The receiver coil labels used in this attribute shall match those given in the attribute "ReceiverSequence."

ReceiverSaturationThreshold

- Definition: The maximum voltage (signed) that can be output by a receiver channel, indicating that the receiver channel is saturated
- Required Status: Yes
- Units: volts

- Example: 10.00,volts
- Notes: This is a signed value, can be positive or negative, and is typically vendor-supplied.
- Notes: For historical context / institutional memory, this value is -4.25 V for the NRL TEMTADS 2x2 and NovaTEM TEMSense.

ReceiverSequence

- Definition: Similar to “FiringSequence,” an enumeration of the labels used for the receiver coils
- Required Status: Yes
- Units: N/A
- Example: AX,AY,AZ,BX,BY,BZ,CX,CY,CZ,DX,DY,DZ
- Notes: None

ReceiverThickness

- Definition: Thickness of the receiver coil, accounting for multiple windings
- Required Status: Yes
- Units: meters
- Example: AX:0.035,AY:0.035,AZ:0.035,BX:0.035,BY:0.035,BZ:0.035,CX:0.035,CY:0.035,CZ:0.035,DX:0.035,DY:0.035,DZ:0.035,meters
- Notes: The order used in “ReceiverSequence” shall be followed here.
- Notes: See Figure 8 below for clarification.

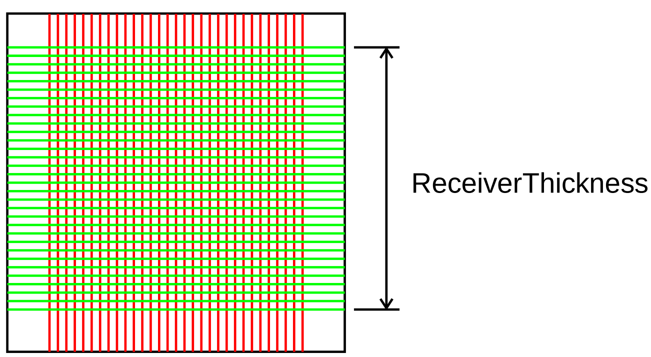


Figure 8 – The “ReceiverThickness” dimension indicated schematically for an example receiver coil

ReceiverTurns

- Definition: Number of turns included in each receiver loop
- Required Status: Yes
- Units: turns
- Example: AX:200,AY:200,AZ:200,BX:200,BY:200,BZ:200,CX:200,CY:200,CZ:200,DX:200,DY:200,DZ:200
- Notes: None

SampleWidth

- Definition: Sampling interval for raw EMI data
- Required Status: Yes

- Units: nanoseconds
- Example: 2000,nanoseconds
- Notes: None

SensorFunctionReferenceOriginalFile

- Definition: The filename of the sensor function reference file (*e.g.*, SFR) to which this file should be compared in a sensor function test
- Required Status: Optional, unless the file contains a sensor function test data (*e.g.*, SFT measurement type)
- Units: N/A
- Example: TEMTADS_FF25ms_SFR_000000_2020095_000.h5
- Notes: Only required for SFT and DFT files.

SpatialRegistrationSystem

- Definition: Alphanumeric string identifying the spatial registration system used in the sensor system (*i.e.*, GPS or RTS)
- Required Status: Yes
- Units: N/A
- Example: GPS,R8GNSSv3
- Notes: This attribute has two field. The first identifies the type of spatial registration system (*i.e.*, GPS or RTS), and the second identifies the specific system.

SpatialRegistrationSystemOffset

- Definition: Three-dimensional offset of the spatial system location from the bottom, center of the EMI array
- Required Status: Yes
- Units: meters
- Example: (x=0.0000,y=0.0000,z=0.946),meters
- Notes: In future versions of this specification, values such as this one will be referenced off a vendor-defined location on the sensor system.

SwathWidth

- Definition: Effective lane width corresponding to the maximum detection or classification width of the sensor
- Required Status: Required for dynamic measurements
- Units: meters
- Example: 0.75,meters
- Notes: Commonly measured as the physical width (outside wire-to-wire) of transmitters coils for the purposes of calculating appropriate lane spacing and coverage.

Tractor

- Definition: Specifies the relative location of the sensor array with respect to a tractor or other conveyance system
- Required Status: Optional
- Units: meters

- Example: (length=0.50,width=0.50,operatorEyeHeight=1.80,distanceBehindCart=1.25,operatorX=0.00,operatorY=0.00),meters
- Notes: None

TransmissionCurrentThreshold

- Definition: Transmission current threshold below which data collection is forced to stop
- Required Status: Yes
- Units: amperes
- Example: 5.50,amperes
- Notes: This value is typically supplied by the hardware vendor. Variations are also specified in the QSR v2.0 and in project specific QAPPs.

TransmitterDutyCycle

- Definition: Defines the ratio of on time vs off time for the EMI transmitter
- Required Status: Yes
- Units: percent
- Example: 50,percent
- Notes: Most current AGC systems use a 50% duty cycle, or equal on time and off time.

TransmitterLayout

- Definition: Vertex by vertex layout of each transmitter loop's location within the EMI array
- Required Status: Yes
- Units: meters
- Example: A:(x=-0.3750,y=0.3750,z=0.000),(x=-0.0250,y=0.3750,z=0.000),(x=-0.0250,y=0.0250,z=0.000),(x=-0.3750,y=0.0250,z=0.000),B:(x=0.0250,y=0.3750,z=0.000),(x=0.3750,y=0.3750,z=0.000),(x=0.3750,y=0.0250,z=0.000),(x=0.0250,y=0.0250,z=0.000),C:(x=0.0250,y=-0.0250,z=0.000),(x=0.3750,y=-0.0250,z=0.000),(x=0.3750,y=-0.3750,z=0.000),(x=0.0250,y=-0.3750,z=0.000),D:(x=-0.3750,y=-0.0250,z=0.000),(x=-0.0250,y=-0.0250,z=0.000),(x=-0.0250,y=-0.3750,z=0.000),(x=-0.3750,y=-0.3750,z=0.000),meters
- Notes: The transmitter coil labels used in this attribute shall match those given in the attribute "FiringSequence."
- Notes: While not required in this version of the specification, one is encouraged to list the vertices in the order of current flow and to be consistent with the contents of "TransmitterNormalVectors."

