Soil Moisture Active Passive (SMAP) Project

Level 1A Radiometer Product Specification Document

Revision A

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DOCUMENT CHANGE LOG

Revision	Date	Sections Changed	Reason for Change (ECR #)
-	13 October 2014		Initial Release
A	20 July 2015	3.2	New Section describes Spacecraft Attitude and Modeling Slews
A	20 July 2015	4.3	Updated volumetric estimates
A	20 July 2015	4.5	Added description of metadata elements that store MD5 checksum of ISO XML files
A	20 July 2015	4.5	Include polygonPosList, westBoundLongitude, eastBoundLongitude, southBoundLatitude and northBoundLatitude to Extent Metadata
A	20 July 2015	4.5	Add/modify ECSVersionID and longName to Metadata
A	20 July 2015	4.6.2, 4.7.23	highResolutionScanIndex in the High Resolution Moments Group is data type Uint32
A	20 July 2015	4.6.3, 4.7.64	Modified telemetry_qual_flag in the Moments Data Group
A	20 July 2015	4.6.3, 4.7.65, 4.7.66, 4.7.67	Added number_of_science_packets, science_packet_CRC_check and

			numbers_science_CRC_errors to the Moments Data Group
A	20 July 2015	4.6.4	Corrected word indices in the House Keeping Data Group text
A	20 July 2015	7, 8	Added ScencePacketCRC Dimension

TBD, TBR, TBS LOG

Section/Page	Description	Due Date
Appendix E	References the other Product Specification Documents. Some have not been written at the time of this publication. Thus, dates of publication are not available. In some cases, document identifiers are not available as well.	2/13/14

1 INTRODUCTION

1.1 Identification

This is the Product Specification Document (PSD) for Level 1A Radiometer data for the Science Data System (SDS) of the Soil Moisture Active Passive (SMAP) project. The Level 1A Radiometer product provides radiometer data which are unwrapped CCSDS instrument packets downloaded from the SMAP spacecraft. This document applies to any standard Level 1A Radiometer product acquired by the SMAP radiometer instrument.

1.2 Scope

This Product Specification Document describes the file format of the Level 1A Radiometer Product. Its intent is to elucidate the Level 1A Radiometer data structure and content for external software interfaces. The SMAP Science Data Management and Archive Plan provides a more comprehensive explanation of these data within the complete context of the SMAP instrument, algorithms, and software.

1.3 The SMAP Experiment

The Soil Moisture Active Passive (SMAP) mission will enhance the accuracy and the resolution of space-based measurements of terrestrial soil moisture and freeze-thaw state. SMAP data products will have a noteworthy impact on multiple relevant and current Earth Science endeavors. These include:

- Understanding of the processes that link the terrestrial water, the energy and the carbon cycles,
- Estimations of global water and energy fluxes over the land surfaces,
- Quantification of the net carbon flux in boreal landscapes
- Forecast skill of both weather and climate,
- Predictions and monitoring of natural disasters including floods, landslides and droughts, and
- Predictions of agricultural productivity.

To provide these data, the SMAP mission will deploy a satellite observatory in a near polar, sun synchronous orbit. The observatory contains an L-band radiometer that operates at 1.414 GHz and an L-band radar that operates at 1.225 GHz. The instruments will share a rotating reflector antenna with a 6 meter aperture that scans over a 1000 km swath.

As the spacecraft flies from north to south on *descending* orbits, the SMAP instruments will view Earth locations at approximately 06:00 local time. As the spacecraft flies from south to north, on *ascending* orbits, the SMAP instruments will view Earth locations at approximately 18:00 local time. The spacecraft will operate in a cycle of 117 repeatable orbits.

Each time that the spacecraft repeats the orbit cycle, the nadir path on the Earth's surface may not vary by more than 20 km. The flight plan enables scientists to collect data over any region of the Earth over seasonal and annual cycles and avoid diurnal variations. The combined flight pattern and viewing design will enable the observatory to view almost all of the Earth's land mass once every three days.

The SMAP radiometer records microwave emissions from the top 5 cm in the soil with a spatial resolution of about 40 km. Scientific applications based on radiometer measure in the same frequency range have established this approach as an accurate means to detect the presence or water in near surface soil. SMAP radar will provide backscatter measurements at 1 km resolution. The combined instrumentation will enable SMAP to generate highly accurate global soil moistures at 9 km resolution.

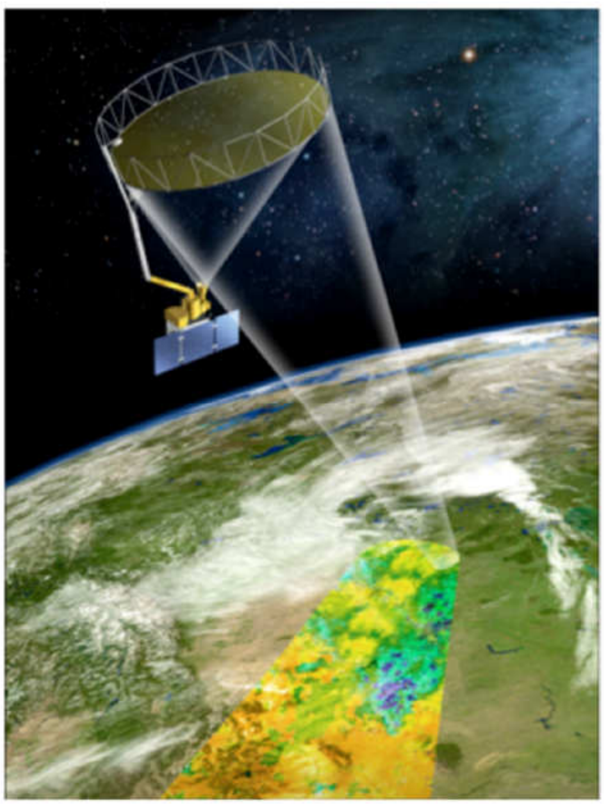

Figure 1: Artist's Concept of SMAP Observatory

Geophysical retrievals based on SMAP radar will indicate the presence of standing water, the freeze/thaw condition of the surface as well as measures of surface roughness and vegetation. The additional information will enable SMAP processors to select appropriate locations for soil moisture retrievals and modeling. In addition, the freeze/thaw data will contribute to models that measure the Net Ecosystem Exchange (NEE) of carbon between the Earth's surface and the atmosphere in Boreal regions.

1.4 SMAP Data Products

The SMAP mission will generate 15 different distributable data products. The products represent four levels of data processing. Level 1 products contain instrument related data. Level 1 products appear in granules that are based on half orbits of the SMAP satellite. The Northernmost and Southernmost orbit locations demarcate half orbit boundaries. Level 2 products contain output from geophysical retrievals that are based on instrument data. Level 2 products also appear in half orbit granules. Level 3 products contain global output of the Level 2 geophysical retrievals for an entire day. Level 4 products contain output from geophysical models that employ SMAP data.

Table 1 lists the distributable SMAP data products. The colors in the table categorize the products by level. The table specifies two sets of short names. The SMAP Mission product short names were adopted by the SMAP mission to identify products. Users will find those short names in SMAP mission documentation, SMAP product file names and in the product metadata. The Data Centers will use short names defined for the Earth Observing System Data and Information System (EOSDIS) Core System (ECS). These short names categorize data products in local databases managed by the ECS. ECS short names will also appear in SMAP product metadata.

SMAP Mission Product Short Name	ECS Short Names	Description
L1A_Radar	SPL1AA	Parsed Radar Instrument Telemetry
L1A_Radiometer	SPL1AP	Parsed Radiometer Instrument Telemetry
L1B_S0_LoRes	SPL1BS0	Low Resolution Radar σ_o in Time Order
L1C_S0_HiRes	SPL1CS0	High Resolution Radar σ_o on Swath Grid
L1B_TB	SPL1BTB	Radiometer T_B in Time Order
L1C_TB	SPL1CTB	Radiometer T_B
L2_SM_A	SPL2SMA	Radar Soil Moisture, includes Freeze/Thaw State
L2_SM_P	SPL2SMP	Radiometer Soil Moisture
L2_SM_AP	SPL2SMAP	Active-Passive Soil Moisture
L3_FT_A	SPL3FTA	Daily Global Composite Freeze/Thaw State
L3_SM_A	SPL3SMA	Daily Global Composite Radar Soil Moisture
L3_SM_P	SPL3SMP	Daily Global Composite Radiometer Soil Moisture
L3_SM_AP	SPL3SMAP	Daily Global Composite Active-Passive Soil Moisture
L4_SM	SPL4TSM	Surface and Root Zone Soil Moisture
L4_C	SPL4C	Carbon Net Ecosystem Exchange

Table 1: SMAP Data Products

1.5 Content Overview

The SMAP Level 1A Radiometer data product contains a time-ordered series of instrument counts which are unwrapped instrument CCSDS packets. The packets are sorted into various radiometric states. Each set of data associated with a PRI/packet of radiometer counts is labeled with time stamps that record the time of instrument acquisition. The product also includes a set of housekeeping telemetry converted to engineering units for each scan. For every pulse repetition interval (PRI) of the radar, the radiometer integrates ~300 µs within the receive window. The exact integration time varies based on the radar PRI length and blanking time length chosen by the instrument designers. Radiometer packets are made up of 4 PRIs. Each science data packet includes both fullband data for each of the four PRIs as well as subbanded data, which have been further integrated into 4 PRIs or ~1.2 ms.

The science telemetry includes the first four sample raw moments of the fullband (24 MHz wide) and 16 subband (each 1.5 MHz wide) signals, for both vertical and horizontal polarizations. The telemetry expresses the in-phase and quadrature components of the signals separately. The instrument flight software produces 3rd and 4th Stokes parameters using complex cross-correlation of the two polarizations for the fullband data as well as each of the 16 subbands. Every science data packet therefore contains 360 elements of time-frequency data in high rate mode and 72 elements of low rate mode time data.

In high rate mode, the subband data are included to provide time and frequency diversity. The inclusion of these data improve detection and mitigation of radio frequency interference (RFI). Since RFI is expected mostly over land, the SMAP spacecraft nominally downlinks high rate mode data over land and low rate mode data over oceans. The SMAP mission selected specific regions over the oceans for calibration/validation. Over those select regions, the spacecraft will downlink high rate mode data.

1.6 Related SMAP Project Documents

SMAP L1B_TB Algorithm Theoretical Basis Document, J. Piepmeier, GSFC SMAP-ALGMS-RPT-0026, May 31, 2012.

SMAP Science Data Management and Archive Plan, JPL D-45973, August 29, 2011.

SMAP Pointing, Positioning, Phasing and Coordinate Systems, Volume 0: Definitions and Principle Coordinate Systems, JPL D-46018, Revision B, April 15, 2014

1.7 Applicable Documents

ISO 19115:2003(E) International Standard – Geographic Information – Metadata, May 1, 2003.

ISO 19115-2:2009 International Standard – Geographic Information – Part 2:Extensions for imagery and gridded data, December 12, 2009.

ISO 19139:2007 International Standard – Geographic Information – Metadata – XML schema implementation, May 14 2009.

Introduction to HDF5, The HDF Group, http://www.hdfgroup.org/HDF5/doc/H5.intro.html.

HDF5: API Specification Reference Manual, The HDF Group http://www.hdfgroup.org/HDF5/doc/RM/RM_H5Front.html

HDF5 User's Guide Release 1.8.9, The HDF Group, http://hdfgroup.com/HDF5/doc/UG, May 2012.

NetCDF Climate and Forecast (CF) Metadata Conventions, Version 1.6, December 5, 2011.

2 DATA PRODUCT ORGANIZATION

2.1 File Format

All SMAP standard products are in the Hierarchical Data Format version 5 (HDF5). HDF5 is a general purpose file format and programming library for storing scientific data. The National Center for Supercomputing Applications (NCSA) at the University of Illinois developed HDF to help scientists share data regardless of the source. Use of the HDF library enables users to read HDF files on multiple platforms regardless of the architecture the platforms use to represent integer and floating point numbers. HDF files are equally accessible to routines written either in Fortran, C or C++.

A spin-off organization of the NCSA, named The HDF Group, is responsible for development and maintenance of HDF. Users should reference The HDF Group website at http://www.hdfgroup.org to download HDF software and documentation.

2.2 HDF5 Notation

HDF5 represents a significant departure from the conventions of previous versions of HDF. The changes that appear in HDF5 provide flexibility to overcome many of the limitations of previous releases. The basic building blocks have been largely redefined, and are more powerful but less numerous. The key concepts of the HDF5 Abstract Data Model are Files, Groups, Datasets, Datatypes, Attributes and Property Lists. The following sections provide a brief description of each of these key HDF5 concepts.

2.2.1 HDF5 File

A File is the abstract representation of a physical data file. Files are containers for HDF5 Objects. These Objects include Groups, Datasets, and Datatypes.

2.2.2 HDF5 Group

Groups provide a means to organize the HDF5 Objects in HDF5 Files. Groups are containers for other Objects, including Datasets, named Datatypes and other Groups. In that sense, groups are analogous to directories that are used to categorize and classify files in standard operating systems.

The notation for files is identical to the notation used for Unix directories. The root Group is “/”. A Group contained in root might be called “/myGroup.” Like Unix directories, Objects appear in Groups through “links”. Thus, the same Object can simultaneously be in multiple Groups.

2.2.3 HDF5 Dataset

The Dataset is the HDF5 component that stores user data. Each Dataset associates with a Dataspace that describes the data dimensions, as well as a Datatype that describes the basic unit of storage element. A Dataset can also have Attributes.

2.2.4 HDF5 Datatype

A Datatype describes a unit of data storage for Datasets and Attributes. Datatypes are subdivided into Atomic and Composite Types.

Atomic Datatypes are analogous to simple basic types in most programming languages. HDF5 Atomic Datatypes include Time, Bitfield, String, Reference, Opaque, Integer, and Float. Each atomic type has a specific set of properties. Examples of the properties associated with Atomic Datatypes are:

- Integers are assigned size, precision, offset, pad byte order, and are designated as signed or unsigned.
- Strings can be fixed or variable length, and may or may not be null-terminated.
- References are constructs within HDF5 Files that point to other HDF5 Objects in the same file.

HDF5 provides a large set of predefined Atomic Datatypes. Table 2 lists the Atomic Datatypes that are used in SMAP data products.

Table 2: HDF5 Atomic Datatypes

HDF5 Atomic Datatypes	Description
H5T_STD_U8LE	unsigned, 8-bit, little-endian integer
H5T_STD_U16LE	unsigned, 16-bit, little-endian integer
H5T_STD_U32LE	unsigned, 32-bit, little-endian integer
H5T_STD_U64LE	unsigned, 64-bit, little-endian integer
H5T_STD_I8LE	signed, 8-bit, little-endian integer
H5T_STD_I16LE	signed, 16-bit, little-endian integer

HDF5 Atomic Datatypes	Description
H5T_STD_I32LE	signed, 32-bit, little-endian integer
H5T_STD_I64LE	Signed, 64-bit, little-endian integer
H5T_IEEE_F32LE	32-bit, little-endian, IEEE floating point
H5T_IEEE_F64LE	64-bit, little-endian, IEEE floating point
H5T_C_S1	character string made up of one or more bytes

Composite Datatypes incorporate sets of Atomic datatypes. Composite Datatypes include Array, Enumeration, Variable Length and Compound.

- The Array Datatype defines a multi-dimensional array that can be accessed atomically.
- Variable Length presents a 1-D array element of variable length. Variable Length Datatypes are useful as building blocks of ragged arrays.
- Compound Datatypes are composed of named fields, each of which may be dissimilar Datatypes. Compound Datatypes are conceptually equivalent to structures in the C programming language.

Named Datatypes are explicitly stored as Objects within an HDF5 File. Named Datatypes provide a means to share Datatypes among Objects. Datatypes that are not explicitly stored as Named Datatypes are stored implicitly. They are stored separately for each Dataset or Attribute they describe.

None of the SMAP data products employ Enumeration or Compound data types.

2.2.5 HDF5 Dataspace

A Dataspace describes the rank and dimension of a Dataset or Attribute. For example, a “Scalar” Dataspace has a rank of 1 and a dimension of 1. Thus, all subsequent references to “Scalar” Dataspace in this document imply a single dimensional array with a single element.

Dataspaces provide considerable flexibility to HDF5 products. They incorporate the means to subset associated Datasets along any or all of their dimensions. When associated with specific properties, Dataspaces also provide the means for Datasets to expand as the application requires.

2.2.6 HDF5 Attribute

An Attribute is a small aggregate of data that describes Groups or Datasets. Like Datasets, Attributes are also associated with a particular Dataspace and Datatype. Attributes cannot be subsetted or extended. Attributes themselves cannot have Attributes.

2.3 SMAP File Organization

2.3.1 Structure

SMAP data products follow a common convention for all HDF5 Files. Use of this convention provides uniformity of data access and interpretation.

The SMAP Project uses HDF5 Groups to provide an additional level of data organization. All metadata that pertain to the complete data granule are members of the “/Metadata” Group. All other data are organized within Groups that are designed specifically to handle the structure and content of each particular data product.

2.3.2 Data

All data in HDF5 files are stored in individual Datasets. All of the Datasets in an SMAP product are assigned to an HDF5 Group. A standard field name is associated with each Dataset. The field name is a unique string identifier. The field name corresponds to the name of the data element the Dataset stores. This document lists these names with the description of each data element that they identify.

Each Dataset is associated with an HDF5 Dataspace and an HDF5 Datatype. They provide a minimally sufficient set of parameters for reading the data using standard HDF5 tools.

2.3.3 Element Types

SMAP HDF5 employs the Data Attribute “Type” to classify every data field as a specific data type. The “Type” is an embellishment upon the standard HDF5 Datatypes that is designed specifically to configure SMAP data products.

Table 3 lists all of the “Type” strings that appear in the SMAP data products. The table maps each SMAP “Type” to a specific HDF5 Datatype in both the HDF5 file and in the data buffer. The table also specifies the common conceptual data type that corresponds to the “Type” in SMAP executable code.

Table 3: Element Type Definitions

Type	HDF5 Datatype (File)	HDF5 Datatype (Buffer)	Conceptual Type
Unsigned8	H5T_STD_U8LE	H5T_NATIVE_UCHAR	unsigned integer
Unsigned16	H5T_STD_U16LE	H5T_NATIVE_USHORT	unsigned integer
Unsigned24	H5T_STD_U16LE, with precision set to 24 bits, and size set to 3 bytes.	H5T_NATIVE_INT	unsigned integer
Unsigned32	H5T_STD_U32LE	H5T_NATIVE_UINT	unsigned integer
Unsigned64	H5T_STD_U64LE	H5T_NATIVE_ULLONG	unsigned integer
Signed8	H5T_STD_I8LE	H5T_NATIVE_SCHAR	signed integer
Signed16	H5T_STD_I16LE	H5T_NATIVE_SHORT	signed integer
Signed32	H5T_STD_I32LE	H5T_NATIVE_INT	signed integer
Signed64	H5T_STD_I64LE	H5T_NATIVE_LLONG	signed integer
Float32	H5T_IEEE_F32LE	H5T_NATIVE_FLOAT	floating point
Float64	H5T_IEEE_F64LE	H5T_NATIVE_DOUBLE	floating point
FixLenStr	H5T_C_S1	H5T_NATIVE_CHAR	character string
VarLenStr	H5T_C_S1, where the length is set to H5T_VARIABLE	H5T_NATIVE_CHAR	character string

SMAP HDF5 files employ two different types of string representation. “VarLenStr” are strings of variable length. “VarLenStr” provides greater flexibility to represent character strings. In an effort to make SMAP HDF5 more friendly to users who wish to use netCDF software, SMAP products restrict the use of “VarLenStr”. “FixLenStr” are strings with a prescribed fixed-length. “FixLenStr” are useful for fixed length strings that are stored in large multi-dimension array. UTC time stamps are an excellent example of the type of data that store well in a “FixLenStr”.

2.3.4 File Level Metadata

All metadata that describe the full content of each granule of the SMAP data product are stored within the explicitly named “/Metadata” Group. SMAP metadata are handled using exactly the same procedures as those that are used to handle SMAP data. The contents of each Attribute that stores metadata conform to one of the SMAP Types. Like data, each metadata element is also assigned a shape. Most metadata elements are stored as scalars. A few metadata elements are stored as arrays.

SMAP data products represent file level metadata in two forms. One form appears in one or more Attributes within the Metadata Group. Combined, those Attributes contain a complete representation of the product metadata. The content of these two attributes conforms to the ISO 19115-2 models in ISO 19139 compliant XML.

The second form of the metadata appears in a set of HDF5 Groups under the “/Metadata” Group. Each of these HDF5 Groups represents one of the major classes in the ISO 19115-2 model. These HDF5 Groups contain a set of HDF5 Attributes. Each HDF5 Attributes represents a specific ISO attribute of the associated ISO class. Although this representation inherits design from the ISO model, it does not completely conform to the model. In many cases, the names of the HDF5 Attributes match those used in the ISO model. In some situations, names were changed to provide greater clarity to SMAP users who are not familiar with the ISO model. Furthermore, to ease metadata searches, the structure of Groups within Groups was limited to four levels.

2.3.5 Local Metadata

SMAP standards incorporate additional metadata that describe each HDF5 Dataset within the HDF5 file. Each of these metadata elements appear in an HDF5 Attribute that is directly associated with the HDF5 Dataset. Wherever possible, these HDF5 Attributes employ names that conform to the Climate and Forecast (CF) conventions. Table 4 lists the CF names for the HDF5 Attributes that SMAP products typically employ.

Table 4: SMAP Specific Local Attributes

CF Compliant Attribute Name	Description	Required?
Units	Units of measure. Appendix E lists applicable units for various data elements in this product.	Yes
valid_max	The largest valid value for any element in the Dataset. The data type in valid_max matches the type of the associated Dataset. Thus, if the associated Dataset stores float32 values, the corresponding valid_max will also be float32.	No
valid_min	The smallest valid value for any element in the Dataset. The data type in valid_min matches the type of the associated Dataset. Thus, if the associated Dataset stores float32 values, the corresponding valid_min will also be float32.	No
_FillValue	Specification of the value that will appear in the Dataset when an element is missing or undefined. The data type of _FillValue matches the type of the associated Dataset. Thus, if the associated Dataset stores float32 values, the corresponding _FillValue will also be float32.	Yes for all numeric data types
long_name	A descriptive name that clearly describes the content of the associated Dataset.	Yes
coordinates	Identifies auxiliary coordinate variables in the data product.	No
flag_values	Provides a list of flag values that appear in bit flag variables. Should be used in conjunction with local HDF5 attribute *flag_meanings*. Only appears with bit flag variables.	No
flag_masks	Provides a list of bit fields that express Boolean or enumerated flags. Only appears	No

CF Compliant Attribute Name	Description	Required?
	with bit flag variables or enumerated data types.	
flag_meanings	Provides descriptive words or phrases for each potential bit flag value. Should be used in conjunction with local HDF5 attribute *flag_values*.	No

2.4 Data Definition Standards

Section 4.6 of this document specifies the characteristics and definitions of every data element stored in this SMAP data product. Table 5 defines each of the specific characteristics that are listed in that section of this document. Some of these characteristics correspond with the SMAP HDF5 Attributes that are associated with each Dataset. Data element characteristics that correspond to SMAP HDF5 Attributes bear the same name. The remaining characteristics are descriptive data that help users better understand the data product content.

In some situations, a standard characteristic may not apply to a data element. In those cases, the field contains the character string 'n/a'. Hexadecimal representation sometimes indicates data content more clearly. Numbers represented in hexadecimal begin with the character string '0x'.

Table 5: Data Element Characteristic Definitions

Characteristic	Definition
Type	The data representation of the element within the storage medium. The storage class specification must conform to a valid SMAP type. The first column in table 3 lists all of the valid values that correspond to this characteristic.
Shape	The name of the shape data element that specifies the rank and dimension of a particular data set. Appendix C lists all of the valid shapes that appear in this data product.
Valid_max	The expected minimum value for a data element. In most instances, data element values never fall below this limit. However, some data elements, particularly when they do not reflect normal geophysical conditions, may contain values that fall below this limit.

