1 SigMF Specification Version v1.2.6

1.1 Abstract

SigMF specifies a way to describe sets of recorded digital signal samples with metadata written in JSON. SigMF can be used to describe general information about a collection of samples, the characteristics of the system that generated the samples, features of signals themselves, and the relationship between different recordings.

1.2 Copyright Notice

1.3 Table of Contents

1.4 Introduction

Sharing sets of recorded signal data is an important part of science and engineering. It enables multiple parties to collaborate, is often a necessary part of reproducing scientific results (a requirement of scientific rigor), and enables sharing data with those who do not have direct access to the equipment required to capture it.

Unfortunately, these datasets have historically not been very portable, and there is not an agreed upon method of sharing metadata descriptions of the recorded data itself. This is the problem that SigMF solves.

By providing a standard way to describe data recordings, SigMF facilitates the sharing of data, prevents the "bitrot" of datasets wherein details of the capture are lost over time, and makes it possible for different tools to operate on the same dataset, thus enabling data portability between tools and workflows.

1.5 Conventions Used in this Document

The key words “MUST”, “MUST NOT”, “REQUIRED”, “SHALL”, “SHALL NOT”, “SHOULD”, “SHOULD NOT”, “RECOMMENDED”, “MAY”, and “OPTIONAL” in this document are to be interpreted as described in RFC 2119.

JSON keywords are used as defined in ECMA-404.

Augmented Backus-Naur form (ABNF) is used as defined by RFC 5234 and updated by RFC 7405.

Fields defined as "human-readable", a "string", or simply as "text" SHALL be treated as plaintext where whitespace is significant, unless otherwise specified. Fields defined "human/machine-readable" SHOULD be short, simple text strings without whitespace that are easily understood by a human and readily parsed by software.

Specific keywords with semantic meaning in the context of this specification are capitalized after being introduced (e.g., Recording).

1.6 Specification Overview

The SigMF specification fundamentally describes two types of information: datasets, and metadata associated with those datasets. Taken together, a Dataset with its SigMF metadata is a SigMF `Recording`.

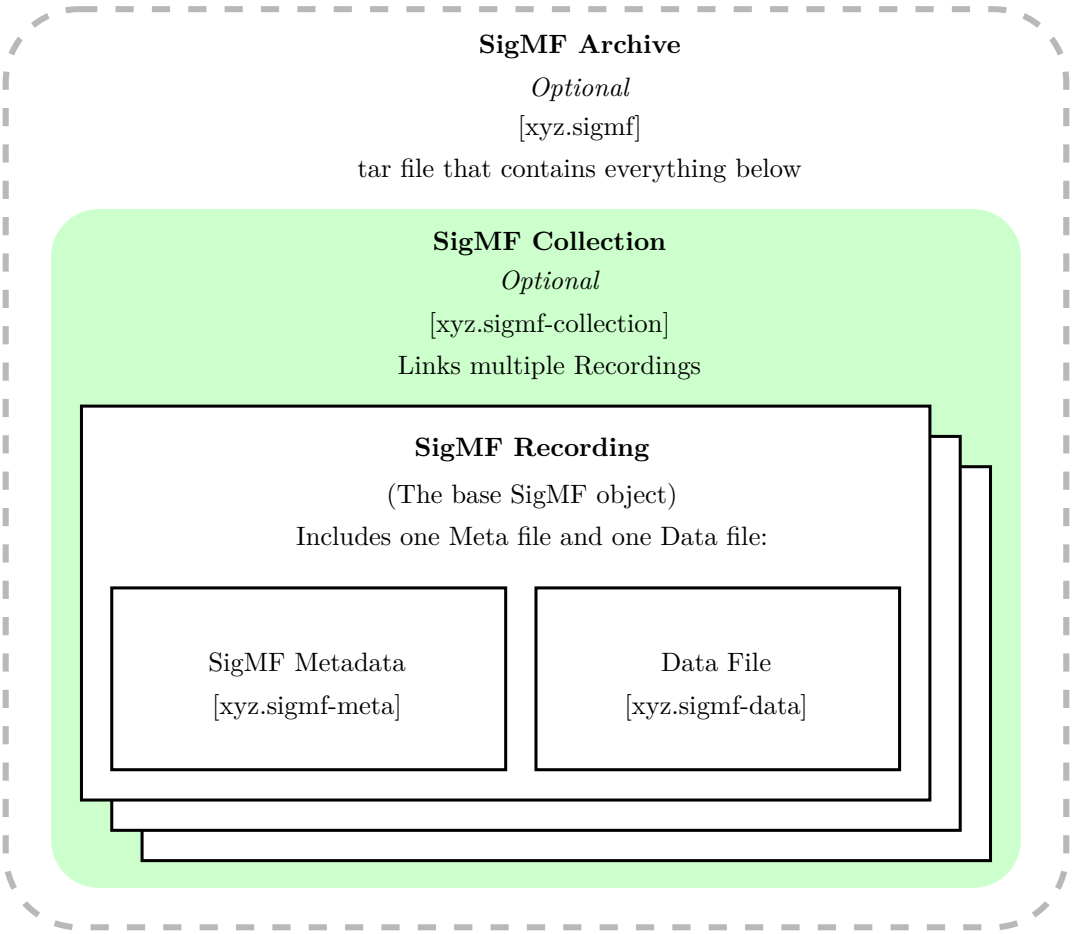
Datasets, for purposes of this specification, are sets of digital measurements generically called `samples` in this document. The samples can represent any time-varying source of information. They MAY, for example, be digital samples created by digital synthesis or by an Analog-to-Digital Converter. They could also be geolocation coordinates from a GNSS receiver, temperature readings from a thermal sensor, or any other stored digital measurement information.