TransmitterNormalVectors

- Definition: Specifies the orientation of each transmitter coil using unit vectors
- Required Status: Yes
- Units: unit vector (e.g., (x=1.0000,y=0.0000,z=0.000))
- Example: A:(x=0.0000,y=0.0000,z=-1.000),B:(x=0.0000,y=0.0000,z=-1.000),C:(x=0.0000,y=0.0000,z=-1.000),D:(x=0.0000,y=0.0000,z=-1.000)
- Notes: The transmitter coil labels used in this attribute shall match those given in the attribute "FiringSequence."

TransmitterThickness

- Definition: Thickness of the transmitter coil, accounting for multiple windings
- Required Status: Yes
- Units: meters
- Example: A:0.08,B:0.08,C:0.08,D:0.08,meters
- Notes: See Figure 9 for clarification
- Notes: The transmitter coil labels used in this attribute shall match those given in the attribute "FiringSequence."

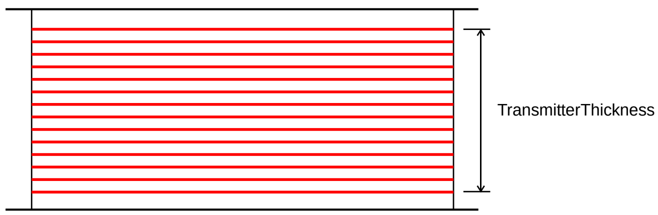


Figure 9 – The "TransmitterThickness" dimension shown schematically for an example transmitter coil

TransmitterTurns

- Definition: Number of turns included in each transmitter loop
- Required Status: Yes
- Units: turns
- Example: A:25,B:25,C:25,D:25
- Notes: The transmitter coil labels used in this attribute shall match those given in the attribute "FiringSequence."

UnsortedChannels

- Definition: Indicates a diagnostic testing mode
- Required Status: Optional
- Units: N/A
- Example: 0
- Notes: 0= false (normal operation), 1= true (diagnostic testing).

WaveformOversampleCount

- Definition: A parameter of the data acquisition hardware
- Required Status: Optional
- Units: N/A
- Example: 2
- Notes: Fixed value asserted by data acquisition hardware.

7.2. Transient Group Attributes

The transient group attributes of the "Transient group" of an SFT HDF5 file, as presented in HDFView 3.0, are shown in Figure 10. The attributes defined in this standard are listed in Table 4.

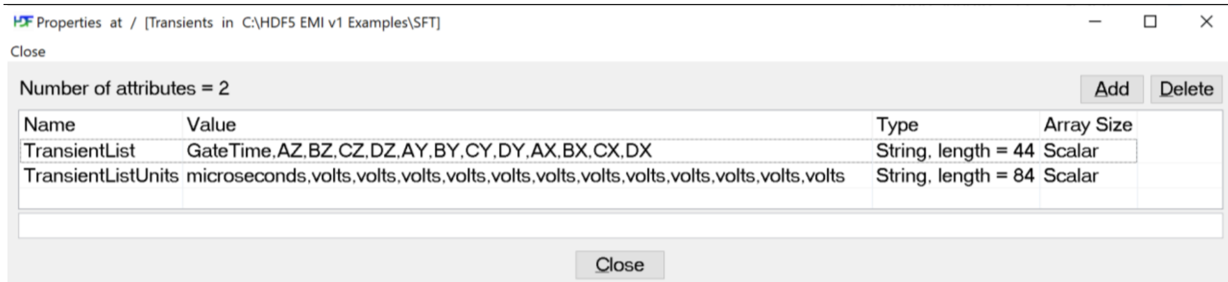


Figure 10 – Example transient group attributes for the “Transient” group in an SFT file

Table 4 – Transient Group Attributes

Name	**Required**	**Optional (Dynamic)**	**Optional (Static)**
TransientList	X		
TransientListUnits	X		

Definitions and data requirements for the attributes listed in Table 4 are described in detail below:

TransientList

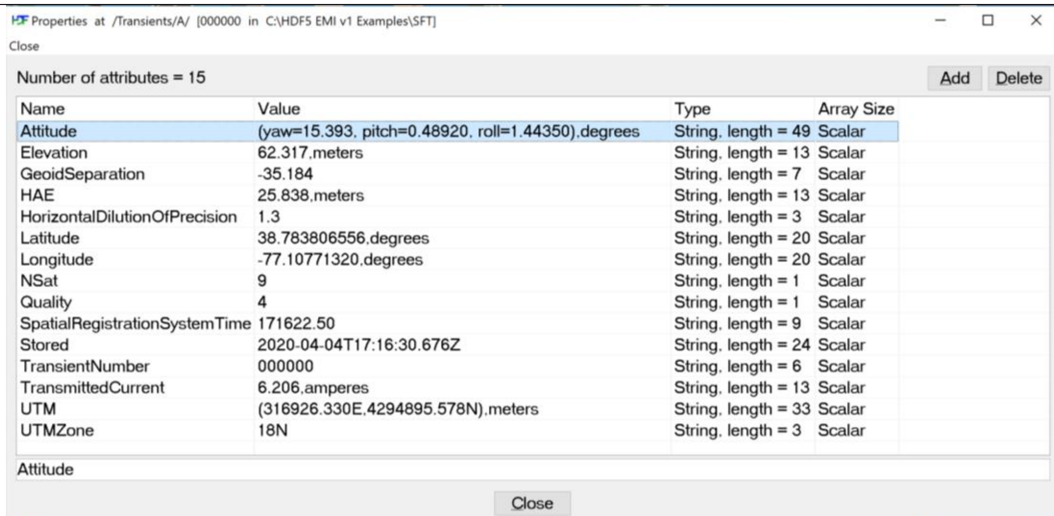
- Definition: Enumeration of data channels included in each set of transient data
- Required Status: Yes
- Units: N/A
- Example: GateTime,AZ,BZ,CZ,DZ,AY,BY,CY,DY,AX,BX,CX,DX
- Notes: The order of receivers here shall be the same as in the file level attribute “ReceiverSequence.”

TransientListUnits

- Definition: Units for values listed in TransientList attribute, in the same order
- Required Status: Yes
- Units: As specified
- Example: microseconds,volts,volts,volts,volts,volts,volts,volts,volts,volts,volts,volts,volts
- Notes: None

7.3. Transient Scalar Dataset Attributes

The scalar attributes of a transient from an SFT HDF5 file, as presented in HDFView 3.0, are shown in Figure 11. The attributes defined in this standard are listed in Table 5.