Characteristic	Definition
Valid_min	The expected maximum value for a data element. In most instances, data element values never exceed this limit. However, some data elements, particularly when they do not reflect normal geophysical conditions, may contain values that exceed this limit.
Valid Values	Some data elements may store a restricted set of values. In those instances, this listing specifies the values that the data element may store.
Nominal Value	Some data elements have an expected value. In those instances, this listing provides that expected value. Nominal values are particularly common among a subset of the metadata elements.
String Length	This characteristic specifies the length of the data string that represents a single instance of the data element. This characteristic appears exclusively for data elements of FixLenStr type.
Units	Units of measure. Typical values include “deg”, “degC”, “Kelvins”, “m/s”, “m”, “m**2”, “s” and “counts”. Appendix A and Appendix E include references to important data measurement unit symbols.

2.4.1 Double Precision Time Variables

SMAP double precision time variables contain measurements relative to the J2000 epoch. Thus, these variables represent a real number of Standard International (SI) compatible seconds since 11:58:55.816 on January 1, 2000 UTC.

2.4.2 Array Representation

This document employs array notation to demonstrate and clarify the correspondence among data elements in different product data elements. The array notation adopted in this document is similar to the standards of the Fortran programming language. Indices are one based. Thus, the first index in each dimension is one. This convention is unlike C or C++, where the initial index in each dimension is zero. In multidimensional arrays, the leftmost subscript index changes most rapidly. Thus, in this document, array elements ARRAY(15,1,5) and ARRAY(16,1,5) are stored contiguously.

HDF5 is designed to read data seamlessly regardless of the computer language used to write an application. Thus, elements that are contiguous using the dimension notation in this document will appear in contiguous locations in arrays for reading applications in any language with an HDF5 interface.

This document differentiates among array indices based on relative contiguity of storage of elements referenced with consecutive numbers in that index position. A faster or fastest moving index implies that the elements with consecutive numbers in that index position are stored in relative proximity in memory. A slower or slowest moving index implies that the elements referenced with consecutive indices are stored more remotely in memory. For instance, given array element ARRAY(15,1,5) in Fortran, the first index is the fastest moving index and the third index is the slowest moving index. On the other hand, given array element array[4][0][14] in C, the first index is the slowest moving index and the third index is the fastest moving index.

3 INTERFACE CHARACTERISTICS

3.1 Coordinate Systems

The SMAP mission will use the Science Orbit Reference Frame (SRF) and the Earth Centered Rotating (ECR) coordinate systems to represent spacecraft attitude, position and relative motion. The SMAP project document entitled SMAP Pointing, Positioning, Phasing and Coordinate Systems, Volume 0: Definitions and Principle Coordinate Systems fully describes both of these coordinate systems.

The Spacecraft Coordinate System is…..

The Science Orbit Reference Frame (SRF) is a right-handed coordinate system with its three axes mutually orthogonal. The SRF is defined such that the origin is at the spacecraft center of mass (CM). The +Z axis points toward Geodetic Nadir. Due to the oblateness of the Earth, the vector from the spacecraft to the geometric center of the Earth (Geocentric Nadir) is different from the vector from the spacecraft to the local WGS84 ellipsoid normal (Geodetic Nadir). The +X axis is coplanar with both the +Z axis and the spacecraft inertial velocity vector. The +X axis closely adheres to the direction of the spacecraft inertial velocity vector. The +Y axis completes the right-handed, orthogonal coordinate system. The +Y axis is normal to the orbit plane with positive sense in the direction opposite the orbit angular momentum vector.

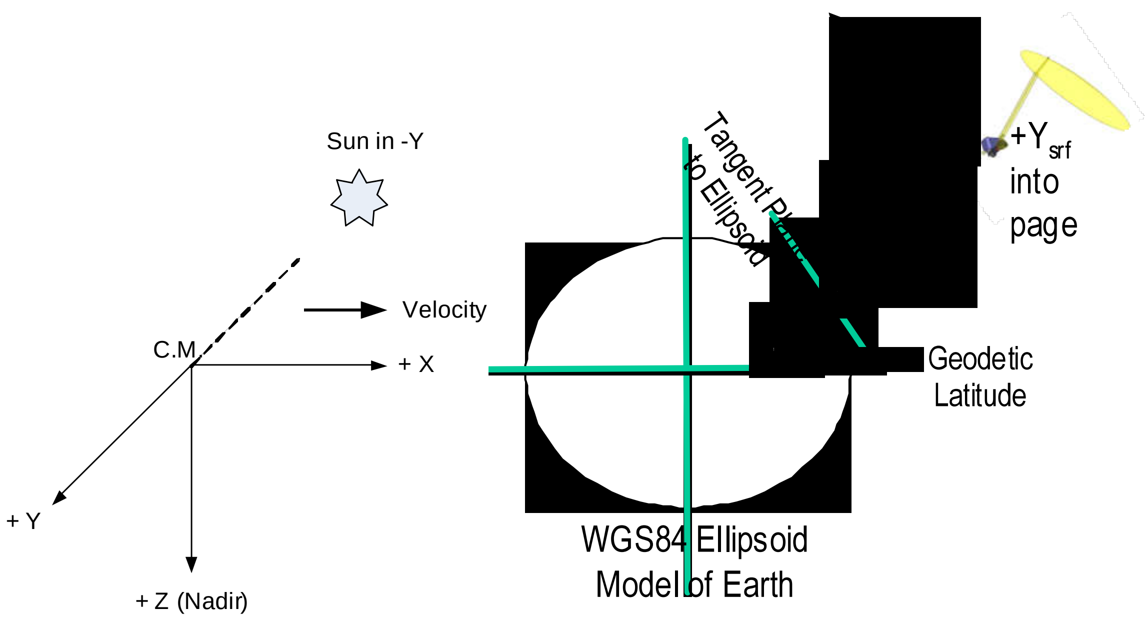

Figure 2: The Science Reference Frame Coordinate System

The Earth Centered Rotating (ECR) or Earth Centered Fixed coordinate system is a right-handed coordinate system with three mutually orthogonal axes. The origin of the system is the Earth's center of mass. The positive x-axis extends from the origin through the intersection of the Equator at 0° latitude and the Greenwich Meridian at 0° longitude . The positive z-axis extends directly North from the origin of the ECR system. Due to a slight wobbling of the Earth, the z-axis does not coincide exactly with the instantaneous rotation axis of the Earth. The y-axis completes the right-handed coordinate system as a vector from the origin to the intersection of the Equator and 90° East longitude.

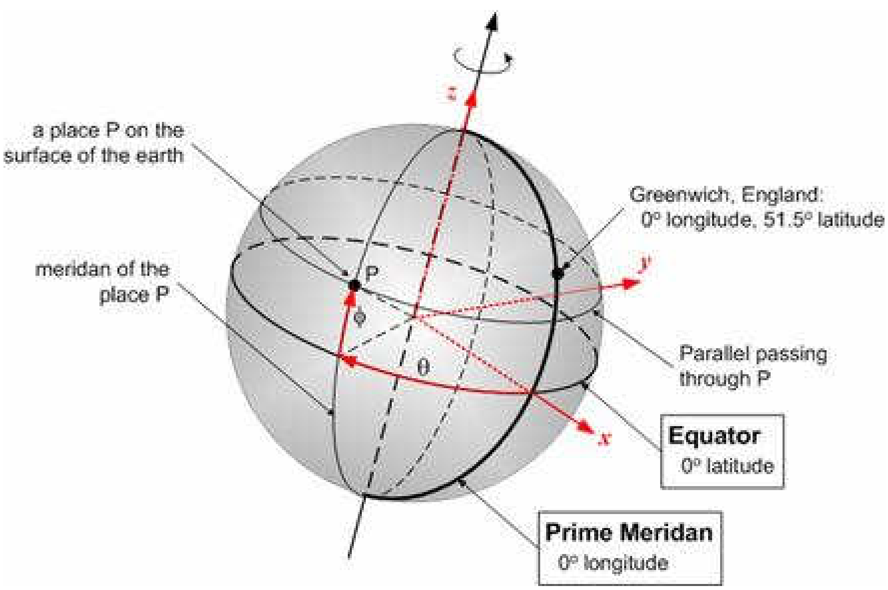

Figure 3: Earth Centered Rotating Coordinate System

The SMAP mission adopted the World Reference System WGS84 ellipsoid to define the horizontal Earth reference coordinates. The WGS84 geoid was adopted as the vertical Earth reference coordinates. Geodetic measure is used to define both the spacecraft location and the instrument target location relative to the Earth's surface.

3.2 Spacecraft Attitude and Modeling Spacecraft Slews

The SMAP SDS receives spacecraft attitude data on a regular basis from the Navigation and Ancillary Information Facility (NAIF) at JPL. Upon arrival from NAIF, these data specify the orientation of the Spacecraft Coordinate System with respect to J2000 coordinates. The NAIF data are represented in quaternions.

The Science Data System converts these data into pitch, yaw and roll angles relative to the SMAP Science Orbit Reference Frame (SRF). Those angular measures appear in the SMAP Level 1 Science Data Products. Both the Science Orbit Reference Frame and the Spacecraft Coordinate System are defined in the SMAP Pointing, Positioning, Phasing and Coordinate System Volume 0, Revision B, April 15, 2014.

During nominal operations, the pitch, yaw and roll angles will be very small. Indeed, in order to retain anticipated incidence angles for radar and radiometer measure, these angles will almost always be less than 1 degree. Thus, under these conditions, the definitions of pitch, yaw and roll conform to the definitions found in the SMAP Level 1 Product Specification Documents.

- Pitch is the angular rotation of the spacecraft body about the Y axis of the SMAP Science Orbit Reference Frame (SRF). The Y axis of the SRF is normal to the spacecraft orbital plane.
- Roll is the angular rotation of the spacecraft body about the X axis of the SMAP Science Orbit Reference Frame (SRF) coordinate system. The X axis of the SRF approximates the direction of spacecraft motion.
- Yaw is the angular rotation of the spacecraft body about the Z axis of the SMAP Science Orbit Reference Frame (SRF) coordinate system. The Z axis of the SRF runs from the center of mass of the spacecraft toward geodetic nadir.

The SMAP mission will maneuver the spacecraft from time to time. Of particular interest are maneuvers that enable the spacecraft antenna to view cold sky. Knowledge of the Euler angle that represents the spacecraft attitude during these maneuvers is critical. Generation of the Euler angle requires specification of the proper order of rotation from the science orbit reference frame to the spacecraft frame. The order of rotation that users should employ is pitch, followed by roll and then yaw. **If SMAP product users wish to reconstruct the Euler angles associated with spacecraft maneuvers, they should employ the following processing steps based on provided values of pitch, yaw and roll:**

- Roll the spacecraft angle by 180 degrees. The roll aligns the Spacecraft Coordinate System with the SMAP Science Orbit Reference Frame.
- Perform a pitch rotation. The pitch rotation is executed about the position of the Y axis of the Spacecraft Coordinate System at the completion of the previous roll rotation.

- Perform roll rotation. The roll rotation is executed about the position of the X axis of the Spacecraft Coordinate System at the completion of the previous pitch rotation.
- Perform the yaw rotation. The yaw rotation is executed about the position of the Z axis of the Spacecraft Coordinate System at the completion of the roll rotation.

To enable representation of maneuver conditions, the pitch, roll and yaw angles will need to take on larger measures. SMAP software thus enables pitch values to range from –180 degrees to 180 degrees, roll values to range from –90 to 90 degrees and yaw values to range from –180 degrees to 180 degrees.

3.3 Fill and Gap Values

SMAP data products employ fill and gap values to indicate when no valid data appear in a particular data element. Fill values ensure that data elements retain the correct shape. Gap values locate portions of a data stream that do not appear in the output data file.

The total number of science packets or PRIs per scan varies depending on the antenna rotation rate and integration time of the instrument. Each science packet contains data in one of 5 radiometric states and the data is parsed and stored in this manner. To preserve the shape of the stored data elements, the size of certain dimensions is assigned a maximum value. Thus, fill values appear in the SMAP L1A Radiometer Product when data in a particular radiometric state does not call for the maximum number of packets or PRIs per antenna rotation. Those elements with indices that do not contain recorded data contain fill values.

All SMAP data products employ a specific set of data values to connote that an element is fill. The selected values that represent fill are dependent on the data type. With a single exception, the Level 1A Radiometer product employs the same set of fill values as other SMAP data products. The other SMAP data products employ a null value of -9999.0 for floating point numbers. That value falls within range of a large number of telemetry elements in the Radiometer telemetry. Thus, the Level 1A Radiometer employs -9.999e20 as the null value for floating point numbers.

Table 6 lists the values that represent fill in the SMAP Level 1A Product based on data type:

Table 6: SMAP Product Fill Values

Type	Value	Pattern

Type	Value	Pattern
Float32, Float64	-9.999e20	Large, negative number
Signed8, NormSigned8	-127	Type minimum + 1
Signed16, NormSigned16	-32767	Type minimum + 1
Signed24	-8388607	Type minimum + 1
Signed32	-2147483647	Type minimum + 1
Signed64	-9223372036854775807	Type minimum + 1
Unsigned8	254	Type maximum - 1
Unsigned16	65534	Type maximum - 1
Unsigned24	16777214	Type maximum - 1
Unsigned32	4294967294	Type maximum - 1
Unsigned64	18446744073709551614	Type maximum - 1
FixedLenString, VarLenString	N/A	Not available

No valid value in the L1A Radiometer product is equal to the values that represent fill. If any exceptions should exist in the future, the L1A Radiometer content will provide a means for users to discern between elements that contain fill and elements that contain genuine data values. This document will also contain a description of the method used to ascertain which elements are fill and which elements are genuine.

The L1A Radiometer Product records gaps in the product level metadata. The following conditions will indicate that no gaps appear in the data product:

- Only one instance of the attributes *Extent/rangeBeginningDateTime* and *Extent/rangeEndingDateTime* will appear in the product metadata.
- The character string stored in metadata element *Extent/rangeBeginningDateTime* will match the character string stored in metadata element *OrbitMeasuredLocation/halfOrbitStartDateTime*.

- The character string stored in metadata element *Extent/rangeEndingDateTime* will match the character string stored in metadata element *OrbitMeasuredLocation/halfOrbitStopDateTime*.

One of two conditions will indicate that gaps appear in the data product:

- The time period covered between *Extent/rangeBeginningDateTime* and *Extent/RangeEndingDateTime* does not cover the entire half orbit as specified in *OrbitMeasuredLocation/halfOrbitStartDateTime* and *OrbitMeasuredLocation/halfOrbitStartDateTime*.
- More than one pair of *Extent/rangeBeginningDateTime* and *Extent/rangeEndingDateTime* appears in the data product. Time periods within the time span of the half orbit that do not fall within the sets of *Extent/rangeBeginningDateTime* and *Extent/rangeEndingDateTime* constitute data gaps.

3.4 Flexible Data Design

HDF5 format gives the SMAP Level Products a high degree of flexibility. This flexibility in turn gives SMAP end product users the capability to write software that does not need to be modified to accommodate unforeseeable changes in the SMAP products. Since changes to the products are certain to take place over the life of the SMAP mission, users are encouraged to use software techniques that take advantage of some of the features in HDF5.

For example, users can write a product reader that selects only those product data elements they wish to read from an SMAP Level Product file. With the appropriate design, this software will not need to change, regardless of the number, the size, or the order of the current data product entries. Indeed, the only changes users need to implement would take place if they should choose to read a newly defined data element after a product upgrade.

For those users who wish to extract a specific subset of the data from an SMAP Product, the HDF5 routines H5Dopen and H5Dread (h5dopen_f and h5dread_f in FORTRAN) are very useful. H5Dopen requires two input parameters, the first is an HDF5 file/group identifier, the second is a character string that contains the name of a Dataset. H5Dopen returns the identifier for the specified Dataset in the product file. HDF5 routine H5Dread then uses the Dataset identifier to fetch the contents. H5Dread places the contents of the Dataset in a specified output variable.

Once the data element is located and read, users can generate standardized code that reads the metadata associated with each element. Users of the SMAP Level Products should employ the same methods to read metadata and standard data elements.

3.5 Access to Product Element Dimensions

Each data element in every SMAP data product is assigned a specific shape. Elements with the same shape have the same number of dimensions, and each of those dimensions have the same extent and meaning. Thus, if two data elements have the same shape, then their constituent array elements with identical indices correspond.

The SMAP L1A Radiometer Product employs a naming convention for shapes. The convention specifies the component dimensions. The final word in all shape names is always “Array”. The text that precedes the word “Array” provides the order of dimensions. The word that just precedes “Array” represents the dimension with the “fastest moving” index. In other words, consecutive indices in this dimension, provided the other dimension indices are identical, represent contiguous storage. For example, the Shape name AntennaScan_AntPRI_Array implies that the dimension where consecutive indices imply contiguous storage represents antenna PRIs. The other, slower moving, dimension represents antenna scans. Appendix C provides the nominal rank and dimension sizes for each shape that appears in the L1A Radiometer Product.

Appendix D provides the nominal or expected maximum product dimensions.

Appendix F contains an example of code that reads dimensions for a particular data element directly from the L1A Radiometer product.

4 DATA DEFINITION

4.1 Product Overview

4.1.1 Level 1A_Radiometer Product

Each Level 1A_Radiometer product granule incorporates all of the radiometer data that were downlinked from the SMAP spacecraft for one specific half orbit. The SMAP project delineates half orbits at the northernmost and southernmost point of each orbit path.

The major contents of the Level 1A_Radiometer product include:

- Instrument counts of the first four sample raw moments of the fullband for both vertical and horizontal polarizations
- Instrument counts of the16 subband signals for both vertical and horizontal polarizations

Both the fullband and subband data are expressed in terms of the in-phase and quadrature components of the signals. The product includes 3rd and 4th Stokes parameters of the two polarizations for the fullband as well as each of the 16 subbands. The product also includes time stamps for each PRI/packet of radiometer counts and housekeeping telemetry converted to engineering units for each scan.

4.1.2 Level 1A_Radiometer Metadata

The SMAP Level 1A_Radiometer metadata are representative of the entire contents of the file. The metadata appear in two forms. One form of the metadata appears in single HDF5 Attribute. That Attribute contains the complete representation of the product metadata that conforms to the ISO 19115-2 model in ISO 19139 compliant XML. The second form of the metadata appears in a set of HDF5 groups. Each HDF5 group contains a set of HDF5 attributes. The arrangement and names of the groups and their attribute components approximate major contents of the ISO model.

Metadata in ISO 19139 conformant XML enables users who are familiar with the ISO metadata standards to extract the metadata they need using software that operates with the ISO 19115-2 model and its formal representation. The set of groups and attributes enable users who are not as familiar with the ISO standard to find the particular metadata elements they need to better comprehend product content and format.

4.1.3 Level 1A_Radiometer Data

All product elements in the Level 1A_Radiometer Product are stored as HDF5 Datasets. Each of these datasets belongs to one of three distinct HDF5 Groups. The data design employs HDF5 Groups to categorize datasets that have corresponding array elements and that relate to a common application.

The HDF5 Groups in the Level 1A_Radiometer product include the Spacecraft Data Group, the Subband Moments Data Group, the Fullband Moments Data Group and the House Keeping Group. Section 4.5 of this document includes more detailed descriptions of each of the HDF5 Groups in the data product.

All of the Level 1A_Radiometer HDF5 Groups are organized relative to the SMAP antenna scan. The single array index for all data elements in the Spacecraft Data Group denotes the representative position of the spacecraft for a given antenna scan. This single index in the Spacecraft Data Group corresponds to the slowest moving index for all elements in all the Data Groups. All array elements with the same antenna scan index fall in the same antenna scan. Within each data granule, the time the spacecraft flew over any given antenna scan is a monotonically increasing function of the antenna scan index. Thus, a smaller antenna scan index represents an antenna scan that took place earlier during flight. A larger antenna scan index represents an antenna scan that took place later during flight.

4.2 Instrument Radiometric States

Radiometer data contain science data packets that will be generated once every 4 PRIs. The switching scheme which indicates the radiometer state of a particular science data packet is pre-determined and used to parse the raw science data. The radiometer digital electronics (RDE) box controls when the radiometer reference switch and noise sources are switched during an antenna azimuth scan. This switching can occur every four PRIs or once every packet. The reference load switches and noise sources are necessary for calibration of science data. The calibration network can produce different combinations of switch and noise diode states. The default radiometer switching sequence produces 5 states:

- Antenna – data acquired when the radiometer is switched to the antenna to observe the scene.
- Reference – data acquired when the radiometer is switched to the reference load. The radiometer front end contains reference load switches coupled independently into each of the V and H channels.
- Reference plus internal noise diode – data acquired when the radiometer is switched to the reference load and the internal noise diode is turned on.

There are internal noise diodes also coupled independently into each of the V and H channels.

- Antenna plus external noise diode – data acquired when a correlated noise diode (referred to as the external noise diode) is used to inject noise into the RF path.
- Antenna plus internal noise diode – data acquired when the radiometer is switched to the antenna to observe the scene and the internal noise diode is turned on.

See Appendix D for more information about the switching scheme.

4.3 Data Volume Estimates

L-band anthropogenic Radio Frequency Interference (RFI), principally from ground-based surveillance radars, can contaminate radiometer measurements. Early measurements and results from the SMOS mission indicate that in some regions, RFI is present and detectable. The SMAP radiometer electronics and algorithms have been designed to include features to mitigate the effects of RFI. To combat this, the SMAP radiometer will implement a combination of time and frequency diversity, kurtosis detection, and the use of 3rd and 4th Stokes parameter thresholds to detect, and where possible, to mitigate RFI. Data elements associated with subbands are included in the L1A Radiometer product to track and enable RFI detection and mitigation. Since RFI is expected to be significantly less over the ocean, the algorithm does not require frequency diversity over this region. Thus, with one major exception, the High Resolution Moments Data Group is not included for data collected over the ocean. The exception covers a selected area over the ocean that the SMAP team will use for radiometer calibration and validation. The calibration and validation activity requires the diversity of frequency in the high rate data. The instrument will download high rate data over those regions..

The Table 7 contains an analysis of the volume of L1A Radiometer products. The table specifies the contribution of each of the HDF5 data Groups to the total data volume of a Level 1A Radiometer product. The estimate assumes that land occupies about 30 % of an average half orbit. The final row provides an estimate of the volume of an average uncompressed data granule.

Table 7: Data Volume Estimates for Data Acquired at 06:00 Local Time

Group	Number of Entries	Bytes Per Entry	Expected Total Volume (MBytes)
Level 1A_TB Metadata	1	10000	0.010
XML Version of ISO Metadata	1	124000	0.124
Spacecraft Data Group	640	112	0.072
High Resolution Moments Data Group	192	4242418	814.544
Moments Data Group	640	1256581	804.212
House Keeping Data Group	640	1106	0.708
Level 1A Radiometer Product			1619.670

4.4 SMAP Level 1A_Radiometer Product File Names

Distributable SMAP L1A Radiometer data product file names are 52 characters in length. The first 5 characters in the name of all mission distributable products are 'SMAP_'. These characters identify all products generated by the SMAP mission. The following 14 characters are always 'L1A_RADIOMETER_'. These characters identify the Level 1A_Radiometer Data Product. The following 35 characters uniquely identify the data stored in the file. The final 3 characters of each SMAP Product file name are '.h5'. These characters specify the format of the data in the file.

More specifically, all SMAP L1A Radiometer data product file names must conform to the following convention:

SMAP_L1A_RADIOMETER_[Orbit Number]_[A|D]_[First Date/Time Stamp]_[Composite Release ID]_[Product Counter].[extension]

The outline below describes the content of each field in the file naming convention:

Orbit Number – The sequential number of the orbit that the SMAP spacecraft flew when the data in the associated product were acquired. Orbit 0 will begin at launch. The orbit number must occupy five digits. Orbit numbers that are smaller than 10000 will appear with leading zeroes.