Metadata describes the Dataset with which it is associated. The metadata includes information meant for the human users of the Dataset, such as a title and description, and information meant for computer applications (tools) that operate on the Dataset.

This specification defines a schema for metadata using a `core` namespace that is a reserved name and can only be defined by this specification. Other metadata MAY be described by extension namespaces. This specification also defines a model and format for how SigMF data should be stored at-rest (on-disk) using JSON.

1.7 SigMF File Types

There are two fundamental filetypes defined by this specification: files with metadata, and the files that contain the Datasets described by the metadata. There are two types of files containing metadata, a SigMF `Metadata` file, and a SigMF `Collection` file. There are also two types of Datasets, a SigMF `Dataset` file, and a `Non-Conforming Dataset` file, abbreviated as `NCD`. NCDs are a mechanism to support using



valid SigMF metadata to describe data that is not valid SigMF and formatted according to SigMF Dataset requirements.

The primary unit of SigMF is a SigMF `Recording`, which comprises a Metadata file and the Dataset file it describes. Collections are an optional feature that are used to describe the relationships between multiple Recordings.

Collections and multiple Recordings can be packaged for easy storage and distribution in a SigMF `Archive`.

Rules for all files:

1. All filetypes MUST be stored in separate files on-disk.
2. It is RECOMMENDED that filenames use hyphens to separate words rather than whitespace or underscores.

Rules for SigMF Metadata files:

1. A Metadata file MUST only describe one Dataset file.
2. A Metadata file MUST be stored in UTF-8 encoding.
3. A Metadata file MUST have a `.sigmf-meta` filename extension.
4. A Metadata file MUST be in the same directory as the Dataset file it describes.
5. It is RECOMMENDED that the base filenames (not including file extension) of a Recording's Metadata and Dataset files be identical.

Rules for SigMF Dataset files:

1. The Dataset file MUST have a `.sigmf-data` filename extension.

Rules for SigMF Non-Conforming Dataset files:

1. The NCD file MUST NOT have a `.sigmf-data` filename extension.

Rules for SigMF Collection files:

1. The Collection file MUST be stored in UTF-8 encoding.
2. The Collection file MUST have a `.sigmf-collection` filename extension.
3. The `sigmf-collection` file MUST be either in the same directory as the Recordings that it references, or in the top-level directory of an Archive (described in later section).

Rules for SigMF Archive files:

1. The Archive MUST use the `tar` archive format, as specified by POSIX.1-2001.
2. The Archive file's filename extension MUST be `.sigmf`.
3. The Archive MUST contain at least one SigMF Recording.
4. The Archive MAY contain one `.sigmf-collection` file in the top-level directory.
5. SigMF Archives MAY contain additional files (not specified by SigMF), and arbitrary directory structures, but the SigMF files within the Archive MUST adhere to all rules above when the archive is extracted.

1.8 SigMF Dataset Format

There are four orthogonal characteristics of sample data: complex or real, floating-point or integer, bit-width, and endianness. The following ABNF rules specify the Dataset formats defined in the Core namespace. Additional Dataset formats MAY be added through extensions.

```
dataset-format = (real / complex) ((type endianness) / byte)

real = "r"
complex = "c"

type = floating-point / signed-integer / unsigned-integer
floating-point = "f32" / "f64"
signed-integer = "i32" / "i16"
unsigned-integer = "u32" / "u16"

endianness = little-endian / big-endian
little-endian = "_le"
big-endian = "_be"

byte = "i8" / "u8"
```

So, for example, the string `"cf32_le"` specifies "complex 32-bit floating-point samples stored in little-endian", the string `"ru16_be"` specifies "real unsigned 16-bit samples stored in big-endian", and the string `"cu8"` specifies "complex unsigned byte".

Only IEEE-754 single-precision and double-precision floating-point types are supported by the SigMF Core namespace. Note that complex data types are specified by the bit width of the individual I/Q components, and not by the total complex pair bitwidth (like Numpy).

The samples SHOULD be written to the Dataset file without separation, and the Dataset file MUST NOT contain any other characters (e.g., delimiters, whitespace, line-endings, EOF characters).

Complex samples MUST be interleaved, with the in-phase component first (i.e., `I[0]` `Q[0]` `I[1]` `Q[1]` ... `I[n]` `Q[n]`).

When `core:num_channels` in the Global Object (described below) indicates that the Recording contains more than one channel, samples from those channels MUST be interleaved in the same manner with the same index from each channel's sample serially in the Recording. This is intended for use in situations where the native SigMF datatypes are not appropriate, such as audio or oscilloscope channels. For best compatibility, is RECOMMENDED that native complex type datatypes be used whenever possible (e.g.: RF data). The data type specified by core:data_type applies to all channels of data. For multiple channels of IQ data (e.g., array processing), it is RECOMMENDED to use SigMF Collections.

1.9 SigMF Metadata Format

SigMF metadata fundamentally takes the form of key/value pairs: `"namespace:name": value,`

Metadata field names in the top level `global` Object, `captures` segment Objects, or `annotations` Objects MUST be of this form. All fields other than those at the top level which contain a `:` delimiter SHALL only use letters, numbers, and the `_` character; all other characters are forbidden. Field names MUST NOT start with a number and MUST NOT not be C++20 or Python 3.10 keywords.