Properties at /Transients/A/ [000000 in C:\HDF5 EMI v1 Examples\SFT]

Close

Number of attributes = 15 Add Delete

Name	Value	Type	Array Size
Attitude	(yaw=15.393, pitch=0.48920, roll=1.44350),degrees	String, length = 49	Scalar
Elevation	62.317,meters	String, length = 13	Scalar
GeoidSeparation	-35.184	String, length = 7	Scalar
HAE	25.838,meters	String, length = 13	Scalar
HorizontalDilutionOfPrecision	1.3	String, length = 3	Scalar
Latitude	38.783806556,degrees	String, length = 20	Scalar
Longitude	-77.10771320,degrees	String, length = 20	Scalar
NSat	9	String, length = 1	Scalar
Quality	4	String, length = 1	Scalar
SpatialRegistrationSystemTime	171622.50	String, length = 9	Scalar
Stored	2020-04-04T17:16:30.676Z	String, length = 24	Scalar
TransientNumber	000000	String, length = 6	Scalar
TransmittedCurrent	6.206,amperes	String, length = 13	Scalar
UTM	(316926.330E,4294895.578N),meters	String, length = 33	Scalar
UTMZone	18N	String, length = 3	Scalar

Attitude

Close

Figure 11 – Example transient scalar dataset attributes for a transient in an SFT file

Definitions and data requirements for the attributes listed in Table 5 are described in detail below:

Table 5 – Transient Scalar Dataset Attributes

Name	Required for GPS	Required for RTS	Required if no GPS / RTS available	Optional for Advanced Navigation Systems
Attitude	X	X		
Elevation	X	X		
GeoidSeparation				
EpochTime				X
HAE				
HorizontalDilutionOfPrecision	X			
Latitude	X			
Longitude	X			
NSat	X			
Quality	X			
SpatialRegistrationSystemTime	X	X		
Stored	X	X	X	
TransientNumber	X	X	X	
TransmittedCurrent	X	X	X	
UTM		X		
UTMZone		X		

Attitude

- Definition: Orientation information for EMI array
- Required Status: Required for GPS and RTS
- Units: degrees, typically, or radians
- Example: (yaw=14.7474,pitch=-4.4293,roll=0.8929),degrees
- Notes: None

Elevation

- Definition: Elevation above Mean Sea Level (MSL)
- Required Status: Required for GPS and RTS
- Units: meters
- Example: 59.317,meters
- Notes: None

GeoidSeparation

- Definition: Offset between MSL and HAE
- Required Status: This attribute is only required if the value is used to calculate HAE from elevation or vice versa
- Units: meters
- Example: -33.505,meters
- Notes: The $GPGGA NMEA sentence provides both elevation and geoid separation. HAE can be computers as HAE = Elevation + Geoid Separation.
- Notes: The value for geoid separation for CONUS locations is typically -30 meters.

EpochTime

- Definition: Time in seconds since the start of an epoch time
- Required Status: Optional for advanced navigation systems
- Units: seconds
- Example: 1598107238.623892338
- Note: Reported to the nanosecond (1x 10^{-9} seconds).
- Note: GPS Time (GPST) is a continuous time scale (no leap seconds) defined by the GPS Control segment on the basis of a set of atomic clocks at the Monitor Stations and onboard the satellites. It starts at 0h UTC (midnight) of January 5th to 6th 1980. At the writing of this document, the GPS epoch time was roughly 1282142567.000.

```
https://gssc.esa.int/navipedia/index.php/Time_References_in_GNSS#
https://www.gw-openscience.org/gps/
```

- Notes: The Unix epoch (or Unix time or POSIX time or Unix timestamp) is the number of seconds that have elapsed since January 1, 1970 (midnight UTC/GMT), not counting leap seconds (in ISO 8601: 1970-01-01T00:00:00Z). At the writing of this document, the Unix epoch time was roughly 1598107238.000.

```
https://www.epochconverter.com/
```

- Notes: See https://www.epochconverter.com/ for more details on epoch time.

HAE

- Definition: Height Above Ellipsoid
- Required Status: No
- Units: meters
- Example: 25.812,meters
- Notes: None

HorizontalDilutionOfPrecision

- Definition: A measure of the 2D precision of a GPS fix
- Required Status: Yes for GPS
- Units: N/A
- Example: 1.0
- Notes: Nominally values increase from 1.0 as the precision of the fix degrades. Values less than 1.0 typically indicate an overdetermined solution.

Latitude

- Definition: Latitude is specified in degrees, starting from -90° at the South Pole and ending up with 90° at the North Pole
- Required Status: Yes for GPS
- Units: degrees
- Example: 38.783806719,degrees
- Notes: The N/S convention should not be used with this standard.

Longitude

- Definition: Longitude is specified in degrees, starting from 0° at the Prime Meridian and ending up with +180/-180° at the antimeridian
- Required Status: Yes for GPS
- Units: degrees
- Example: -77.10771341,degrees
- Notes: The E/W convention should not be used with this standard.

NSat

- Definition: Number of GPS satellites used in the solution
- Required Status: Yes for GPS
- Units: N/A
- Example: 11
- Notes: For systems like RTK, the value reflects the number of common satellites.

Quality

- Definition: Quality of the GPS Fix, or solution
- Required Status: Yes for GPS
- Units: N/A
- Example: 4
- Notes: For $GPGGA, the possible values of fix quality currently are:
- Fix quality:
    - 0 = invalid
    - 1 = GPS fix (SPS)
    - 2 = DGPS fix
    - 3 = PPS fix
    - 4 = Real Time Kinematic
    - 5 = Float RTK
    - 6 = estimated (dead reckoning)
    - 7 = Manual input mode
    - 8 = Simulation mode

SpatialRegistrationSystemTime

- Definition: Time in UTC, format is HHMMSS.ss
- Required Status: Required for GPS and RTS
- Units: format is HHMMSS.ss
- Example: 170922.00
- Notes: None

Stored

- Definition: Time that the transient was stored in ISO 8601 format
- Required Status: Yes
- Units: See https://en.wikipedia.org/wiki/ISO_8601
- Example: 2020-04-04T17:09:30.682Z
- Notes: See https://en.wikipedia.org/wiki/ISO_8601

TransientNumber

- Definition: A unique, sequential number identifying the transient
- Required Status: Yes
- Units: N/A
- Example: 000001
- Notes: Value is zero-padded to 6 digits.