The Half Orbit Designator - SMAP divides orbits into two distinct parts. Division of half orbits takes place at the northernmost and southernmost point on the spacecraft path. Half orbits where the spacecraft moves from North to South are *descending* half orbits. Local time for measurements acquired during a *descending* half orbit is approximately 6 AM. The character "D" appears as the Half Orbit Designator in the file names of products that contain data representing *descending* half orbits. Half orbits where the spacecraft moves from South to North are classified as *ascending* half orbits. Local time for measurements acquired during an *ascending* half orbit is approximately 6 PM. The character "A" appears as the Half Orbit Designator in the file names of products that contain data represent *ascending* half orbits.

First Date/Time Stamp – The date/time stamp of the first data element that appears in the product. Date/time stamps in SMAP file names are always recorded in Universal Coordinated Time (UTC). Date/time stamps conform to the following convention:

YYYYMMDD**T**hhmmss

where:

YYYY is the calendar year. The full calendar year must appear in the file name.

MM designates the month of the year. The month designator always occupies two digits. Months that can be represented with fewer than two digits must employ a leading zero.

DD designates the day of the month. The day designator always occupies two digits. Days of the month that can be represented with fewer than two digits must employ a leading zero.

T delineates the date from the time, and is a required character in all time stamps in product names.

hh designates the hour of the day on a 24 hour clock in UTC. The hour designator always occupies two digits. Hours that can be represented with fewer than two digits must employ a leading zero.

mm designates the minute of the hour in UTC. The minute designator always occupies two digits. Minutes that can be represented with fewer than two digits must employ leading zeroes.

ss designates the truncated second of the minute in UTC. Fractional second specification is not necessary in file names. The second designator always occupies two digits. Seconds that can be represented with fewer than two digits must employ leading zeroes.

Composite Release ID – The Composite Release ID incorporates changes to any processing condition that might impact product results. The format of the Composite Release ID is as follows:

"R"	The character "R" always precedes this identifier
Launch indicator	Distinguishes between pre-launch or pre-instrument commissioned data and data generated under mission operation conditions. A launch indicator of "0" implies the data are simulated or acquired under early mission conditions that exempt the content from mission requirements. A launch indicator of "1" implies the data are acquired by the instrument at or after the time of instrument commissioning, and must therefore meet mission requirements.
Major ID	One digit indicates major releases. Major changes in algorithm or processing approach will generate an update to this identifier.
Minor ID	Three digits indicate minor releases. Any change to any component that impacts data processing, such as algorithm, software or parameters will lead to a change in this identifier.

Product Counter – Files that represent the same half orbit of any particular product type may be generated multiple times. In some instances, the same half orbit may be processed multiple times using the same version of the software. This counter tracks the number of times that a particular product type for a specific half orbit was generated under the same Composite Release ID. The system assigns the first instance of a file that represents a half orbit of a particular Composite Release ID and product type with a Product Counter of 001. The system assigns each subsequent instance of the same half orbit, same Composite Release ID and same product type with the next consecutive integer. The Product Counter always occupies three digits. Product Counters that do not require three digits contain leading zeroes.

Extension – The extension for all SMAP L1A Radiometer data products is "h5". That extension indicates that the product contents are in HDF5 format. The SMAP SDS will generate a QA file with every data granule. The QA file contains statistical information that will enable users to better assess the quality of the associated granule. QA products bear exactly the same name as the products that they represent. The only difference in names is the extension. The extension for all QA products is ".qa".

Example File Names – Based on the above standard, the following name describes a simulated data product from pre-launch release 4 of the Radiometer Level 1A data product that is labeled to cover the ascending half of orbit 934. The first data point acquired 7:49:51 UTC on December 25, 2014. The file represents the second time an L1A Radiometer product was generated for the ascending half of orbit 924:

`SMAP_L1A_RADIOMETER_00934_A_20141225T074951_R04000_002.h5`

The name of the QA product that assesses the output of the above L1A Radiometer granule would be:

`SMAP_L1A_RADIOMETER_00934_A_20141225T074951_R04000_002.qa`

4.5 L1A RADIOMETER Product Metadata

As mentioned in section 4.1.2, the metadata elements in the Level 1A Radiometer product appear in two forms.

One form appears in two specific HDF Attributes within the Metadata Group. The content of the first of these two HDF Attributes is the complete set of series metadata. The series metadata apply to all L1A Radiometer files in any given SMAP mission release. The content of the second HDF Attribute is the complete set of dataset metadata. The dataset metadata are specific to each product file. Combined, these two Attributes represent all of the metadata that apply to the associated L1A Radiometer product. The content of these Attributes conforms to the ISO 19115-2 models in ISO 19139 compliant XML.

The second form of the metadata appears in a set of HDF5 groups under the Metadata Group. Each of these HDF5 Groups represents one of the major classes in the ISO structure. These groups contain a set of HDF5 attributes. Each HDF5 Attribute represents a specific ISO attribute of the associated ISO class. Although this representation inherits design from the ISO model, it does not completely conform to the model. In many cases, the names of the HDF5 Attributes match those used in the ISO model. In some situations, names were changed to provide greater clarity to SMAP users who are not familiar with the ISO model. Furthermore, to ease metadata searches, the structure of Groups within Groups was limited to four levels.

In addition, the Metadata group includes two attributes that contain MD5 checksums. These two checksum attributes specify the size of the two ISO metadata sets expressed in XML. Thus, *attribute iso_19139_dataset_xml_md5* contains the MD5 checksum of the contents of element *iso_19139_dataset_xml*. Likewise, attribute *iso_19139_series_xml_md5* contains the MD5 checksum of the contents of element *iso_19139_series_xml*.

Table 8 describes the subgroups of the Metadata group, and the attributes within each group. The first column of Table 8 specifies a major class in the ISO 19115 metadata model. The second column provides the name of the HDF5 Group under “/Metadata” where attributes associated with the corresponding class will appear. The third column lists the names of the subgroups and attributes where specific metadata values appear. The fourth column provides valid values for each element. Constant values appear with no diacritical marks. Variable values are encapsulated by brackets <>. All of the metadata elements that appear in Table 8 appear in every Level 1A Radiometer Product file.

Table 8: Granule Level Metadata in the L1A RADIOMETER Product

ISO Major Class	SMAP HDF5 Metadata SubGroup	Subgroup/Attribute in SMAP HDF5	Valid Values
DQ_DataQuality	DataQualiity	Scope	Moments_Data
		CompletenssOmission/evaluationMethodType	directInternal
		CompletenessOmission/measureDescription	Fraction of time period within the half orbit when radiometer data appear to be missing.
		CompletenessOmission/nameOfMeasure	Percent of Missing Data
		CompletenessOmission/value	<A measure between 0 and 100>
		CompletenessOmission/unitOfMeasure	percent
		BitFlipOmission/evaluationMethodType	directInternal
		BitFlipOmission/measureDescription	Percent of telemetry records negatively impacted by uncorrectable bit flip errors.
		BitFlipOmission/nameOfMeasure	Percent of Missing Data due to Bit Flips
		BitFlipOmission/value	<A measure between 0 and 100>
		BitFlipOmission/unitOfMeasure	Percent
		SubBandCompletenssOmission/evaluationMe	directInternal

		thodType	
		SubBandCompletenessOmission/measureDescription	Fraction of time period covered by half orbit when anticipated sub band data appear to be missing.
		SubBandCompletenessOmission/nameOfMeasure	Percent of Sub Band Data that appear to be Missing
		SubBandCompletenessOmission/value	<A measure between 0 and 100>
		SubBandCompletenessOmission/unitOfMeasure	Percent
		DomainConsistency/evaluationMethodType	directInternal
		DomainConsistency/measureDescription	Percent of the radiometer science packets that were deemed usable for radiometer processing relative to the number that appear in the input telemetry.
		DomainConsistency/nameOfMeasure	Percent of Usable Science Data Packets.
		DomainConsistency/value	<A measure between 0 and 100>
		DomainConsistency/unitOfMeasure	percent
EX_Extent	Extent	Description	Time range of the telemetry that contains both full band and sub band radiometer data downlinked from the SMAP spacecraft.
		polygonPosList	<An array of vertices of a polygon the defines the region occupied by the data set in the corresponding

			data product. Each vertex is represented by an ordered pair. Latitudes precede longitudes. Vertices appear in clockwise order. Spaces delineate each value.>
		westBoundLongitude	<Longitude measure between -180 degrees and 180 degrees>
		eastBoundLongitude	<Longitude measure between -180 degrees and 180 degrees>
		southBoundLatitude	<Latitude measure between -90 degrees and 90 degrees>
		northBoundLatitude	<Latitude measure between -90 degrees and 90 degrees>
		rangeBeginningDateTime	<Time stamp that indicates the initial time element in the product>
		rangeEndingDateTime	<Time stamp that indicates the final time of data in the product.>
[LI_Lineage/LE_ProcessStep	ProcessStep	Processor	Soil Moisture Active Passive (SMAP) Mission Science Data System (SDS) Operations Facility
		stepDateTime	< A date time stamp that specifies when the product was generated.>
		processDescription	Parses Radiometer Telemetry into discretely defined elements. Converts temperature and voltage measures from data numbers to engineering units.

		documentation	<A reference to software description document.>
		documentVersion	<Time stamp that specifies the release date of the software description document.>
		documentDate	<Version identifier of the software description document.>
		Identifier	L1A_RADIOMETER_SPS
		runTimeParameters	<Specification of any run time parameters if they were used.>
		SWVersionID	<A software version identifier that runs from 001 to 999>
		softwareDate	<A date stamp that specifies when software used to generate this product was released.>
		softwareTitle	L1A Radiometer SPS
		timeVariableEpoch	J2000
		epochJulianDate	2451545.00
		epochUTCDate	2000-01-01T11:58:55.816Z
		subBandDataPresent	Indicates whether subBand data are available in the data product. Value is either “True” or “False”.

		ATBDTitle	<Document that describes Level 1A Radiometer processing>
		ATBDDate	<Time stamp that specifies the release date of the Algorithm Theoretical Basis Document.>
		ATBDVersion	<Version identifier of the Algorithm Theoretical Basis Document.>
		parameterVersionID	<Version identifier of the current set of parameters that are used to generate Level 1A Radiometer data products.>
		algorithmTitle	Soil Moisture Active Passive (SMAP) Radiometer telemetry parsing and interpretation algorithm
		algorithmDescription	Parses Radiometer Telemetry into discretely defined elements. Converts temperature and voltage measures from data numbers to engineering units.
		algorithmDate	<Time stamp that identifies the date when the current version of the algorithm was implemented.>
		algorithmVersionID	<An algorithm version identifier that runs from 001 to 999>
LI_Lineage/LE_Source	L0B_Radiometer.	description	<Description of each input file>

	Ephemeris. Attitude, Antenna Azimuth. SCLK-UTC Correlation, LeapSeconds, Reconstructed High Resolution Earth Orientation, ScaleFactorsFile, VoltageCurrentCoeffFile , TempCoeffFile, SignedMaskFile[1]	filename	<Complete file name of the input data product>
		creationDate	<A date stamp that specifies when the input data product was generated.>
		version	<The version number associated with the input data product.>
		identifier	<The short name associated with the product, if applicable.>
		DOI	<A digital object identifier associated with the product, if available>
DS_Dataset/MD_DataIdentification	DataSetIdentification	creationDate	<Date when the L1A Radiometer data product file was created>
		CompositeReleaseID	<SMAP Composite Release ID associated with this data product – See section 4.4>
		fileName	<Name of the L1A Radiometer output data file.>
		originatorOrganizationName	Jet Propulsion Laboratory
		shortName	SPL1AP
		SMAPShortName	L1A_Radiometer
		ECSVersionID	<Identifier that specifies major version delivered to ECS. Value runs from 001 to 999.>

		UUID	<A universally unique identifier for each data granule.>
		abstract	Parsed full-band and sub-band radiometer instrument telemetry with spacecraft position, attitude and antenna azimuth information as well as voltage and temperature sensor measurements converted from telemetry data numbers into engineering units.
		purpose	This product enables users to interpret and read the contents of the SMAP Radiometer telemetry using clearly delineated and described data elements.
		credit	The software that generates the Level 1A Radiometer product was designed and implemented at the Goddard Space Flight Center in Greenbelt, Maryland. The data system that automates its production was designed and implemented at the Jet Propulsion Laboratory, California Institute of Technology in Pasadena, California.
		status	Ongoing
		characterSet	utf8
		language	Eng
		topicCategory	geoscientificInformation

		QADataSetIdentification/creationDate	<The date that the QA product that accompanies the L1A Radiometer data granule was generated.>
		QADataSetIdentification/filename	<The name of QA product associated with the Level 1A Radiometer Product.>
		QADataSetIdentifciation/abstract	An ASCII product that contains statistical information on data product results. These statistics enable data producers and users to assess the quality of the data in the data product granule.
DS_Series/MD_DataIdentification	SeriesIdentification	revisionDate	<Date of the software release that was used to generate this data product.>
		CompositeReleaseID	<SMAP Composite Release ID that identifies the release used to generate this data product – See section 4.4>
		longName	SMAP L1A Radiometer Time-Ordered Parsed Telemetry
		shortName	SPL1AP
		identifier_product_DOI	10.5067/3G0GFQR7OT5E
		ECSVersionID	<Identifier that specifies major version delivered to ECS. Value runs from 001 to 999.>

		resourceProviderOrganizationName	National Aeronautics and Space Administration
		otherCitationDetails	<Description of the current software release.>
		abstract	Parsed full-band and sub-band radiometer instrument telemetry with spacecraft position, attitude and antenna azimuth information as well as voltage and temperature sensor measurements converted from telemetry data numbers into engineering units.
		purpose	This product enables users to interpret and read the contents of the SMAP Radiometer telemetry using clearly delineated and described data elements.
		credit	The software that generates the Level 1A Radiometer product was designed and implemented at the Goddard Space Flight Center in Greenbelt, Maryland. The data system that automates its production was designed and implemented at the Jet Propulsion Laboratory, California Institute of Technology in Pasadena, California.
		status	ongoing
		spatialRepresentationInformation	Vector

		characterSet	utf8
		language	eng
		topicCategory	geoscientificInformation
		pointOfContact	National Snow and Ice Data Center, Boulder, Colorado
		ProductSpecificationDocument/publicationDate	<Date of publication of the Product Specification Document>
		ProductSpecificationDocument/edition	<Edition identifier for the Product Specification Document>
		ProductSpecificationDocument/title	Soil Moisture Active Passive Mission L1A Radiometer Product Specification Document
		ProductSpecificationDocument/characterSet	utf8
		ProductSpecificationDocument/language	eng
		ProductSpecificationDocument/SMAPShortName	L1A Radiometer
		Mission	Soil Moisture Active Passive (SMAP)
		maintenanceAndUpdateFrequency	asNeeded
		maintenanceDate	<Specifies a date when the next update to this product might be anticipated>
		format	HDF5

		formatVersion	1.8.9
MD_AcquisitionInformation	AcquisitionInformation	platform/antennaRotationRate	14.6 rpm (13.0 rpm)
		platformDocument/publicationDate	<The date of publication of the document that describes the SMAP platform, if available to the general public>
		platformDocument/edition	<The edition of publication of the document that describes the SMAP platform, if available to the general public.>
		platformDocument/title	<The title of the publication of the document that describes the SMAP platform, if available to the general public.>
		platform/description	The SMAP observatory houses an L-band radiometer that operates at 1.414 GHz and an L-band radar that operates at 1.225 GHz. The instruments share a rotating reflector antenna with a 6 meter aperture that scans over a 1000 km swath. The bus is a 3 axis stabilized spacecraft that provides momentum compensation for the rotating antenna.
		platform/identifier	SMAP
		radarDocument/publicationDate	<The date of publication of the document that describes the SMAP radar instrument, if available to the

			general public.>
		radarDocument/edition	<The edition of publication of the document that describes the SMAP radar instrument, if available to the general public.>
		radarDocument/title	<The title of the publication of the document that describes the SMAP radar instrument, if available to the general public.>
		radar/description	The SMAP radar instrument employs an L-band conically scanned system and SAR processing techniques to achieve moderate resolution (1 km) backscatter measurements over a very wide 1000 km swath.
		radar/identifier	SMAP SAR
		radar/type	L-band Synthetic Aperture Radar
		radiometerDocument/publicationDate	<The date of publication of the document that describes the SMAP radiometer instrument, if available to the general public.>
		radiometerDocument/edition	<The edition of publication of the document that describes the SMAP radiometer instrument, if available to the general public.>
		radiometerDocument/title	<The title of the publication of the document that describes the SMAP radiometer instrument, if available to the general public.>

		radiometer/description	The SMAP L-band Radiometer records V-pol, H-pol, 3rd and 4th Stokes brightness temperatures at 40 km resolution at 4.3 Megatbits per second with accuracies of 1.3 Kelvin or better.
		radiometer/identifier	SMAP RAD
		radiometer/type	L-band Radiometer
SD_OrbitMeasuredLocation	OrbitMeasuredLocation	argumentOfPerigee	<The angle in the satellite's orbit plane between the point of perigee and ascending node. The angle is measured in the direction of spacecraft motion.>
		cycleNumber	<The SMAP satellite flies in a cycle that repeats after 117 orbits. This element specifies the cycle of orbits when the data were taken. First cycle is assigned the number 1.>
		eccentricity	<The eccentricity of the satellite orbit.>
		epoch	2000-01-01T11:58:55.816Z
		equatorCrossingDateTime	<A time stamp that specifies the date and time of ascending node crossing for the current orbit.>

		equatorCrossingLongitude	<The longitude of the ascending node crossing for the current orbit.>
		inclination	<The angle between the spacecraft's orbital plane and the Earth's equatorial plane. An angle greater than 90 degrees indicates an orbit retrograde path.>
		meanMotion	<The constant angular speed that would be required for a body travelling in an undisturbed elliptical orbit with the specified semi-major axis to complete one revolution in the actual orbital period, expressed as a number of revolutions per day.>
		orbitDirection	<SMAP Level 1 and Level 2 products appear in half orbit granules. This element provides direction of orbital path relative to equatorial plane. Values are "Ascending" or "Descending":>
		halfOrbitStartDateTime	<A time stamp that specifies the date and time of the instant the spacecraft crosses either the southernmost point or the northernmost point in its path, marking the beginning of the half orbit.>
		halfOrbitStopDateTime	<A time stamp that specifies the date and time of the instant the spacecraft crosses either the southernmost point or the northernmost point in its path, marking the end of the half

			orbit.>
		orbitPathNumber	< The SMAP satellite flies in a cycle the repeats after 117 orbits. This element specifies which of the 117 possible paths the spacecraft flew when the data in the file were acquired. The orbitPathNumber varies from 1 to 117.>
		orbitPeriod	<Time required to complete a the spacecraft orbit.>
		reference_CRS	<A description of the coordinate reference system used to describe spacecraft orbital data.>
		revNumber	<The count of orbits from beginning of mission to the orbit that the spacecraft flew when the data in the file were acquired. Orbit zero begins at launch and extends until the spacecraft crosses the southernmost point in its path for the first time. Orbit one commences at that instant.>
		rightAscensionAscendingNode	<The angle eastward on the equatorial plan from the vernal equinox to the orbit ascending node.>
		semiMajorAxis	<The length of the semi-major axis of the spacecraft orbit.>

[1] The metadata will allocate a group for each input data set that requires provenance tracking. The most critical ones listed in this document are those that are likely to vary from one orbit granule to the next. The metadata will track and list additional files for user information.

4.6 Data Structure

4.6.1 Spacecraft Data Group

The Spacecraft Data contain elements that specify either geometric or geographic information that are representative of an entire antenna scan in the instrument swath in the L1A Radiometer product. All of the product elements in the Spacecraft Data Group are stored in a single HDF5 Group named "/Spacecraft_Data". A distinct HDF5 Dataset stores each data element. The name of each Dataset object matches the data element that it stores. Table 9 lists all of the elements in the Spacecraft Data Group.

All the HDF5 Datasets in the Spacecraft Data Group have AntennaScan_Array shape. The AntennaScan_Array shape describes a one-dimensional array, where each array element represents a specific antenna scan in the instrument swath. Thus, array element *x_pos(6212)* lists the representative spacecraft position in the x dimension, array element *yaw(6212)* lists the representative spacecraft yaw, and array element *sc_geodetic_alt_ellipsoid(6212)* lists the representative spacecraft altitude for the antenna scan that was acquired within a few seconds of the time specified in array element *antenna_scan_time_utc(6212).* The precise range of time covered by each antenna scan depends on the antenna rotation rate. The antenna rotation rate may vary from 13 revolutions per minute to 14.6 revolutions per minute.

Table 9: The Spacecraft Data Group

Element Name	Type	Shape	Valid_Min	Valid_Max	Units
antenna_scan_time	Float64	AntennaScan_Array	0	946000000	seconds
antenna_scan_time_utc	FixedLenString	AntennaScan_Array	n/a	n/a	n/a
antenna_scan_counter	Uint16	AntennaScan_Array	1	800	counts
antenna_scan_mode_flag	Uint16	AntennaScan_Array	n/a	n/a	n/a
antenna_scan_qual_flag	Uint16	AntennaScan_Array	n/a	n/a	n/a
sc_nadir_lat	Float32	AntennaScan_Array	-90	90	degrees

Element Name	Type	Shape	Valid_Min	Valid_Max	Units
sc_nadir_lon	Float32	AntennaScan_Array	-180.0	179.999	degrees
sc_nadir_angle	Float32	AntennaScan_Array	0	180	degrees
sc_geodetic_alt_ellipsoid	Float32	AntennaScan_Array	650000	750000	meters
sc_alongtrack_velocity	Float32	AntennaScan_Array	-8000	8000	meters/second
sc_radial_velocity	Float32	AntennaScan_Array	-8000	8000	meters/second
x_pos	Float32	AntennaScan_Array	-999999	9999999	meters
y_pos	Float32	AntennaScan_Array	-999999	9999999	meters
z_pos	Float32	AntennaScan_Array	-999999	9999999	meters
x_vel	Float32	AntennaScan_Array	-8000	8000	meters/second
y_vel	Float32	AntennaScan_Array	-8000	8000	meters/second
z_vel	Float32	AntennaScan_Array	-8000	8000	meters/second
roll	Float32	AntennaScan_Array	-90	90	degrees
pitch	Float32	AntennaScan_Array	-90	90	degrees
yaw	Float32	AntennaScan_Array	-180	180	degrees
antenna_rotation_rate	Float32	AntennaScan_Array	13	14.6	rpm
antenna_look_angle	Float32	AntennaScan_Array	0	180	degrees

4.6.2 High Resolution Moments Data Group

The High Resolution Moments Data provides the first four sample raw moments of the 16 sub-band signals parsed into 5 radiometric states. Section 4.2 describes the 5 radiometric states. The moments are provided for both vertical and horizontal polarizations and separately expressed in terms of the in-phase (real) and quadrature (imaginary) components of the signals. The 3rd and 4th Stokes parameters of the two polarizations are also included for each of the 16 sub-bands. All of the product elements in the High Resolution Moments Data are stored in a single HDF5 Group named "/HighResolution_Moments_Data". A distinct HDF5 Dataset stores each data element. The name of each Dataset object matches the data element that it stores. Table 10 lists the elements in the High Resolution Moments Data Group.

Radiometer data include science data packets that will be generated once every 4 PRIs. These packets are stored in the High Resolution Moments Data Group.

The data elements in the High Resolution Moments Data Group have varying shapes depending on the radiometric state. The switching scheme that indicates the radiometric state of a particular science data packet is pre-determined and used to parse the raw science data. For example the HighResolutionScan_AntPacket_Subband_Polarization_Array shape describes a 4-dimensional array. The slowest moving dimension represents a particular antenna scan. The second dimension represents the maximum number of packets when the instrument is operating in the antenna radiometric state. The third dimension represents the 16 subbands. The fastest moving dimension represents one of four polarizations; the order of storage is real h, imaginary h, real v, imaginary v. Elements with different second dimensions are associated with different radiometric states, and thus different maximum array sizes. Appendix B and Appendix C provide more detail about the shapes and dimension sizes used in the Level 1A Radiometer product.