When stored on-disk (at-rest), these rules apply:

1. The Metadata file MUST be written in JSON, as specified by ECMA-404.
2. The entire contents of the Metadata file MUST be contained within a single top-level JSON Object.
3. The top-level Object MUST contain three JSON Objects named `global`, `captures`, and `annotations`.
4. Metadata key/value pairs SHALL NOT be assumed to have carried over between capture or annotation segments. If a name/value pair applies to a particular segment, then it MUST appear in that segment, even if the value is unchanged relative to the previous segment.

All SigMF metadata is defined using the structural concepts of JSON, and when stored on-disk, metadata MUST be proper JSON to be SigMF compliant.

1.9.1 Datatypes

The values in each key/value pair MUST be one of the following datatypes.

Type	Long-form Name	Description
int	integer	Signed 64-bit integer.
uint	unsigned long	Unsigned 64-bit integer.
double	double-precision floating-point	A 64-bit float as defined by IEEE 754.
string	string	A string of characters, as defined by the JSON standard.
boolean	boolean	Either `true` or `false`, as defined by the JSON standard.
null	null	`null`, as defined by the JSON standard.
array	JSON array	An `array` of other values, as defined by the JSON standard.
object	JSON object	An `object` of other values, as defined by the JSON standard.
GeoJSON	GeoJSON point Object	A single GeoJSON `point` Object as defined by RFC 7946.

1.9.2 Namespaces

Namespaces provide a way to further classify key/value pairs in metadata. This specification defines the `core` namespace. Only this specification can add fields to the Core namespace.

The goal of the Core namespace is to capture the foundational metadata necessary to work with SigMF data. Some keys within the Core namespace are OPTIONAL, and others are REQUIRED. The REQUIRED fields are those that are minimally necessary to parse and process the Dataset, or that have obvious defaults that are valid. All other fields are OPTIONAL, though they can be strongly RECOMMENDED.

Extension Namespaces

Fields not defined in the Core namespace MAY be defined in extension namespaces. The SigMF specification defines some extension namespaces to provide canonical definitions for commonly needed metadata fields that do not belong in Core. These canonical extension namespaces can be found in the `extensions/` directory of the official SigMF repository. Other extension namespaces MAY be defined by the user as needed.

1. An extension namespace MUST be defined in a single file, named meta-syntactically as `N.sigmf-ext.md`, where `N` is the name of the extension.
2. A `N.sigmf-ext.md` file MUST be a Github-Flavored Markdown file stored in UTF-8 encoding.
3. Extensions MUST have version numbers. It is RECOMMENDED that extensions use Semantic Versioning.
4. An extension namespace MAY define new top-level SigMF Objects, key/value pairs, new files, new Dataset formats, or new datatypes.
5. New key/value pairs defined by an extension namespace MUST be defined in the context of a specific SigMF top-level Object - i.e., `global`, `captures`, `annotations`, or a new user-defined Object.
6. It is RECOMMENDED that an extension namespace file follow the structure of the canonical extension namespaces.

1.10 Global Object

The `global` object consists of key/value pairs that provide information applicable to the entire Dataset. It contains the information that is minimally necessary to open and parse the Dataset file, as well as general information about the Recording itself.

Field	Required	Type	Short Description
datatype	Required	string	The SigMF Dataset format of the stored samples in the Dataset file
sample_rate		number	The sample rate of the signal in samples per second
author		string	A text identifier for the author potentially including name, handle, email, and/or other ID like Amateur Call Sig
collection		string	The base filename of a ‘collection‘ with which this Recording is associated
dataset		string	The full filename of the Dataset file this Metadata file describes, used ONLY with Non-Conforming Datasets
data_doi		string	The registered DOI (ISO 26324) for a Recording’s Dataset file
description		string	A text description of the SigMF Recording
hw		string	A text description of the hardware used to make the Recording
license		string	A URL for the license document under which the Recording is offered
metadata_only		boolean	Indicates the Metadata file is intentionally distributed without the Dataset
meta_doi		string	The registered DOI (ISO 26324) for a Recording’s Metadata file
num_channels		integer	Number of interleaved channels in the Dataset file, if omitted this is implied to be 1, for multiple channels of IQ data, it is RECOMMENDED to use SigMF Collections instead of num_channels for widest application support
offset		integer	The index number of the first sample in the Dataset
recorder		string	The name of the software used to make this SigMF Recording
sha512		string	The SHA512 hash of the Dataset file associated with the SigMF file
trailing_bytes		integer	The number of bytes to ignore at the end of a Dataset, used ONLY with Non-Conforming Datasets
version	Required	string	The version of the SigMF specification used to create the Metadata file, in the format X.Y.Z
geolocation		object	The location of the Recording system (note, using the Captures scope ‘geolocation‘ field is preferred)
extensions		array	The ‘core:extensions‘ field in the Global Object is an array of extension objects that describe SigMF extensions

1.10.1 datatype

The SigMF Dataset format of the stored samples in the Dataset file.
examples: [’cf32_le’, ’ri16_le’]
default: cf32_le
type: string

1.10.2 sample_rate

The sample rate of the signal in samples per second.
exclusiveMinimum: 0
maximum: 1000000000000
type: number

1.10.3 author

A text identifier for the author potentially including name, handle, email, and/or other ID like Amateur Call Sign

examples: ['Bruce Wayne bruce@waynetech.com', 'Bruce (K3X)']
type: string

1.10.4 collection

The base filename of a `collection` with which this Recording is associated. This field is used to indicate that this Recording is part of a SigMF Collection (described later in this document). It is strongly RECOMMENDED that if you are building a Collection, that each Recording referenced by that Collection use this field to associate up to the relevant `sigmf-collection` file.
type: string