TransmittedCurrent

- Definition: The recorded current through the transmitter loop corresponding to the transient
- Required Status: Yes
- Units: amperes
- Example: 6.243,amperes
- Notes: None

UTM

- Definition: 2D location in UTM where the EMI array was located, within the specified UTM zone) when the transient was acquired
- Required Status: Yes for RTS
- Units: meters
- Example: (316926.312E,4294895.596N),meters
- Notes: Standard is to list easting first, northing second.

UTMZone

- Definition: The UTM zone which corresponds to the location stored in the UTM attribute
- Required Status: Yes for RTS
- Units: N/A
- Example: 18N
- Notes: The N/S convention is used. Latitude Band letters are not to be included.

8. Example – Static Anomaly Measurement (SAM)

8.1. File Attributes and Definitions

For each HDF5 file, the following attributes are defined. The attribute names, data type details, and an example set of values for a SAM measurement type are given in Table 6.

Table 6 – SAM File Attributes

Name	**Example Value**	**Data Type**	**Array Size**
AcquisitionMode	SAM	String	Scalar
AcquisitionSoftwareVersion	TEM_Datalogger:6.1.0	String	Scalar
Ambient	1	String	Scalar
AmbientCps	60,hertz	String	Scalar
AveragedTransients	162	String	Scalar
BackgroundAcqReminderInterval	60,minutes	String	Scalar
BackgroundOriginalFile	REDWOOD_YARD_SBR_001492_2020095_000.h5	String	Scalar
Cart	(width=0.75,length=0.75,height=0.08),meters	String	Scalar
Continuous	0	String	Scalar
Created	2020-04-04T17:12:11.851Z	String	Scalar
DayStamp	2020095	String	Scalar
DecayTime	25.00,milliseconds	String	Scalar
EquipmentSerialNumber	F/F	String	Scalar
EquipmentSerialNumberConfirm	Yes	String	Scalar
EquipmentVersion	TEMTADS2x2 Mark 2	String	Scalar
FiringSequence	A,B,C,D	String	Scalar
FiringSequenceTimes	0,16200.00,32400.00,48600.00,milliseconds	String	Scalar
GateFirstValidTime	18	String	Scalar
GateWidths	25,1,1,1,2,2,2,2,2,2,2,2,2,2,3,3,3,3,3,3,4,4,4,4,4,5,5,5,5,6,6,6,7,7,7,8,8,8,9,9,10,10,11,12,12,13,13,14,15,16,17,17,18,19,20,21,22,24,25,26,27,29,30,32,34,35,37,39,41,43,46,48,51,53,56,59,62,65,69,72,76,80,85,89,94,99,104,109,115,121,127,134,141,149,156,165,173,182,192,202,213,224,236,248,261,275,290,305,321,338,356,374,394,415,436,459,484,509,536,564,594,625	String	Scalar
GeoID	YARD	String	Scalar
GeodeticDatum	WGS84	String	Scalar
HDF5EMITagDefinitionVersion	1.0	String	Scalar
HeightOfTransmitterAssemblyAboveGround	0.20,meters	String	Scalar
HeightOfZCoilCenterAboveTransmitterAssembly	0.04635,meters	String	Scalar
Holdoff	50,microseconds	String	Scalar
LocationID	001492	String	Scalar
LogarithmicallyDecimated	1	String	Scalar
MagneticDeclination	-10.70,degrees	String	Scalar
MeasurementNumber	000	String	Scalar
NominalDecimationFraction	5.00,percent	String	Scalar
Operator	Operator	String	Scalar
OrientationRegistrationSystem	3DMGX3-25	String	Scalar
OrientationRegistrationSystemOffset	(x=0.0000,y=0.0000,z=0.634),meters	String	Scalar
OriginalBasePath	C:\Users\Operator\Documents\TEM Data\REDWOOD\YARD\2020095\SAM	String	Scalar
ProjectID	REDWOOD	String	Scalar
QcWindowEndTime	1071.0,microseconds	String	Scalar
QcWindowStartTime	136.0,microseconds	String	Scalar
ReceiverGains	AX:1562.5,AY:1562.5,AZ:1562.5,BX:1562.5,BY:1562.5,BZ:1562.5,CX:1562.5,CY:1562.5,CZ:1562.5,DX:1562.5,DY:1562.5,DZ:1562.5	String	Scalar
ReceiverLayout	AX:(x=-0.200,y=0.240,z=0.040),(x=-0.020,y=0.240,z=-0.040),(x=-0.200,y=0.160,z=-0.040),(x=-0.200,y=0.160,z=0.040),AY:(x=-0.240,y=0.200,z=0.040),(x=-0.160,y=0.200,z=0.040),(x=-0.160,y=0.200,z=-0.040),(x=-0.240,y=0.200,z=-0.040),AZ:(x=-0.240,y=0.240,z=0.000),(x=-0.160,y=0.240,z=0.000),(x=-0.160,y=0.160,z=0.000),(x=-0.240,y=0.160,z=0.000),BX:(x=0.200,y=0.240,z=0.040),(x=0.200,	String	Scalar