Table 10: High Resolution Moments Data Group

Element Name	Type	Shape	Valid_Min	Valid_Max	Units
m1_16_ant	Float32	HighResolutionScan_AntPacket_Subband_Polarization_Array	-6.85×10^8	6.85×10^8	counts
m1_16_ant_xnd	Float32	HighResolutionScan_AntXndPacket_Subband_Polarization_Array	-6.85×10^8	6.85×10^8	counts
m1_16_ant_nd	Float32	HighResolutionScan_AntNdPacket_Subband_Polarization_Array	-6.85×10^8	6.85×10^8	counts

Element Name	Type	Shape	Valid_Min	Valid_Max	Units
m1_16_ref	Float32	HighResolutionScan_RefPacket_Subband_Polarization_Array	-6.85×10^{8}	6.85×10^{8}	counts
m1_16_ref_nd	Float32	HighResolutionScan_RefNdPacket_Subband_Polarization_Array	-6.85×10^{8}	6.85×10^{8}	counts
m2_16_ant	Float32	HighResolutionScan_AntPacket_Subband_Polarization_Array	0	5.88×10^{18}	counts
m2_16_ant_xnd	Float32	HighResolutionScan_AntXndPacket_Subband_Polarization_Array	0	5.88×10^{18}	counts
m2_16_ant_nd	Float32	HighResolutionScan_AntNdPacket_Subband_Polarization_Array	0	5.88×10^{18}	counts
m2_16_ref	Float32	HighResolutionScan_RefPacket_Subband_Polarization_Array	0	5.88×10^{18}	counts
m2_16_ref_nd	Float32	HighResolutionScan_RefNdPacket_Subband_Polarization_Array	0	5.88×10^{18}	counts
m3_16_ant	Float32	HighResolutionScan_AntPacket_Subband_Polarization_Array	-2.94×10^{18}	2.94×10^{18}	counts
m3_16_ant_xnd	Float32	HighResolutionScan_AntXndPacket_Subband_Polarization_Array	-2.94×10^{18}	2.94×10^{18}	counts
m3_16_ant_nd	Float32	HighResolutionScan_AntNdPacket_Subband_Polarization_Array	-2.94×10^{18}	2.94×10^{18}	counts
m3_16_ref	Float32	HighResolutionScan_RefPacket_Subband_Polarization_Array	-2.94×10^{18}	2.94×10^{18}	counts
m3_16_ref_nd	Float32	HighResolutionScan_RefNdPacket_Subband_Polarization_Array	-2.94×10^{18}	2.94×10^{18}	counts
m4_16_ant	Float32	HighResolutionScan_AntPacket_Subband_Polarization_Array	0	1.09×10^{38}	counts
m4_16_ant_xnd	Float32	HighResolutionScan_AntXndPacket_Subband_Polarization_Array	0	1.09×10^{38}	counts
m4_16_ant_nd	Float32	HighResolutionScan_AntNdPacket_Subband_Polarization_Array	0	1.09×10^{38}	counts
m4_16_ref	Float32	HighResolutionScan_RefPacket_Subband_Polarization_Array	0	1.09×10^{38}	counts

Element Name	Type	Shape	Valid_Min	Valid_Max	Units
m4_16_ref_nd	Float32	HighResolutionScan_RefNdPacket_Subband_Polarization_Array	0	1.09×10^{38}	counts
t3_16_ref_nd	Float32	HighResolutionScan_RefNdPacket_Subband_Array	-2.94×10^{18}	2.94×10^{18}	counts
t3_16_ant	Float32	HighResolutionScan_AntPacket_Subband_Array	-2.94×10^{18}	2.94×10^{18}	counts
t3_16_ant_xnd	Float32	HighResolutionScan_AntXndPacket_Subband_Array	-2.94×10^{18}	2.94×10^{18}	counts
t3_16_ant_nd	Float32	HighResolutionScan_AntNdPacket_Subband_Array	-2.94×10^{18}	2.94×10^{18}	counts
t3_16_ref	Float32	HighResolutionScan_RefPacket_Subband_Array	-2.94×10^{18}	2.94×10^{18}	counts
t4_16_ref_nd	Float32	HighResolutionScan_RefNdPacket_Subband_Array	-2.94×10^{18}	2.94×10^{18}	counts
t4_16_ant	Float32	HighResolutionScan_AntPacket_Subband_Array	-2.94×10^{18}	2.94×10^{18}	counts
t4_16_ant_xnd	Float32	HighResolutionScan_AntXndPacket_Subband_Array	-2.94×10^{18}	2.94×10^{18}	counts
t4_16_ant_nd	Float32	HighResolutionScan_AntNdPacket_Subband_Array	-2.94×10^{18}	2.94×10^{18}	counts
t4_16_ref	Float32	HighResolutionScan_RefPacket_Subband_Array	-2.94×10^{18}	2.94×10^{18}	counts
moments16_lat	Float32	HighResolutionScan_AntPacket_Array	-90	90	degrees
moments16_lon	Float32	HighResolutionScan_AntPacket_Array	-180	179.999	degrees
moments16_declination	Float32	HighResolutionScan_AntPacket_Array	-90	90	degrees
moments16_right_ascension	Float32	HighResolutionScan_AntPacket_Array	0	359.999	degrees
ant_16_time_seconds	Float64	HighResolutionScan_AntPacket_Array	0	946000000	seconds

Element Name	Type	Shape	Valid_Min	Valid_Max	Units
ant_xnd_16_time_seconds	Float64	HighResolutionScan_AntXndPacket_Array	0	946000000	seconds
ant_nd_16_time_seconds	Float64	HighResolutionScan_AntNdPacket_Array	0	946000000	seconds
ref_16_time_seconds	Float64	HighResolutionScan_RefPacket_Array	0	946000000	seconds
ref_nd_16_time_seconds	Float64	HighResolutionScan_RefPacket_Array	0	946000000	seconds
highresolution_scan_index	Uint32	HighResolutionScan_Array	0	800	counts

4.6.3 Moments Data Group

The Moments Data provides the first four sample raw moments of the fullband signal parsed into 5 radiometric states. Section 4.2 describes the 5 radiometric states. The moments are provided for both vertical and horizontal polarizations and separately expressed in terms of the in-phase (real) and quadrature (imaginary) components of the signals. The 3rd and 4th Stokes parameters of the two polarizations are also included in the fullband data. All of the product elements in the Fullband Moments Data are stored in a single HDF5 Group named "/Moments_Data". A distinct HDF5 Dataset stores each data element. The name of each Dataset object matches the data element that it stores. Table 11 lists the elements in the Moments Data Group.

The data elements in the Moments Data Group have varying shapes depending on the radiometric state. Radiometer data stored in the Moments Data Group are at the PRI resolution. For example the AntennaScan_AntPRI_Polarization_Array shape describes a 3-dimensional array. The slowest moving dimension represents a particular antenna scan. The second dimension represents the maximum number of packets when the instrument is operating in the specified radiometric state. The fastest moving dimension represents one of four polarizations, stored real h, imaginary h, real v, imaginary v. Elements with different second dimensions are associated with different radiometric states, and thus different maximum array sizes. Appendix B and Appendix C provide more detail about the shapes and dimension sizes used in the Level 1A Radiometer product.

Table 11: Moments Data Group

Element Name	Type	Shape	Valid_Min	Valid_Max	Units
telemetry_qual_flag	Uint16	AntennaScan_Array	n/a	n/a	n/a
telemetry_mode_flag	Uint16	AntennaScan_Array	n/a	n/a	n/a
number_of_science_packets	Uint16	AntennaScan_Array	0	3624	n/a
science_packet_CRC_check	Char	AntennaScan_SciencePacketCRC_Array	n/a	n/a	n/a
number_science_CRC_errors	Uint16	AntennaScan_Array	0	3624	n/a

moments_lat	Float32	AntennaScan_AntPRI_Array	-90	90	degrees
moments_lon	Float32	AntennaScan_AntPRI_Array	-180	179.999	degrees
moments_declination	Float32	AntennaScan_AntPRI_Array	-90	90	degrees
moments_right_ascension	Float32	AntennaScan_AntPRI_Array	0	359.999	degrees
ant_time_seconds	Float64	AntennaScan_AntPRI_Array	n/a	n/a	seconds
ant_xnd_time_seconds	Float64	AntennaScan_AntXndPRI_Array	n/a	n/a	seconds
ant_nd_time_seconds	Float64	AntennaScan_AntNdPRI_Array	n/a	n/a	seconds
ref_time_seconds	Float64	AntennaScan_RefPRI_Array	n/a	n/a	seconds
ref_nd_time_seconds	Float64	AntennaScan_RefNdPRI_Array	n/a	n/a	seconds
m1_ant	Float32	AntennaScan_AntPRI_Polarization_Array	-1.71×10^{8}	1.71×10^{8}	counts
m1_ant_xnd	Float32	AntennaScan_AntXndPRI_Polarization_Array	-1.71×10^{8}	1.71×10^{8}	counts
m1_ant_nd	Float32	AntennaScan_AntNdPRI_Polarization_Array	-1.71×10^{8}	1.71×10^{8}	counts
m1_ref	Float32	AntennaScan_RefPRI_Polarization_Array	-1.71×10^{8}	1.71×10^{8}	counts
m1_ref_nd	Float32	AntennaScan_RefNdPRI_Polarization_Array	-1.71×10^{8}	1.71×10^{8}	counts
m2_ant	Float32	AntennaScan_AntPRI_Polarization_Array	0	1.47×10^{18}	counts
m2_ant_xnd	Float32	AntennaScan_AntXndPRI_Polarization_Array	0	1.47×10^{18}	counts

m2_ant_nd	Float32	AntennaScan_AntNdPRI_Polarization_Array	0	1.47×10^{18}	counts
m2_ref	Float32	AntennaScan_RefPRI_Polarization_Array	0	1.47×10^{18}	counts
m2_ref_nd	Float32	AntennaScan_RefNdPRI_Polarization_Array	0	1.47×10^{18}	counts
m3_ant	Float32	AntennaScan_AntPRI_Polarization_Array	-7.36×10^{17}	7.35×10^{17}	counts
m3_ant_xnd	Float32	AntennaScan_AntXndPRI_Polarization_Array	-7.36×10^{17}	7.35×10^{17}	counts
m3_ant_nd	Float32	AntennaScan_AntNdPRI_Polarization_Array	-7.36×10^{17}	7.35×10^{17}	counts
m3_ref	Float32	AntennaScan_RefPRI_Polarization_Array	-7.36×10^{17}	7.35×10^{17}	counts
m3_ref_nd	Float32	AntennaScan_RefNdPRI_Polarization_Array	-7.36×10^{17}	7.35×10^{17}	counts
m4_ant	Float32	AntennaScan_AntPRI_Polarization_Array	0	2.71×10^{37}	counts
m4_ant_xnd	Float32	AntennaScan_AntXndPRI_Polarization_Array	0	2.71×10^{37}	counts
m4_ant_nd	Float32	AntennaScan_AntNdPRI_Polarization_Array	0	2.71×10^{37}	counts
m4_ref	Float32	AntennaScan_RefPRI_Polarization_Array	0	2.71×10^{37}	counts
m4_ref_nd	Float32	AntennaScan_RefNdPRI_Polarization_Array	0	2.71×10^{37}	counts
t3_ref_nd	Float32	AntennaScan_RefNdPacket_Subband_Array	-7.36×10^{17}	7.35×10^{17}	counts
t3_ant	Float32	AntennaScan_AntPRI_Array	-7.36×10^{17}	7.35×10^{17}	counts
t3_ant_xnd	Float32	AntennaScan_AntXndPRI_Array	-7.36×10^{17}	7.35×10^{17}	counts
t3_ant_nd	Float32	AntennaScan_AntNdPRI_Array	-7.36×10^{17}	7.35×10^{17}	counts

t3_ref	Float32	AntennaScan_RefPRI_Array	-7.36×10^{17}	7.35×10^{17}	counts
t4_ref_nd	Float32	AntennaScan_RefNdPRI_Array	-7.36×10^{17}	7.35×10^{17}	counts
t4_ant	Float32	AntennaScan_AntPRI_Array	-7.36×10^{17}	7.35×10^{17}	counts
t4_ant_xnd	Float32	AntennaScan_AntXndPRI_Array	-7.36×10^{17}	7.35×10^{17}	counts
t4_ant_nd	Float32	AntennaScan_AntNdPRI_Array	-7.36×10^{17}	7.35×10^{17}	counts
t4_ref	Float32	AntennaScan_RefPRI_Array	-7.36×10^{17}	7.35×10^{17}	counts

4.6.4 House Keeping Data Group

The House Keeping group contains house keeping telemetry or engineering data in digital numbers as well as in engineering units for each scan. All of the product elements in the House Keeping Group are stored in a single HDF5 Group named "/House_Keeping_Data". A distinct HDF5 Dataset stores each data element. The name of each Dataset object matches the data element that it stores. Table 12 lists the elements in the House Keeping Group.

The data elements in the House Keeping Group have varying shapes depending on the type of engineering data being stored. For example the AntennaScan_HouseKeepingAnalog_Array shape describes a 2-dimensional array. The slower moving array index represents each Antenna Scan. The faster moving index represents either a specific temperature monitor point, a voltage or a current measure. See Table 13 for a detailed list of house keeping data.

Table 12: House Keeping Group

Element Name	Type	Shape	Valid_Min	Valid_Max	Units
status_dn	Uint16	AntennaScan_HouseKeepingStatus_Array	0	65535	counts
digital_dn	Uint16	AntennaScan_HouseKeepingStatusDigital_Array	0	65535	counts
analog_dn	Uint16	AntennaScan_HouseKeepingAnalog_Array	0	65535	counts
analog_eu	Float32	AntennaScan_HouseKeepingAnalog_Array	n/a	n/a	

Table 13 lists the elements that appear in the Radiometer housekeeping telemetry. Data in the HousekeepingStatus dimension appear in words 1 to 22 of the housekeeping telemetry. Data in the HouseKeepingStatusDigital dimension appear in words 23 to 73. HouseKeepingAnalog data appear in words 74 to 233.

Table 13: Detailed list of House Keeping Data

RAD TLM Message Data List		
Word No.	**TLM Name**	**TLM Description**
TLM Header List		
1	Message 1 Sequence No & Master Error Flags	8-bit of Message 1 Sequence No. & 8-bit indicating major error flags (TBD)
2	Packet DPU MET2	Bits 16-31 of the DPU MET at the time TLM packet generated
3	1553 Receive & Transmit Message Counters	8-bit counter to indicate number of received messages & 8-bit to indicate number of transmit messages
4	Application layer Receive & Executed CMD Counters	8-bit counter to indicate number of received CMDs & 8-bit to indicate number of Executed CMDs
5	Error Flags	Error Flags
6	RAD Mode	Current RAD operating mode
7	1553 Error counter & Programming Mode Error Flags	8-bit counter indicate 1553 errors & 8-bit flag for Errors occurred during the Programming Mode
8	CMD Mode error counter & CMD Struc error counter	8-bit counter indicate mode error & 8-bit counter indicate cmd structure error
9	RPM Counter	16-Bit RPM Counter defining the current value of the RPM count at the time being read
RAD TLM List		
10	Message ID/sequence No	8-bit of Message ID and a 8-bit Message Sequence No.
11	Packet DPU MET2	Bits 16-31 of the DPU MET at the time TLM packet generated
12	Packet DPU MET1	Bits 0-15 of the DPU MET at the time TLM packet generated
13	STM DPU MET2	MSW of the DPU MET at the time STM was valid
14	STM DPU MET1	LSW of the DPU MET at the time STM was valid
15	STM Word-1 (most recent)	Message ID, Word-1
16	STM Word-2	Current S/C Time, MSW
17	STM Word-3	Current S/C Time, LSW
18	STM Word-4	Current RTI and sub-RTI rates

19	Memory Image AD2	MSW of the Memory/Register address inserted
20	Memory Image AD1	LSW of the Memory/Register address inserted
21	Memory Image D2	MSW of the Memory/Register content inserted
22	Memory Image D1	LSW of the Memory/Register content inserted
RAD Digital TLM List		
23	RAD Digital TLM W1	RAD Mode
24	RAD Digital TLM W2	WDT
25	RAD Digital TLM W3	WDT Status
26	RAD Digital TLM W4	CC Internal/External Timing
27	RAD Digital TLM W5	PRI Sync Status
28	RAD Digital TLM W6	Land/Ocean and Over write flag
29	RAD Digital TLM W7	PRF Index Value
30	RAD Digital TLM W8	Number of PRIs
31	RAD Digital TLM W9	MET at double pulse
32	RAD Digital TLM W10	Programming Error
33	RAD Digital TLM W11	SC Interfaces
34	RAD Digital TLM W12	ADC Oversample register
35	RAD Digital TLM W13	Internal RPM Counter
36	RAD Digital TLM W14	Over Writes
37	RAD Digital TLM W15	Full Band H Transfer Count LSW Register
38	RAD Digital TLM W16	Sub Band H Transfer Count LSW Register
39	RAD Digital TLM W17	Full Band V Transfer Count LSW Register
40	RAD Digital TLM W18	Sub Band V Transfer Count LSW Register
41	RAD Digital TLM W19	Spare
42	RAD Digital TLM W20	Spare
43	RAD Digital TLM W21	CCError Flag Counter 1
44	RAD Digital TLM W22	CC Error Flga Counter 2
45	RAD Digital TLM W23	CC Error Flga Counter 3
46	RAD Digital TLM W24	CC Error Flga Counter 4
47	RAD Digital TLM W25	Spare
48	RAD Digital TLM W26	App Layer Rec No
49	RAD Digital TLM W27	App Layer Tx No
50	RAD Digital TLM W28	App Layer Rec CMDs

51	RAD Digital TLM W29	App Layer Ex CMDs
52	RAD Digital TLM W30	FPGA 1 (CC) Ver
53	RAD Digital TLM W31	FPGA 2 (DP) Ver
54	RAD Digital TLM W32	APU-H_PDDC_H&S_Reg
55	RAD Digital TLM W33	APU-H_PTV_H&S_Reg
56	RAD Digital TLM W34	APU-H_SCU_H&S_Reg
57	RAD Digital TLM W35	APU-H_PDDC_Sync_CNTR
58	RAD Digital TLM W36	APU-H_PTV_Sync_CNTR
59	RAD Digital TLM W37	APU-H_SCU_Sync_CNTR
60	RAD Digital TLM W38	APU-H_PDDC_FPGA_Reg
61	RAD Digital TLM W39	APU-H_PTV_FPGA_Reg
62	RAD Digital TLM W40	APU-H_ADC_Overflow
63	RAD Digital TLM W41	APU-H_PDDC_DRDY
64	RAD Digital TLM W42	APU-V_PDDC_H&S_Reg
65	RAD Digital TLM W43	APU-V_PTV_H&S_Reg
66	RAD Digital TLM W44	APU-V_SCU_H&S_Reg
67	RAD Digital TLM W45	APU-V_PDDC_Sync_CNTR
68	RAD Digital TLM W46	APU-V_PTV_Sync_CNTR
69	RAD Digital TLM W47	APU-V_SCU_Sync_CNTR
70	RAD Digital TLM W48	APU-V_PDDC_FPGA_Reg
71	RAD Digital TLM W49	APU-V_PTV_FPGA_Reg
72	RAD Digital TLM W50	APU-V_ADC_Overflow
73	RAD Digital TLM W51	APU-V_PDDC_DRDY
RAD Analog TLM List		
Temperature Monitor Points		
Internal To RFE Box		
74	**CNS_TEMP**	**Measures the Temp of the CNS for Calibration**
75	**H_REF_PRT**	**Temp of the Dickie Sw High Resolution**
76	**V_REF_PRT**	**Temp of the Vertical Reference Sw High Resolution**
77	RBE1-2	RBE1
78	RDE1-2	RDE1
79	**INS_PRT**	**Temp of the Internal Noise Diode High Resolution**
80	**Diplexer1-2**	**Diplexer 1 - Mid Range**

81	H_LNA1_T	Temp of LNA
82	H_LNA2_T	Temp of LNA
83	H_LNA3_T	Temp of LNA
84	V_LNA1_T	Temp of LNA
85	V_LNA2_T	Temp of LNA
86	V_LNA3_T	Temp of LNA
87	**Diplexer2-2**	**Diplexer 2 - Mid Range**
88	12V+_Reg_T	Temp Sensors Located to indicate Temps of Lin Reg +12V Analog
89	12V-_Reg_T	Temp Sensors Located to indicate Temps of Lin Reg -12V Analog
90	RBE1-3	RBE1
91	H_5V_LNA_T	Temp Sensors Located to indicate Temps of Lin Reg LNAH
92	V_5V_LNA_T	Temp Sensors Located to indicate Temps of Lin Reg LNAV
93	5V_Digital_T	Temp Sensors Located to indicate Temps of Lin Reg Digital Circuitry
94	RFE_CTRL_BRD_T	Board temperature
95	**H_Coax_T**	**Temp Sensors to Monitor H Coaxial Chamber Plate**
96	**V_Coax_T**	**Temp Sensors to Monitor V Coaxial Chamber Plate**
97	Temp Cal 500	Temp Cal(2 wire 500)
98	**Temp Cal 2000**	**PRT Cal (4 wire 2K)**
RFE Area -- External to RAD		
99	**RFE1**	**RFE1 - High Range**
100	#	**RFE1 - Mid Range**
101	#	**RFE1 - Low Range**
102	**RFE2**	**RFE2 - High Range**
103	#	**RFE2 - Mid Range**
104	#	**RFE2 - Low Range**
105	**RFE3**	**RFE3 - High Range**
106	#	**RFE3 - Mid Range**
107	#	**RFE3 - Low Range**
108	**H_RFE_PRT -2**	**Temp of the Dickie Sw High Resolution**
109	**V_RFE_PRT -2**	**Temp of the Vertical Reference Sw High Resolution**
110	**INS_PRT -2**	**Temp of the Internal Noise Diode High Resolution**
111	RBE1	RBE1
112	RBE2	RBE2
113	RDE1	RDE1

114	RDE2	RDE2
115	RDE3	RDE3
116	Horn 1	Horn 1
117	Isolator	Isolator
118	H Probe	H Probe
119	V Probe	V Probe
120	**Diplexer 1**	**Diplexer 1 - High Range**
121	#	**Diplexer 1 - Mid Range**
122	#	**Diplexer 1 - Low Range**
123	**Diplexer 2**	**Diplexer 2 - High Range**
124	#	**Diplexer 2 - Mid Range**
125	#	**Diplexer 2 - Low Range**
126	RDE1-3	RDE1
127	**H-Coupler 1**	**H Coupler 1 - Mid Range**
128	**H_RFE_PRT -3**	**Temp of the Dickie Sw High Resolution**
129	**V_RFE_PRT -3**	**Temp of the Vertical Reference Sw High Resolution**
130	**V-Coupler 2**	**V Coupler 2 - Mid Range**
131	**INS_PRT -3**	**Temp of the Internal Noise Diode High Resolution**
132	Picnic Table 2	Picnic Table 2
Internal To RBE Box		
133	H-POL	Temp of Mixer H-Pol
134	V-POL	Temp of Mixer V-Pol
Internal To RDE Box		
135	APU-H Board Sensor 1	TBD (near the hotest location)
136	APU-H Board Sensor 2	TBD (near the 2nd hotest location)
137	APU-H Board Sensor 3	TBD (near the 3rd hotest location)
138	APU-V Board Sensor 1	TBD (near the hotest location)
139	APU-V Board Sensor 2	TBD (near the 2nd hotest location)
140	APU-V Board Sensor 3	TBD (near the 3rd hotest location)
141	DPU Board Sensor	TBD (near the hotest location)
142	DPU Cal Sensor 500	DPU 500 Ohm, 2 wire Calibration Reistor
143	DPU Cal Sensor 2000	DPU 2000 Ohm, 4 wire Calibration Reistor
144	PDU Board Sensor 1	TBD (near the hotest location)
145	PDU Board Sensor 2	TBD (near the 2nd hotest location)