1.10.5 dataset

The full filename of the Dataset file this Metadata file describes, used ONLY with Non-Conforming Datasets. If provided, this string MUST be the complete filename of the Dataset file, including the extension. The Dataset file must be in the same directory as the .sigmf-meta file; note that this string only includes the filename, not directory. If a Recording does not have this field, it MUST have a compliant SigMF Dataset (NOT a Non-Conforming Dataset) which MUST use the same base filename as the Metadata file and use the `.sigmf-data` extension. If a SigMF Recording or Archive is renamed this field MUST also be updated, because of this it is RECOMMENDED that Compliant SigMF Recordings avoid use of this field. This field SHOULD NOT be used in conjunction the `core:metadata_only` field. If both fields exist and the file specified by `core:dataset` exists, then `core:metadata_only` SHOULD be ignored by the application.
type: string

1.10.6 data_doi

The registered DOI (ISO 26324) for a Recording's Dataset file.
type: string

1.10.7 description

A text description of the SigMF Recording.
type: string

1.10.8 hw

A text description of the hardware used to make the Recording.
type: string

1.10.9 license

A URL for the license document under which the Recording is offered. (RFC 3986)
examples: ['https://creativecommons.org/licenses/by-sa/4.0/']
format: uri
type: string

1.10.10 metadata_only

Indicates the Metadata file is intentionally distributed without the Dataset. This field should be defined and set to `true` to indicate that the Metadata file is being distributed without a corresponding `.sigmf-data` file. This may be done when the Dataset will be generated dynamically from information in the schema, or because just the schema is sufficient for the intended application. A metadata only distribution is not a SigMF Recording. If a Compliant SigMF Recording uses this field, it MAY indicate that the Dataset was dynamically generated from the metadata. This field MAY NOT be used in conjunction with Non-Conforming Datasets or the `core:dataset` field.
type: boolean

1.10.11 meta_doi

The registered DOI (ISO 26324) for a Recording's Metadata file.
type: string

1.10.12 num_channels

Number of interleaved channels in the Dataset file, if omitted this is implied to be 1, for multiple channels of IQ data, it is RECOMMENDED to use SigMF Collections instead of num_channels for widest application support.
default: 1
minimum: 1
maximum: 9223372036854775807
type: integer

1.10.13 offset

The index number of the first sample in the Dataset. If not provided, this value defaults to zero. Typically used when a Recording is split over multiple files. All sample indices in SigMF are absolute, and so all other indices referenced in metadata for this recording SHOULD be greater than or equal to this value.
default: 0
minimum: 0
!comment: The maximum value for this property is equal to 2^63 - 1, making it easy to fit into a signed 64-bit integer.
maximum: 9223372036854775807
type: integer

1.10.14 recorder

The name of the software used to make this SigMF Recording.
type: string

1.10.15 sha512

The SHA512 hash of the Dataset file associated with the SigMF file.
type: string

1.10.16 trailing_bytes

The number of bytes to ignore at the end of a Dataset, used ONLY with Non-Conforming Datasets. This field is used with Non-Conforming Datasets to indicate some number of bytes that trail the sample data in the NCD file that should be ignored for processing. This can be used to ignore footer data in non-SigMF filetypes.
type: integer
minimum: 0
maximum: 9223372036854775807

1.10.17 version

The version of the SigMF specification used to create the Metadata file, in the format X.Y.Z.
type: string

1.10.18 geolocation

The location of the Recording system (note, using the Captures scope `geolocation` field is preferred). See the `geolocation` field within the Captures metadata for details. While using the Captures scope

`geolocation` is preferred, fixed recording systems may still provide position information within the Global object so it is RECOMMENDED that applications check and use this field if the Captures `geolocation` field is not present.
type: object
required: ['type', 'coordinates']
properties: {'type': {'type': 'string', 'enum': ['Point']}, 'coordinates': {'type': 'array', 'minItems': 2, 'maxItems': 3, 'items': {'type': 'number'}}, 'bbox': {'type': 'array', 'minItems': 4, 'items': {'type': 'number'}}}

1.10.19 extensions

The `core:extensions` field in the Global Object is an array of extension objects that describe SigMF extensions. Extension Objects MUST contain the three key/value pairs defined below, and MUST NOT contain any other fields.

Name	Required	Type	Description
name	true	string	The name of the SigMF extension namespace.
version	true	string	The version of the extension namespace specification used.
optional	true	boolean	If this field is `false` , then the application MUST support this extension in order to parse the Recording; if the application does not support this extension, it SHOULD report an error.

In the example below, `extension-01` is optional, so the application may ignore it if it does not support `extension-01` . But `extension-02` is not optional, so the application must support `extension-02` in order to parse the Recording.

```
"global": {
     ...
     "core:extensions" : [
         {
         "name": "extension-01",
         "version": "0.0.5",
         "optional": true
         },
         {
         "name": "extension-02",
         "version": "1.2.3",
         "optional": false
         }
     ]
     ...
 }
```

type: array
default: []

1.11 Captures Array

The `captures` Object is an array of capture segment objects that describe the parameters of the signal capture. It MUST be sorted by the value of each capture segment's `core:sample_start` key, ascending. Capture Segment Objects are composed of key/value pairs, and each Segment describes a chunk of samples that can be mapped into memory for processing. Each Segment MUST contain a `core:sample_start` key/value pair, which indicates the sample index relative to the Dataset where this Segment's metadata applies. The fields that are described within a Capture Segment are scoped to that Segment only and need

to be explicitly declared again if they are valid in subsequent Segments. While it is recommended there be at least one segment defined, if there are no items in the captures array it is implied that a single capture exists with `core:sample_start` equal to zero (no other metadata is implied), i.e., `"captures": []` implies `"captures": ["core:sample_start": 0]`.