Name	Example Value	Data Type	Array Size
	y=0.240,z=-0.040),(x=0.200,y=0.160,z=-0.040),(x=0.200,y=0.160,z=0.040),BY:(x=0.160,y=0.200,z=0.040),(x=0.240,y=0.200,z=0.040),(x=0.240,y=0.200,z=-0.040),(x=0.160,y=0.200,z=-0.040),BZ:(x=0.160,y=0.240,z=0.000),(x=0.240,y=0.240,z=0.000),(x=0.240,y=0.160,z=0.000),(x=0.160,y=0.160,z=0.000),CX:(x=0.200,y=-0.160,z=0.040),(x=0.200,y=-0.160,z=-0.040),(x=0.200,y=-0.240,z=-0.040),(x=0.200,y=-0.240,z=0.040),CY:(x=0.160,y=-0.200,z=0.040),(x=0.240,y=-0.200,z=0.040),(x=0.240,y=-0.200,z=-0.040),(x=0.160,y=-0.200,z=-0.040),CZ:(x=0.160,y=-0.160,z=0.000),(x=0.240,y=-0.160,z=0.000),(x=0.240,y=-0.240,z=0.000),(x=0.160,y=-0.240,z=0.000),DX:(x=-0.200,y=-0.160,z=0.040),(x=-0.200,y=-0.160,z=-0.040),(x=-0.200,y=-0.240,z=-0.040),(x=-0.200,y=-0.240,z=0.040),DY:(x=-0.240,y=-0.200,z=0.040),(x=-0.160,y=-0.200,z=0.040),(x=-0.160,y=-0.200,z=-0.040),(x=-0.240,y=-0.200,z=-0.040),DZ:(x=-0.240,y=-0.160,z=0.000),(x=-0.160,y=-0.160,z=0.000),(x=-0.160,y=-0.240,z=0.000),(x=-0.240,y=-0.240,z=0.000),meters		
ReceiverNormalVectors	AX:(x=1.0000,y=0.0000,z=0.000),AY:(x=0.0000,y=1.0000,z=0.000),AZ:(x=0.0000,y=0.0000,z=1.000),BX:(x=1.0000,y=0.0000,z=0.000),BY:(x=0.0000,y=1.0000,z=0.000),BZ:(x=0.0000,y=0.0000,z=1.000),CX:(x=1.0000,y=0.0000,z=0.000),CY:(x=0.0000,y=1.0000,z=0.000),CZ:(x=0.0000,y=0.0000,z=1.000),DX:(x=1.0000,y=0.0000,z=0.000),DY:(x=0.0000,y=1.0000,z=0.000),DZ:(x=0.0000,y=0.0000,z=1.000)	String	Scalar
ReceiverSaturationThreshold	-4.25,volts	String	Scalar
ReceiverSequence	AX,AY,AZ,BX,BY,BZ,CX,CY,CZ,DX,DY,DZ	String	Scaler
ReceiverThickness	AX:0.035,AY:0.035,AZ:0.035,BX:0.035,BY:0.035,BZ:0.035,CX:0.035,CY:0.035,CZ:0.035,DX:0.035,DY:0.035,DZ:0.035,meters	String	Scalar
ReceiverTurns	AX:200,AY:200,AZ:200,BX:200,BY:200,BZ:200,CX:200,CY:200,CZ:200,DX:200,DY:200,DZ:200	String	Scalar
SampleWidth	2000,nanoseconds	String	Scalar
SpatialRegistrationSystem	GPS,R8GNSSv3	String	Scalar
SpatialRegistrationSystemOffset	(x=0.0000,y=0.0000,z=0.946),meters	String	Scalar
Tractor	*	String	Scalar
TransmissionCurrentThreshold	5.50,amperes	String	Scalar
TransmitterDutyCycle	50,percent	String	Scalar
TransmitterLayout	A:(x=-0.3750,y=0.3750,z=0.000),(x=-0.0250,y=0.3750,z=0.000),(x=-0.0250,y=0.0250,z=0.000),(x=-0.3750,y=0.0250,z=0.000),B:(x=0.0250,y=0.3750,z=0.000),(x=0.3750,y=0.3750,z=0.000),(x=0.3750,y=0.0250,z=0.000),(x=0.0250,y=0.0250,z=0.000),C:(x=0.0250,y=-0.0250,z=0.000),(x=0.3750,y=-0.0250,z=0.000),(x=0.3750,y=-0.3750,z=0.000),(x=0.0250,y=-0.3750,z=0.000),D:(x=-0.3750,y=-0.0250,z=0.000),(x=-0.0250,y=-0.0250,z=0.000),(x=-0.0250,y=-0.3750,z=0.000),(x=-0.3750,y=-0.3750,z=0.000),meters	String	Scalar
TransmitterNormalVectors	A:(x=0.0000,y=0.0000,z=-1.000),B:(x=0.0000,y=0.0000,z=-1.000),C:(x=0.0000,y=0.0000,z=-1.000),D:(x=0.0000,y=0.0000,z=-1.000)	String	Scalar
TransmitterThickness	A:0.08,B:0.08,C:0.08,D:0.08,meters	String	Scalar
TransmitterTurns	A:25,B:25,C:25,D:25	String	Scalar

8.2. Transient Group Attributes and Definitions

For each transient group stored in the HDF5 file, the following attributes are required. The “Transients” transient group is required. There can be additional transient groups in a given HDF5 file, depending on the measurement type. If the measurement type supports, the “BackgroundTransients” transient group may be present as well. Each transient group then contains a Transmitter group for each transmitter, which therein contain a scalar dataset for each transient collected. The attribute names, data type details, and an example set of values for a SAM measurement type are given in Table 7.

Table 7 – Transient Group Attributes for a SAM File

Name	**Example Value**	**Data Type**	**Array Size**
TransientList	GateTime,AZ,BZ,CZ,DZ,AY,BY,CY,DY,AX,BX,CX,DX	String	Scalar
TransientListUnits	microseconds,volts,volts,volts,volts,volts,volts,volts,volts,volts,volts,volts,volts	String	Scalar

8.3. Transient Scalar Dataset Attributes and Definitions

For each transient stored in the HDF5 file, the following attributes are required. The attribute names, data type details, and an example set of values for a SAM measurement type are given in Table 8.

Note: The DAGCAP HDF5 standard describes the raw file created from merging three data sources – AGC sensor data, platform positioning data, and platform attitude data. Platform positioning data are typically provided by GNSS systems (e.g., GPS) and platform attitude data are typically provided by IMU or attitude and heading reference systems (AHRS). The output specifications for these three sources are manufacturer dependent and does not currently fall under DAGCAP standardization requirements.

Table 8 – Transient Scalar Dataset Attributes for a SAM File

Name	**Example Value**	**Data Type**	**Array Size**
Attitude	(yaw=15.393,pitch=0.44526,roll=1.42937),degrees	String	Scalar
Elevation	59.317,meters	String	Scalar
GeoidSeparation	-33.505,meters	String	Scalar
HAE	25.812,meters	String	Scalar
HorizontalDilutionOfPrecision	1.0	String	Scalar
Latitude	38.783806719,degrees	String	Scalar
Longitude	-77.10771341,degrees	String	Scalar
NSat	11	String	Scalar
Quality	4	String	Scalar
SpatialRegistrationSystemTime	170922.00	String	Scalar
Stored	2020-04-04T17:09:30.682Z	String	Scalar
TransientNumber	000000	String	Scalar
TransmittedCurrent	6.243,amperes	String	Scalar
UTM	(316926.312E,4294895.596N),meters	String	Scalar
UTMZone	18N	String	Scalar

9. Example – Dynamic Anomaly Measurement (DAM)

9.1. File Attributes and Definitions

For each HDF5 file, the following attributes are defined. An example, as presented in HDFView 3.0 is shown in Figure 2. The attribute names, data type details, and an example set of values for a DAM measurement type are given in Table 9.