146	Spare	Spare 1
Analog Monitor Points (Voltages & Currents)		
Internal To RFE Box		
147	Voltage+12	+12V Reg Output
148	Voltage-12	-12V Reg Output
149	Voltage+5_D	+5V Digital Reg Output
150	Voltage+5_H	+5V HLNA Reg Output
151	Voltage+5_V	+5V VLNA Reg Output
152	I_H_LNA1_Lo_Res	H LNA 1 Current Low Res
153	I_H_LNA1_Hi_Res	H LNA 1 Current High Res
154	I_H_LNA2_Lo_Res	H LNA 2 Current Low Res
155	I_H_LNA2_Hi_Res	H LNA 2 Current High Res
156	I_H_LNA3_Lo_Res	H LNA 3 Current Low Res
157	I_H_LNA3_Hi_Res	H LNA 3 Current High Res
158	I_V_LNA1_Lo_Res	V LNA 1 Current Low Res
159	I_V_LNA1_Hi_Res	V LNA 1 Current High Res
160	I_V_LNA2_Lo_Res	V LNA 2 Current Low Res
161	I_V_LNA2_Hi_Res	V LNA 2 Current High Res
162	I INS	Internal Noise Source Current
163	I_V_LNA3_Hi_Res	V LNA 3 Current High Res
164	I_V_LNA3_Lo_Res	V LNA 3 Current Low Res
165	I CNS	Correlated Noise Source Current
166	I Zero	Offset CAL for LNA current measurements.
167	I Gain Hi	Gain CAL for LNA current measurements.
168	I Gain Lo	Gain CAL for LNA current measurements.
169	RFE GND	RFE Common Ground
Internal To RBE Box		
170	V +9.125	After the regulator +9.1V
171	V +5-A	After the regulator +5V-A
172	V +10V	After the regulator +10V
173	V +3.3	After the regulator +3.3V
174	V +3	After the regulator +3V
175	PLO Lock	PLO Lock or not (a digital level)
176	RBE GND	RBE Gorund

Internal To RDE Box		
177	PDU, RDE +2.5 V	PDU, DC/DC 1, +2.5 Voltage, RDE internally used
178	PDU, RDE +2.5 I	PDU, DC/DC 1, +2.5 Current, RDE internally used
179	PDU, RDE +5 V	PDU, DC/DC 2, +5 Voltage, RDE internally used
180	PDU, RDE +5 I	PDU, DC/DC 2, +5 Current, RDE internally used
181	PDU, RDE +15 V	PDU, DC/DC 7, +15 Voltage, RDE internally used
182	PDU, RDE +15 I	PDU, DC/DC 7, +15 Current, RDE internally used
183	PDU, RDE -15 V	PDU, DC/DC 7, -15 Voltage, RDE internally used
184	PDU, RDE -15 I	PDU, DC/DC 7, -15 Current, RDE internally used
185	I INS	Internal Noise Source Current
186	PDU, +5V Mux Ref	PDU, +5V Mux Ref Voltage, Internal
187	PDU, RFE +7 V	PDU, DC/DC 3, +7 Voltage, RFE used
188	PDU, RFE +7 I	PDU, DC/DC 3, +7 Current, RFE used
189	PDU, RFE +15 V	PDU, DC/DC 4, +15 Voltage, RFE used
190	PDU, RFE +15 I	PDU, DC/DC 4, +15 Current, RFE used
191	PDU, RFE -15 V	PDU, DC/DC 4 -15 Voltage, RFE used
192	PDU, RFE -15 I	PDU, DC/DC 4, -15 Current, RFE used
193	PDU, RBE +13.5 V	PDU, DC/DC 6, +13.5 Voltage, RBE used
194	PDU, RBE +13.5 I	PDU, DC/DC 6, +13.5 Current, RBE used
195	PDU, GND2	PDU, DC/DC1 GND2
196	PDU, GND3	PDU, DC/DC2 GND3
197	PDU, GND7	PDU, DC/DC7 GND7
198	PDU, GND4	PDU, DC/DC2 GND4
199	PDU, GND5	PDU, DC/DC3 GND5
200	PDU, GND6	PDU, DC/DC4 GND6
201	PDU, GND8	PDU, DC/DC6 GND8
202	DPU, +10V	DPU, Regulated +10V TLM Voltage
203	DPU, -10V	DPU, Regulated -10V TLM Voltage
204	PDU, RDE +5A V	PDU, DC/DC 7, +5A Voltage, RDE internally used
205	Voltage INS	Internal Noise Source Voltage
206	APU-H, +1.5 V, Logic	APU-H, +1.5 Voltage, FPGA core voltage
207	APU-H, +1.8 V, PRI	APU-H, +1.8 Voltage, ADC Logic Interface Voltage
208	APU-H, +3.3 V, ADC	APU-H, +3.3 Voltage, ADC

209	APU-H, +3.3 V, Logic	APU-H, +3.3 Voltage, Logic
210	Voltage INS	Internal Noise Source Voltage
211	APU-H, 3.3V Logic I	APU-H, Logic 3.3V Current
212	APU-H, 3.3V ADC I	APU-H, ADC 3.3V Current
213	APU-H, 1.5V I	APU-H, FPGA Core Voltage Current
214	APU-H, APU Ground	APU-H, APU Ground
215	APU-H, +2.5 V, Logic	APU-H, +2.5V Voltage, LDO Input
216	APU-V, +1.5 V, Logic	APU-V, +1.5 Voltage, FPGA core voltage
217	APU-V, +1.8 V, PRI	APU-V, +1.8 Voltage, ADC Logic Interface Voltage
218	APU-V, +3.3 V, ADC	APU-V, +3.3 Voltage, ADC
219	APU-V, +3.3 V, Logic	APU-V, +3.3 Voltage, Logic
220	APU-V, +2.5 V, Logic	APU-V, +2.5V Voltage, LDO Input
221	APU-V, 3.3V Logic I	APU-V, Logic 3.3V Current
222	APU-V, 3.3V ADC I	APU-V, ADC 3.3V Current
223	APU-V, 1.5V I	APU-V, FPGA Core Voltage Current
224	APU-V, APU Ground	APU-V, APU Ground
225	DPU, Zero Offset, G40	DPU, TLM zero Offset Cal for gain of 40
226	DPU, +1.5 V, Digital	DPU, +1.5 Voltage, Digital, DPU internally used
227	DPU, 3.3 V, Digital	DPU, +3.3 Voltage, Digital, DPU internally used
228	DPU, 3.3 V, 1553	DPU, +3.3 Voltage, 1553 TXV, DPU internally used
229	DPU, +10 V, Analog	DPU, +10 Voltage, measured at PDU
230	DPU, -10 V, Analog	DPU, -10 Voltage, measured at PDU
231	DPU, Cal V	DPU, +2.5V Reference Voltage used for Cal
232	DPU, Zero Offset, G2	DPU, TLM zero Offset Cal for gain of 2
233	Voltage INS	Internal Noise Source Voltage

Table 14: Detailed list of House Keeping Data

4.7 Element Definitions

4.7.1 antenna_rotation_rate

The number of rotations the SMAP antenna assembly completes within a single minute.

antenna_rotation_rate is a one-dimensional array. Each array index is representative of a specific antenna scan.

Type: Float32

Group: Spacecraft Data

Shape: AntennaScan_Array

Valid_min: 13

Valid_max: 14.6

Units: rpm (rotations per minute)

4.7.2 antenna_scan_counter

The numerical index of the detected antenna scan rotations in the current granule. This index is zero-based.

antenna_scan_counter is a one-dimensional array. Each array index is representative of a specific antenna scan.

Type: Uint32

Group: Spacecraft Data

Shape: AntennaScan_Array

Valid_min: 1

Valid_max: 800

Units: counts

4.7.3 antenna_scan_mode_flag

Bit flags that indicate operational conditions for each antenna scan. Table 14 specifies the meaning of individual bits in the *antenna_scan_mode_flag*:

Table 15: The antenna_scan_mode_flag

Bits	Value	Interpretation
0		**Instrument viewing mode**

Bits	Value	Interpretation
	0	Spacecraft antenna is positioned so that the SMAP instrument views locations on the Earth's surface.
	1	Spacecraft antenna is positioned so that the SMAP instrument does not view the Earth. SMAP spacecraft is either in maneuver, running a cold sky calibration for the radiometer or in transition state.
1		**Ephemeris Usage Flag**
	0	Processing employed reconstructed ephemeris
	1	Processing employed predicted ephemeris
2		**Data Resolution Flag**
	0	High resolution data contribute to this pixel
	1	Low resolution data contribute to this pixel
3		**Eclipse Flag**
	0	The SMAP spacecraft is not in eclipse. The Sun is visible from the SMAP spacecraft.
	1	The SMAP spacecraft is in eclipse. The Sun is not visible from the SMAP spacecraft.
4-15		**Undefined**

antenna_scan_mode_flag is a one-dimensional array. Each array index is representative of a specific cross track row in the swath grid.

Type: Uint16

Group: Spacecraft Data

Shape: AntennaScan_Array

Units: n/a

4.7.4 antenna_scan_qual_flag

Bit flags that indicate the quality of spacecraft position and orientation, or antenna pointing data for each antenna scan. Table 15 specifies the meaning of individual bits in the *antenna_scan_qual_flag*:

Table 16: The antenna_scan_qual_flag

Bits	Value	Interpretation
0		**Ephemeris Quality**
	0	Quality and frequency of the ephemeris data is within acceptable range.
	1	Quality or frequency of the ephemeris data may not be adequate to yield a sufficiently accurate measure of spacecraft location to meet mission geolocation requirements.
1		**Attitude Quality**
	0	Quality and frequency of the attitude data is within acceptable range.
	1	Quality or frequency of the attitude data may not be adequate to interpolate a sufficiently accurate measure of spacecraft attitude to meet mission requirements.
2		**Antenna Azimuth Quality**
	0	Quality and frequency of the antenna azimuth data is within acceptable range.
	1	Quality or frequency of the antenna pointing data may not be adequate to yield a sufficiently accurate measure to meet mission geolocation requirements.
3-15		**Undefined**

antenna_scan_qual_flag is a one-dimensional array. Each array index is representative of a specific antenna scan.

Type: Uint16

Group: Spacecraft Data

Shape: AntennaScan_Array

Units: n/a

4.7.5 antenna_scan_time

The time for each antenna rotation interpolated to antenna boresight azimuth of 0 degrees. Time values are counts of International System (SI) seconds based on the J2000 epoch in Ephemeris Time (ET). The J2000 epoch starting point is January 1, 2000 at 12:00 ET, which translates to January 1, 2000 at 11:58:55.816 Universal Coordinated Time (UTC).

antenna_scan_time is a one-dimensional array. Each array index is representative of a specific antenna scan.

Type:	Float64
Group:	Spacecraft Data
Shape:	AntennaScan_Array
Valid_min:	0
Valid_max:	946000000
Units:	seconds

4.7.6 antenna_scan_time_utc

The Universal Coordinated Time (UTC) for each antenna rotation when antenna boresight azimuth is 0 degrees. For each antenna scan, the *antenna_scan_time_utc* records the same time instant as the *antenna_scan_time*. The *antenna_scan_time_utc* appears as an easily interpretable character string.

The format of the *antenna_scan_time_utc* is YYYY-MM-DDThh:mm:ss.dddZ, where YYYY represents the calendar year, MM represents the month of the year and DD represents the day of the month. The character ‘T’ demarcates the date from the time. hh represents the hour in twenty-four hour time, mm represents the minutes, ss represents the seconds, and ddd represents thousandths of a second. The character ‘Z’ designates Greenwich Mean Time. All numerical fields must occupy the allotted space. If any numerical value does not require the allotted space to represent the appropriate number, the field that specifies the number must contain leading zeroes.

antenna_scan_time_utc is a one-dimensional array. Each array index is representative of a specific antenna scan.

Type:	FixLenStr
String Length:	24 characters
Group:	Spacecraft Data
Shape:	AntennaScan_Array
Valid_min:	‘2014-10-31T00:00:00.000Z’

Valid_max: ‘2030-12-31T23:59:60.999Z’

Units: n/a

4.7.7 antenna_look_angle

The angle defined by the antenna boresight vector and the spacecraft nadir vector interpolated to an antenna scan angle of 0 degrees.

antenna_look_angle is a one-dimensional array. Each array index is representative of a specific antenna scan.

Type: Float32

Group: Spacecraft Data

Shape: AntennaScan_Array

Valid_min: 0

Valid_max: 180

Units: degrees

4.7.8 pitch

The angular rotation of the spacecraft body about the Y axis of the SMAP Science Orbit Reference Frame (SRF). The Y axis of the SRF is normal to the spacecraft orbital plane. Pitch values are interpolated to the corresponding antenna_scan_time, which is equivalent to the instant when the antenna boresight azimuth is 0 degrees within the corresponding scan.

Pitch is a one-dimensional array. Each array index is representative of a specific antenna scan.

Type: Float32

Group: Spacecraft Data

Shape: AntennaScan_Array

Valid_min: -90

Valid_max: 90

Units: degrees

4.7.9 roll

The angular rotation of the spacecraft body about the X axis of the SMAP Science Orbit Reference Frame (SRF) coordinate system. The X axis of the

SRF approximates the direction of spacecraft motion. Roll values are interpolated to the corresponding antenna_scan_time, which is equivalent to the instant when the antenna boresight azimuth is 0 degrees within the corresponding scan.

Roll is a one-dimensional array. Each array index is representative of a specific antenna scan.

Type: Float32

Group: Spacecraft Data

Shape: AntennaScan_Array

Valid_min: -90

Valid_max: 90

Units: degrees

4.7.10 sc_alongtrack_velocity

The spacecraft velocity in the direction of the spacecraft orbital track interpolated to an antenna scan angle of 0 degrees.

sc_alongtrack_velocity is a one-dimensional array. Each array index is representative of a specific antenna scan.

Type: Float32

Group: Spacecraft Data

Shape: AntennaScan_Array

Valid_min: -8000

Valid_max: 8000

Units: m/s

4.7.11 sc_geodetic_alt_ellipsoid

The spacecraft altitude above Earth WGS84 reference ellipsoid along the nadir track interpolated to an antenna scan angle of 0 degrees.

sc_geodetic_alt_ellipsoid is a one-dimensional array. Each array index is representative of a specific antenna scan.

Type: Float32

Group: Spacecraft Data

Shape: AntennaScan_Array

Valid_min: 650000

Valid_max: 750000

Units: m

4.7.12 sc_nadir_lat

The spacecraft latitude along nadir track interpolated to an antenna scan angle of 0 degrees.

sc_nadir_lat is a one-dimensional array. Each array index is representative of a specific antenna scan.

Type: Float32

Group: Spacecraft Data

Shape: AntennaScan_Array

Valid_min: -90

Valid_max: 90

Units: degrees

4.7.13 sc_nadir_lon

The spacecraft longitude along nadir track interpolated to an antenna scan angle of 0 degrees.

sc_nadir_lon is a one-dimensional array. Each array index is representative of a specific antenna scan.

Type: Float32

Group: Spacecraft Data

Shape: AntennaScan_Array

Valid_min: -180.0

Valid_max: 179.999

Units: degrees

4.7.14 sc_nadir_angle

The angle defined by the spacecraft geodetic nadir vector an the negative Z axis of the spacecraft coordinate system at each instance when the antenna scan angle is 0 degrees.

sc_nadir_angle is a one-dimensional array. Each array index is representative of a specific antenna scan.

Type: Float32

Group: Spacecraft Data

Shape: AntennaScan_Array

Valid_min: 0

Valid_max: 180

Units: degrees

4.7.15 sc_radial_velocity

The spacecraft velocity in the direction of the radius of the orbital track interpolated to an antenna scan angle of 0 degrees. The velocity that records change in altitude.

sc_radial_velocity is a one-dimensional array. Each array index is representative of a specific antenna scan.

Type: Float32

Group: Spacecraft Data

Shape: AntennaScan_Array

Valid_min: -8000

Valid_max: 8000

Units: m/s

4.7.16 x_pos

The spacecraft position in the X direction of the Earth Centered Rotation (ECR) system interpolated to an antenna scan angle of 0 degrees.

x_pos is a one-dimensional array. Each array index is representative of a specific antenna scan.

Type: Float32

Group: Spacecraft Data

Shape: AntennaScan_Array

Valid_min: -9999999

Valid_max: 9999999

Units: m

4.7.17 x_vel

The spacecraft velocity in the X direction of the Earth Centered Rotating (ECR) system interpolated to an antenna scan angle of 0 degrees.

x_vel is a one-dimensional array. Each array index is representative of a specific antenna scan.

Type:	Float32
Group:	Spacecraft Data
Shape:	AntennaScan_Array
Valid_min:	-8000
Valid_max:	8000
Units:	m/s

4.7.18 yaw

The angular rotation of the spacecraft body about the Z axis of the SMAP Science Orbit Reference Frame (SRF) coordinate system. The Z axis of the SRF runs from the center of mass of the spacecraft toward geodetic nadir. Yaw values are interpolated to the corresponding antenna_scan_time, which is equivalent to the instant when the antenna boresight azimuth is 0 degrees within the corresponding scan.

Yaw is a one-dimensional array. Each array index is representative of a specific antenna scan.

Type:	Float32
Group:	Spacecraft Data
Shape:	AntennaScan_Array
Valid_min:	-180
Valid_max:	180
Units:	degrees

4.7.19 y_pos

The spacecraft position in the Y direction of the Earth Centered Rotation (ECR) system interpolated to an antenna scan angle of 0 degrees.

Y_pos is a one-dimensional array. Each array index is representative of a specific antenna scan.

Type:	Float32

Group: Spacecraft Data

Shape: AntennaScan_Array

Valid_min: -9999999

Valid_max: 9999999

Units: m

4.7.20 y_vel

The spacecraft velocity in the Y direction of the Earth Centered Rotating (ECR) system interpolated to an antenna scan angle of 0 degrees.

Y_vel is a one-dimensional array. Each array index is representative of a specific antenna scan.

Type: Float32

Group: Spacecraft Data

Shape: AntennaScan_Array

Valid_min: -8000

Valid_max: 8000

Units: m/s

4.7.21 z_pos

The spacecraft position in the Z direction of the Earth Centered Rotation (ECR) system interpolated to an antenna scan angle of 0 degrees.

Z_pos is a one-dimensional array. Each array index is representative of a specific antenna scan.

Type: Float32

Group: Spacecraft Data

Shape: AntennaScan_Array

Valid_min: -9999999

Valid_max: 9999999

Units: m

4.7.22 z_vel

The spacecraft velocity in the Z direction of the Earth Centered Rotating (ECR) system interpolated to an antenna scan angle of 0 degrees.

Z_vel is a one-dimensional array. Each array index is representative of a specific antenna scan.

Type: Float32

Group: Spacecraft Data

Shape: AntennaScan_Array

Valid_min: -8000

Valid_max: 8000

Units: m/s

4.7.23 highresolution_scan_index

An array of indices of the high resolution antenna scan rotations in the current granule. The value in this array references in the matching index in the Antenna Scan array. This array is also zero-based.

highresolution_scan_index is a one-dimensional array. Each array index is representative of a specific antenna scan.

Type: Uint32

Group: High Resolution Moments Data

Shape: HighResolutionScan_Array

Valid_min: 0

Valid_max: 800

Units: count

4.7.24 m1_16_ant

The first raw moment in each packet of subband radiometer data in the antenna state, which have been integrated to 4 pulse repetition intervals (PRIs) or ~1.2 ms.

m1_16_ant is a four-dimensional array. The first dimension or the slowest moving dimension index represents the antenna scan. The second dimension index represents the number of packets with data in the antenna radiometric state in the antenna scan. The number of packets in each antenna scan can vary depending on the exact integration time and the antenna rotation rate for that particular scan. As a result, a maximum value is set for this dimension. The third index represents the 16 subbands and the fourth index is the polarization. Both vertical and horizontal polarizations are separated into their in-phase and quadrature components. The order of storage is real h, imaginary h, real v, imaginary v.

Type: Float32

Group: High Resolution Moments Data

Shape: HighResolutionScan_AntPacket_Subband_Polarization_Array

Valid_min: -6.85×10^{8}

Valid_max: 6.85×10^{8}

Units: counts

4.7.25 m2_16_ant

The second raw moment in each packet of subband radiometer data in the antenna state, which have been integrated to 4 pulse repetition intervals (PRIs) or ~1.2 ms.

m2_16_ant is a four-dimensional array. The first dimension or the slowest moving dimension index represents the antenna scan. The second dimension index represents the number of packets with data in the antenna radiometric state in the antenna scan. The number of packets in each antenna scan can vary depending on the exact integration time and the antenna rotation rate for that particular scan. As a result, a maximum value is set for this dimension. The third index represents the 16 subbands and the fourth index is the polarization. Both vertical and horizontal polarizations are separated into their in-phase and quadrature components. The order of storage is real h, imaginary h, real v, imaginary v.

Type: Float32

Group: High Resolution Moments Data

Shape: HighResolutionScan_AntPacket_Subband_Polarization_Array

Valid_min: 0

Valid_max: 5.88×10^{18}

Units: counts

4.7.26 m3_16_ant

The third raw moment in each packet of subband radiometer data in the antenna state, which have been integrated to 4 pulse repetition intervals (PRIs) or ~1.2 ms.

m3_16_ant is a four-dimensional array. The first dimension or the slowest moving dimension index represents the antenna scan. The second dimension index represents the number of packets with data in the antenna radiometric state in the antenna scan. The number of packets in each antenna scan can vary depending on the exact integration time and the antenna rotation rate for that particular scan. As a result, a maximum value is set for this dimension. The third index represents the 16 subbands and the fourth index is the polarization. Both vertical and horizontal polarizations are separated into their in-phase and quadrature components. The order of storage is real h, imaginary h, real v, imaginary v.

Type: Float32

Group: High Resolution Moments Data

Shape: HighResolutionScan_AntPacket_Subband_Polarization_Array

Valid_min: -2.94×10^{18}

Valid_max: 2.94×10^{18}

Units: counts

4.7.27 m4_16_ant

The fourth raw moment in each packet of subband radiometer data in the antenna state, which have been integrated to 4 pulse repetition intervals (PRIs) or ~1.2 ms.

m4_16_ant is a four-dimensional array. The first dimension or the slowest moving dimension index represents the antenna scan. The second dimension index represents the number of packets with data in the antenna radiometric state in the antenna scan. The number of packets in each antenna scan can vary depending on the exact integration time and the antenna rotation rate for that particular scan. As a result, a maximum value is set for this dimension. The third index represents the 16 subbands and the fourth index is the polarization. Both vertical and horizontal polarizations are separated into their in-phase and quadrature components. The order of storage is real h, imaginary h, real v, imaginary v.

Type: Float32

Group: High Resolution Moments Data

Shape: HighResolutionScan_AntPacket_Subband_Polarization_Array

Valid_min: 0

Valid_max: 1.09×10^{38}

Units: counts

4.7.28 m1_16_ant_xnd

The first raw moment in each packet of subband radiometer data in the antenna plus external noise diode state, which have been integrated to 4 pulse repetition intervals (PRIs) or ~1.2 ms.

m1_16_ant_xnd is a four-dimensional array. The slowest moving dimension index represents the antenna scan. The second dimension index represents the number of packets in the external noise diode radiometric state in the antenna scan. The third index represents the 16 subbands and the fourth index is the polarization. Both vertical and horizontal polarizations are separated into their in-phase and quadrature components. The order of storage is real h, imaginary h, real v, imaginary v.