Field	Required	Type	Short Description
sample_start	Required	integer	Index of first sample of this chunk
datetime		string	An ISO-8601 string indicating the timestamp of the sample index specified by sample_start
frequency		number	The center frequency of the signal in Hz
global_index		integer	The index of the sample referenced by 'sample_start' relative to an original sample stream
header_bytes		integer	The number of bytes preceding a chunk of samples that are not sample data, used for NCDs
geolocation		object	The location of the recording system at the start of this Captures segment, as a single RFC 7946 GeoJSON 'point' Object

1.11.1 sample_start

Index of first sample of this chunk. This field specifies the sample index where this Segment takes effect relative to the recorded Dataset file. If the Dataset is a SigMF Dataset file, this field can be immediately mapped to physical disk location since conforming Datasets only contain sample data.
default: 0
minimum: 0
maximum: 9223372036854775807
type: integer

1.11.2 datetime

An ISO-8601 string indicating the timestamp of the sample index specified by sample_start. This key/value pair MUST be an ISO-8601 string, as defined by [RFC 3339](https://www.ietf.org/rfc/rfc3339.txt), where the only allowed `time-offset` is `Z`, indicating the UTC/Zulu timezone. The ABNF description is:

```
date-fullyear   = 4DIGIT
date-month      = 2DIGIT  ; 01-12
date-mday       = 2DIGIT  ; 01-28, 01-29, 01-30, 01-31 based on month/year

time-hour       = 2DIGIT  ; 00-23
time-minute     = 2DIGIT  ; 00-59
time-second     = 2DIGIT  ; 00-58, 00-59, 00-60 based on leap second rules

time-secfrac    = "." 1*DIGIT
time-offset     = "Z"

partial-time    = time-hour ":" time-minute ":" time-second [time-secfrac]
full-date       = date-fullyear "-" date-month "-" date-mday
full-time       = partial-time time-offset

date-time       = full-date "T" full-time
```

Thus, timestamps take the form of `YYYY-MM-DDTHH:MM:SS.SSSZ`, where any number of digits for fractional seconds is permitted.
examples: ['1955-11-05T14:00:00.000Z']
type: string

1.11.3 frequency

The center frequency of the signal in Hz.
type: number
minimum: -1000000000000
maximum: 1000000000000
examples: [915000000, 2400000000]

1.11.4 global_index

The index of the sample referenced by `sample_start` relative to an original sample stream. The entirety of which may not have been captured in a recorded Dataset. If omitted, this value SHOULD be treated as equal to `sample_start`. For example, some hardware devices are capable of 'counting' samples at the point of data conversion. This sample count is commonly used to indicate a discontinuity in the datastream between the hardware device and processing. For example, in the below Captures array, there are two Segments describing samples in a SigMF Dataset file. The first Segment begins at the start of the Dataset file. The second segment begins at sample index 500 relative to the recorded samples (and since this is a conforming SigMF Dataset, is physically located on-disk at location `sample_start * sizeof(sample)`), but the `global_index` reports this was actually sample number 1000 in the original datastream, indicating that 500 samples were lost before they could be recorded.

```
...
"captures": [
   {
       "core:sample_start": 0,
       "core:global_index": 0
   },
   {
       "core:sample_start": 500,
       "core:global_index": 1000
   }
],
...
```

type: integer
minimum: 0
maximum: 9223372036854775807

1.11.5 header_bytes

The number of bytes preceding a chunk of samples that are not sample data, used for NCDs. This field specifies a number of bytes that are not valid sample data that are physically located at the start of where the chunk of samples referenced by this Segment would otherwise begin. If omitted, this value SHOULD be treated as equal zero. If included, the Dataset is by definition a Non-Conforming Dataset. For example, the below Metadata for a Non-Conforming Dataset contains two segments describing chunks of 8-bit complex samples (2 bytes per sample) recorded to disk with 4-byte headers that are not valid for processing. Thus, to map these two chunks of samples into memory, a reader application would map the `500 samples` (equal to `1000 bytes`) in the first Segment, starting at a file offset of `4 bytes`, and then the remainder of the file through EOF starting at a file offset of `1008 bytes` (equal to the size of the previous Segment of samples plus two headers).

```
{
"global": {
   "core:datatype": "cu8",
   "core:version": "1.2.0",
   "core:dataset": "non-conforming-dataset-01.dat"
},
"captures": [
   {
       "core:sample_start": 0,
       "core:header_bytes": 4,
   },
   {
       "core:sample_start": 500,
       "core:header_bytes": 4,
   }
],
"annotations": []
}
```

type: integer
minimum: 0
maximum: 9223372036854775807

1.11.6 geolocation

The location of the recording system at the start of this Captures segment, as a single RFC 7946 GeoJSON `point` Object. For moving emitters, this provides a rudimentary means to manage location through different captures segments. While `core:geolocation` is also allowed in the Global object for backwards compatibility reasons, adding it to Captures is preferred. Per the GeoJSON specification, the point coordinates use the WGS84 coordinate reference system and are `longitude`, `latitude` (REQUIRED, in decimal degrees), and `altitude` (OPTIONAL, in meters above the WGS84 ellipsoid) - in that order. An example including the altitude field is shown below:

```
"captures": {
  ...
  "core:geolocation": {
    "type": "Point",
    "coordinates": [-107.6183682, 34.0787916, 2120.0]
  }
  ...
}
```