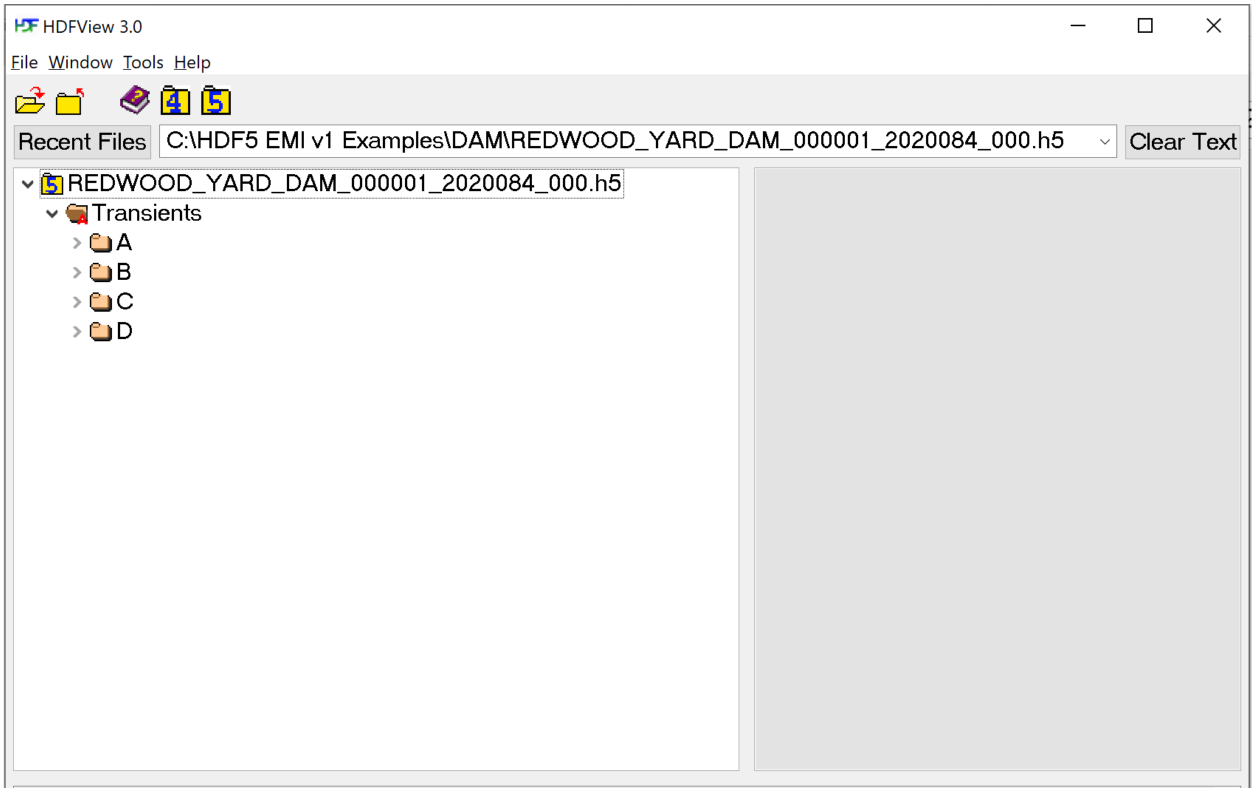


Figure 12 – Example DAM HDF5 as presented in HDFView 3.0

Table 9 – DAM File Attributes

Name	**Example Value**	**Data Type**	**Array Size**
AcquisitionMode	DAM	String	Scalar
AcquisitionSoftwareVersion	EM3Dv9.9.20.726	String	Scalar
Ambient	1	String	Scalar
AmbientCps	60,hertz	String	Scalar
AveragedTransients	3	String	Scalar
BackgroundAcqReminderInterval	60,minutes	String	Scalar
BackgroundOriginalFile	*	String	Scalar
Cart	(width=0.7500,length=0.7500,height=0.0800),meters	String	Scalar
Continuous	1	String	Scalar
CountsPerMillivolt	3.27675,1/millivolts	String	Scalar
Created	2020-04-04T17:12:11.851Z	String	Scalar
DayStamp	2020095	String	Scalar
DecayTime	2.78,milliseconds	String	Scalar
EquipmentSerialNumber	F	String	Scalar
EquipmentSerialNumberConfirm	yes	String	Scalar
EquipmentVersion	LOGGEROVER	String	Scalar
FinalDecayLevel	0,percent	String	Scalar
FiringSequence	T1Z,T2Z,T3Z,T4Z	String	Scalar
FiringSequenceTimes	0.000,33.336,66.672,100.008,milliseconds	String	Scalar
GateFirstValidTime	2	String	Scalar
GateWidths	25,6,8,10,12,15,19,24,30,37,47,58,73,91,114,142,178,222,278	String	Scalar
GeoID	GR	String	Scalar
GeodeticDatum	WGS84	String	Scalar
HDF5EMITagDefinitionVersion	1.0	String	Scalar
HeightOfTransmitterAssemblyAboveGround	0.2000,meters	String	Scalar
HeightOfZCoilCenterAboveTransmitterAssembly	0.0000,meters	String	Scalar
Holdoff	50,microseconds	String	Scalar
LocationID	000006	String	Scalar
LogarithmicallyDecimated	1	String	Scalar
MagneticDeclination	-10.70,degrees	String	Scalar
MeasurementNumber	000	String	Scalar
NominalDecimationFraction	20.00,percent	String	Scalar
Operator	Operator	String	Scalar
OrientationRegistrationSystem	Microstrain3Dmgx325	String	Scalar
OrientationRegistrationSystemOffset	(x=0.0000,y=0.0000,z=0.634),meters	String	Scalar
OriginalBasePath	C:\EM3D\Data	String	Scalar
ProjectID	HM	String	Scalar
QcWindowEndTime	524.0,microseconds	String	Scalar
QcWindowStartTime	137.0,microseconds	String	Scalar
ReceiverGains	AZ:1562.5,AY:1562.5,AX:1562.5,BZ:1562.5,BY:1562.5,BX:1562.5,CZ:1562.5,CY:1562.5,CX:1562.5,DZ:1562.5,DY:1562.5,DX:1562.5	String	Scalar
ReceiverLayout	AZ:(x=-00.240,y=00.160,z=00.000),(x=-00.240,y=00.160,z=00.000),(x=-00.160,y=00.240,z=00.000),(x=-00.160,y=00.240,z=00.000),AY:(x=-00.240,y=00.200,z=-00.040),(x=-00.240,y=00.200,z=00.040),(x=-00.160,y=00.200,z=00.040),(x=-00.160,y=00.200,z=-00.040),AX:(x=-00.200,y=00.160,z=-00.040),(x=-00.200,y=00.160,z=00.040),(x=-00.200,y=00.240,z=00.040),(x=-00.200,y=00.240,z=-00.040),BZ:(x=00.160,y=00.160,z=00.000),(x=00.160,y=00.160,z=00.000),(x=00.240,y=00.240,z=00.000),(x=00.240,y=00.240,z=00.000),BY:(x=00.160,y=00.200,z=-00.040),(x=00.160,y=00.200,z=00.040),(x=00.240,y=00.200,z=00.040),(x=00.240,y=00.200,z=-00.040),BX:(x=00.200,y=00.160,z=-00.040),(x=00.200,y=00.160,z=00.040),(x=00.200,y=00.240,z=00.040),(x=00.200,y=00.240,z=-00.040),CZ:(x=00.160,y=-00.240,z=00.000),(x=00.160,y=-00.240,z=00.000),(x=00.240,y=-00.160,z=00.000),(x=00.240,y=-00.160,z=00.000),CY:(x=00.160,y=-00.200,z=-00.040),(x=00.160,y=-00.200,z=00.040),(x=00.240,y=-00.200,z=00.040),(x=00.240,y=-00.200,z=-00.040),	String	Scalar