Type: Float32

Group: High Resolution Moments Data

Shape: HighResolutionScan_AntXndPacket_Subband_Polarization_Array

Valid_min: -6.85×10^{8}

Valid_max: 6.85×10^{8}

Units: counts

4.7.29 m2_16_ant_xnd

The second raw moment of subband radiometer data in the antenna plus external noise diode state, which have been integrated to 4 pulse repetition intervals (PRIs) or ~1.2 ms.

m2_16_ant_xnd is a four-dimensional array. The slowest moving dimension index represents the antenna scan. The second dimension index represents the number of packets in the external noise diode radiometric state in the antenna scan. The third index represents the 16 subbands and the fourth index is the polarization. Both vertical and horizontal polarizations are separated into their in-phase and quadrature components. The order of storage is real h, imaginary h, real v, imaginary v.

Type: Float32

Group: High Resolution Moments Data

Shape: HighResolutionScan_AntXndPacket_Subband_Polarization_Array

Valid_min: 0

Valid_max: 5.88×10^{18}

Units: counts

4.7.30 m3_16_ant_xnd

The third raw moment of subband radiometer data in the antenna plus external noise diode state, which have been integrated to 4 pulse repetition intervals (PRIs) or ~1.2 ms.

m3_16_ant_xnd is a four-dimensional array. The slowest moving dimension index represents the antenna scan. The second dimension index represents the number of packets in the external noise diode radiometric state in the antenna scan. The third index represents the 16 subbands and the fourth index is the polarization. Both vertical and horizontal polarizations are separated into their in-phase and quadrature components. The order of storage is real h, imaginary h, real v, imaginary v.

Type: Float32

Group: High Resolution Moments Data

Shape: HighResolutionScan_AntXndPacket_Subband_Polarization_Array

Valid_min: -2.94×10^{18}

Valid_max: 2.94×10^{18}

Units: counts

4.7.31 m4_16_ant_xnd

The fourth raw moment of subband radiometer data in the antenna plus external noise diode state, which have been integrated to 4 pulse repetition intervals (PRIs) or ~1.2 ms.

m4_16_ant_xnd is a four-dimensional array. The slowest moving dimension index represents the antenna scan. The second dimension index represents the number of packets in the external noise diode radiometric state in the antenna scan. The third index represents the 16 subbands and the fourth index is the polarization. Both vertical and horizontal polarizations are separated into their in-phase and quadrature components. The order of storage is real h, imaginary h, real v, imaginary v.

Type: Float32

Group: High Resolution Moments Data

Shape: HighResolutionScan_AntXndPacket_Subband_Polarization_Array

Valid_min: 0

Valid_max: 1.09×10^{38}

Units: counts

4.7.32 m1_16_ant_nd

The first raw moment in each packet of the subband radiometer data in the antenna plus internal noise diode state, which have been integrated to 4 pulse repetition intervals (PRIs) or ~1.2 ms.

m1_16_ant_nd is a four-dimensional array. The slowest moving dimension index represents the antenna scan. The second dimension index represents the number of packets in the antenna plus noise diode state in the antenna scan. The third index represents the 16 subbands and the fourth index is the polarization. Both vertical and horizontal polarizations are separated into their in-phase and quadrature components. The order of storage is real h, imaginary h, real v, imaginary v.

Type: Float32

Group: High Resolution Moments Data

Shape: HighResolutionScan_AntNdPacket_Subband_Polarization_Array

Valid_min: -6.85×10^{8}

Valid_max: 6.85×10^{8}

Units: counts

4.7.33 m2_16_ant_nd

The second raw moment in each packet of subband radiometer data in the antenna plus internal noise diode state, which have been integrated to 4 pulse repetition intervals (PRIs) or ~1.2 ms.

m2_16_ant_nd is a four-dimensional array. The slowest moving dimension index represents the antenna scan. The second dimension index represents the number of packets in the antenna plus noise diode state in the antenna scan. The third index represents the 16 subbands and the fourth index is the polarization. Both vertical and horizontal polarizations are separated into their in-phase and quadrature components. The order of storage is real h, imaginary h, real v, imaginary v.

Type: Float32

Group: High Resolution Moments Data

Shape: HighResolutionScan_AntNdPacket_Subband_Polarization_Array

Valid_min: 0

Valid_max: 5.88×10^{18}

Units: counts

4.7.34 m3_16_ant_nd

The third raw moment of subband radiometer data in the antenna plus internal noise diode state, which have been integrated to 4 pulse repetition intervals (PRIs) or ~1.2 ms.

m3_16_ant_nd is a four-dimensional array. The slowest moving dimension index represents the antenna scan. The second dimension index represents the number of packets in the antenna plus noise diode state in the antenna scan. The third index represents the 16 subbands and the fourth index is the polarization. Both vertical and horizontal polarizations are separated into their in-phase and quadrature components. The order of storage is real h, imaginary h, real v, imaginary v.

Type: Float32

Group: High Resolution Moments Data

Shape: HighResolutionScan_AntNdPacket_Subband_Polarization_Array

Valid_min: $-2.94x10^{18}$

Valid_max: $2.94x10^{18}$

Units: counts

4.7.35 m4_16_ant_nd

The fourth raw moment of subband radiometer data in the antenna plus internal noise diode state, which have been integrated to 4 pulse repetition intervals (PRIs) or ~1.2 ms.

m4_16_ant_nd is a four-dimensional array. The slowest moving dimension index represents the antenna scan. The second dimension index represents the number of packets in the antenna plus noise diode state in the antenna scan. The third index represents the 16 subbands and the fourth index is the polarization. Both vertical and horizontal polarizations are separated into their in-phase and quadrature components. The order of storage is real h, imaginary h, real v, imaginary v.

Type: Float32

Group: High Resolution Moments Data

Shape: HighResolutionScan_AntNdPacket_Subband_Polarization_Array

Valid_min: 0

Valid_max: $1.09x10^{38}$

Units: counts

4.7.36 m1_16_ref

The first raw moment of subband radiometer data in the reference state, which have been integrated to 4 pulse repetition intervals (PRIs) or ~1.2 ms.

m1_16_ref is a four-dimensional array. The slowest moving dimension index represents the antenna scan. The second dimension index represents the number of packets in the reference state in the antenna scan. The third index represents the 16 subbands and the fourth index is the polarization. Both vertical and horizontal polarizations are separated into their in-phase and quadrature components. The order of storage is real h, imaginary h, real v, imaginary v.

Type: Float32

Group: High Resolution Moments Data

Shape: HighResolutionScan_RefPacket_Subband_Polarization_Array

Valid_min: -6.85×10^{8}

Valid_max: 6.85×10^{8}

Units: counts

4.7.37 m2_16_ref

The second raw moment of subband radiometer data in the reference state, which have been integrated to 4 pulse repetition intervals (PRIs) or ~1.2 ms.

m2_16_ref is a four-dimensional array. The slowest moving dimension index represents the antenna scan. The second dimension index represents the number of packets in the reference state in the antenna scan. The third index represents the 16 subbands and the fourth index is the polarization. Both vertical and horizontal polarizations are separated into their in-phase and quadrature components. The order of storage is real h, imaginary h, real v, imaginary v.

Type: Float32

Group: High Resolution Moments Data

Shape: HighResolutionScan_RefPacket_Subband_Polarization_Array

Valid_min: 0

Valid_max: 5.88×10^{18}

Units: counts

4.7.38 m3_16_ref

The third raw moment of subband radiometer data in the reference state, which have been integrated to 4 pulse repetition intervals (PRIs) or ~1.2 ms.

m3_16_ref is a four-dimensional array. The slowest moving dimension index represents the antenna scan. The second dimension index represents the number of packets in the reference state in the antenna scan. The third index represents the 16 subbands and the fourth index is the polarization. Both vertical and horizontal polarizations are separated into their in-phase and quadrature components. The order of storage is real h, imaginary h, real v, imaginary v.

Type: Float32

Group: High Resolution Moments Data

Shape: HighResolutionScan_RefPacket_Subband_Polarization_Array

Valid_min: -2.94×10^{18}

Valid_max: 2.94×10^{18}

Units: counts

4.7.39 m4_16_ref

The fourth raw moment of subband radiometer data in the reference state, which have been integrated to 4 pulse repetition intervals (PRIs) or ~1.2 ms.

m4_16_ref is a four-dimensional array. The slowest moving dimension index represents the antenna scan. The second dimension index represents the number of packets in the reference state in the antenna scan. The third index represents the 16 subbands and the fourth index is the polarization. Both vertical and horizontal polarizations are separated into their in-phase and quadrature components. The order of storage is real h, imaginary h, real v, imaginary v.

Type: Float32

Group: High Resolution Moments Data

Shape: HighResolutionScan_RefPacket_Subband_Polarization_Array

Valid_min: 0

Valid_max: 1.09×10^{38}

Units: counts

4.7.40 m1_16_ref_nd

The first raw moment of subband radiometer data in the reference plus internal noise diode state, which have been integrated to 4 pulse repetition intervals (PRIs) or ~1.2 ms.

m1_16_ref_nd is a four-dimensional array. The slowest moving dimension index represents the antenna scan. The second dimension index represents the number of packets in the reference plus noise diode state in the antenna scan.

The third index represents the 16 subbands and the fourth index is the polarization. Both vertical and horizontal polarizations are separated into their in-phase and quadrature components. The order of storage is real h, imaginary h, real v, imaginary v.

Type: Float32

Group: High Resolution Moments Data

Shape: HighResolutionScan_RefNdPacket_Subband_Polarization_Array

Valid_min: -6.85×10^{8}

Valid_max: 6.85×10^{8}

Units: counts

4.7.41 m2_16_ref_nd

The second raw moment of subband radiometer data in the reference plus internal noise diode state, which have been integrated to 4 pulse repetition intervals (PRIs) or ~1.2 ms.

m2_16_ref_nd is a four-dimensional array. The slowest moving dimension index represents the antenna scan. The second dimension index represents the number of packets in the reference plus noise diode state in the antenna scan. The third index represents the 16 subbands and the fourth index is the polarization. Both vertical and horizontal polarizations are separated into their in-phase and quadrature components. The order of storage is real h, imaginary h, real v, imaginary v.

Type: Float32

Group: High Resolution Moments Data

Shape: HighResolutionScan_RefNdPacket_Subband_Polarization_Array

Valid_min: 0

Valid_max: 5.88×10^{18}

Units: counts

4.7.42 m3_16_ref_nd

The third raw moment of subband radiometer data in the reference plus internal noise diode state, which have been integrated to 4 pulse repetition intervals (PRIs) or ~1.2 ms.

m3_16_ref_nd is a four-dimensional array. The slowest moving dimension index represents the antenna scan. The second dimension index represents the number of packets in the reference plus noise diode state in the antenna scan.

The third index represents the 16 subbands and the fourth index is the polarization. Both vertical and horizontal polarizations are separated into their in-phase and quadrature components. The order of storage is real h, imaginary h, real v, imaginary v.

Type: Float32

Group: High Resolution Moments Data

Shape: HighResolutionScan_RefNdPacket_Subband_Polarization_Array

Valid_min: -2.94×10^{18}

Valid_max: 2.94×10^{18}

Units: counts

4.7.43 m4_16_ref_nd

The fourth raw moment of subband radiometer data in the reference plus internal noise diode state, which have been integrated to 4 pulse repetition intervals (PRIs) or ~1.2 ms.

m4_16_ref_nd is a four-dimensional array. The slowest moving dimension index represents the antenna scan. The second dimension index represents the number of packets in the reference plus noise diode state in the antenna scan. The third index represents the 16 subbands and the fourth index is the polarization. Both vertical and horizontal polarizations are separated into their in-phase and quadrature components. The order of storage is real h, imaginary h, real v, imaginary v.

Type: Float32

Group: High Resolution Moments Data

Shape: HighResolutionScan_RefNdPacket_Subband_Polarization_Array

Valid_min: 0

Valid_max: 1.09×10^{38}

Units: counts

4.7.44 t3_16_ant

The real portion of the cross correlation of the two polarizations (vertical and horizontal) for subband radiometer data in the antenna state, which have been integrated to 4 pulse repetition intervals (PRIs) or ~1.2 ms.

t3_16_ant is a three-dimensional array. The slowest moving dimension index represents the antenna scan. The second dimension index represents the number of packets in the antenna radiometric state in the antenna scan. The number of packets in each antenna scan can vary depending on the exact integration time and the antenna rotation rate for that particular scan. The third index represents the 16 subbands.

Type: Float32

Group: High Resolution Moments Data

Shape: HighResolutionScan_AntPacket_Subband_Array

Valid_min: -2.94×10^{18}

Valid_max: 2.94×10^{18}

Units: counts

4.7.45 t3_16_ant_xnd

The real portion of the cross correlation of the two polarizations (vertical and horizontal) for subband radiometer data in the antenna state plus external noise diode state, which have been integrated to 4 pulse repetition intervals (PRIs) or ~1.2 ms.

t3_16_ant_xnd is a three-dimensional array. The slowest moving dimension index represents the antenna scan. The second dimension index represents the number of packets in the antenna plus external noise diode state in the antenna scan. The third index represents the 16 subbands.

Type: Float32

Group: High Resolution Moments Data

Shape: HighResolutionScan_AntXndPacket_Subband_Array

Valid_min: -2.94×10^{18}

Valid_max: 2.94×10^{18}

Units: counts

4.7.46 t3_16_ant_nd

The real portion of the cross correlation of the two polarizations (vertical and horizontal) for subband radiometer data in the antenna state plus internal noise diode state, which have been integrated to 4 pulse repetition intervals (PRIs) or ~1.2 ms.

t3_16_ant_nd is a three-dimensional array. The slowest moving dimension index represents the antenna scan. The second dimension index represents the number of packets in the antenna plus noise diode state in the antenna scan. The third index represents the 16 subbands.

Type: Float32

Group: High Resolution Moments Data

Shape: HighResolutionScan_AntNdPacket_Subband_Array

Valid_min: -2.94×10^{18}

Valid_max: 2.94×10^{18}

Units: counts

4.7.47 t3_16_ref

The real portion of the cross correlation of the two polarizations (vertical and horizontal) for subband radiometer data in the reference state, which have been integrated to 4 pulse repetition intervals (PRIs) or ~1.2 ms.

t3_16_ref is a three-dimensional array. The slowest moving dimension index represents the antenna scan. The second dimension index represents the number of packets in the reference state in the antenna scan. The third index represents the 16 subbands.

Type: Float32

Group: High Resolution Moments Data

Shape: HighResolutionScan_RefPacket_Subband_Array

Valid_min: -2.94×10^{18}

Valid_max: 2.94×10^{18}

Units: counts

4.7.48 t3_16_ref_nd

The real portion of the cross correlation of the two polarizations (vertical and horizontal) for subband radiometer data in the reference plus internal noise diode state, which have been integrated to 4 pulse repetition intervals (PRIs) or ~1.2 ms.

t3_16_ref_nd is a three-dimensional array. The slowest moving dimension index represents the antenna scan. The second dimension index represents the number of packets in the reference plus noise diode state in the antenna scan. The third index represents the 16 subbands.

Type: Float32

Group: High Resolution Moments Data

Shape: HighResolutionScan_RefNdPacket_Subband_Array

Valid_min: -2.94×10^{18}

Valid_max: 2.94×10^{18}

Units: counts

4.7.49 t4_16_ant

The imaginary portion of the cross correlation of the two polarizations (vertical and horizontal) for subband radiometer data in the antenna state, which have been integrated to 4 pulse repetition intervals (PRIs) or ~1.2 ms.

t4_16_ant is a three-dimensional array. The slowest moving dimension index represents the antenna scan. The second dimension index represents the number of packets in the antenna state in the antenna scan. The number of packets in each antenna scan can vary depending on the exact integration time and the antenna rotation rate for that particular scan. The third index represents the 16 subbands.

Type: Float32

Group: High Resolution Moments Data

Shape: HighResolutionScan_AntPacket_Subband_Array

Valid_min: -2.94×10^{18}

Valid_max: 2.94×10^{18}

Units: counts

4.7.50 t4_16_ant_xnd

The imaginary portion of the cross correlation of the two polarizations (vertical and horizontal) for subband radiometer data in the antenna state plus external noise diode state, which have been integrated to 4 pulse repetition intervals (PRIs) or ~1.2 ms.

t4_16_ant_xnd is a three-dimensional array. The slowest moving dimension index represents the antenna scan. The second dimension index represents the number of packets in the antenna plus external noise diode state in the antenna scan. The third index represents the 16 subbands.

Type: Float32

Group: High Resolution Moments Data

Shape: HighResolutionScan_AntXndPacket_Subband_Array

Valid_min: -2.94×10^{18}

Valid_max: 2.94×10^{18}

Units: counts

4.7.51 t4_16_ant_nd

The imaginary portion of the cross correlation of the two polarizations (vertical and horizontal) for subband radiometer data in the antenna state plus internal noise diode state, which have been integrated to 4 pulse repetition intervals (PRIs) or ~1.2 ms.

t4_16_ant_nd is a three-dimensional array. The slowest moving dimension index represents the antenna scan. The second dimension index represents the number of packets in the antenna plus noise diode state in the antenna scan. The third index represents the 16 subbands.

Type: Float32

Group: High Resolution Moments Data

Shape: HighResolutionScan_AntNdPacket_Subband_Array

Valid_min: -2.94×10^{18}

Valid_max: 2.94×10^{18}

Units: counts

4.7.52 t4_16_ref

The imaginary portion of the cross correlation of the two polarizations (vertical and horizontal) for subband radiometer data in the reference state, which have been integrated to 4 pulse repetition intervals (PRIs) or ~1.2 ms.

t4_16_ref is a three-dimensional array. The slowest moving dimension index represents the antenna scan. The second dimension index represents the number of packets in the reference state in the antenna scan. The third index represents the 16 subbands.

Type: Float32

Group: High Resolution Moments Data

Shape: HighResolutionScan_RefPacket_Subband_Array

Valid_min: -2.94×10^{18}

Valid_max: 2.94×10^{18}

Units: counts

4.7.53 t4_16_ref_nd

The imaginary portion of the cross correlation of the two polarizations (vertical and horizontal) for subband radiometer data in the reference plus internal noise diode state, which have been integrated to 4 pulse repetition intervals (PRIs) or ~1.2 ms.

t4_16_ref_nd is a three-dimensional array. The slowest moving dimension index represents the antenna scan. The second dimension index represents the number of packets in the reference plus noise diode state in the antenna scan. The third index represents the 16 subbands.

Type: Float32

Group: High Resolution Moments Data

Shape: HighResolutionScan_RefNdPacket_Subband_Array

Valid_min: -2.94×10^{18}

Valid_max: 2.94×10^{18}

Units: counts

4.7.54 moments16_lat

The latitude of the antenna look packet on the surface of the Earth.

moments16_lat is a two-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents the number of packets in the antenna state in the scan.

Type: Float32

Group: High Resolution Moments Data

Shape: HighResolutionScan_AntPacket_Array

Valid_min: -90

Valid_max: 90

Units: degrees

4.7.55 moments16_lon

The longitude of the antenna look packet on the surface of the Earth.

moments16_long is a two-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents the number of packets in the antenna state in the scan.

Type: Float32

Group: High Resolution Moments Data

Shape: HighResolutionScan_AntPacket_Array

Valid_min: -180.0

Valid_max: 179.999

Units: degrees

4.7.56 moments16_declination

The declination of the spacecraft boresight vector.

moments16_declination is a two-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents the number of packets in the antenna state in the scan.

Type: Float32

Group: High Resolution Moments Data

Shape: HighResolutionScan_AntPacket_Array

Valid_min: -90

Valid_max: 90

Units: degrees

4.7.57 moments16_right_ascension

The right ascension of the spacecraft boresight vector.

moments16_right_ascension is a two-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents the number of packets in the antenna state in the scan.

Type: Float32

Group: High Resolution Moments Data

Shape: HighResolutionScan_AntPacket_Array

Valid_min: 0

Valid_max: 359.999

Units: degrees

4.7.58 ant_16_time_seconds

The number of Standard International (SI) compatible seconds since 11:58:55.816 on January 1, 2000 UTC for each antenna look packet interpolated to antenna boresight azimuth of 0 degrees.

*ant_16_time_seconds i*s a two-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents the time of each of the antenna packets in the scan.

Type: Float64

Group: High Resolution Moments Data

Shape: HighResolutionScan_AntPacket_Array

Valid_min: 0

Valid_max: 946000000

Units: seconds

4.7.59 ant_xnd_16_time_seconds

The number of Standard International (SI) compatible seconds since 11:58:55.816 on January 1, 2000 UTC for each antenna plus external noise diode look packet interpolated to antenna boresight azimuth of 0 degrees.

*ant_xnd_16_time_seconds i*s a two-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents the times of each of the antenna plus external noise diode packets packets in the scan.

Type: Float64

Group: High Resolution Moments Data

Shape: HighResolutionScan_AntXndPacket_Array

Valid_min: 0

Valid_max: 946000000

Units: seconds

4.7.60 ant_nd_16_time_seconds

The number of Standard International (SI) compatible seconds since 11:58:55.816 on January 1, 2000 UTC for each antenna plus internal noise diode look packet interpolated to antenna boresight azimuth of 0 degrees.

*ant_nd_16_time_seconds i*s a two-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents the times of each of the antenna plus internal noise diode packets in the scan.

Type: Float64

Group: High Resolution Moments Data

Shape: HighResolutionScan_AntNdPacket_Array

Valid_min: 0

Valid_max: 946000000

Units: seconds

4.7.61 ref_16_time_seconds

The number of Standard International (SI) compatible seconds since 11:58:55.816 on January 1, 2000 UTC for each reference look packet interpolated to antenna boresight azimuth of 0 degrees.

*ref_16_time_seconds i*s a two-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents the time of each of the reference packets in the scan.

Type: Float64

Group: High Resolution Moments Data

Shape: HighResolutionScan_RefPacket_Array

Valid_min: 0

Valid_max: 946000000

Units: seconds

4.7.62 ref_nd_16_time_seconds

The number of Standard International (SI) compatible seconds since 11:58:55.816 on January 1, 2000 UTC for each reference plus internal noise diode look packet interpolated to antenna boresight azimuth of 0 degrees.

*ref_nd_16_time_seconds i*s a two-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents the time of each of the reference plus internal noise diode packets in the scan.

Type: Float64

Group: High Resolution Moments Data

Shape: HighResolutionScan_RefNdPacket_Array

Valid_min: 0

Valid_max: 946000000

Units: seconds

4.7.63 telemetry_mode_flag

Bit flags that indicate operational conditions for each antenna scan. Table 16 specifies the meaning of individual bits in the *telemetry_mode_flag*:

Table 17: The telemetry_mode_flag

Bits	Value	Interpretation
0		**Telemetry Resolution Flag**
	0	Fullband and Subband data available
	1	Only Fullband data are available
1-15		**Undefined**

telemetry_mode_flag is a one-dimensional array. Each array index is representative of an antenna scan.