GeoJSON permits the use of *Foreign Members* in GeoJSON documents per RFC 7946 Section 6.1. Because the SigMF requirement for the `geolocation` field is to be a valid GeoJSON `point` Object, users MAY include *Foreign Member* fields here for user-defined purposes (position valid indication, GNSS SV counts, dillution of precision, accuracy, etc). It is strongly RECOMMENDED that all fields be documented in a SigMF Extension document. *Note:* Objects named `geometry` or `properties` are prohibited Foreign Members as specified in RFC 7946 Section 7.1.
type: object
required: ['type', 'coordinates']
properties: {'type': {'type': 'string', 'enum': ['Point']}, 'coordinates': {'type': 'array', 'minItems': 2, 'maxItems': 3, 'items': {'type': 'number'}}, 'bbox': {'type': 'array', 'minItems': 4, 'items': {'type': 'number'}}}

1.12 Annotations Array

The `annotations` Object is an array of annotation segment objects that describe anything regarding the signal data not part of the Captures and Global objects. It MUST be sorted by the value of each Annotation Segment's `core:sample_start` key, ascending. Annotation segment Objects contain key/value pairs and MUST contain a `core:sample_start` key/value pair, which indicates the first index at which the rest of the Segment's key/value pairs apply. There is no limit to the number of annotations that can apply to the same group of samples. If two annotations have the same `sample_start`, there is no defined ordering between them. If `sample_count` is not provided, it SHOULD be assumed that the annotation applies from `sample_start` through the end of the corresponding capture, in all other cases `sample_count` MUST be provided.

Field	Required	Type	Short Description
sample_start	Required	integer	The sample index at which this Segment takes effect
sample_count		integer	The number of samples that this Segment applies to
freq_lower_edge		number	The frequency (Hz) of the lower edge of the feature described by this annotation
freq_upper_edge		number	The frequency (Hz) of the upper edge of the feature described by this annotation
label		string	A short form human/machine-readable label for the annotation
comment		string	A human-readable comment, intended to be used for longer comments (it is recommended to use 'label' for shorter text)
generator		string	Human-readable name of the entity that created this annotation
uuid		string	RFC-4122 unique identifier

1.12.1 sample_start

The sample index at which this Segment takes effect.
default: 0
minimum: 0
maximum: 9223372036854775807
type: integer

1.12.2 sample_count

The number of samples that this Segment applies to.
type: integer
minimum: 0
maximum: 9223372036854775807

1.12.3 freq_lower_edge

The frequency (Hz) of the lower edge of the feature described by this annotation. The `freq_lower_edge` and `freq_upper_edge` fields SHOULD be at RF if the feature is at a known RF frequency. If there is no known center frequency (as defined by the `frequency` field in the relevant Capture Segment Object), or the center frequency is at baseband, the `freq_lower_edge` and `freq_upper_edge` fields SHOULD be relative to baseband. It is REQUIRED that both `freq_lower_edge` and `freq_upper_edge` be provided, or neither; the use of just one field is not allowed.
type: number
minimum: -1000000000000
maximum: 1000000000000

1.12.4 freq_upper_edge

The frequency (Hz) of the upper edge of the feature described by this annotation.
type: number
minimum: -1000000000000
maximum: 1000000000000

1.12.5 label

A short form human/machine-readable label for the annotation. The `label` field MAY be used for any purpose, but it is RECOMMENDED that it be limited to no more than 20 characters as a common use is a short form GUI indicator. Similarly, it is RECOMMENDED that any user interface making use of this field be capable of displaying up to 20 characters.
type: string

1.12.6 comment

A human-readable comment, intended to be used for longer comments (it is recommended to use `label` for shorter text).
type: string

1.12.7 generator

Human-readable name of the entity that created this annotation.
type: string

1.12.8 uuid

RFC-4122 unique identifier.
format: uuid
type: string

1.13 SigMF Collection Format

The `sigmf-collection` file contains metadata in a single top-level Object called a `collection`. The Collection Object contains key/value pairs that describe relationships between SigMF Recordings.

The Collection Object associates SigMF Recordings together by specifying `SigMF Recording Objects` in the `core:streams` JSON array. Each Object describes a specific associated SigMF Recording.

The following rules apply to SigMF Collections:

1. The Collection Object MUST be the only top-level Object in the file.

2. Keys in the Collection Object SHOULD use SigMF Recording Objects when referencing SigMF Recordings.

3. SigMF Recording Objects MUST contain both a `name` field, which is the base-name of a SigMF Recording, and a `hash` which is the SHA512 hash of the Recording Metadata file `[base-name].sigmf-meta`.