Name	Example Value	Data Type	Array Size
	CX:(x=00.200,y=-00.240,z=-00.040),(x=00.200,y=-00.240,z=00.040),(x=00.200,y=-00.160,z=00.040),(x=00.200,y=-00.160,z=-00.040),DZ:(x=-00.240,y=-00.240,z=00.000),(x=-00.240,y=-00.240,z=00.000),(x=-00.160,y=-00.160,z=00.000),(x=-00.160,y=-00.160,z=00.000),DY:(x=-00.240,y=-00.200,z=-00.040),(x=-00.240,y=-00.200,z=00.040),(x=-00.160,y=-00.200,z=00.040),(x=-00.160,y=-00.200,z=-00.040),DX:(x=-00.200,y=-00.240,z=-00.040),(x=-00.200,y=-00.240,z=00.040),(x=-00.200,y=-00.160,z=00.040),(x=-00.200,y=-00.160,z=-00.040),meter		
ReceiverNormalVectors	AZ:(x=0.0,y=0.0,z=1.0),AY:(x=0.0,y=1.0,z=0.0),AX:(x=1.0,y=0.0,z=0.0),BZ:(x=0.0,y=0.0,z=1.0),BY:(x=0.0,y=1.0,z=0.0),BX:(x=1.0,y=0.0,z=0.0),CZ:(x=0.0,y=0.0,z=1.0),CY:(x=0.0,y=1.0,z=0.0),CX:(x=1.0,y=0.0,z=0.0),DZ:(x=0.0,y=0.0,z=1.0),DY:(x=0.0,y=1.0,z=0.0),DX:(x=1.0,y=0.0,z=0.0)	String	Scalar
ReceiverSaturationThreshold	-4.25,volts	String	Scalar
ReceiverSequence	AZ,AY,AX,BZ,BY,BX,CZ,CY,CX,DZ,DY,DX	String	Scaler
ReceiverThickness	AZ:0.035,AY:0.035,AX:0.035,BZ:0.035,BY:0.035,BX:0.035,CZ:0.035,CY:0.035,CX:0.035,DZ:0.035,DY:0.035,DX:0.035,meters	String	Scalar
ReceiverTurns	AZ:200,AY:200,AX:200,BZ:200,BY:200,BX:200,CZ:200,CY:200,CX:200,DZ:200,DY:200,DX:200	String	Scalar
SampleWidth	2000.0,nanoseconds	String	Scalar
SensorFunctionReferenceOriginalFile	*	String	Scalar
SpatialRegistrationSystem	GPS,R8GNSSv3_Gpggartk	String	Scalar
SpatialRegistrationSystemOffset	(x=0.0000,y=0.0000,z=0.9460),meters	String	Scalar
SwathWidth	0.75,meters	String	Scalar
Tractor	*	String	Scalar
TransmissionCurrentThreshold	5.50,amperes	String	Scalar
TransmitterDutyCycle	50.0,percent	String	Scalar
TransmitterLayout	T1Z:(x=-0.025,y=0.025,z=0.000)(x=-0.375,y=0.025,z=0.000)(x=-0.375,y=0.375,z=0.000)(x=-0.025,y=0.375,z=0.000),T2Z:(x=0.375,y=0.025,z=0.000)(x=0.025,y=0.025,z=0.000)(x=0.025,y=0.375,z=0.000)(x=0.375,y=0.375,z=0.000),T3Z:(x=0.375,y=-0.375,z=0.000)(x=0.025,y=-0.375,z=0.000)(x=0.025,y=-0.025,z=0.000)(x=0.375,y=-0.025,z=0.000),T4Z:(x=-0.025,y=-0.375,z=0.000)(x=-0.375,y=-0.375,z=0.000)(x=-0.375,y=-0.025,z=0.000)(x=-0.025,y=-0.025,z=0.000),meters	String	Scalar
TransmitterNormalVectors	T1Z:(x=0.0000,y=0.0000,z=-1.0000),T2Z:(x=0.0000,y=0.0000,z=-1.0000),T3Z:(x=0.0000,y=0.0000,z=-1.0000),T4Z:(x=0.0000,y=0.0000,z=-1.0000)	String	Scalar
TransmitterThickness	T1Z:0.0800,T2Z:0.0800,T3Z:0.0800,T4Z:0.0800,meters	String	Scalar
TransmitterTurns	T1Z:25,T2Z:25,T3Z:25,T4Z:25	String	Scalar
UnsortedChannels	0	String	Scalar
WaveformOversampleCount	2	Scalar	String

9.2. Transient Group Attributes and Definitions

For each transient group stored in the HDF5 file, the following attributes are required. The “Transients” transient group is required. There can be additional transient groups in a given HDF5 file, depending on the measurement type. If the measurement type supports, the “BackgroundTransients” transient group may be present as well. Each transient group then contains a Transmitter group for each transmitter, which therein contain a scalar dataset for each transient collected. The attribute names, data type details, and an example set of values for a DAM measurement type are given in Table 10.