Type: Uint16

Group: Moments Data

Shape: AntennaScan_Array

Units: n/a

4.7.64 telemetry_qual_flag

Bit flags that indicate quality of each antenna scan. Table 17 specifies the meaning of individual bits in the *telemetry_qual_flag*:

Table 17: The telemetry_qual_flag

Bits	Value	Interpretation
0		**Scan quality flag**
	0	Data in the corresponding scan are usable for radiometer processing.
	1	The data in the corresponding scan are questionable or

Bits	Value	Interpretation
		unusable for radiometer processing.
1		**Header Packet CRC flag**
	0	Cyclic redundancy check succeeds for the header packet within this telemetry frame.
	1	Cyclic redundancy check fails for the header packet within this telemetry frame.
2		**Engineering Packet CRC flag**
	0	Cyclic redundancy check succeeds for the engineering packet within this telemetry frame.
	1	Cyclic redundancy check fails for the engineering packet within this telemetry frame.
3		**Science CRC flag**
	0	Cyclic redundancy checks succeed for all telemetry packets associated with the corresponding antenna scan.
	1	Cyclic redundancy checks fail for one or more of the telemetry packets associated with the corresponding antenna scan
4		**Correct scan length flag**
	0	The packet scan length in the telemetry is correct.
	1	The packet scan length field in the telemetry does not appear to be correct.
5		**Scan length adjusted flag**
	0	The scan length field was either correct in the telemetry or the L1A Radiometer software adjusted the scan length to an expected value.
	1	The L1A Radiometer software was unable to adjust the scan length. Data may be lost.
6		**Correct APID flag**

Bits	Value	Interpretation
	0	The APID field in the telemetry is correct.
	1	The APID field in the telemetry does not appear to be correct.
7		**APID adjusted flag**
	0	The APID field was either correct in the telemetry or the L1A Radiometer software adjusted the APID to an expected value.
	1	The L1A Radiometer software was unable to adjust the APID field. Data may be lost.
8		**Correct Pulse Repetition Interval (PRI) flag**
	0	The calculated duration of a PRI based on the telemetry is correct.
	1	The calculated duration of a PRI does not appear to be correct.
9		**Pulse Repetition Interval (PRI) adjusted flag**
	0	The calculated duration of a PRI based on the telemetry was either correct or the L1A Radiometer software adopted the duration of the PRI duration of a neighboring scan.
	1	The L1A Radiometer software was unable to adjust the PRI duration. Data may be lost.
10		**Radiometer Clock error detected flag**
	0	The Radiometer Clock field in the Engineering Packet in the original telemetry is correct.
	1	The L1A Radiometer code detected an anomaly in the Radiometer Clock field in the Engineering Packet.
11		**Radiometer Clock adjusted flag**
	0	The Radiometer Clock field was either correct in the Engineering Packet or the L1A Radiometer software

Bits	Value	Interpretation
		adopted the Radiometer Clock time in the Header Packet for this scan.
	1	The L1A Radiometer software was unable to employ the Radiometer Clock field. Data may be lost.
12		**Radiometer Clock/Spacecraft Clock correlation flag**
	0	The L1A Radiometer algorithm successfully correlated the spacecraft clock with the radiometer clock.
	1	The L1A Radiometer code was unable to correlate the spacecraft clock with the radiometer clock. Data may be lost.
13-15		**Undefined**

telemetry_qual_flag is a one-dimensional array. Each array index is representative of a specific antenna scan.

Type: Uint16

Group: Moments Data

Shape: AntennaScan_Array

Units: n/a

4.7.65 number_of_science_packets

The number of science telemetry packets that appear in each antenna scan. Based on the instrument Pulse Repetition Interval (PRI) and the spacecraft antenna rotation rate, the maximum number of science packets in a telemetry scan is 3624.

number_of_science_packets is a one-dimensional array. Each array index is representative of a specific antenna scan.

Type: Uint16

Group: Moments Data

Shape: AntennaScan_Array

Valid_min: 0

Valid_max: 3624

Units: n/a

4.7.66 science_packet_CRC_check

A bit packed string that indicates whether a Cyclic Redundancy Check (CRC) failed for any of the science telemetry packets within the current antenna scan. The string size is adjustable based on the number of bits required to represent all of the science telemetry packets in the largest antenna scan in the L1A Radiometer product.

Based on the instrument Pulse Repetition Interval (PRI) and the spacecraft antenna rotation rate, the maximum number of science telemetry packets in an antenna scan is 324. Thus, the maximum size of the bit packed string is 453 bytes or 3624 bits.

Each bit in the *science_packet_CRC_check* represents a science telemetry packet. The order of the bits in *science_packet_CRC_check* corresponds precisely with science packets in the telemetry.

Science_packet_CRC_check is a two-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents the number of bytes required to represent all of the science telemetry packets within each scan.

Type:	Char
Group:	Moments Data
Shape:	AntennaScan_SciencePacketCRC_Array
Valid_min:	n/a
Valid_max:	n/a
Units:	n/a

4.7.67 number_science_CRC_errors

The number of science telemetry packets with detected Cyclic Redundancy Check (CRC) errors within each antenna scan. The corresponding element in the array *number_of_science_packets* specifies the maximum number of CRC errors that might be flagged in the scan.

number_science_CRC_errors is a one-dimensional array. Each array index is representative of a specific antenna scan.

Type:	Uint16
Group:	Moments Data
Shape:	AntennaScan_Array
Valid_min:	0

Valid_max: 3624

Units: n/a

4.7.68 m1_ant

The first raw moment in each packet of the fullband radiometer data in the antenna state, which have been integrated to ~300 µs or one pulse repetition interval (PRI).

m1_ant is a three-dimensional array. The slowest moving dimension index represents the antenna scan. The second dimension index represents the number of PRIs acquired in the antenna radiometric state in the antenna scan. The number of PRIs in each antenna scan can vary depending on the exact integration time and the antenna rotation rate for that particular scan. The third index is the polarization where both vertical and horizontal polarizations are separated into their in-phase and quadrature components. The order of storage is real h, imaginary h, real v, imaginary v.

Type: Float32

Group: Moments Data

Shape: AntennaScan_AntPRI_Polarization_Array

Valid_min: -1.71×10^{8}

Valid_max: 1.71×10^{8}

Units: counts

4.7.69 m2_ant

The second raw moment of fullband radiometer data in the antenna state, which have been integrated to ~300 µs or one pulse repetition interval (PRI).

m2_ant is a three-dimensional array. The slowest moving dimension index represents the antenna scan. The second dimension index represents the number of PRIs in the antenna state in the antenna scan. The number of PRIs in each antenna scan can vary depending on the exact integration time and the antenna rotation rate for that particular scan. The third index is the polarization where both vertical and horizontal polarizations are separated into their in-phase and quadrature components. The order of storage is real h, imaginary h, real v, imaginary v.

Type: Float32

Group: Moments Data

Shape: AntennaScan_AntPRI_Polarization_Array

Valid_min: 0

Valid_max: 1.47×10^{18}

Units: counts

4.7.70 m3_ant

The third raw moment of fullband radiometer data in the antenna state, which have been integrated to ~300 µs or one pulse repetition interval (PRI).

m3_ant is a three-dimensional array. The slowest moving dimension index represents the antenna scan. The second dimension index represents the number of PRIs in the antenna state in the antenna scan. The number of PRIs in each antenna scan can vary depending on the exact integration time and the antenna rotation rate for that particular scan. The third index is the polarization where both vertical and horizontal polarizations are separated into their in-phase and quadrature components. The order of storage is real h, imaginary h, real v, imaginary v.

Type: Float32

Group: Moments Data

Shape: AntennaScan_AntPRI_Polarization_Array

Valid_min: -7.36×10^{17}

Valid_max: 7.35×10^{17}

Units: counts

4.7.71 m4_ant

The fourth raw moment of fullband radiometer data in the antenna state, which have been integrated to ~300 µs or one pulse repetition interval (PRI).

m4_ant is a three-dimensional array. The slowest moving dimension index represents the antenna scan. The second dimension index represents the number of PRIs in the antenna state in the antenna scan. The number of PRIs in each antenna scan can vary depending on the exact integration time and the antenna rotation rate for that particular scan. The third index is the polarization where both vertical and horizontal polarizations are separated into their in-phase and quadrature components. The order of storage is real h, imaginary h, real v, imaginary v.

Type: Float32

Group: Moments Data

Shape: AntennaScan_AntPRI_Polarization_Array

Valid_min: 0

Valid_max: 2.71×10^{37}

Units: counts

4.7.72 m1_ant_xnd

The first raw moment of fullband radiometer data in the antenna plus external noise diode state, which have been integrated to ~300 µs or one pulse repetition interval (PRI).

m1_ant_xnd is a three-dimensional array. The slowest moving dimension index represents the antenna scan. The second dimension index represents the number of PRIs in the antenna state in the antenna scan. The third index is the polarization where the vertical and horizontal polarizations are separated into their in-phase and quadrature components. The order of storage is real h, imaginary h, real v, imaginary v.

Type: Float32

Group: Moments Data

Shape: AntennaScan_AntXndPRI_Polarization_Array

Valid_min: -1.71×10^{8}

Valid_max: 1.71×10^{8}

Units: counts

4.7.73 m2_ant_xnd

The second raw moment of fullband radiometer data in the antenna plus external noise diode state, which have been integrated to ~300 µs or one pulse repetition interval (PRI).

m2_ant_xnd is a three-dimensional array. The slowest moving dimension index represents the antenna scan. The second dimension index represents the number of PRIs in the antenna plus external noise diode state in the antenna scan. The third index is the polarization where the vertical and horizontal polarizations are separated into their in-phase and quadrature components. The order of storage is real h, imaginary h, real v, imaginary v.

Type: Float32

Group: Moments Data

Shape: AntennaScan_AntXndPRI_Polarization_Array

Valid_min: 0

Valid_max: 1.47×10^{18}

Units: counts

4.7.74 m3_ant_xnd

The third raw moment of fullband radiometer data in the antenna plus external noise diode state, which have been integrated to ~300 μs or one pulse repetition interval (PRI).

m3_ant_xnd is a three-dimensional array. The slowest moving dimension index represents the antenna scan. The second dimension index represents the number of PRIs in the antenna plus external noise diode state in the antenna scan. The third index is the polarization where the vertical and horizontal polarizations are separated into their in-phase and quadrature components. The order of storage is real h, imaginary h, real v, imaginary v.

Type: Float32

Group: Moments Data

Shape: AntennaScan_AntXndPRI_Polarization_Array

Valid_min: -7.36×10^{17}

Valid_max: 7.35×10^{17}

Units: counts

4.7.75 m4_ant_xnd

The fourth raw moment of fullband radiometer data in the antenna plus external noise diode state, which have been integrated to ~300 μs or one pulse repetition interval (PRI).

m4_ant_xnd is a three-dimensional array. The slowest moving dimension index represents the antenna scan. The second dimension index represents the number of PRIs in the antenna plus external noise diode state in the antenna scan. The third index is the polarization where the vertical and horizontal polarizations are separated into their in-phase and quadrature components. The order of storage is real h, imaginary h, real v, imaginary v.

Type: Float32

Group: Moments Data

Shape: AntennaScan_AntXndPRI_Polarization_Array

Valid_min: 0

Valid_max: 2.71×10^{37}

Units: counts

4.7.76 m1_ant_nd

The first raw moment of fullband radiometer data in the antenna plus internal noise diode state, which have been integrated to ~300 µs or one pulse repetition interval (PRI).

m1_ant_nd is a three-dimensional array. The slowest moving dimension index represents the antenna scan. The second dimension index represents the number of PRIs in the antenna plus noise diode state in the antenna scan. The third index is the polarization where the vertical and horizontal polarizations are separated into their in-phase and quadrature components. The order of storage is real h, imaginary h, real v, imaginary v.

Type: Float32

Group: Moments Data

Shape: AntennaScan_AntNdPRI_Polarization_Array

Valid_min: -1.71×10^{8}

Valid_max: 1.71×10^{8}

Units: counts

4.7.77 m2_ant_nd

The second raw moment of fullband radiometer data in the antenna plus internal noise diode state, which have been integrated to ~300 µs or one pulse repetition interval (PRI).

m2_ant_nd is a three-dimensional array. The slowest moving dimension index represents the antenna scan. The second dimension index represents the number of PRIs in the antenna plus noise diode in the antenna scan. The third index is the polarization where the vertical and horizontal polarizations are separated into their in-phase and quadrature components. The order of storage is real h, imaginary h, real v, imaginary v.

Type: Float32

Group: Moments Data

Shape: AntennaScan_AntNdPRI_Polarization_Array

Valid_min: 0

Valid_max: 1.47×10^{18}

Units: counts

4.7.78 m3_ant_nd

The third raw moment of fullband radiometer data in the antenna plus internal noise diode state, which have been integrated to ~300 µs or one pulse repetition interval (PRI).

m3_ant_nd is a three-dimensional array. The slowest moving dimension index represents the antenna scan. The second dimension index represents the number of PRIs in the antenna plus noise diode state in the antenna scan. The third index is the polarization where the vertical and horizontal polarizations are separated into their in-phase and quadrature components. The order of storage is real h, imaginary h, real v, imaginary v.

Type: Float32

Group: Moments Data

Shape: AntennaScan_AntNdPRI_Polarization_Array

Valid_min: -7.36×10^{17}

Valid_max: 7.35×10^{17}

Units: counts

4.7.79 m4_ant_nd

The fourth raw moment of fullband radiometer data in the antenna plus internal noise diode state, which have been integrated to ~300 µs or one pulse repetition interval (PRI).

m4_ant_nd is a three-dimensional array. The slowest moving dimension index represents the antenna scan. The second dimension index represents the number of PRIs in the antenna plus noise diode state in the antenna scan. The third index is the polarization where the vertical and horizontal polarizations are separated into their in-phase and quadrature components. The order of storage is real h, imaginary h, real v, imaginary v.

Type: Float32

Group: Moments Data

Shape: AntennaScan_AntNdPRI_Polarization_Array

Valid_min: 0

Valid_max: 2.71×10^{37}

Units: counts

4.7.80 m1_ref

The first raw moment of fullband radiometer data in the reference state, which have been integrated to ~300 μs or one pulse repetition interval (PRI).

m1_ref is a three-dimensional array. The slowest moving dimension index represents the antenna scan. The second dimension index represents the number of PRIs in the reference state in the antenna scan. The third index is the polarization where the vertical and horizontal polarizations are separated into their in-phase and quadrature components. The order of storage is real h, imaginary h, real v, imaginary v.

Type:	Float32
Group:	Moments Data
Shape:	AntennaScan_RefPRI_Polarization_Array
Valid_min:	-1.71×10^{8}
Valid_max:	1.71×10^{8}
Units:	counts

4.7.81 m2_ref

The second raw moment of fullband radiometer data in the reference state, which have been integrated to ~300 μs or one pulse repetition interval (PRI).

m2_ref is a three-dimensional array. The slowest moving dimension index represents the antenna scan. The second dimension index represents the number of PRIs in the reference state in the antenna scan. The third index is the polarization where the vertical and horizontal polarizations are separated into their in-phase and quadrature components. The order of storage is real h, imaginary h, real v, imaginary v.

Type:	Float32
Group:	Moments Data
Shape:	AntennaScan_RefPRI_Polarization_Array
Valid_min:	0
Valid_max:	1.47×10^{18}
Units:	counts

4.7.82 m3_ref

The third raw moment of subband radiometer data in the reference state, which have been integrated to ~300 μs or one pulse repetition interval (PRI).

m3_ref is a three-dimensional array. The slowest moving dimension index represents the antenna scan. The second dimension index represents the number of PRIs in the reference state in the antenna scan. The third index is the polarization where the vertical and horizontal polarizations are separated into their in-phase and quadrature components. The order of storage is real h, imaginary h, real v, imaginary v.

Type: Float32

Group: Moments Data

Shape: AntennaScan_RefPRI_Polarization_Array

Valid_min: $-7.36x10^{17}$

Valid_max: $7.35x10^{17}$

Units: counts

4.7.83 m4_ref

The fourth raw moment of fullband radiometer data in the reference state, which have been integrated to ~300 µs or one pulse repetition interval (PRI).

m4_16_ref is a three-dimensional array. The slowest moving dimension index represents the antenna scan. The second dimension index represents the number of PRIs in the reference state in the antenna scan. The third index is the polarization where the vertical and horizontal polarizations are separated into their in-phase and quadrature components. The order of storage is real h, imaginary h, real v, imaginary v.

Type: Float32

Group: Moments Data

Shape: AntennaScan_RefPRI_Polarization_Array

Valid_min: 0

Valid_max: $2.71x10^{37}$

Units: counts

4.7.84 m1_ref_nd

The first raw moment of fullband radiometer data in the reference plus internal noise diode state, which have been integrated to ~300 µs or one pulse repetition interval (PRI).

m1_ref_nd is a three-dimensional array. The slowest moving dimension index represents the antenna scan. The second dimension index represents the number of PRIs in the reference plus noise diode state in the antenna scan. The third index is the polarization where the vertical and horizontal polarizations are separated into their in-phase and quadrature components. The order of storage is real h, imaginary h, real v, imaginary v.

Type:	Float32
Group:	Moments Data
Shape:	AntennaScan_RefNdPRI_Polarization_Array
Valid_min:	-1.71×10^{8}
Valid_max:	1.71×10^{8}
Units:	counts

4.7.85 m2_ref_nd

The second raw moment of subband radiometer data in the reference plus internal noise diode state, which have been integrated to ~300 µs or one pulse repetition interval (PRI).

m2_ref_nd is a three-dimensional array. The slowest moving dimension index represents the antenna scan. The second dimension index represents the number of PRIs in the reference plus noise diode state in the antenna scan. The third index is the polarization where the vertical and horizontal polarizations are separated into their in-phase and quadrature components. The order of storage is real h, imaginary h, real v, imaginary v.

Type:	Float32
Group:	Moments Data
Shape:	AntennaScan_RefNdPRI_Polarization_Array
Valid_min:	0
Valid_max:	1.47×10^{18}
Units:	counts

4.7.86 m3_ref_nd

The third raw moment of fullband radiometer data in the reference plus internal noise diode state, which have been integrated to ~300 µs or one pulse repetition interval (PRI).

m3_ref_nd is a three-dimensional array. The slowest moving dimension index represents the antenna scan. The second dimension index represents the number of PRIs in the reference plus noise diode state in the antenna scan. The third index is the polarization where the vertical and horizontal polarizations are separated into their in-phase and quadrature components. The order of storage is real h, imaginary h, real v, imaginary v.

Type: Float32

Group: Moments Data

Shape: AntennaScan_RefNdPRI_Polarization_Array

Valid_min: -7.36×10^{17}

Valid_max: 7.35×10^{17}

Units: counts

4.7.87 m4_ref_nd

The fourth raw moment of fullband radiometer data in the reference plus internal noise diode state, which have been integrated to ~300 µs or one pulse repetition interval (PRI).

m4_ref_nd is a three-dimensional array. The slowest moving dimension index represents the antenna scan. The second dimension index represents the number of PRIs in the reference plus noise diode state in the antenna scan. The third index is the polarization where the vertical and horizontal polarizations are separated into their in-phase and quadrature components. The order of storage is real h, imaginary h, real v, imaginary v.

Type: Float32

Group: Moments Data

Shape: AntennaScan_RefNdPRI_Polarization_Array

Valid_min: 0

Valid_max: 2.71×10^{37}

Units: counts

4.7.88 t3_ant

The real portion of the cross correlation of the two polarizations (vertical and horizontal) for fullband radiometer data in the antenna state, which have been integrated to ~300 µs or one pulse repetition interval (PRI).

t3_ant is a two-dimensional array. The slower moving dimension index represents the antenna scan. The second dimension index represents the number of PRIs in the antenna state in the antenna scan. The number of PRIs in each antenna scan can vary depending on the exact integration time and the antenna rotation rate for that particular scan.

Type: Float32

Group: Moments Data

Shape: AntennaScan_AntPRI_Array

Valid_min: -7.36×10^{17}

Valid_max: 7.35×10^{17}

Units: counts

4.7.89 t3_ant_xnd

The real portion of the cross correlation of the two polarizations (vertical and horizontal) for fullband radiometer data in the antenna state plus external noise diode state, which have been integrated to ~300 µs or one pulse repetition interval (PRI).

t3_ant_xnd is a two-dimensional array. The slower moving dimension index represents the antenna scan. The second dimension index represents the number of PRIs in the antenna plus external noise diode state in the antenna scan.

Type: Float32

Group: Moments Data

Shape: AntennaScan_AntXndPRI_Array

Valid_min: -7.36×10^{17}

Valid_max: 7.35×10^{17}

Units: counts

4.7.90 t3_ant_nd

The real portion of the cross correlation of the two polarizations (vertical and horizontal) for fullband radiometer data in the antenna state plus internal noise diode state, which have been integrated to ~300 µs or one pulse repetition interval (PRI).

t3_ant_nd is a two-dimensional array. The slower moving dimension index represents the antenna scan. The second dimension index represents the number of PRIs in the antenna plus noise diode state in the antenna scan.

Type: Float32

Group: Moments Data

Shape: AntennaScan_AntNdPRI_Array

Valid_min: -7.36×10^{17}

Valid_max: 7.35×10^{17}

Units: counts

4.7.91 t3_ref

The real portion of the cross correlation of the two polarizations (vertical and horizontal) for fullband radiometer data in the reference state, which have been integrated to ~300 µs or one pulse repetition interval (PRI).

t3_ref is a two-dimensional array. The slower moving dimension index represents the antenna scan. The second dimension index represents the number of PRIs in the reference state in the antenna scan.

Type: Float32

Group: Moments Data

Shape: AntennaScan_RefPRI_Array

Valid_min: -7.36×10^{17}

Valid_max: 7.35×10^{17}

Units: counts

4.7.92 t3_ref_nd

The real portion of the cross correlation of the two polarizations (vertical and horizontal) for fullband radiometer data in the reference plus internal noise diode state, which have been integrated to ~300 µs or one pulse repetition interval (PRI).

t3_ref_nd is a two-dimensional array. The slower moving dimension index represents the antenna scan. The second dimension index represents the number of PRIs in the reference plus noise diode state in the antenna scan.

Type: Float32

Group: Moments Data

Shape: AntennaScan_RefNdPRI_Array

Valid_min: -7.36×10^{17}

Valid_max: 7.35×10^{17}

Units: counts

4.7.93 t4_ant

The imaginary portion of the cross correlation of the two polarizations (vertical and horizontal) for fullband radiometer data in the antenna state, which have been integrated to ~300 µs or one pulse repetition interval (PRI).

t4_ant is a two-dimensional array. The slower moving dimension index represents the antenna scan. The second dimension index represents the number of PRIs in the antenna state in the scan. The number of PRIs in each antenna scan can vary depending on the exact integration time and the antenna rotation rate for that particular scan.

Type:	Float32
Group:	Moments Data
Shape:	AntennaScan_AntPRI_Array
Valid_min:	-7.36×10^{17}
Valid_max:	7.35×10^{17}
Units:	counts

4.7.94 t4_ant_xnd

The imaginary portion of the cross correlation of the two polarizations (vertical and horizontal) for fullband radiometer data in the antenna state plus external noise diode state, which have been integrated to ~300 µs or one pulse repetition interval (PRI).

t4_ant_xnd is a two-dimensional array. The slower moving dimension index represents the antenna scan. The second dimension index represents the number of PRIs in the antenna plus external noise diode state in the antenna scan.

Type:	Float32
Group:	Moments Data
Shape:	AntennaScan_AntXndPRI_Array
Valid_min:	-7.36×10^{17}
Valid_max:	7.35×10^{17}
Units:	counts

4.7.95 t4_ant_nd

The imaginary portion of the cross correlation of the two polarizations (vertical and horizontal) for fullband radiometer data in the antenna state plus internal noise diode state, which have been integrated to ~300 µs or one pulse repetition interval (PRI).

t4_ant_nd is a two-dimensional array. The slower moving dimension index represents the antenna scan. The second dimension index represents the number of PRIs in the antenna plus noise diode state in the antenna scan.

Type: Float32

Group: Moments Data

Shape: AntennaScan_AntNdPRI_Array

Valid_min: -7.36×10^{17}

Valid_max: 7.35×10^{17}

Units: counts

4.7.96 t4_ref

The imaginary portion of the cross correlation of the two polarizations (vertical and horizontal) for fullband radiometer data in the reference state, which have been integrated to ~300 µs or one pulse repetition interval (PRI).

t4_ref is a two-dimensional array. The slower moving dimension index represents the antenna scan. The second dimension index represents the number of PRIs in the reference state in the antenna scan.

Type: Float32

Group: Moments Data

Shape: AntennaScan_RefPRI_Array

Valid_min: -7.36×10^{17}

Valid_max: 7.35×10^{17}

Units: counts

4.7.97 t4_ref_nd

The imaginary portion of the cross correlation of the two polarizations (vertical and horizontal) for fullband radiometer data in the reference plus internal noise diode state, which have been integrated to ~300 µs or one pulse repetition interval (PRI).

t4_ref_nd is a two-dimensional array. The slower moving dimension index represents the antenna scan. The second dimension index represents the number of PRIs in the reference plus noise diode state in the antenna scan.