4. SigMF Recording Objects MUST appear in a JSON array.

Example `top-level.sigmf-collection` file:

```
{
"collection": {
      "core:version": "1.2.0",
      "core:extensions" : [
          {
              "name": "antenna",
              "version": "1.0.0",
              "optional": true
          }
      ],
      "antenna:hagl": 120,
      "antenna:azimuth_angle": 98,
      "core:streams": [
          {
             "name": "example-channel-0-basename",
             "hash": "b4071db26f5c7b0c70f5066eb9bc3a8b506df0f5af09991ba481f63f97f7f48e9396584bc1c296650
                  },
          {
             "name": "example-channel-1-basename",
             "hash": "7132aa240e4d8505471cded716073141ae190f763bfca3c27edd8484348d6693d0e8d3427d0bf1990
                  }
           ]
  }
}
```

Field	Required	Type	Short Description
version	Required	string	The version of the SigMF specification used to create the Collection file
description		string	A text description of the SigMF Collection
author		string	A text identifier for the author potentially including name, handle, email, and/or other ID like Amateur Call Sign
collection_doi		string	The registered DOI (ISO 26324) for a Collection
license		string	A URL for the license document under which this Collection metadata is offered
extensions		array	The ‘core:extensions‘ field in the Global Object is an array of extension objects that describe SigMF extensions
streams		array	An ordered array of SigMF Recording Tuples, indicating multiple recorded streams of data (e.g., channels from a phased array)

1.13.1 version

The version of the SigMF specification used to create the Collection file.
examples: ['1.2.0']
type: string

1.13.2 description

A text description of the SigMF Collection.
default:
type: string

1.13.3 author

A text identifier for the author potentially including name, handle, email, and/or other ID like Amateur Call Sign.
default:
examples: ['Bruce Wayne bruce@waynetech.com', 'Bruce (K3X)']
type: string

1.13.4 collection_doi

The registered DOI (ISO 26324) for a Collection.
default:
type: string

1.13.5 license

A URL for the license document under which this Collection metadata is offered.
default:
examples: ['https://creativecommons.org/licenses/by-sa/4.0/']
type: string

1.13.6 extensions

The `core:extensions` field in the Global Object is an array of extension objects that describe SigMF extensions. Extension Objects MUST contain the three key/value pairs defined in Table (FIX REF), and MUST NOT contain any other fields.
default: []
type: array

1.13.7 streams

An ordered array of SigMF Recording Tuples, indicating multiple recorded streams of data (e.g., channels from a phased array).
default: []
type: array

1.14 SigMF Recording Objects

`SigMF Recording Objects` reference the base-name of the SigMF Recording and the SHA512 hash of the Metadata file, and SHOULD BE specified as a JSON Object:

```
{
  "name": "example-channel-0-basename",
  "hash": "b4071db26f5c7b0c70f5066eb9..."
}
```

Recording Tuples are also permitted and have a similar form. The order of the tuple: [`name` , `hash`] is REQUIRED when using tuples:

```
["example-channel-0-basename", "b4071db26f5c7b0c70f5066e..."]
```

Tuples will be removed in SigMF version 2.0, so JSON Objects are RECOMMENDED. Additional optional user fields MAY be added to `SigMF Recording Objects` if they are defined in a compliant SigMF extension. Additional fields are NOT permitted in tuples.

1.15 Licensing

Open licenses are RECOMMENDED but you can specify any license. You can refer to resources provided by the Open Data Commons when deciding which open license fits your needs best. Cornell University has also created a guide to help you make these choices.

1.16 SigMF Compliance

The term 'SigMF Compliant' is used throughout this document, which can take on one of several contextually dependent meanings. In order for a schema, Recording, or application to be 'SigMF Compliant', specific conditions MUST be met, outlined in the following sections. Provided the below criteria are met, an application or Recording can indicate that it is 'SigMF Compliant'.

1.16.1 SigMF Schema Compliance

In order to be 'SigMF Compliant', a schema MUST meet the following requirements:

1. Adheres to and supports the metadata file naming conventions, `objects`, `namespaces`, and `names` specified by this document.
2. MUST contain all REQUIRED fields with the correct datatype listed the `core` namespace, and any namespace listed in the `extensions` array.
3. MUST NOT contain fields that are not outlined in the `core` or a listed `extensions` namespace.

1.16.2 SigMF Recording Compliance

In order to be 'SigMF Compliant', a Recording MUST meet the following requirements:

1. The Recording's schema file MUST be SigMF Compliant.
2. Adheres to and supports the file naming conventions and Dataset formats specified in this document.
3. Stores data using the on-disk representation described by the `datatype`.

Recordings with Non-Conforming Datasets MAY have SigMF Compliant schema, but cannot be SigMF Compliant Recordings.

1.16.3 SigMF Collection Compliance

In order to be 'SigMF Compliant', a Collection must meet the following requirements:

1. The collection MUST contain only compliant Recordings.
2. The Collection Object MUST only contain SigMF key/value pairs provided by the core specification or a compliant SigMF extension.

1.16.4 SigMF Application Compliance

In order to be 'SigMF Compliant', an application MUST meet the following requirements:

1. Is capable of parsing and loading SigMF Compliant Recordings. Support for SigMF Collections and Archives is RECOMMENDED but not REQUIRED.
2. Adheres to and supports the file rules, Dataset formats, `objects`, `namespaces`, and `names` specified by this document.
3. MUST be able to ignore any `object` or `namespace` not specified by this document and still function normally.
4. Capture Segments referring to non-existent samples SHOULD be ignored.
5. MUST treat consecutive Capture Segments whose metadata is equivalent for purposes of that application (i.e., it may be different in values ignored by the application such as optional values or unknown extensions) as it would a single segment.
6. MUST support parsing ALL required fields in the `core` namespace, and defines which optional fields are used by the application.
7. MUST define which extensions are supported, parses ALL required fields in listed extension namespaces, and defines which optional fields are used. This definition can be in user documentation or within the code itself, though explicit documentation is RECOMMENDED.
8. Support for ALL SigMF Datatypes is NOT REQUIRED as certain datatypes may not make sense for a particular application, but Compliant applications MUST define which datatypes are supported, and be capable of loading Compliant Recordings using supported datatypes.