Table 10 – Transient Group Attributes for a DAM File

Name	Example Value	Data Type	Array Size
TransientList	GateTime,Rx1Z,Rx2Z,Rx3Z,Rx4Z,Rx1Y,Rx2Y,Rx3Y,Rx4Y,Rx1X,Rx2X,Rx3X,Rx4X	String	Scalar
TransientListUnits	microseconds,volts,volts,volts,volts,volts,volts,volts,volts,volts,volts,volts,volts	String	Scalar

9.3. Transient Scalar Dataset Attributes and Definitions

For static measurements, there is a transient group for each transmitter with a single transient scalar data set within. For dynamic measurements, there are multiple transient scalar data sets for each transmitter. Figure 13 shows this for the "Transients" group, transmitter "A" expanded from an Example DAM HDF5, as presented in HDFView 3.0, to show the transient group structure. For each transient stored in the HDF5 file, the following attributes are required. The attribute names, data type details, and an example set of values for a DAM measurement type are given in Table 11.

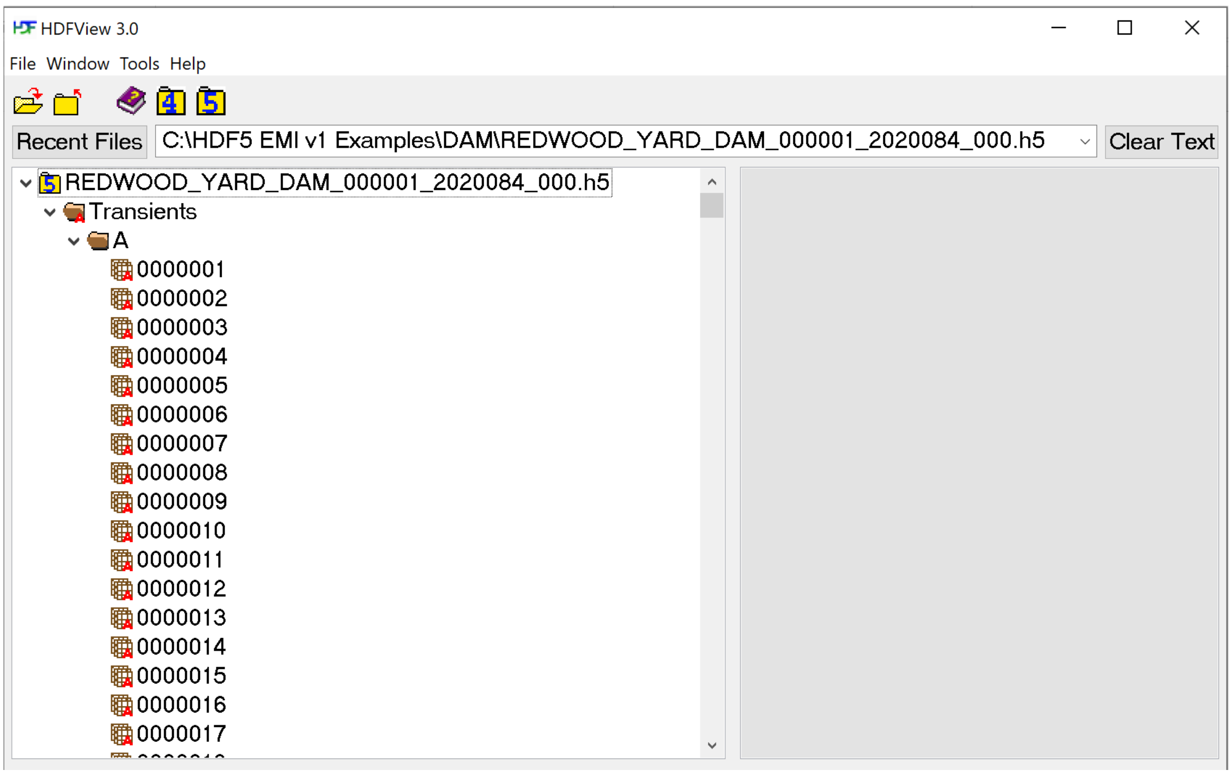


Figure 13 – Example of Transient Group "Transients", "A" Expanded

Table 11 – Transient Scalar Dataset Attributes for a DAM File

Name	**Example Value**	**Data Type**	**Array Size**
Attitude	(yaw=14.7474,pitch=-4.4293,roll=0.8929),degrees	String	Scalar
Elevation	61.2780,meters	String	Scalar
GeoidSeparation	*	String	Scalar
HAE	*	String	Scalar
HorizontalDilutionOfPrecision	2.9	String	Scalar
Latitude	038.7841220792,degrees	String	Scalar
Longitude	-077.1079248025,degrees	String	Scalar
NSat	7	String	Scalar
Quality	4	String	Scalar
SpatialRegistrationSystemTime	172549.20	String	Scalar
Stored	2020-04-04T17:09:30.682Z	String	Scalar
TransientNumber	000001	String	Scalar
TransmittedCurrent	6.339,amperes	String	Scalar
UTM	(316908.756E,4294931.018N),meters	String	Scalar
UTMZone	18N	String	Scalar

10. Acronyms

The following acronyms are used in this document. Measurement code definitions are available in Table 1 and Table 2.

Acronym	**Description**
AGC	Advanced Geophysical Classification
AGCS	Advanced Geophysical Classification Subgroup
AHRS	Attitude and Heading Reference System
ASCII	American Standard Code for Information Interchange
DAGCAP	DoD Advanced Geophysical Classification Accreditation Program
DoD	Department of Defense
EDQW	Environmental Data Quality Workgroup
EMI	Electromagnetic Induction
HDF5	Hierarchical Data Format (HDF), version 5
GMT	Greenwich Mean Time
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HAE	Height Above Ellipsoid
IMU	Inertial Measurement Unit
ISO	International Organization for Standardization
sISO	Small Industry Standard Object
MSL	Mean Sea Level
PPS	Or 1PPS, one pulse per second
QC	Quality Control
QSR	Quality System Requirements
QAPP	Quality Assurance Project Plan
RTS	Robotic Total Station
RTK	Real-time Kinematic
UTC	Coordinated Universal Time
UTM	Universal Transverse Mercator
WGS84	World Geodetic System 1984