Type: Float32

Group: Moments Data

Shape: AntennaScan_RefNdPRI_Array

Valid_min: -7.36×10^{17}

Valid_max: 7.35×10^{17}

Units: counts

4.7.98 moments_lat

The latitude of the antenna look PRI on the surface of the Earth.

moments_lat is a two-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents the number of PRIs in the antenna state in the scan.

Type: Float32

Group: Moments Data

Shape: AntennaScan_AntPRI_Array

Valid_min: -90

Valid_max: 90

Units: degrees

4.7.99 moments_lon

The longitude of the antenna look PRI on the surface of the Earth.

moments_lon is a two-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents the number of PRIs in the antenna state in the scan.

Type: Float32

Group: Moments Data

Shape: AntennaScan_AntPRI_Array

Valid_min: -180.0

Valid_max: 179.999

Units: degrees

4.7.100 moments_declination

The declination of the spacecraft boresight vector.

moments_declination is a two-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents the number of PRIs in the antenna state in the scan.

Type: Float32

Group: Moments Data

Shape: AntennaScan_AntPRI_Array

Valid_min: -90

Valid_max: 90

Units: degrees

4.7.101 moments_right_ascension

The right ascension of the spacecraft boresight vector.

moments_right_ascension is a two-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents the number of PRIs in the antenna state in the scan.

Type: Float32

Group: Moments Data

Shape: AntennaScan_AntPRI_Array

Valid_min: 0

Valid_max: 359.999

Units: degrees

4.7.102 ant_time_seconds

The number of Standard International (SI) compatible seconds since 11:58:55.816 on January 1, 2000 UTC for each antenna look PRI interpolated to antenna boresight azimuth of 0 degrees.

*ant_time_seconds i*s a two-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents the time of the antenna PRIs in the scan.

Type: Float64

Group: Moments Data

Shape: AntennaScan_AntPRI_Array

Valid_min: 0

Valid_max: 946000000

Units: seconds

4.7.103 ant_xnd_time_seconds

The number of Standard International (SI) compatible seconds since 11:58:55.816 on January 1, 2000 UTC for each antenna plus external noise diode look PRI interpolated to antenna boresight azimuth of 0 degrees.

*ant_xnd_time_seconds i*s a two-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents the time of the antenna plus external noise diode PRIs in the scan.

Type:	Float64
Group:	Moments Data
Shape:	AntennaScan_AntXndPRI_Array
Valid_min:	0
Valid_max:	946000000
Units:	seconds

4.7.104 ant_nd_time_seconds

The number of Standard International (SI) compatible seconds since 11:58:55.816 on January 1, 2000 UTC for each antenna plus internal noise diode look PRI interpolated to antenna boresight azimuth of 0 degrees.

*ant_nd_time_seconds i*s a two-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents the time for the antenna plus internal noise diode PRIs in the scan.

Type:	Float64
Group:	Moments Data
Shape:	AntennaScan_AntNdPRI_Array
Valid_min:	0
Valid_max:	946000000
Units:	seconds

4.7.105 ref_time_seconds

The number of Standard International (SI) compatible seconds since 11:58:55.816 on January 1, 2000 UTC for each reference look PRI interpolated to antenna boresight azimuth of 0 degrees.

*ref_time_seconds i*s a two-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents the time for the reference PRIs in the scan.

Type:	Float64
Group:	Moments Data
Shape:	AntennaScan_RefPRI_Array
Valid_min:	0
Valid_max:	946000000
Units:	seconds

4.7.106 ref_nd_time_seconds

The number of Standard International (SI) compatible seconds since 11:58:55.816 on January 1, 2000 UTC for each reference plus internal noise diode look PRI interpolated to antenna boresight azimuth of 0 degrees.

*ref_nd_time_seconds i*s a two-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents the time for the reference plus internal noise diode PRIs in the scan.

Type:	Float64
Group:	Moments Data
Shape:	AntennaScan_RefNdPRI_Array
Valid_min:	0
Valid_max:	946000000
Units:	seconds

4.7.107 status_dn

The status data from the engineering telemetry in digital numbers.

*status_dn i*s a two-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents all the status data from the engineering telemetry packet for that particular scan. These data points can be found in words 1 to 22 of the engineering telemetry. See Table 13.

Type:	Uint16
Group:	House Keeping Data
Shape:	AntennaScan_HouseKeepingStatus_Array
Valid_min:	0
Valid_max:	65535
Units:	counts

4.7.108 digital_dn

The digital data from the engineering telemetry in digital numbers.

*digital_dn i*s a two-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents all the digital data from the engineering telemetry packet for that particular scan. These data points can be found in words 23 to 73 of the engineering telemetry. See Table 13.

Type:	Uint16
Group:	House Keeping Data
Shape:	AntennaScan_HouseKeepingDigital_Array
Valid_min:	0
Valid_max:	65535
Units:	counts

4.7.109 analog_dn

The analog data from the engineering telemetry such as temperatures, voltages and current monitor points in digital numbers.

*analog_dn i*s a two-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents all the analog data from the engineering telemetry packet for that particular scan. These data points can be found in words 74 to 233 of the engineering telemetry. See Table 13.

Type:	Uint16
Group:	House Keeping Data
Shape:	AntennaScan_HouseKeepingAnalog_Array
Valid_min:	0

Valid_max: 65535

Units: counts

4.7.110 analog_eu

The analog data from the engineering telemetry such as temperatures, voltages and current monitor points in engineering units.

*analog_eu i*s a two-dimensional array. The slower moving dimension index represents the antenna scan. The faster moving dimension index represents all the analog data from the engineering telemetry packet for that particular scan. These data points correspond to the words found in 74 to 233 of the engineering telemetry. These data points are converted to engineering units.

Type: Uint16

Group: House Keeping Data

Shape: AntennaScan_HouseKeepingAnalog_Array

Valid_min: n/a

Valid_max: n/a

Units: ℃, mV, mA

5 APPENDIX A – ACRONYMS AND ABBREVIATIONS

This is the standard Soil Moisture Active Passive (SMAP) Science Data System (SDS) list of acronyms and abbreviations. Not all of these acronyms and abbreviations appear in every SMAP SDS document.

ADT	Algorithm Development Team
AMSR	Advanced Microwave Scanning Radiometer
ANSI	American National Standards Institute
AOS	Acquisition of Signal
APF	Algorithm Parameter File
ARS	Agricultural Research Service
ASF	Alaska Satellite Facility
ATBD	Algorithm Theoretical Basis Document
ATLO	Assembly Test Launch and Operations
BFPQ	Block Floating Point Quantization
BIC	Beam Index Crossing
CARA	Criticality and Risk Assessment
CBE	Current Best Estimate
CCB	Configuration Control Board
CCSDS	Consultative Committee on Space Data Systems
CDR	Critical Design Review
CEOS	Committee on Earth Observing Systems
CF	Climate and Forecast (metadata convention)
CM	Configuration Management
CM	Center of Mass
CONUS	Continental United States
COTS	Commercial Off the Shelf
CR	Change Request
DAAC	Distributed Active Archive Center
DB	Database
DBA	Database Administrator
dB	decibels
deg	degrees

deg/sec	degrees per second
deg C	degrees Celsius
DEM	Digital Elevation Model
DFM	Design File Memorandum
DIU	Digital Interface Unit
DN	Data Number
DOORS	Dynamic Object Oriented Requirements
DQC	Data Quality Control
DSK	Digital Skin Kernel
DVD	Digital Versatile Disc
EASE	Equal Area Scalable Earth
ECMWF	European Centre for Medium Range Weather Forecasts
ECHO	EOS Clearing House
ECI	Earth Centered Inertial Coordinate System
ECR	Earth Centered Rotating Coordinate System
ECR	Engineering Change Request
ECS	EOSDIS Core System
EDOS	EOS Data Operations System
EM	Engineering Model
EOS	Earth Observing System
EOSDIS	Earth Observing System Data and Information System
EPO	Education and Public Outreach
ESDIS	Earth Science Data and Information System Project
ESDT	Earth Science Data Type
ESH	EDOS Service Header
ESSP	Earth Science System Pathfinder
ET	Ephemeris Time
EU	Engineering Units
FOV	Field of View
FRB	Functional Requirements Baseline

FS	Flight System
FSW	Flight Software
F/T	Freeze/Thaw
FTP	File Transfer Protocol
GByte	gigabyte
GDS	Ground Data System
GHA	Greenwich Hour Angle
GHz	gigahertz
GLOSIM	Global Simulation
GMAO	Global Modeling and Assimilation Office
GMT	Greenwich Mean Time
GN	Ground Network
GPMC	Governing Program Management Council
GPP	Gross Primary Production
GPS	Global Positioning System
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
HDF	Hierarchical Data Format
HK	Housekeeping (telemetry)
Hz	Hertz
HSD	Health and Status Data
ICE	Integrated Control Electronics
ICESat	Ice, Cloud and Land Elevation Satellite
IDL	Interactive Data Language
I&T	Integration and Test
ICD	Interface Control Document
IEEE	Institute of Electrical and Electronics Engineers
IFOV	Instantaneous Field of View
I/O	Input/Output
IOC	In-Orbit Checkout
IRU	Inertial Reference Unit
ISO	International Organization for Standardization

IV&V	Independent Verification and Validation
ITAR	International Traffic in Arms Regulations
I&T	Integration and Test
JPL	Jet Propulsion Laboratory
KHz	kilohertz
km	kilometers
LAN	Local Area Network
LBT	Loopback Trap
LEO	Low Earth Orbit
LEOP	Launch and Early Operations
LOE	Level Of Effort
LOM	Life Of Mission
LOS	Loss of Signal
LSK	Leap Seconds Kernel
LZPF	Level Zero Processing Facility
m	meters
MHz	megahertz
MIT	Massachusetts Institute of Technology
MMR	Monthly Management Review
MOA	Memorandum of Agreement
MOC	Mission Operations Center
MODIS	Moderate Resolution Imaging Spectroradiometer
MOS	Mission Operations System
m/s	meters per second
ms	milliseconds
MS	Mission System
NAIF	Navigation and Ancillary Information Facility
NASA	National Aeronautics and Space Administration
NCEP	National Centers for Environmental Protection
NCP	North Celestial Pole
NCSA	National Center for Supercomputing Applications
NEDT	Noise Equivalent Diode Temperature

NEE	Net Ecosystem Exchange
NEN	Near Earth Network
netCDF	Network Common Data Form
NFS	Network File System/Server
NISN	NASA Integrated Services Network
NRT	Near Real Time
NOAA	National Oceanic and Atmospheric Administration
NSIDC	National Snow and Ice Data Center
NVM	Non-Volatile Memory
NWP	Numerical Weather Product
n/a	not applicable
OCO	Orbiting Carbon Observatory
OEF	Orbit Events File
ORBNUM	Orbit Number File
OODT	Object Oriented Data Technology
ORR	Operational Readiness Review
ORT	Operational Readiness Test
OSSE	Observing System Simulation Experiment
OSTC	One Second Time Command
PALS	Passive and Active L-Band System
PALSAR	Phased Array L-Band Synthetic Aperture Radar
PcK	Planetary Constants Kernel
PDR	Preliminary Design Review
PPPCS	Pointing, Position, Phasing and Coordinate System
PR	Problem Report
PRF	Pulse Repetition Frequency
PRI	Pulse Repetition Interval
PROM	Programmable Read Only Memory
PSD	Product Specification Document
QA	Quality Assurance
rad	radians
RAM	Random Access Memory

RBA	Reflector Boom Assembly
RBD	Rate Buffered Data
RBE	Radiometer Back End
RDD	Release Description Document
RDE	Radiometer Digital Electronics
RF	Radio Frequency
RFA	Request For Action
RFE	Radiometer Front End
RFI	Radio Frequency Interference
RMS	root mean square
RSS	root sum square
ROM	Read Only Memory
RPM	revolutions per minute
RVI	Radar Vegetation Index
SA	System Administrator
SAR	Synthetic Aperture Radar
S/C	Spacecraft
SCE	Spin Control Electronics
SCLK	Spacecraft Clock
SDP	Software Development Plan
SDS	Science Data System
SDT	Science Definition Team
SI	International System
SITP	System Integration and Test Plan
SMAP	Soil Moisture Active Passive
SMEX	Soil Moisture Experiment
SMOS	Soil Moisture and Ocean Salinity Mission
SMP	Software Management Plan
SNR	signal to noise ratio
SOC	Soil Organic Carbon
SOM	Software Operators Manual
SQA	Software Quality Assurance

SPDM	Science Process and Data Management
SPG	Standards Process Group
SPK	Spacecraft Kernel
SQA	Software Quality Assurance
SPS	Science Production Software
SRF	Science Orbit Reference Frame
SRR	System Requirements Review
SRTM	Shuttle Radar Topography Mission
SSM/I	Special Sensor Microwave/Imager
STP	Software Test Plan
sec	seconds
TAI	International Atomic Time
T_b	Brightness Temperature
TBC	To Be Confirmed
TBD	To Be Determined
TBR	To Be Resolved
TBS	To Be Specified
TCP/IP	Transmission Control Protocol/Internet Protocol
TEC	Total Electron Content
TM	Trademark
TOA	Time of Arrival
TPS	Third Party Software
UML	Unified Modeling Language
U-MT	University of Montana
USDA	United States Department of Agriculture
UTC	Coordinated Universal Time
V&V	Verification and Validation
VWC	Vegetation Water Content

6 APPENDIX B - SMAP Data Product Specification Documents

SMAP Level 1A Radar Product Specification Document, JPL D-72543 Revision B, July 20, 2015.

SMAP Level 1B Radar (L1B_S0_LoRes) Product Specification Document, JPL D-72544 Revision A, July 20, 2015.

SMAP Level 1C Radar (L1C_S0_HiRes) Product Specification Document, JPL D-72554 Revision B, July 20, 2015.

SMAP Level 1B Radiometer (L1B_TB_ Product Specification Document, JPL D-92339 Revision A, July 20, 2015.

SMAP Level 1C Radiometer (L1C_TB) Product Specification Document, JPL D-72545, June 12, 2014.

SMAP Level 2 Active Soil Moisture (L2_SM_A) Product Specification Document, JPL D-72546, June 12, 2014.

SMAP Level 2 Passive Soil Moisture (L2_SM_P) Product Specification Document, JPL D-72547, June 12, 2014.

SMAP Level 2 Active/Passive Soil Moisture (L2_SM_AP) Product Specification Document, JPL D-72548, June 12, 2014.

SMAP Level 3 Freeze-Thaw (L3_FT_A) Product Specification Document, JPL D-72549, June 12, 2014.

SMAP Level 3 Active Soil Moisture (L3_SM_A) Product Specification Document, JPL D-72550, June 12, 2014.

SMAP Level 3 Passive Soil Moisture (L3_SM_P) Product Specification Document, JPL D-72551, June 12, 2014.

SMAP Level 3 Active/Passive Soil Moisture (L3_SM_AP) Product Specification Document, JPL D-72552, June 12, 2014.

SMAP Level 4 Carbon (L4_C) Product Specification Document, Document Identifier (**TBD)**, Date (**TBD)**.

SMAP Level 4 Soil Moisture (L4_SM) Product Specification Document, June 17, 2014.

7 APPENDIX C – SHAPES IN THE L1A RADIOMETER PRODUCT

Table 18 lists all of the Shapes that appear in the L1A RADIOMETER Product. The table also lists the rank, the nominal dimensions and the maximum dimensions for each Shape in the L1A RADIOMETER Product.

The naming convention for shape names places the dimension where consecutive indices represent contiguous storage positions last. The naming convention thus conforms to index representation in the C language.

On the other hand, since a large contingent of the SMAP science community programs are in Fortran, index order of arrays in this document conforms to the Fortran standard. Thus, in array dimension representation, the dimension where consecutive indices represent contiguous storage appears first.

Table 18: Shapes in the SMAP L1A RADIOMETER Data Product

Shape	Rank	Nominal Product Dimensions	Maximum Product Dimensions
AntennaScan_Array	1	676	759
AntennaScan_HouseKeepingStatus_Array	2	(676,22)	(759,22)
AntennaScan_HouseKeepingDigital_Array	2	(676,51)	(759,51)
AntennaScan_HouseKeepingAnalog_Array	2	(676,160)	(759,160)
HighResolutionScan_AntPacket_Array	2	(338,2171)	(338,2411)
HighResolutionScan_AntXndPacket_Array	2	(338,12)	(338,12)
HighResolutionScan_AntNdPacket_Array	2	(338,1)	(338,1)
HighResolutionScan_RefPacket_Array	2	(338,540)	(338,600)
HighResolutionScan_RefNdPacket_Array	2	(338,540)	(338,600)
AntennaScan_AntPRI_Array	2	(676,8684)	(676,9644)
AntennaScan_AntXndPRI_Array	2	(676,48)	(676,48)
AntennaScan_AntNdPRI_Array	2	(676,4)	(676,4)
AntennaScan_RefPRI_Array	2	(676,2160)	(676,2400)

Shape	Rank	Nominal Product Dimensions	Maximum Product Dimensions
AntennaScan_RefNdPRI_Array	2	(676,2160)	(676,2400)
AntennaScan_AntPRI_Polarization_Array	3	(676,8684,4)	(676,9644,4)
AntennaScan_AntXndPRI_Polarization_Array	3	(676,48,4)	(676,48,4)
AntennaScan_AntNdPRI_Polarization_Array	3	(676,4,4)	(676,4,4)
AntennaScan_RefPRI_Polarization_Array	3	(676,2160,4)	(676,2400,4)
AntennaScan_RefNdPRI_Polarization_Array	3	(676,2160,4)	(676,2400,4)
AntennaScan_SciencePacketCRC_Array	2	(676,350)	(676,453)
HighResolutionScan_AntPacket_Subband_Array	3	(338,2171,16)	(338,2411,16)
HighResolutionScan_AntXndPacket_Subband_Array	3	(338,12,16)	(338,12,16)
HighResolutionScan_AntNdPacket_Subband_Array	3	(338,1,16)	(338,1,16)
HighResolutionScan_RefPacket_Subband_Array	3	(338,540,16)	(338,600,16)
HighResolutionScan_RefNdPacket_Subband_Array	3	(338,540,16)	(338,600,16)
HighResolutionScan_AntPacket_Subband_Polarization_Array	4	(338,2171,16,4)	(338,2411,16,4)
HighResolutionScan_AntXndPacket_Subband_Polarization_Array	4	(338,12,16,4)	(338,12,16,4)
HighResolutionScan_AntNdPacket_Subband_Polarization_Array	4	(338,1,16,4)	(676,1,16,4)
HighResolutionScan_RefPacket_Subband_Polarization_Array	4	(338,540,16,4)	(338,600,16,4)
HighResolutionScan_RefNdPacket_Subband	4	(338,540,16,4)	(338,600,16,4)

Shape	Rank	Nominal Product Dimensions	Maximum Product Dimensions
_Polarization_Array			

8 APPENDIX D – L1A Radiometer DIMENSIONS

Table 21 lists all of the Dimensions that are used by data elements in the Level L1A Radiometer Product. The name of each Dimension matches the name given in the Dimension column below. The table also lists the anticipated nominal value and the maximum value for each dimension that appears in the L1A Radiometer Product.

Some of the dimension sizes of the L1A Radiometer Product are based on the radiometer switching scheme. The existing radiometer states are antenna (Ant), antenna plus external noise diode (AntXnd), antenna plus noise diode (AntNd), reference (Ref) and reference plus noise diode (RefNd). The switching sequence is described below.

- The number of antenna scans per file depends on the antenna rotation rate and the length of the file. A half orbit L1A radiometer file contains approximately 52 minutes of data. The nominal number of scans is therefore 13 rpm*52 mins = 676 scans. The maximum number of scans is 14.6 rpm*52 mins = 759 scans.
- Each antenna scan contains several footprints. The maximum number of footprints possible based on the antenna rotation rate and PRI time is 302.
  Minimum rotation rate = 13 RPM
  Minimum PRI time = 318.4 µs
  Max number of footprints per scan = (Rotation time (sec)*Number of PRIs per second)/48 PRIs per footprint
  = (60 seconds/13 RPM)*(1/318.4 µs)/48 = 302
- Each footprint contains 12 packets of science data. Radiometer packets are each made up of 4 PRIs. Each science data packet therefore includes fullband or time domain data for each of the 4 PRIs and subband data which have been further integrated over 4 PRIs.

The following holds true except for the last 2 footprints in each scan:

- The radiometer is in the antenna state for the following packets of each footprint: 1-4, 7-10.
- The 5^{th} and 11^{th} packets of each footprint contains reference data and the 6^{th} and 12^{th} packets of each footprint contains reference plus noise diode data.
- The maximum number of reference and reference plus noise diode data packets is 600 each.

The following holds true for only the last 2 footprints in each scan:

- The radiometer is in the antenna state for all 12 packets in the penultimate footprint of each scan.
- The correlated noise source (CNS) or external noise diode is turned on during the last 2 footprints of each scan for the odd numbered packets. Therefore, the number of packets in the AntXnd state is always 12.

- The radiometer is in the antenna state for the 1st 11 packets of the last footprint of each scan.
- The 12th packet of the last footprint contains antenna plus noise diode data. Therefore, the number of packets in the AntNd state is always 1.

See Tables 19 and 20 explicitly define the radiometric state of the data as they appear in the instrument telemetry packets

The maximum number of antenna packets is 2411.

Table 19: Switching scheme except for last 2 footprints in each scan

Packet	State
1	ANT
2	ANT
3	ANT
4	ANT
5	REF
6	REF+ND
7	ANT
8	ANT
9	ANT
10	ANT
11	REF
12	REF+ND

Table 20: Switching scheme for last 2 footprints in each scan

Packet	State	CNS
1	ANT	ON
2	ANT	
3	ANT	ON
4	ANT	
5	ANT	ON
6	ANT	
7	ANT	ON
8	ANT	
9	ANT	ON
10	ANT	
11	ANT	ON
12	ANT	
13	ANT	ON
14	ANT	
15	ANT	ON
16	ANT	
17	ANT	ON
18	ANT	
19	ANT	ON
20	ANT	
21	ANT	ON
22	ANT	

23	ANT	ON
24	ANT+ND	

Table 21: Dimensions in the SMAP L1A Radiometer Product

Dimension	Nominal Size	Maximum Size
AntennaScan	676	759
AntPacket	2171	2411
AntXndPacket	12	12
AntNdPacket	1	1
RefPacket	540	600
RefNdPacket	540	600
Subband	16	16
Polarization	4	4
AntPRI	8684	9644
AntXndPRI	48	48
AntNdPRI	4	4
RefPRI	2160	2400
RefNdPRI	2160	2400
HouseKeepingStatus	22	22
HouseKeepingDigital	51	51
HouseKeepingAnalog	160	160
SciencePacketCRC	350	453

9 APPENDIX E – L1A RADIOMETER UNITS

Table 22 lists the units that are used by the L1A_RADIOMETER product elements. The SMAP implementation of HDF5 stores unit information for each data element in the local metadata. The first column in the Table 22 identifies units that apply to data in the L1A_RADIOMETER Product. The second column lists the Common Symbol used to represent the unit. The third column lists the matching label that appears in the local metadata in the L1A_RADIOMETER Product.

Table 22: Units in the SMAP L1A_Radiometer Product

Unit	Common Symbol	Level 1A_Radiometer Label	Typical Use
counts	Counts	counts	number of elements in a set
degrees	degrees	degrees	angular measure
dimensionless	n/a		dimensionless quantity
Gigahertz	GHz	GHz	frequency measure
meters per second	m/s	m/s	velocity measure
megabytes	MBytes	MBytes	computer storage units
meters	m	m	distance measure
kilometers	km	km	distance measure
percent	%	percent	per hundred
seconds	s	sec	time measure
revolutions per minute	rpm	rpm	rotational measure
degrees Celsius	℃	degrees_Celsius	temperature meas ure