Compliant applications are NOT REQUIRED to support Non-Conforming Datasets or Metadata Only schema files, but it is RECOMMENDED that they parse the respective metadata fields in the `global` Object to provide descriptive messages to users regarding why the files are not supported.

Support for SigMF Collections is OPTIONAL for SigMF Compliant applications, however it is RECOMMENDED that applications implementing SigMF make use of Collections when appropriate for interoperability and consistency.

1.17 Citing SigMF

To cite the SigMF specification, we recommend the following format:

`The Signal Metadata Format (SigMF), <release>, <date of release>, https://sigmf.org`

1.18 Acknowledgements

This specification originated at the DARPA Brussels Hackfest 2017.

2 Extensions

2.1 Antenna

The following names are specified in the `antenna` namespace and should be used in the `global` object:

Field	Required	Type	Short Description
antenna:model	Required	string	Antenna make and model number
antenna:type		string	Antenna type
antenna:low_frequency		number	Low frequency of operational range, in Hz
antenna:high_frequency		number	High frequency of operational range, in Hz
antenna:gain		number	Antenna gain in direction of maximum radiation or reception, in units of dBi
antenna:horizontal_gain_pattern		array	Antenna gain pattern in horizontal plane from 0 to 359 degrees in 1 degree steps, in units of dBi
antenna:vertical_gain_pattern		array	Antenna gain pattern in vertical plane from -90 to +90 degrees in 1 degree steps, in units of dBi
antenna:horizontal_beam_width		number	Horizontal 3-dB beamwidth, in degrees
antenna:vertical_beam_width		number	Vertical 3-dB beamwidth, in degrees
antenna:cross_polar_discrimination		number	Cross-polarization discrimination
antenna:voltage_standing_wave_ratio		number	Voltage standing wave ratio, in units of volts
antenna:cable_loss		number	Cable loss for cable connecting antenna and preselector, in dB
antenna:steerable		boolean	Defines if the antenna is steerable or not
antenna:mobile		boolean	Defines if the antenna is mobile or not
antenna:hagl		number	Antenna phase center height above ground level, in meters

2.1.1 antenna:model

Antenna make and model number. E.g. ARA CSB-16, L-com HG3512UP-NF.
type: string

2.1.2 antenna:type

Antenna type. E.g. dipole, biconical, monopole, conical monopole
type: string

2.1.3 antenna:low_frequency

Low frequency of operational range, in Hz.
type: number

2.1.4 antenna:high_frequency

High frequency of operational range, in Hz.
type: number

2.1.5 antenna:gain

Antenna gain in direction of maximum radiation or reception, in units of dBi.
type: number

2.1.6 antenna:horizontal_gain_pattern

Antenna gain pattern in horizontal plane from 0 to 359 degrees in 1 degree steps, in units of dBi.
type: array

2.1.7 antenna:vertical_gain_pattern

Antenna gain pattern in vertical plane from -90 to +90 degrees in 1 degree steps, in units of dBi.
type: array

2.1.8 antenna:horizontal_beam_width

Horizontal 3-dB beamwidth, in degrees.
type: number

2.1.9 antenna:vertical_beam_width

Vertical 3-dB beamwidth, in degrees.
type: number

2.1.10 antenna:cross_polar_discrimination

Cross-polarization discrimination.
type: number

2.1.11 antenna:voltage_standing_wave_ratio

Voltage standing wave ratio, in units of volts.
type: number

2.1.12 antenna:cable_loss

Cable loss for cable connecting antenna and preselector, in dB.
type: number

2.1.13 antenna:steerable

Defines if the antenna is steerable or not.
type: boolean

2.1.14 antenna:mobile

Defines if the antenna is mobile or not.
type: boolean

2.1.15 antenna:hagl

Antenna phase center height above ground level, in meters.
type: number

The following names are specified in the `antenna` namespace and should be used in the `annotations` object:

Field	Required	Type	Short Description
antenna:azimuth_angle		number	Angle of main beam in azimuthal plane from North, in degrees
antenna:elevation_angle		number	Angle of main beam in elevation plane from horizontal, in degrees
antenna:polarization		string	E.g

2.1.16 antenna:azimuth_angle

Angle of main beam in azimuthal plane from North, in degrees.
type: number

2.1.17 antenna:elevation_angle

Angle of main beam in elevation plane from horizontal, in degrees.
type: number

2.1.18 antenna:polarization

E.g. "vertical", "horizontal", "slant-45", "left-hand circular", "right-hand circular".
type: string

The following fields are specificed in SigMF Collections:

Field	Required	Type	Short Description
antenna:azimuth_angle		number	Angle of main beam in azimuthal plane from North, in degrees
antenna:elevation_angle		number	Angle of main beam in elevation plane from horizontal, in degrees
antenna:hagl		number	Nominal antenna phase center height above ground level, in meters

2.1.19 antenna:azimuth_angle

Angle of main beam in azimuthal plane from North, in degrees.
type: number

2.1.20 antenna:elevation_angle

Angle of main beam in elevation plane from horizontal, in degrees.
type: number

2.1.21 antenna:hagl

Nominal antenna phase center height above ground level, in meters.
type: number